The effect of personality on attentional strategy in category learning

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Declaration

I, Ian James Tharp, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

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Dedication

This thesis is dedicated to
my parents, John and Anna Tharp,
and my brother Graham

Abstract

This thesis explores the mediating effects of personality on attention and performance during the learning of novel categories. Major theories of category learning emphasise the role of dopamine on a variety of processes engaged during such learning. Two core personality domains, namely extraversion and a cluster of traits collectively termed impulsive, anti-social, sensation seeking (ImpASS), were considered. These personality traits were of interest because it has been suggested that their biological basis may partly reflect variation in dopaminergic neurotransmission. Schizotypal personality, owing to its association with schizophrenia, may also reflect dopaminergic function and was also considered.

A series of behavioural experiments were undertaken to examine the relationship between these key personality constructs and the learning of new stimulus-category associations. In particular the manner in which the properties (e.g., size, shape, colour etc) of the stimuli were utilised during the learning of the category labels was considered. Various studies allowed assessment of both accuracy performance and attentional strategy. The first study involved the comparison of performance on two distinct tasks, with identical stimuli and responses. The category structure was manipulated such that the rule for one task was simple and verbalisable, whereas the rule for the other was more complex and not easily verbalisable. A subsequent study explored the ability to adapt a reasonably accurate simple response strategy to a more complex, yet more appropriate (and beneficial) strategy. Eye-tracking methods were employed, in further similar studies, to measure the 'attention' given to different stimulus features. Reaction time methodology was used in another study to explore the degree of incidental learning about nominally task irrelevant stimulus information, during a simple classification task.

Extraversion and ImpASS often appeared differentially associated with categorisation performance and strategy use. The latter trait was associated with a preference for simplistic or more salient category rules and, in contrast to extraversion, was associated with less flexible modification of response strategy. The results presented also emphasized the important role of attentional processes during category learning. For example, positive schizotypy was associated with *decreased* processing of nominally irrelevant stimulus features during speeded categorisation. The implications of the results for future work, and for theories of the personality constructs investigated, were also considered.

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List of Abbreviations

Generic Abbreviations

ADHD	Attention-Deficit/Hyperactivity Disorder
AIC	Akaike Information Criterion
DCE	Distractor Cueing Effect(s)
EEG	Electroencephalogram
EMG	Electromyography
ERP	Event Related Potential
EBR	Eye-Blink Rate
ET	Eye-Tracking
FB	Feedback
fMRI	Functional Magnetic Resonance Imaging
LI	Latent Inhibition
MTL	Medial Temporal Lobe
PA	Paired-Associate
PET	Positron Emission Tomography
RT	Reaction/Response Time
RST	Reinforcement Sensitivity Theory
S-R/S	Stimulus-Response/Stimulus
WM	Working-Memory

Category-Learning Terminology Abbreviations

CL	Category Learning
RB	Rule-Based
II	Information-Integration
COVIS	Competition between Verbal and Implicit Systems
DBT	Decision Bound Theory
ALCOVE	Attention Learning Covering Map
GCM	Generalised Context Model
TTC	Trials-To-Criterion

Personality Scale Abbreviations

BFI:	Big Five Inventory
BFI-E	Extraversion
BFI-N	Neuroticism
BFI-C	Conscientiousness
BFI-A	Agreeableness
BFI-O	Openess
EPQ(-R):	Eysenck's Personality Questionnaire (-Revised)
EPQ-E	Extraversion
EPQ-N	Neuroticism
EPQ-P	Psychoticism
SSS:	Sensation Seeking Scale
TAS	Thrill and Adventure Seeking
ES	Experience Seeking
D	Disinhibition
BS	Boredom Susceptibility
BIS/BAS:	Behavioural Inhibition Scale/ Behavioural Activation Scale
BIS	Behavioural Inhibition Scale
BAS-D	Behavioural Activation Scale – Drive
BAS-FS	Behavioural Activation Scale – Fun Seeking
BAS-RR	Behavioural Activation Scale – Reward-Reactivity
OLIFE:	Oxford-Liverpool Inventory of Feelings and Experiences
UnEx	Unusual Experiences
CogDis	Cognitive Disorganisation
IntAnh	Introvertive Anhedonia
ImpNon	Impulsive-Nonconformity
SPQ:	Schizotypal Personality Questionnaire
IoR	Ideas of Reference
OddBel	Odd Beliefs/Magical Thinking
UPE	Unusual Perceptual Experiences
Susp	Suspiciousness
ESA	Excessive Social Anxiety
NCF	No Close Friends
CA	Constricted Affect
OddBeh	Odd/Eccentric Behaviour
OddSp	Odd Speech
ImpASS:	Impulsive Anti-social Sensation Seeking

Chapter 1

Personality and Cognition

Chapter Aims

This opening chapter forms the first of three introductory sections. The aim is to provide a background to the thesis topic and underlying rationale of the research programme. The current chapter comprises a brief overview of the relationship between personality and cognition. More specifically, the association between three personality domains (extraversion, impulsivity and schizotypy) and facets of cognition concerning attention and learning will be explored. This will include the consideration of previous research in this area as well as a brief examination of plausible neurobiological mechanisms which may be involved in inter-individual variation in both personality and cognition.

Extraversion

There are many behavioural descriptors associated with extraverted individuals; lively, sociable, assertive, outgoing, energetic, sensation-seeking, carefree etc. Conversely, at the opposite end of the continuum, introverted individuals are described as being less sociable and outgoing, more reserved and less inclined to engage in uninhibited, or impulsive, behaviour. The extraversion – introversion trait (henceforth referred to simply as extraversion) is a core personality dimension and its presence, albeit in a variety of guises (e.g., cf. 'positive emotionality', Tellegen, 1982, 1985), is observed within almost all influential personality theories (Matthews, Deary, & Whiteman, 2003).

Despite divergent conceptual perspectives, Costa and McCrae's (1992) five factor model and Eysenck's (1967) three factor model are two prominent exemplars of personality theory which prescribe extraversion as a fundamental personality dimension. Costa and McCrae's five factor model arose, broadly speaking, from a 'lexical' approach to the assessment of personality; following the hypothesis that the most critical domains of personality are likely to be reflected in everyday language. This method derives key personality dimensions (which subsume a number of lower order traits) through the consideration and statistical examination (i.e., factor analysis) of the most important descriptors of human behaviour. Thus, extraversion is purported to be one of five core personality dimensions (or factors) which reliably encapsulate variance in (descriptors of) human personality. In contrast, although reliant upon some of the same psychometric methods, Eysenck's personality model is clearly distinct. One key distinguishing feature is a proposed underlying biological basis for observed inter-individual variation in extraversion (and the two remaining factors of neuroticism and psychoticism). This proposed hypothetical framework, which prescribes biological processes as fundamental causal components of personality, is of particular interest for the current topic concerning the relationship between personality and cognition.

In broad terms, Eysenck's (1967) theory of extraversion suggested that variation in this personality trait reflects differences in baseline levels of cortical arousal. Consequently, the typical behaviours of more introverted individuals (i.e., reserved, less sociable etc) arise as a result of generally higher, supra-optimal levels of arousal. In contrast, under-aroused extraverts seek to increase the degree of brain 'activation' and thus engage in more sociable, sensation-seeking and invigorating behaviours. Crucially, Eysenck's theory of extraversion suggests that this trait may be predictably associated with performance upon tasks in which the level of cortical arousal (and arousability) may play a contributory role (e.g., the interaction between extraversion and manipulations which are proposed to affect arousal, such as task-demands or situational/environmental factors, can be assessed).

Detailed consideration of this *arousal* theory of extraversion is not essential to the current debate. What is most important, however, is that the framework of this model allows the exploration of experimental predictions which arise from the assertion that personality traits, such as extraversion, reflect the functioning of biological systems (i.e., those involved in cortical arousal). Accordingly, as summarised in Matthews et al. (2003), these ideas have generated a lot of research which has examined the association between extraversion and various aspects of cognition (such as memory, attention, problem solving etc) as well as 'non-cognitive' functioning (e.g., conditioning).

Extraversion and Attention

The relationship between extraversion and attentional abilities was considered in a meta-analysis by Koelega (1992). This summarised 30 years (1960 – 1990) of research on the interplay between extraversion and performance on sustained vigilance tasks. This research was built upon the arousal hypothesis of extraversion (discussed above), and the prediction of inferior levels of performance of extraverted individuals on such tasks (i.e., it is considered that introverts are better able to sustain attention across monotonous, un-arousing tasks due to being more cortically aroused than extraverts). While not able to clarify the likely causal mechanisms involved (from the proposed candidates; e.g., better discrimination of targets, greater allocation of attentional resources), the meta-analysis did indeed appear to support the notion that introverts were better in overall performance (e.g., a greater number of hits) on vigilance tasks (although not in terms of sustained performance).

Syzmura and Necka (1998) adopted a visual selective attention paradigm to compare different candidate models of extraversion. The arousal model was again considered, with the specific hypothesis that extraverts would demonstrate superior performance (fewer errors and quicker responses) on more difficult detection tasks. The greater level of attention required on the more difficult tasks was proposed to increase the level of arousal to the point where extraverts' performance would be facilitated (relative to the impaired performance of the 'over-aroused' introverts). In contrast, this pattern of performance would be reversed when the vigilance task was simple; not causing heightened levels of arousal.

The predictions of the arousal model of extraversion were compared with those of the resource availability model (Matthews, Davies, & Holley, 1990; Matthews, Davies, & Lees, 1990). This model suggests that extraverts may have an increased capacity or a more effective system for dealing with incoming information. Matthews, Davies, and Lees (1990) found that extraversion was positively related to a greater availability of attentional resources (on more demanding tasks). Hence, extraverts may be at an advantage on selective attention tasks in which a greater level of information processing is required. However, on more simple tasks there should be no performance differences.

To test these differing predictions Syzmura and Necka (1998) compared performance on selective attention tasks which varied on their difficulty (e.g., level of distraction) and also the degree of attentional load (through the use of dual task methodology). The results appeared to support the arousal model of extraversion; introverts performed better (higher accuracy and more quickly) on the easier version of the task whereas extraverts performed more accurately on the more difficult version of the task. The lack of differentiation on reaction time measures between extraverts and introverts on the more difficult task was argued to suggest that the differences in attention were more at the 'sensory' as opposed to 'cognitive' level of attention (i.e., the increased difficulty, involving semantic attentional processes, introduced an additional level of processing compared to the purely sensory processing – visual similarity – required in the easier version of the task).

The relationship between extraversion and directed attention has also been explored. Stenberg, Rosen and Risberg (1990) found greater reactivity in the ERPs of introverts in relation to attention given towards the visual stimuli eliciting the evoked (EEG) response. Introverts appeared to demonstrate a greater ability to narrow the focus of their attention; they showed higher amplitudes (and greater effects of increased stimulus intensity on amplitudes) when attending to the visual stimulus and lower when attending to an auditory distractor. The decreased level of augmentation and reduction in amplitude measures found in extraverts, when exposed to the attentional manipulation, was again argued to relate to the higher levels of arousal in introverts.

Blumenthal (2001) also used an attentional manipulation and examined the relationship between extraversion and the (degree of) modulated eye-blink startle response. The startle reflex is an involuntary response to a sudden, intense stimulus. In humans the degree of startle can most reliably be measured using the eye-blink component (using EMG). The modulation of this component (in terms of both amplitude and latency) can be affected by a variety of parameters. For example, the manipulation of affective states through the use of negatively- and positively-valenced stimuli facilitate and inhibit the startle reflex respectively (for a review see Grillon & Baas, 2003).

The eye-blink startle response is found to be attenuated when attention is directed away from the startle eliciting stimulus towards incoming input of a different modality. Likewise, the startle is augmented when attention is instead directed towards the startle eliciting stimulus itself (e.g., see Blumenthal, 2001). Therefore, if introverts are better able to focus their attention then one would predict that the degree of modulation of the startle response would be greater than that for extraverts (cf. Stenberg et al., 1990). This was indeed the pattern of results found by Blumenthal (2001). The effect was especially evident when comparing the effect of directing attention away from the auditory startle stimulus towards the visual task, with introverts showing a greater decrease in startle response relative to extraverts.

Research has continued to assess the association between extraversion and attention and has additionally addressed other factors which may influence performance. For example, using an auditory vigilance task, Schmidt, Beauducel, Brocke, and Strobel, (2004) successfully demonstrated that the performance (as assessed by reaction time to the target stimuli) of extraverts decreased to a greater extent than that of introverts (i.e., there was an interaction between extraversion and time on the task; extraverts response times became slowed to a greater extent). This result was considered to support the basic arousal hypothesis of extraversion (i.e., the lower arousal of extraverts lead to a greater decrease in performance on the un-stimulating task). Furthermore, it was suggested that the lack of any differences in target detection rates between the introversion-extraversion groups may support the additional proposal that extraverts invest more effort in the task in an attempt to increase arousal to optimal levels: The additional 'effort' may have been insufficient to maintain response-time performance, although adequate for the detection of targets.

A subsequent study by Beauducel, Brocke, and Leue (2006) extended the work just described with the inclusion of EEG. This enabled the additional assessment of putative measures of arousal (spontaneous EEG alpha activity) and effort (ERP, P300 component) alongside the typical measures of task performance. The results of the task appeared to support the previous findings; compared to introverts, extraverts demonstrated a lower hit-rate and appeared to invest more effort in the task (with an additional trend for lower levels of arousal).

Dopamine, Cognition and Attention

There is a wide variety of evidence connecting the neurotransmitter dopamine and cognitive function (for a review see Nieoullon, 2002). A substantial amount of data has arisen from the investigation of a range of distinct neuropsychological disorders. Possibly the most studied condition is that of Parkinson's disease which is most strongly associated with dopamine depletion in the nigrostriatal and, to a lesser degree, mesocorticolimbic pathways. This neurodegenerative disorder is primarily associated with impairments in motor function, although it is also linked to deficits in cognition.

For example, one facet of cognitive impairment in Parkinson's disease appears to be impairment of working memory performance, an executive process associated with dopaminergic function (Goldman-Rakic, 1995). Research suggests that the impairment relates to a reduced working memory capacity although the deficit may be selective; related to the *manipulation* as opposed to the *updating* of information (Gilbert, Belleville, Bherer, & Chouinard, 2005) and dependent upon the complexity of processing (Bublak, Muller, Gron, Reuter, & von Cramon, 2002). Furthermore, recent studies have implicated a dopaminergic basis in the reported working memory impairments. For example, Lewis, Slabosz, Robbins, Barker, and Owen (2005) reported the finding that the administration of levodopa medication to Parkinson's disease patients ameliorated the impaired performance on the manipulation component of a working memory task.

Furthermore, a range of studies appear to suggest that a deficit in cognitive flexibility, such as that required in task switching for example, as well as other attentional deficits are associated with Parkinson's disease (Cools, 2006). In one example of a task requiring cognitive flexibility, Swainson et al. (2006) found that, during a trial-and-error learning task, patients with Parkinson's disease were impaired in the selection of the appropriate dimension from a multi-dimensional compound stimulus (an additional study suggested that the impairment reflected the inability to attend to the individual components of the stimuli rather than simply an impairment of reinforcement-driven learning). This result would appear to be in line with the finding of Shohamy, Myers, and Gluck (2004), which suggested that individuals with Parkinson's disease failed to modify their response strategy during a classification task involving multi-dimensional stimuli. Instead, relative to controls, these individuals persisted with sub-optimal single-cue strategies.

The role of dopaminergic function in such processes has also been demonstrated. For example, using a task-switching paradigm Cools, Barker, Sahakian, and Robbins (2003) showed that levodopa medication remediated the attentional *in*flexibility of Parkinson's disease patients: relative to their medicated state, these individuals demonstrated elevated switch costs when changing between the letter and digit naming tasks (this was only observed in the absence of external cues of the task switch requirement). Evidently, this would appear to implicate dopaminergic function in the attentional component of tasks such as the one just described.

The processes mentioned above – broadly concerned with the 'management' of cognitive resources – are considered to reflect *executive control*, a common feature in a number of influential theories of working memory and attention (e.g., Baddeley & Hitch, 1974; Norman & Shallice, 1986; Posner & Petersen, 1990). For example, a key element of the multi-component model of working memory is the *central executive* (Baddeley, 1986; Baddeley & Hitch, 1974). This system is thought to be engaged in a variety of processes including the co-ordination of dual-task performance, selective attention (and inhibition of irrelevant information), manipulation of information in long-term memory, and the ability to switch between different response strategies (Baddeley, 1996). However, although the central executive has proved to be a useful concept, evidence from both behavioural (e.g., Miyake et al., 2000) and neuro-imaging data (e.g., Collette & Van der Linden, 2002) appears to suggest that this component of working memory may more accurately reflect a collection of inter-related control processes rather than a single, albeit multi-faceted, system.

Executive control is also seen as an important, and relatively independent, component of the attention system (Posner & Petersen, 1990). The attentional *executive control* network, considered to represent the Supervisory Attentional System (Norman & Shallice, 1986), is thought to be engaged in conflict situations (e.g., inhibiting pre-potent responses, error monitoring, decision making etc) and can therefore be involved in a wide variety of cognitive functions. Interestingly, the neuro-anatomical areas implicated in this network (anterior cingulate cortex and lateral prefrontal cortex) are associated with the mesocortical dopamine system and evidence from molecular genetics also connect executive attention with this neurotransmitter (Fan, Fossella, Sommer, Wu, & Posner, 2003; Fossella et al., 2002).

A recent study by Wang et al. (2005) found that patients with schizophrenia demonstrated particular deficits on cognitive tasks specifically associated with executive control. Schizophrenia is a psychological disorder long associated with (hyper-)dopaminergic function, initially based upon the findings from the use of neuroleptics (e.g., Krieckhaus, Donahoe, & Morgan, 1992; Snyder, 1981, cited in Rosenhan & Seligman, 1995) and although somewhat problematic, the dopamine hypothesis still appears to be prominent in models of the disorder (Duncan, Sheitman, & Lieberman, 1999). A central feature of positive schizophrenia symptomatology is disordered thought. This can be characterised by attentional impairments, for example, the inability to selectively 'filter' only relevant stimuli for further processing which in turn may give rise to 'over-inclusive' thinking and increased cognitive distractibility by irrelevant information (Rosenhan & Seligman, 1995). Accordingly, schizophrenia has been associated with a general level of cognitive impairment (Heinrichs & Zakzanis, 1998).

Recent work by Kapur (2003) has developed a framework for connecting the phenomenological experience of psychosis in schizophrenia with the underlying neurobiology of the disorder: the role of dopamine being paramount. According to Kapur, psychosis is considered to reflect a state of *aberrant salience*; the misattribution of the motivational value or importance towards information in the 'mind' of the perceiver (i.e., thoughts and events). Hence, phenomenological features of the disorder (e.g., delusions and hallucinations) are thought to arise as a result of experiencing ostensibly unimportant (i.e., motivationally neutral; neither attractive nor aversive) events as salient. Dopamine has been implicated as a fundamental component in the determination of the motivational salience of stimuli (e.g., Berridge & Robinson, 1998, 2003). Hence, it is suggested that it is the dysregulation of the dopaminergic system in schizophrenia, and subsequent abnormal allocation of motivational salience to non-significant stimuli, that gives rise to the phenomenological experiences of psychosis. The association between this disorder, dopaminergic function and deficits in cognitive function (especially involving the filtering of irrelevant information) will be discussed later in the chapter.

Attention Deficit Hyperactivity Disorder (ADHD) is a neuro-developmental disorder that is also thought to relate to dopaminergic function. In common with schizophrenia, this hypothesis is supported by the finding that medications beneficial in the treatment of the disorder are associated with dopaminergic neurotransmission (e.g., Methylphenidate-Ritalin, Nieoullon, 2002). This proposition is further supported by evidence from molecular genetic studies (e.g., Swanson et al., 2000). As the title suggests, a core component of the disorder concerns an attentional deficit, particularly related to sustained attention (Nieoullon, 2002) and is demonstrated in standard cognitive tasks, for example by increased Stroop interference (Lansbergen, Kenemans, & van Engeland, 2007).

It would seem clear that evidence from neuropsychological research and associated data demonstrate a plausible link between dopaminergic function and cognition including attentional processes. While the exact nature of dopamine's role in attentional processing is still a matter of debate, there is evidence that impaired dopaminergic function is associated with decreased attentional focus and elevated distractibility (Nieoullon, 2002). A variety of methods have been utilised to explore the role of dopamine in such cognitive processes. In an extensive review of molecular imaging of the dopaminergic system, Cropley, Fujita, Innis, and Nathan (2006) considered a variety of research evidence supporting the role of dopaminergic systems in a range of cognitive function, including attention. For example, reduced Stroop interference in medicated (male) schizophrenia patients was associated with (dopamine-related) presynaptic activity in the (dorsal) anterior cingulate (McGowan, Lawrence, Sales, Quested, & Grasby, 2004, cited in Cropley et al., 2006). Monchi, Hyun Ko, and Strafella (2006) provide a specific example using PET in which an increase in striatal dopamine release was related to the planned switching of attention from one feature of a stimulus to another (set-switching)[1].

Dreisbach, Muller and colleagues (Dreisbach et al., 2005; Muller et al., 2007) explored attentional control, in terms of set-shifting flexibility, in relation to dopamine gene polymorphisms, spontaneous eye-blink rate and gender. These studies compared performance on two types of task. In both tasks, participants were instructed to make categorisation responses based upon the relevant stimulus feature (e.g., grey letter) and ignore the remaining feature (e.g., white letter). In the *learned irrelevance* condition, instructions were given which indicated that participants must switch to responding based upon the value of the previously irrelevant stimulus feature (i.e., white letter) while the new irrelevant feature is now presented in a previously unused colour (e.g., black letter). In contrast, in the *perseveration* condition, instructions are given which indicated that participants must switch to responding based upon the stimulus presented in the new, previously unused colour (e.g., black letter) while ignoring the previously relevant stimulus feature (i.e., grey letter). In the perseveration condition, it was proposed that increased 'cognitive' flexibility would facilitate the switch to the novel stimulus feature as well as disengagement from the previously relevant stimulus, thereby leading to decreased 'switch-costs' (i.e., less reaction-time interference). In contrast, increased cognitive flexibility in the learned irrelevance condition was suggested to result in greater switch-costs, as participants would be more distracted by the novel yet *irrelevant* stimulus feature.

In light of previous research Dreisbach, Muller and colleagues (Dreisbach & Goschke, 2004; Dreisbach et al., 2005; Muller et al., 2007) suggested that performance on these tasks may be modulated by dopaminergic function; increased dopamine levels (in the prefrontal cortex) may facilitate cognitive flexibility that, in addition, may increase distractibility. The primary measure of dopaminergic function applied in the studies was spontaneous eye-blink rate (EBR). The proposal that EBR is a valid indicator of dopaminergic function is discussed by Dreisbach et al. (2005) and will not be presented here, suffice to say that it would appear that lower EBR is associated with decreased levels of dopaminergic activity, thus, greater EBR was predicted to be associated with enhanced cognitive flexibility.

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[1]In this instance, and throughout the remainder of the thesis, the term 'stimulus' refers to a single item, for example a visual representation of a playing card, which may be presented to a participant during a task (e.g. via a computer monitor). The 'features' or 'dimensions' of a stimulus refer to the elements that comprise the 'stimulus' and distinguish it from other stimuli within the set (i.e. physical elements that do not vary, a white rectangular background for the playing cards for example, are not considered features or dimensions). For example, if a set of 4 different playing cards each contain a single element; either a red or blue, square or circle. The features/dimensions of the playing cards are therefore *colour* – red or blue, and *shape* – circle or square. Consequently, the usage of terms such as feature, stimulus etc may be somewhat distinct from their usual application in other areas of cognitive research.

In accord with their predictions, Dreisbach et al. (2005) reported that participants with higher EBR showed greater cognitive flexibility (decreased switch costs on the perseveration task) in addition to greater distractibility (greater switch costs in the learned irrelevance condition). Furthermore, the study also reported that a dopaminergic gene polymorphism (D4 dopamine receptor exon III) appeared to influence the magnitude of the cognitive flexibility effect on task performance (the error cost appeared greater for participants with D4/7 cf. D4/4 allele).

In the subsequent study (Muller et al., 2007), the positive association between EBR and cognitive flexibility was replicated although it appeared the differences in switch costs were greater for men than women. However, a significant association with the DRD4 gene polymorphisms was not observed. Nonetheless, this replication would appear to provide support for the association between dopaminergic function and cognitive flexibility in the manipulation of attentional processes involved in set-switching.

The two tasks just described, considered performance in the situations where selective attention toward a novel stimulus (feature) was either beneficial (perseveration condition) or detrimental (learned irrelevance condition). All other factors being equal, a novel stimulus may be considered to be of high salience. The processing of stimulus salience is related to the allocation of one's limited attentional resources; observation of a highly salient stimulus would require that increased resources are devoted to the stimulus, whereas stimuli of a lower salience would receive less attention.

Though still a matter of debate (Ungless, 2004), research has suggested a role of the dopaminergic system in the signalling of various forms of stimulus saliency (Franken, Booij, & van den Brink, 2005; Young, Moran, & Joseph, 2005; Zink, Pagnoni, Chappelow, Martin-Skurski, & Berns, 2006). Using fMRI, Zink et al. (2006) observed that activity in the human striatum was proportional to stimulus saliency. The degree to which a novel sound interfered with current attentional focus (measured by increased response times) was considered a measure of the saliency, and this was found to be related to increased activity in the striatum (specifically the caudate nucleus). In their review of the involvement of dopamine in conditioning and latent inhibition, Young et al. (2005) suggest that the modulation of saliency information is one of a number of roles of dopamine release (in the nucleus accumbens). Additionally they conclude that a more general definition for the function of this system could be the "broadening of attention to take in potentially conditionable stimuli, which have previously been devalued" (Young et al., 2005, p. 963).

Dopamine and Extraversion

Given the previous research exploring the relationship between extraversion and attentional performance, and the research just discussed, a link of between this personality trait and dopaminergic function would not be unanticipated. Indeed, there are many references in the literature proposing an association between this particular neurotransmitter and extraverted and related types of behaviour (e.g., see Rammsayer, 2004, for a brief review of the extraversion-dopamine hypothesis). Some specific examples will be considered below. In the most part, however, this connection has been made on the basis of a more established role of dopamine function; the signalling of reward.

Berridge and Robinson (2003) distinguish three components of reward: motivation, learning and affect. Dopamine has been implicated to some extent in all of these components, particularly the learning and motivational components (e.g., Arbuthnott & Wickens, 2007; Holroyd & Coles, 2002; Salzman, Belova, & Paton, 2005). For example, one functional role of dopamine is thought to be concerned with reward-based learning (Schultz, 1998, 2006). Crucially, in addition to primary 'reinforcement' effects, phasic dopamine activity is linked to the reward-prediction-error (RPE) component; increased activity occurs in response to an unexpected reward (a positive RPE), decreased activity occurs when a predicted reward is not presented (a negative RPE) – and the dopaminergic response is neutral when a predicted reward occurs (zero RPE). Accordingly, the RPE may serve as a 'teaching' signal which guides the learning of associations between stimuli, response and outcome. Furthermore, as considered further below, dopamine activity has also been associated with motivational effects; increasing the incentive to engage in a particular behaviour because of prior association with appetitive outcomes (Wise, 2004). Thus, it may be expected that individual variation in the functioning of the dopaminergic system could have effects on behaviour associated with reward (in terms of both motivational and learning components).

Depue and Collins (1999) characterised extraversion as comprising of two components: interpersonal engagement and impulsivity. However, Depue and Collins questioned the homogeneity of impulsivity as a unified trait, and in particular the assertion of impulsivity as a central feature of extraversion. They also noted that several trait theorists classified extraversion and impulsivity as distinct constructs. However, as will be discussed later, the relationship between these components of personality, in terms of both their trait validity and proposed underlying neurobiology, is a complex issue.

The interpersonal component was further characterised into two subcomponents; affiliation and agency. Affiliation can be considered as a measure of sociability, reflecting interpersonal style and descriptors such as 'warmth' and 'outgoing'. Agency on the other hand encompasses the motivational nature of extraversion, relating to constructs such as dominance, leadership and ambition. It is this aspect of extraversion in particular which they related to the functioning of neurobiological system of positive incentive motivation. Furthermore, they attributed variation in the functioning of this system to be the largest cause of variance in individual differences in levels of extraversion.

Positive incentive motivation refers to the activation induced by signals of positive incentivising stimuli, or signals of reward. Goal directed behaviour is subsequently modulated by the enhanced motivational state produced. Depue and Collins (1999) describe this motivational structure as the behavioural facilitation system (BFS), as it is concerned with the modification of behaviour towards the motivationally salient stimuli. A more reactive BFS is therefore related to a greater tendency of 'approach' type behaviours and experience of the associated motivational-emotional states. Hence, extraversion is thought to be the higher-order personality trait which reflects the variation in the functioning of this motivational system (BFS). As previously discussed the dopaminergic system is thought to play a key role in processes related to reward and motivation. In accordance with this view, Depue and Collins (1999) propose that the BFS, and hence (particularly) the agency facet of extraversion, is related to the functioning of the mesocorticolimbic dopamine system. Clearly then this prescribes that a key aspect of extraversion relates to dopaminergic function.

At the time of their proposal Depue and Collins (1999) noted the lack of empirical data with which their model of extraversion and dopamine could be assessed. However, promising studies exploring the relationship between this trait and dopaminergic function are beginning to appear. Support for a link between extraversion and reactivity to reward was shown by Cohen, Young, Baek, Kessler, & Ranganath (2005). Participants performed a simple decision making task in which the amount of monetary reward received at the end of each trial varied. The participants were in an fMRI scanner while performing the task. Although extraversion was unrelated to behavioural performance, the study found that when receiving rewards extraversion was positively related to increased activity in brain regions associated with reward processing (i.e., the magnitude of activation differences between reward/non-reward trials was greater in extraverted individuals). A second study suggested that this was related to the evaluation, as opposed to the anticipation, of the reward. The neural regions implicated (orbitofrontal cortex, nucleus accumbens and amygdala) were in accord with the proposed neurobiological model of extraversion put forward by Depue and Collins (1999).

Two recent studies also appear to establish an association between extraversion and dopaminergic function. Using a pharmacological intervention, Wacker, Chavanon, and Stemmler (2006) demonstrated that (agentic) extraversion modulated performance (reaction time) on a working memory task. Introverts had longer reaction times than extraverts in the placebo condition, whereas the D2 antagonist sulpiride reversed this pattern of performance. Additionally using EEG, a corresponding interaction between extraversion and the dopaminergic manipulation was found in relation to theta activity across the frontal and parietal regions. A similar study by Chavanon, Wacker, Leue, & Stemmler (2007) also demonstrated a dopaminergic link between (agentic) extraversion and working memory and showed that sulpiride again reversed the pattern of association between extraversion and working memory load as assessed by EEG measures of (low-band) alpha activity.

Impulsivity

Biological Basis of Trait Impulsivity

Reinforcement Sensitivity Theory (RST, Gray, 1970, 1981; Pickering et al., 1997) is an influential personality theory which proposes that specific personality traits arise from differences in the functioning of basic emotional-motivational systems. The Behavioural Approach System (BAS) is one such system. In the revised form of RST it is proposed that the BAS is responsive to all stimulus inputs related to reward (Gray & McNaughton, 2000). Engagement of the BAS by appropriate environmental conditions (i.e., the presence of appetitive stimuli) is thought to have an effect on the motivational (increased arousal and approach behaviour toward the appetitive stimuli) and emotional (increased positive affect) state of the individual. Inter-individual variation in the functioning, or reactivity, of this system is thought to reflect individual differences in reward sensitivity. It is therefore suggested that individuals with a more reactive BAS are more responsive to inputs related to reward, and would therefore experience greater levels of motivational and emotional activation relative to individuals with lower BAS reactivity (Pickering & Gray, 2001).

Gray proposed variation in BAS reactivity to be the causal basis of individual differences in a major personality trait and, rather speculatively, suggested that the trait was impulsivity (for a review of RST & personality see Corr, 2004; Smillie, Pickering, & Jackson, 2006). This suggestion arose from a critique of Eysenck's biologically based model of personality, with its orthogonal traits of extraversion and neuroticism (Gray, 1970). Gray suggested that the BAS was more congruent with underlying physiology, and that extraversion and neuroticism reflected variation in the combined functioning of the BAS and a second emotional-motivational system; the Behavioural Inhibition System (BIS). In the original presentation of RST, the BIS was proposed to be responsive to (conditioned) signals of punishment, and therefore reflected punishment sensitivity. The BIS was considered to be the causal determinant of anxiety and in common with the BAS, thought to relate to both the emotional (i.e., experience of anxiety) and motivational (e.g., anxiety related avoidance behaviours) aspects of behaviour. Extraversion was considered to reflect the balance of BAS/BIS sensitivities, a more reactive BAS (cf. BIS) related to increased trait extraversion. In contrast, Esyenck's neuroticism factor was thought to relate to the joint sensitivities of the two systems; with higher overall levels of reactivity related to neuroticism (cf. stability).

Despite a divergent view on the relationship to specific proposed personality traits, similarity between the nature of the BAS and the BFS, described by Depue and Collins' (1999) paper, is clear. An additional parallel can be seen in the proposed underlying neurobiology of the BAS, considered to be predominantly mediated by dopaminergic neurotransmission. Likewise, the theory allows testable hypotheses; if impulsivity reflects BAS reactivity, it should be predictably related to performance on BAS engaging tasks. For example, BAS variation may impact on reward contingent learning or conditioning through motivational and learning effects induced by rewarding stimuli.

Pickering and Gray (2001) reviewed the evidence for impulsivity as an index of BAS reactivity through the consideration of data relating reinforcement learning and psychometric measures of impulsivity (and related traits). It was noted that there existed evidence for a relationship between dopaminergic function and both extraversion and impulsivity; suggestive of the possibility that the functioning of this neurobiological system may underlie more than one personality dimension. The determination of the true BAS-related trait is further complicated by the multi-faceted nature of the impulsivity construct (e.g., Dickman, 1990; Leshem & Glicksohn, 2007; Miller, Joseph, & Tudway, 2004; Whiteside & Lynam, 2001). For example, Dawe, Gullo, and Loxton (2004) propose two factors of impulsivity; *rash impulsiveness*, reflecting the behavioural tendency to act without due deliberation, planning or foresight, and *reward sensitivity*, a more BAS-like feature reflecting an individual's reactivity to signals of reward. The likely distinction between reward reactivity (cf. sensitivity) and trait impulsivity (cf. rash impulsiveness), as well as the potential association between both facets and BAS function, was further highlighted by Smillie, Jackson and Dalgleish (2006). Their study found that while 2 of the 3 subscales (Drive and Reward-Responsiveness) of the most popular measure of (trait-)BAS function (The BIS/BAS scales, Carver & White, 1994 - see chapter 3) appeared to reflect reward reactivity, the third subscale (Fun Seeking), in addition to reward-reactivity, was also associated with impulsivity. Accordingly, it has been suggested that, while undoubtedly related, the constructs of impulsivity and BAS are best conceived as distinct entities; the BAS encompassing a broader range of behavioural outcomes (Quilty & Oakman, 2004).

Furthermore, it appears that facets of impulsivity (and BAS measures) often overlap with measures of extraversion (Diaz & Pickering, 1993; Smillie & Jackson, 2006; Smillie, Jackson et al., 2006; Smillie, Pickering et al., 2006). For example, Smillie and Jackson (2006) considered the conceptual similarity of Dickman's (1990; 1993) *functional impulsivity* (reflecting more positive attributes of impulsivity – e.g., a drive to get things done quickly) and the function of the BAS. In contrast with, and separate from, *dysfunctional impulsivity* (the more typical conception of rash, reckless impulsive behaviours), which appeared to be related to Eysenck's psychoticism measure and more typical 'trait impulsivity' measures, Smillie and Jackson found functional impulsivity to be associated with measures of extraversion (and purported BAS measures). Thus, given the multi-faceted nature impulsivity (i.e., the conceptual distinction between reward-sensitivity/reactivity and rash/trait impulsivity), together with the potential overlap between measures of extraversion, impulsivity and reward-sensitivity, determination of the true BAS-related personality trait remains unclear. However, the concept of a BAS-related trait may retain a degree of utility and in the following discussion the focus is upon evidence from the literature in which BAS function was assessed by trait impulsivity (and related constructs).

In their review, Pickering and Gray (2001) concluded that empirical evidence for the association between BAS-related traits and learning performance was somewhat contradictory and inconclusive. Consequently, the association between BAS function and specific personality traits was uncertain. However, the lack of appropriate research paradigms was put forward as one causal factor in these inconsistent findings. Consideration of results obtained from the simulation of BAS related learning effects, using a biologically-constrained neural network model, suggested that difficulties in obtaining significant correlations between, for example, trait impulsivity and measures of BAS mediated behavioural outcomes were likely in many experimental designs.

To reiterate, one theoretical prediction from RST suggests that BAS function may impact upon behaviour that involves the processing of reward. Hence, in situations where positive reinforcement drives the learning of new stimulus-response associations, an individual with a more reactive BAS may learn better (e.g., more quickly) relative to an individual with a less reactive BAS. In what Pickering and Gray (2001) describe as possibly the best examination of the relationship between BAS related traits and learning, Ball and Zuckerman (1990) used a concept learning task to explore personality differences and sensitivity to reinforcement. The task in this study employed stimuli that varied across 8 distinct dimensions. The dimensions of the stimuli were binary valued (e.g., each stimulus contained one of two letters – 'T' or 'X', letters were either small or large, surrounded by a single or double border, either black or white, underlined with either a dashed or solid line etc). On each trial of the task, two stimuli were presented, one being the target with the other a distractor. The target stimulus was determined by the value of two of the dimensions (e.g., size and letter, hence if a large letter 'T' was the target, the distractor stimulus was a small, letter 'X') with the remaining stimulus dimension values being irrelevant (the target and distractor stimuli did not share any dimension values, i.e., the complementary value of each dimension which comprised the target stimulus was used for the distractor. For example, if the target stimulus – a large letter 'T', was presented in white font surrounded by a single border, the distractor stimulus – a small letter 'X', would be presented in black font surrounded by a double border etc).

In essence this task involved learning to focus on the relevant dimensions and their associated values in order to distinguish between, or categorise, a target and non-target stimulus presented simultaneously. To explore the relationship between reinforcement and personality, four different feedback conditions were employed, formed from two between-participant factors. Therefore, dependent on the second factor of reward- or punishment-feedback only, two verbal (right or wrong) and two monetary (win or lose money) reinforcement conditions were created. Participants' learning was indexed by the number of trials taken to reach a criterion of 5 correct target stimulus selections. When this criterion was reached a non-reversal rule switch occurred, to which the participants were not explicitly alerted, whereby two previously irrelevant dimensions became relevant in order to discriminate the target stimulus. With reinforcement suitably configured to reflect the switch of rule, trials again continued until the learning criterion was reached.

Participants in this study had been selected for their extreme scores (those from the upper and lower deciles) on Zuckerman's Sensation Seeking Scale (SSS, Zuckerman, 1979). The relationship of this scale with major personality dimensions will be discussed briefly in due course, however, impulsivity and sensation seeking are thought by many personality researchers to reflect similar, possibly overlapping constructs. A key finding in this study was that those participants in the high scoring SSS group (i.e., greater sensation seeking) took fewer trials to reach the criterion, i.e., they learned the task quicker, than the low scoring group. This result would therefore appear to provide support for a BAS trait being related to superior learning in the predicted manner. Pickering (2004) also found similar positive relationships between (arguably) BAS-related traits and enhanced learning on two comparable categorisation tasks (this will be discussed further in the following chapter).

Crucially, however, one of the reinforcement manipulations (positive- versus negative-only feedback) in Ball and Zuckerman's task (1990), failed to show the expected interaction with the personality. Superior performance for the high sensation-seeking (high BAS reactivity) group was predicted to occur only in the positive-feedback condition (thought to involve the BAS) and not the punishment-feedback condition (where BAS involvement is not predicted). However, the same relationship between the BAS-related trait and performance was seen in both conditions, in fact, a sub-grouping of high scorers on Eysenck's Psychoticism scale (EPQ-P: Eysenck & Eysenck, 1975), another Impulsivity-related trait measure (Pickering & Gray, 2001), actually performed better in the punishment condition. Critically, this affords the prospect that the BAS may influence learning, or other cognitive abilities, through mechanisms other than those related to reward processing and positive reinforcement.

In line with this, Pickering (2004) also suggested that the relationship observed between BAS-related traits and superior learning on two categorisation tasks (discussed further in the following chapter) may also have been due to other mechanisms (possibly enhanced hippocampal/memory function) unrelated to reinforcement learning. Ball and Zuckerman (1990) put forward two means through which the superior learning performance of the high sensation-seeking group may have occurred. Firstly, it was suggested that the high sensation seeking group may have performed better on these tasks (learning to correctly categorise the targets more quickly) by adopting a more risky response strategy. Secondly, citing previous work by Martin (1985), that found high, compared to low sensation seekers, were more efficient at focusing their attention in an embedded figures task, Ball & Zuckerman (1990) suggested that such an advantage in the ability to focus attention may help in selecting the salient aspects of a complex stimuli. The increased ability to focus attention may facilitate learning in the present situation wherein the successful categorisation of the target requires attention to the critical features of the stimuli, which in this case are merely a subset of all stimuli features (i.e., values on 2 of 8 dimensions).

Given the research described earlier in the chapter, describing an association between attention and another supposedly dopaminergic personality trait (extraversion), this second proposal of a relationship between (a trait related to) impulsivity and attentional function is worthy of note. Developing the idea that the BAS (and hence related traits) might mediate learning performance through mechanisms other than those connected to reinforcement sensitivity, Pickering & Gray (2001) suggested that it is possible that (one aspect of) the BAS may be involved in the processing of stimulus saliency.

Attention and Impulsivity

Despite the caveat mentioned above, regarding the true nature of the BAS-related trait, research exploring the relationship between BAS function (as indexed by trait impulsivity) and attentional processes warrants further discussion. Reviewing previous work on impulsivity and learning, Avila and Parcet (2002) surmised that a more reactive BAS leads to increased goal-directed attention. Hence, more impulsive (i.e., high cf. low BAS) individuals exhibit an over-focusing of attention towards goal-related stimuli and consequently are less able to monitor additional information, which in turn may lead to a decreased likelihood of response modulation. However, their study suggested that this style of cognitive processing was a more general feature of individuals with a more reactive BAS, not necessarily contingent upon reward related processing. In addition, the study attempted to separate two distinct modes of attentional focus: spatial and semantic. Previous studies had confounded these two possible sources of interference on target detection speed (i.e., with a high association between prime and target location, target detection speed is facilitated when the target appears in the expected, rather than unexpected, location. The deficit in the unexpected condition could be due to impairment in the switching of spatial attention, or could be more cognitive in nature, and related solely to the expected prime-target association but not in terms of spatial location).

To explore these issues, Avila and Parcet (2002) modified the general paradigm so that the prime-target association was purely semantic (i.e., not related to spatial location as all stimuli were presented centrally). In addition, the tasks did not involve a reward based component, to allow the assessment of non-reward based attentional processing. The two experiments demonstrated an increased priming effect for more impulsive individuals, suggesting that such individuals develop greater expectancies of the semantic relationships between prime and target. This result was observed only in the condition when the target items were sufficiently delayed after the primes, thus allowing 'conscious', rather than solely 'automatic', processing of the prime. The authors suggested that this indicated that expectancies are manifest in 'top-down' processes, and that subsequently differences between high and low impulsives are more likely when considering conscious processing.

In a subsequent study, Poy, Eixarch, and Avila (2004) found that higher levels of impulsivity were also related to an enhanced ability to modulate spatial attention. Reaction times to targets in unexpected locations were less slowed in more impulsive individuals, suggesting that they were faster to shift, and more able to disengage attention from the expected location when the target was presented elsewhere. The BAS is thought to play an important role in the processing of goal relevant stimuli. Hence, after the presence of a goal-relevant cue, impulsive individuals (i.e., with a more reactive BAS) are facilitated in the detection of a target stimulus even when it appears in an unexpected location. This result was again observed only when the temporal interval between cue and target was sufficient for conscious processing (of the cue). Additionally, the effect was not observed when cues were presented peripherally. Together with the previous study, this demonstrates that impulsivity may influence a variety of conscious, attention related processes including the development of expectancies between environmental cues and goal related stimuli and increased modulation of (spatial) attention.

Attentional style and impulsivity has also been considered in a number of other studies. Using a visual search paradigm Dickman (2000) tested the relationship between 'dysfunctional impulsivity' and the effects of arousal and attentional processes. Dysfunctional impulsivity is thought to reflect the detrimental aspects of acting without sufficient consideration of future consequences and is compared with 'functional impulsivity' that reflects rapid response tendencies which may be beneficial in certain circumstances (e.g., where 'quantity' over 'quality' may be a successful strategy). The study examined Dickman's 'attentional-fixity' theory (Dickman, 1993, 1996) in which impulsivity is related to individual differences in the ability to modulate attention. In line with the findings of Poy et al. (2004), this theory proposed that the attentional fixation of low-impulsives is less easily switched compared to high-impulsives, who in contrast are able to switch the focus of their attention more easily. Increased arousal was predicted to facilitate high-impulsives ability to fixate, whereas the complementary effect would be seen for the ability in low-impulsives. The interaction between arousal and impulsivity was predicted only to occur on a task that required attentional switching. The results supported the predictions of the theory, and further demonstrate that differences in impulsivity can lead to differences in task performance through their association with attentional processes.

Dysfunctional impulsivity has also been related to another mode of attentional function. Franken, Nijs, and Van Strien (2005) found that more impulsive individuals exhibited increased levels of pre-attentional processing. This study found ERP differences related to the attentional processing of salient, yet irrelevant, auditory stimuli. These were observed in the absence of any behavioural response. In contrast to the literature considered above, which implicated the influence of impulsivity on attention at the conscious (top-down) level, this study raises the possibility that trait impulsivity can also potentially influence automatic (bottom-up) attentional processing.

Interestingly, research exploring cognition and the effects of Parkinson's disease medication has further demonstrated an association between impulsivity and attentional function. As discussed previously, Cools et al. (2003) showed that levodopa medication remediated the exaggerated costs of task-switching observed in Parkinson's disease patients while 'off' medication. Consequently, it was suggested that the medication enabled increased attentional flexibility when required to alternate between two tasks. However, on a separate decision-making task it was also shown that, relative to their off medication performance, these individuals demonstrated more 'impulsive' betting strategies when given the dopaminergic medication. Consequently, while beneficial for performance on the task requiring cognitive flexibility, the medication also appeared to increase impulsivity. This finding would seem to support the association between higher levels of impulsivity and attentional flexibility while concurrently supporting the involvement of the dopaminergic system in impulsive behaviours and attentional processes.

Schizotypy

Atypical dopaminergic function has been widely considered to play a major causal role in the psychopathology of schizophrenia and was briefly discussed earlier in the chapter. Key aspects of the observed disruption in cognitive function concern the impairments related to information processing and attention. For example, Frith's (1979, cited in Corr, 2006) 'filter deficit' theory suggested that positive schizophrenia symptomatology resulted from a defect in the mechanism which governs the access to, and contents of, 'consciousness'. Consequently, one hypothesis is that this mechanism may be crucially involved in processes such as selective attention; which may be dependent on active inhibition of irrelevant information (Peters, Pickering, & Hemsley, 1994). Deficient inhibitory mechanisms may thus provide a plausible explanation of positive schizophrenia symptoms such as hallucinations (e.g., arising from misinterpretation of information that would not normally be attended) and delusions (e.g., arising from the attempted incorporation of information that was not selectively filtered from consciousness).

Furthermore, it would appear possible to assess the validity of such models with the use of appropriate cognitive behavioural paradigms. For example, negative priming tasks may be particularly suitable for the exploration of cognitive inhibition (Tipper, 2001). Negative priming refers to interference, usually demonstrated by the slowing of participants' reaction times, when asked to respond to a stimulus (or stimulus feature) that has previously been ignored as a distractor (Tipper, 2001). Consequently, it is predicted that deficient inhibitory mechanisms would result in an observed reduction in negative priming effects (however, as will be discussed below, inferring reduced inhibition from reduced negative priming is not without issue). In support of the proposal that schizophrenia is associated with impairments in selective attention, an association between reduced negative priming and positive schizophrenia has indeed been demonstrated (e.g., Peters et al., 2000). Crucially, the fact that *reduced* negative priming was associated with schizophrenia enables this specific effect to be distinguished from a more general level of cognitive impairment (i.e., reduced negative priming actually reflects *faster* task performance).

Latent Inhibition

Latent Inhibition (LI) is another phenomenon widely considered to involve attentional processes and regarded as a key paradigm in the investigation of schizophrenia and cognition. Relative to the learning of an association between a novel stimulus and outcome, LI refers to the impairment in learning to attribute a stimulus (or stimulus component) as salient (e.g., associated with an outcome), when in a previous phase the stimulus was seen to be irrelevant (un-associated with any outcome – i.e., inconsequential and hence of low saliency). Lubow (e.g., 2005) suggests that this inhibition is an adaptive mechanism which serves to protect limited attentional resources, and hence explains the relative importance given to a novel stimulus as opposed to a stimulus which was previously (novel) attended, and which has been learned to be of low salience.

Latent inhibition can therefore be seen as a process likely to engage selective attention, reflecting the ability to appropriately apportion interest to stimuli in light of what is already known (i.e., an old irrelevant stimulus can receive decreased, while an old but salient stimulus may require increased, levels of attention. A novel stimulus may need investigation, and require increased attention etc). The LI phenomenon is widely observed in both animals and humans (Lubow & Gewirtz, 1995). An important finding concerns the effect of dopaminergic drugs (Moser, Hitchcock, Lister, & Moran, 2000). It has been demonstrated that amphetamine attenuates, whereas antipsychotics exacerbate, the degree of LI observed and thus strongly implies an important role of dopaminergic systems in LI (Moser et al., 2000). Indeed, Young et al. (2005) suggest that dopamine release in nucleus accumbens is critical in the reversal of LI; and this release corresponds, in their view, to learning to re-attribute salience to a previously non-salient stimulus.

As mentioned above, schizophrenia has long been associated with dysfunctional selective attention, and dopaminergic function. This was reflected in a study by Baruch, Hemsley, and Gray (1988; cited in Gray & Snowden, 2005) who found decreased levels of (auditory) LI in patients with (acute) schizophrenia. Attenuated LI in this instance actually equates to better performance (i.e., fewer trials needed to *re*-associate the previously irrelevant stimulus with a new, salient, outcome); hence the patients with schizophrenia actually performed better than healthy controls. This is therefore an important finding as it demonstrates features of cognitive functioning in schizophrenia patients in circumstances which are able to delineate differential (and enhanced) performance, distinct from the more typical pattern of general cognitive impairment. Furthermore, studies demonstrating that reduced LI can also be induced in healthy participants, for example with the administration of low doses of amphetamine (e.g., Gray, Pickering, Hemsley, Dawling, & Gray, 1992; Swerdlow et al., 2003), would also appear to support the role of dopaminergic function in schizophrenia.

<u>Schizophrenia, Schizotypy and Cognition</u>

It is considered by many researchers that the symptoms and characteristic behaviours of schizophrenia can be observed across the general population and, consequently, that variation upon this dimension of psychotic-like symptoms can be viewed as a continuum of behavioural tendencies (e.g., Johns & van Os, 2001). Consequently, exploration of cognitive function and schizophrenia has been additionally pursued through the consideration of this personality trait, namely schizotypy, thought to reflect schizophrenia-like symptomatology across the general (healthy) population. Indeed, there now exists a wide variety of literature demonstrating the similarity between schizophrenia patients and individuals scoring high on schizotypy in their performance on cognitive tasks (e.g., Burch, Hemsley, Corr, & Gwyer, 2006; Peters et al., 1994; Tsakanikos, 2004, 2006).

In common with schizophrenia, this trait is generally conceived as a multi-dimensional construct. A popular measure of schizotypy, the Oxford-Liverpool Inventory of Feelings & Experiences (OLIFE, Mason, Claridge, & Jackson, 1995), has 4 factors three of which (positive – unusual experiences, negative – introvertive anhedonia, and cognitive disorganisation) appear to relate directly to symptoms of schizophrenia. However, the fourth factor, entitled Impulsive-nonconformity, is considered by some (e.g., Pickering, 2004) to be distinct from the preceding 3 factors as it does not directly reflect the symptoms and behaviours observed in schizophrenia. (In fact this factor may be more aligned with a cluster of traits reflecting impulsivity and asocial behaviour. This issue will be discussed in more detail in chapter 3).

Thus, the schizotypy construct enables the useful comparison of the performance of healthy individuals scoring highly on schizotypy with the performance (or theorised performance) of patients with schizophrenia. For example, early work by Beech, Claridge and colleagues (Beech, Baylis, Smithson, & Claridge, 1989; Beech & Claridge, 1987) employed the negative priming paradigm to assess cognitive inhibition in healthy individuals (assessed by self-report schizotypy measures). As predicted from the literature pertaining to schizophrenia and impaired inhibitory mechanisms, schizotypy was found to be significantly associated with reduced negative priming (Beech & Claridge, 1987). The association between schizotypy and impaired inhibition (as indexed by reduced negative priming) was supported by later work (although this appeared to be confined to early processing effects, i.e., occurring only when presentation times were very short) which additionally found that this trait was unrelated to (Stroop) interference effects (Beech et al., 1989).

However, recent work has failed to replicate the findings of Beech, Claridge and colleagues in studies involving measures of schizotypy (e.g., Moritz & Andresen, 2004). Furthermore, it has been suggested that the previous results may have been affected by specific experimental conditions (brief presentation times and backward masking) and thus the mechanism(s) underlying the observed reduction in negative priming may not have involved impaired inhibition and instead reflect impairments in early visual processing abilities (Moritz & Andresen, 2004; Moritz et al., 2001). Additionally, evidence supporting alternative accounts of negative priming effects also appear to provide a challenge for the impaired inhibition hypothesis (Tipper, 2001). For example, recent neuro-imaging data reported by Egner and Hirsch (2005) found that negative priming was related to activation in brain areas associated with episodic memory retrieval which, they argued, supported episodic retrieval accounts of the phenomena (e.g., Neill, 1997).

In parallel with research on negative priming, LI has also been explored in relation to schizotypy. In their discussion of personality traits which may reflect BAS-mediated individual differences in the processing of stimulus salience, Pickering and Gray (2001) provided a (partial) review of the literature concerning schizotypy and latent inhibition. The studies examined employed between-participants methodology, whereby LI was operationalised as the detrimental effect on the learning of a stimulus-outcome association shown by the group who received pre-exposure to the stimulus in circumstances where it was irrelevant (low salience), relative to a control group receiving no pre-exposure to the stimulus. (More recently, within-participants designs have also successfully demonstrated that high (positive) schizotypy is related to attenuated LI, e.g., Evans, Gray, & Snowden, in press).

In their summary, Pickering and Gray reported that both schizotypy and a cluster of traits related to impulsivity, asocial and sensation seeking behaviours (to be discussed further in chapter 3), appeared to be associated with decreased latent inhibition, suggesting that people scoring more highly on these measures may have treated the pre-exposed stimuli as salient. However, it was further observed that neither schizotypy nor the other cluster of traits (related to impulsivity) appeared to be dominant in the various studies reviewed. A positive association between some schizotypy factors (e.g., positive and cognitive disorganisation) and some measures of the impulsivity cluster was also noted, giving rise to the possibility that: i) either these traits are both individually related to LI or ii) the relationship for one of these traits occurs solely because of its relationship with the true LI related trait.

As with the issue of which trait is specifically related to LI, uncertainty also exists with regards to the actual process underlying the LI phenomenon. As discussed previously, Pickering and Gray (2001) consider the processing of stimulus saliency as paramount, thereby endorsing an attentional account (for a review see Lubow, 2005). Hence, during the pre-exposure phase the stimulus is learned to be of low salience and consequently attention is attenuated. This gives rise to the inhibition of learning during the subsequent phase. While this may be the most popular theoretical account (Gray & Snowden, 2005), other explanations have been put forward. For example, some consider that during pre-exposure an association is formed between the stimulus and the non-occurrence of any outcome. It is the interference caused by this initial association which leads to the subsequent hindrance in learning the stimulus-outcome association in the following phase. As summarised by Gray and Snowden (2005), Weiner (2003) suggests that the reduced LI observed in schizophrenia/schizotypy arises from an impaired switching mechanism, such that the original association is ignored (or considered fleetingly), hence giving rise to the observed disruption of LI. A study by Tsakanikos and Reed (2004) assessed the relative merits of associative and attentional accounts, through the manipulation of context change. Though the results appeared to support the attentional theory the possibility that LI was comprised of both attentional and associative components, was suggested.

The notion that more than one specific cognitive deficit may be related to schizotypy (and by extrapolation schizophrenia) was also explored by Steel, Hemsley and Pickering (2002). The background to their study was again the hypothesized impairment of inhibitory mechanisms in schizophrenia, particularly during an acute phase (positive symptomatology), which lead to increased distractibility and over-attention to irrelevant stimuli. Negative priming, the observed increase in response time to a target which was initially presented as an irrelevant distractor, is considered to reflect the operation of such mechanisms. Building on research that demonstrated decreased negative priming in schizophrenia patients, Peters et al. (2000) confirmed that (positive) schizophrenia symptomatology was indeed related to decreased negative priming, lending further support to the reduced cognitive inhibition hypothesis.

However, Steel et al. (2002) reviewed a study by Jones, Hemsley and Gray (1991) in which the task performance of schizophrenia patients appeared to be inconsistent with the notion of impaired attentional inhibition. The task was a simple reaction time task in which the participants responded to the central letter (either 'A' or 'B') of a letter triad. The two flanker letters, which comprised the remainder of the stimulus, were nominally irrelevant distractors. However, in approximately 90% of trials the central letters were flanked by the same distractors (e.g., 'XAX' and 'YBY'), and these were referred to as 'valid trials', as the flanker letters were legitimate cues to the target response. In the remaining trials (10%) the centre/flanker letter pairings were reversed (i.e., 'YAY' and 'XBX'), and these were referred to as invalid trials as the flanker letters were more associated with the opposite response to that of the target. Control participants demonstrated a distractor cueing effect, whereby reaction times on the invalid trials were slowed relative to the valid trials.

The relative slowing on the invalid trials can be considered to reflect the processing of the flanker letters which, in the case of the invalid trials, are associated with the opposite response to that which is required, resulting in the increased reaction times. Therefore, it follows that one prediction would be that individual differences in selective attention may mediate the degree of distractor cueing effect. Hence, participants with superior selective attentional abilities are more likely to show decreased distractor effects.

From the preceding discussion, it may therefore be expected that schizophrenia patients (particularly those in the acute phase with positive symptoms) would show enhanced distractor cueing effects because of poorer selective attention resulting from defective cognitive inhibition of the nominally irrelevant stimuli. However, Jones et al. (1991) found the exact opposite of this prediction, with (acute) schizophrenia patients (with high levels of positive symptomatology) showing significantly less distractor cueing relative to healthy controls. Steel et al. (2002) successfully replicated this pattern in healthy participants who scored highly on positive schizotypy. Together with the results from the study with schizophrenia patients (Jones et al., 1991), it is argued that this demonstrates the distractor cueing effect to be core feature of (acute) schizophrenia, as the same effect is observed in healthy individuals scoring highly on positive schizotypy. The precise mechanism underlying this distractor effect is unknown and a number of candidates were put forward by Steel et al. (2002). Crucially, however, Steel et al. suggest that it is difficult to reconcile the distractor cueing effect with findings related to impaired distractor inhibition (leading to the observed reduction in negative priming), and therefore postulate that these two features of cognitive functioning in (acute) schizophrenia (and positive schizotypy) are likely to be due to distinct causal mechanisms.

While this short discussion of the association between schizotypy and performance on attentional tasks is by no means exhaustive, a clear parallel can be made with the preceding discussion, concerning the putatively dopaminergic traits of extraversion and impulsivity and their association with similar aspects of cognitive function.

Summary

This chapter provided a brief overview of the proposed neurobiological bases of specific personality dimensions, namely extraversion, impulsivity and schizotypy. Specifically, the association between these traits and dopaminergic function was discussed. Furthermore, the influence of variation in the functioning of the proposed underlying biological systems (associated with inter-individual variation in personality) on cognitive function was also considered. Accordingly, research which explored the relationship between these personality traits and cognitive performance, particularly concerning attentional processes, was also presented and it would appear that additional experimentation in this area may be beneficial and help further elucidate the biological bases of personality traits and their association with cognition.

It should be noted, however, that the suggestion that these traits (and indeed cognitive function) may be uniquely related to the function of a single neurotransmitter or neurobiological system would be a gross oversimplification and is not the intended implication of this opening chapter. However, while the true biological bases of personality is undoubtedly more complex (and indeed there exists much evidence to suggest that personality traits considered in this thesis may, for example, relate to the function of distinct neurotransmitters, e.g., serotonin and impulsivity, Carver & Miller, 2006) the outline of the previous research just presented may support the rationale of the thesis and suggest that, with the use of appropriate paradigms, exploration of the association between personality and cognitive performance may be a fruitful venture.

Chapter 2

Category Learning Paradigm and Personality

Category Learning Paradigm

Categorisation is the process by which objects or events are assigned to categories and the development of this ability, to allocate different responses towards distinct classes of stimuli, is referred to as category-learning (CL) (Ashby & Spiering, 2004a; Ashby & Waldron, 2000). An appealing aspect of the paradigm is the diversity and broad range of skills and processes that appear to be involved in learning novel categories. The structures of categories that can be learned vary from the very simple (e.g., squares and circles) to more complex, possibly implicit, distinctions (e.g., 'knowing' your merlot from your cabernet), and can be essential for survival (e.g., distinguishing between edible/poisonous food). Consequently, the wide-ranging nature of such categorisation abilities and the scope of the learning associated with such skills can be seen to encompass a broad spectrum.

CL has been explored and used extensively within the area of cognitive psychology over the past twenty-five years. For example, a key topic concerns the issue of whether CL is underpinned by single or multiple systems (e.g., Ashby & Ell, 2002a; Ashby, Maddox, & Bohil, 2002; Maddox & Ashby, 1993; Minda & Smith, 2002; Zaki, Nosofsky, Stanton, & Cohen, 2003). Accordingly, human CL is also considered to be dependent, to varying degrees, on most of the major systems of memory such as working memory, episodic/semantic and procedural memory (Ashby & O'Brien, 2005).

However, until relatively recently little was known about the underlying neurobiological factors associated with the CL process (Ashby & Ell, 2001). Recent advances in neuroimaging capabilities together with increased neuropsychological research with, for example, patients with Parkinson's disease (e.g., Ashby, Noble, Filoteo, Waldron, & Ell, 2003; Reber & Squire, 1999; Shohamy et al., 2004), amnesic patients (e.g., Filoteo, Maddox, & Davis, 2001b), patients with Alzheimer's disease (e.g., Filoteo et al., 2001b; Keri, Kalman, Kelemen, Benedek, & Janka, 2001; Keri, Kalman et al., 1999), and schizophrenia patients (e.g., Keri et al., 2000; Keri, Szekeres et al., 1999) appear to have fuelled current interest, especially among the field of cognitive neuroscience. Additional methods have also been adopted, such as mathematical modelling, and taken together this multidisciplinary approach has led to some general consensus regarding the variety of brain regions that underlie components of CL, from stimulus representation in the sensory cortex to category response/reward associations in striatal regions (Ashby & Spiering, 2004b; Keri, 2003).

The CL paradigm focuses upon the learning of 'new' categories, as distinguished from categorisation performance related to well-established categories that are already known to the participant. A key strategy that is frequently employed to explore the nature of CL processes is to present participants with completely novel stimuli (at least in terms of their category structure). The effect of the exact manner in which such novel categories are generated, and subsequently how they may be distinguished, appears to have a major impact upon categorisation performance. A distinction between two such category/task structures types is illustrated below (it is important to note that these labels refer to the tasks themselves and do not imply any exclusivity in the way in which these tasks can be learned/performed).

Ashby & Ell (2001) describe rule-based (RB) tasks as those in which the categories can be distinguished by a simple rule, which can be discovered through explicit reasoning abilities. Generally the category distinguishing rule is easily verbalisable and may involve consideration of only one aspect or dimension of the stimuli in order to make appropriate category judgements. As an illustration, consider the following 6 stimuli.

YY YY YYY

These stimuli vary across three different dimensions: size, colour and numerosity of characters (i.e., whether there are 2 or 3 characters). Either one of these three dimension variables could be used as a category-distinguishing rule and would create 3 items per category (e.g., Grey items are the 1st category, black items are the 2nd category etc), with values on the remaining dimensions being irrelevant. Variation across each of the three dimensions is easily recognised and hence explicit reasoning may be used to test the relative importance of the dimensions in order to ascertain the appropriate rule that defines the categories. Probably the most well known task of this type, frequently used in neuropsychological assessment (particularly in investigating frontal lobe impairments), is the Wisconsin Card Sorting Test (Grant & Berg, 1948).

A second type of CL task, identified by Ashby & Ell (2001), is referred to as Information-Integration (II) tasks. As the name suggests a key component, in contrast with many RB tasks, is that often more than one feature or dimension of the stimulus must be considered in order to obtain optimal categorisation ability. An important additional proviso to this distinction is that the combination of the information from the various sources must occur prior to the determination of category membership, i.e., the integration of information is pre-decisional. Hence, were conjunctive rules to be applied, whereby decisions are made for each (relevant) dimension and then combined, the task would be considered rule-based (RB).

This distinction between the two tasks can best be illustrated by again considering the previous 6 stimuli. For example, an RB task may involve a conjunctive rule: if the stimulus consists of small grey 'Y's then they are members of category 'A' (2 of the 6 stimuli in this case). However, if one level of each of the three dimensions receives an arbitrary weighting of 1 (e.g., grey=1, large=1, 3 characters=1) and the alternate level of the three dimensions receive a weighting of 0 (i.e., black=0, small=0, 2 characters=0) then an II task may use a category rule such that members of category 'A' 'score' greater than 1.5 on (summed) dimension weightings (and subsequently category 'B' members score less than 1.5). Therefore, in order to successfully categorise a stimulus, the II task would involve full integration of information from the stimulus' features before a category decision can be made. (The distinction between RB/II category structures comparable to the ones just described will be revisited in chapter 4).

Rules that define such II category structures are often extremely difficult and sometimes impossible to verbalise. In contrast to RB tasks, this is reflected in participants' general inability to accurately describe the category rule or the rule that they themselves employed, even when learning had been at optimal levels (Ashby & Ell, 2001). A key component required for successful learning in II tasks is that appropriate feedback (i.e., response accuracy) is provided during the task in order to obtain sufficient knowledge of the complex (i.e., difficult/impossible to verbalise) category structure (Ashby, Alfonso-Reese, Turken, & Waldron, 1998). With appropriate feedback tasks and category structures/rules, such as that described above, can be learned by healthy individuals (Ashby & Ell, 2001).

While both types of CL task described above share the common aim of learning to distinguish categories of novel stimuli (and may even involve identical stimuli), both appear to demonstrate qualitative differences. Therefore, an initial question that arises is the matter of whether the variety in observed CL application and abilities are encompassed by a single set of basic systems/processes or alternatively whether there exists a correspondent variety of systems/processes.

While not universally accepted (e.g., Nosofsky & Kruschke, 2002) recent neuropsychological and neuroimaging evidence (e.g., Aizenstein et al., 2000; Ashby & Ell, 2002a; Knowlton, Mangels, & Squire, 1996; Maddox, Ashby, & Bohil, 2003; Poldrack et al., 2001) appears to suggest that a range of distinct CL systems do exist. For example, Knowlton et al. (1996) demonstrated a double dissociation between amnesics and patients with Parkinson's disease performance on a probabilistic CL task. Amnesic patients performed normally in learning an association between a series of cues and probabilistic outcomes (in this instance 'sunny' or 'rainy' weather), despite having no recollection of the training episode. Conversely, Parkinson's patients remembered the training episode yet demonstrated impaired learning on the task. This supported the view of discrete learning systems and also suggested that the neostriatum (caudate nucleus and putamen), the area generally most affected by Parkinson's disease, plays a key role in the learning of new associations.

Likewise, using fMRI imaging, Poldrack et al. (2001) demonstrated differential engagement of the medial temporal lobe (MTL) and basal ganglia dependent on whether the learning task involved associative training (paired-associate, with stimulus and category presented simultaneously) or with (probabilistic) trial by trial feedback contingent upon participants' responses. Greater activity in the medial temporal lobe was observed in the paired associate task compared to the feedback task, while the reverse was true for the basal ganglia (caudate nucleus). The implication is that the MTL is engaged in 'remembering' the stimulus-category pairings during the paired-associate training, while the striatum is crucial for learning, in a more 'procedural' like fashion, during the probabilistic training. This again supports the suggestion that differences in the way structurally identical classification tasks are learned may draw upon distinct learning systems within the brain.

Multiple Category Learning Systems

Until recently theories of CL did not attempt to distinguish between the learning of categories that, for example, could or could not be distinguished by a simple verbalisable rule. Some recent research has provided evidence of dissociation between these two specific types of CL using behavioural measures of performance. Maddox et al. (2003) manipulated timing of post-response accuracy feedback on RB and II CL tasks. When feedback was delayed learning was disrupted for II categorisation while performance on the RB task was unaffected. Further evidence of dissociable CL systems relating to RB and II tasks was found by Waldron and Ashby (2001).

Their study demonstrated that a concurrent numerical Stroop task, designed to load upon working memory, was detrimental to performance on a simple RB task, but did not significantly impair performance on a more complex II task

In correspondence with such research, new theories of multiple category learning systems have been proposed. In relation to the types of CL described above, it has been suggested that a verbally-mediated rule acquisition system may be employed in learning associated with RB tasks (Ashby et al., 1998; Ashby et al., 2002). This 'verbal' system appears to operate through conscious hypothesis generation and testing and is consequently 'explicit' in nature. Working memory and executive attention have therefore been considered as key features of this system, so it is proposed that it is critically dependent upon the functioning of the prefrontal cortex. This view is supported by findings that patients with frontal lobe damage are impaired on such tasks (Ashby & Ell, 2001). In contrast, the complex nature and performance of II tasks, coupled with the requirement of response feedback, suggests an 'implicit', slow-learning system that is engaged in a procedural-learning fashion. This is likely to involve striatal/basal ganglia systems (Ashby et al., 1998; Ashby & Ell, 2001). Recent evidence using fMRI has supported separable neural involvement in these distinct forms of CL systems (Nomura et al., 2007).[1]

Together, the two systems described above comprise the neurobiologically based, COmpetition between Verbal and Implicit Systems (COVIS) model (Ashby et al., 1998; Ashby & Waldron, 1999) of category learning. This theory suggests that the two systems compete during the learning of novel categories. As discussed previously the verbal, or explicit, system excels when the category structure to be learned is fairly simple and accessible to logical reasoning (cf. RB tasks), in addition learning can occur rapidly. In contrast, although more able to learn a wider variety of categories, the implicit (procedural) system, requires appropriately timed reinforcement and learning occurs more slowly (cf. II tasks).

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[1] This study found dissociable activation in the anterior MTL and caudate during RB and II CL respectively. While the activation of the MTL during RB CL does not directly support the neurobiological aspects of the explicit system in the COVIS model (i.e., which emphasizes the role of the prefrontal cortex) – see COVIS description below, it does appear to provide support for the likely explicit nature of RB CL (cf. the implicit learning associated with the II system). Furthermore, a recent revision of the COVIS model includes the involvement of hippocampal areas (Ashby & Valentin, 2005)

Explicit System

From the brief introduction to the CL paradigm outlined above, it would seem evident that a degree of overlap is likely to exist between the processes involved in various forms CL and the range of cognitive function described in the preceding chapter. Therefore, it may be prudent at this time to further enunciate specific areas of intersection which may be of interest. In essence the first chapter considered the evidence for a relationship between various personality traits and cognitive function, more specifically learning and attentional processes. An additional theme appeared to be the possible (causal) link between personality, cognition and dopaminergic function. The relationship between cognitive function and dopaminergic systems and specific forms of CL will therefore be considered in more detail; firstly by exploring the prominent model of CL mentioned in the previous paragraph.

The neurobiological basis of COVIS is of particular interest. To differing degrees both the explicit (verbal) and implicit systems are thought to be mediated by dopaminergic neurotransmission. While direct evidence (e.g., using pharmacological interventions) for the involvement of dopamine in CL is limited, the range of evidence supporting the role of dopaminergic function in the systems of COVIS is substantial. For example, the caudate nucleus (within the basal ganglia) is prescribed as a core neurobiological component of the implicit system (discussed further in the following section) and critically, learning in this system is thought to be mediated by dopaminergic reward signals from the *substantia nigra* in the striatum (e.g., see Ashby & Valentin, 2005). Crucially the learning performance of neuropsychological patients with damage to these areas (e.g., striatal dysfunction observed in Parkinson's and Huntington's disease) has been shown to be impaired on CL tasks associated with the implicit system (i.e., II tasks, Ashby, Noble et al., 2003; Filoteo, Maddox, & Davis, 2001a; Maddox & Filoteo, 2001). Furthermore, these learning deficits have been dissociated from the (ostensibly) normal performance of neuropsychological patients with damage to brain regions not implicated in the implicit system (e.g., amensic patients, Filoteo et al., 2001b). Additional support for the involvement of striatal brain areas in CL associated with the implicit system has been also been provided by recent neuro-imaging data (Nomura et al., 2007; Seger & Cincotta, 2002).

Evidence for the role of dopamine in the explicit (verbal) CL system can be drawn from the wider cognitive neuroscience literature through the consideration of various processes (e.g., working memory) that have been, both theoretically and behaviourally, implicated in RB CL. Firstly, both working memory (WM) and executive attention are considered as core components of the verbal system; respectively involved in the active maintenance of the current rule being tested and any subsequent modulation of executive attention towards a new rule. Dopamine has been implicated in both of these processes (Frank & O'Reilly, 2006; Goldman-Rakic, 1995; Tanaka, 2006). While traditionally conceived as an executive function, dependent on the PFC, recent evidence supports the proposed modulatory role of the mesocortical dopaminergic system in WM (Arnsten, 1998; Chavanon et al., 2007; Cools, Stefanova, Barker, Robbins, & Owen, 2002; Frank & O'Reilly, 2006; Lewis et al., 2005; Tanaka, 2006). Ashby and O'Brien (2005) briefly review evidence from Parkinson's patients and neuroimaging studies implicating fronto-striatal circuitry in WM, which appear to corroborate the link between dopaminergic function, RB CL and WM.

A second key feature of the explicit system is the ability to switch attentional focus; required in order to change to an alternate rule. Ashby and Valentin (2005) describe two forms of attentional switch; automatic and volitional. An unexpected salient cue would lead to an automatic attentional switch whereas a volitional switch arises as the result of an internally generated intention. Some issues relating to saliency (and stimulus novelty) were discussed in the previous chapter, and dopaminergic neurotransmission was suggested to play a key role in such processes. However, it is suggested that it is volitional attentional switching which is crucial for CL and that this process is likely to be mediated by a distinct system within in the brain; less critically dependent upon dopamine (Ashby & Valentin, 2005). However, while volitional switching may originate in the PFC it is suggested that the switching process may be mediated within the basal ganglia and hence some aspects of RB CL performance (e.g., responding to a change in rule) may reflect dopaminergic function, as supported by evidence from Parkinson's disease patients (e.g., Filoteo, Maddox, Ing, & Song, 2007).

Another example of possible attentional effects of Parkinson's disease on RB CL was demonstrated by Filoteo, Maddox, Ing, Zizak, and Song (2005). In this study the value on a single dimension, of 4-dimensional, binary-valued stimuli determined category membership. The category structure was learned through trial-and-error, with appropriate reinforcement (correct and incorrect) given after each category assignment. The experimental manipulation involved variation on the irrelevant dimensions. In the first condition the (category irrelevant) dimensions remained constant (i.e., only one of the two possible values on each of the 3 remaining dimensions was presented). There were 3 additional conditions in which 1, 2 or 3 (all) of the irrelevant dimensions varied (randomly) on each trial. The key issue was whether the variation in irrelevant stimulus information would affect learning in patients with Parkinson's disease (relative to both younger an older controls). Increasing the number of (irrelevant) dimensions on which there was random variation was found to lead to greater learning impairments in the Parkinson's disease patients (relative to both younger an older controls).

In consideration of the task design (and previous literature concerning RB CL) it was suggested that the impairment in performance was likely driven by deficits in working memory and selective attention. Irrespective of which of these processes may best account for the observed results, Filoteo et al. (2005) suggested that deficits in underlying inhibitory mechanisms offered a plausible explanation; increasing levels of irrelevant information would result in a corresponding reduction in performance levels for those with poorer inhibition. However, examination of set loss errors (an incorrect categorisation response made after a series of correct responses) revealed that the Parkinson's disease patients appeared to make more of these errors when there was greater variation in the irrelevant dimension values in the preceding trials. This was tentatively suggested to reflect the involvement of selective attention; poorer performance induced by increased distractability from greater variation in (irrelevant) stimulus dimensions.

In a subsequent follow-up study Filoteo et al. (2007) were able to address the issue of whether these impairments reflected deficits in working memory or selective attention by the consideration of performance across three (RB CL) tasks. The same type of two-dimensional stimuli (Gabor patterns) was used in each task. The two dimensions were the spatial frequency and orientation (see appendix A for an example, p. 305), and variation on these dimensions were (sampled) from a continuous distribution of possible values. On the first task the category of each stimulus was determined by the value upon one of the dimensions, with a discrete cut-off point (i.e., stimuli with a spatial frequency above 'x' were category 'A', if below 'x' they were category 'B'). The value upon the remaining dimension was therefore irrelevant, hence an important component of performance on this task was considered to reflect selective attention; the ability to focus on the relevant dimension and exclude information from the irrelevant dimension.

In contrast, the remaining two tasks required the consideration and combination of information from both stimulus dimensions, thereby reducing the selective attention component. The category structure of these tasks was determined by a conjunctive rule (e.g., if the frequency is high *and* orientation is relatively horizontal respond category 'A'; otherwise respond 'B') and disjunctive rule (e.g., if the frequency is high and the orientation is relatively horizontal *or* if the frequency is low and the orientation is relatively vertical respond 'A'; the complementary expressions hold for category 'B' stimuli) respectively. These tasks therefore required a greater degree of information to be considered and maintained in memory in order to produce the appropriate response; and were therefore more reliant upon WM abilities. The results found Parkinson's patients to be impaired only upon the first task (in which only one of the two stimulus dimensions were relevant), with normal performance on the two remaining tasks thought to involve WM. It was concluded that observed deficits with Parkinson's patients are likely due to deficits in selective attention.

Implicit System

The implicit system is thought to be able to categorise stimuli through procedural learning; gradually developing appropriate responses to different stimuli. This system can therefore be described as mechanism through which distinct stimulus-response associations are formed (i.e., categorisation) rather than the generation of (for example) verbal category labels (Ashby & Valentin, 2005). In contrast to the explicit system, the procedural learning system necessarily prescribes a critical role of (nigro-striatal) dopamine in the learning of novel categories. As described briefly in the preceding chapter, it is widely regarded that dopaminergic neurotransmission plays a crucial role in reward based learning (Wickens & Kotter, 1995). In the present context, it is considered that when a (correct) response to a stimulus is made and consequent feedback is given, the reward related dopamine signal facilitates the strengthening of the stimulus-response association (3-factor learning).[2] Consequently, this system is thought to be dependent upon an appropriately timed reinforcement signal for the successful learning of stimulus-response associations (Ashby et al., 1998; Ashby & Valentin, 2005).

Knowledge of the (proposed) underlying neurobiology of the implicit CL system has generated a variety of testable predictions related to its function, and in addition, possible dissociation from the explicit system. Ashby and Maddox (2004) considered empirical evidence for the dissociation of the implicit and explicit CL systems, finding support for six predictions of the COVIS model in their review of nine studies. Three key areas of distinction between RB and II CL are highlighted by Ashby and Valentin (2005): reinforcement parameters, procedural learning characteristics, and executive function involvement. Firstly, reinforcement (or feedback) appears to be essential for the learning of II categories, whereas it may be possible to learn some RB structures without any feedback (Ashby, Queller, & Berretty, 1999). An additional prerequisite for II CL is that reinforcement is appropriately timed. The neurobiological basis of the implicit system requires that the reward feedback signal is received within a critical time frame (at most a few seconds) after the response is made in order that the stimulus-response association is potentiated.

In contrast, the involvement of WM and attention in RB CL allows a greater degree of flexibility in the timing of feedback. Evidence to support this dissimilarity includes the finding that observational learning (whereby, during the training episode, the correct category label is shown prior to the presentation of the stimulus and subsequent response of the participant) was poorer than standard feedback learning in II categorisation tasks whereas no such difference in learning was observed in RB tasks (Ashby et al., 2002). In addition, delaying the feedback signal by a mere 2.5 seconds was able to disrupt II learning whereas delays up to 10 seconds did not affect RB learning performance (Maddox et al., 2003; Maddox & Ing, 2005).

The II system is considered to be reliant upon procedural learning, which involves the development of specific stimulus-response associations (e.g., category 'A' = left button). Hence, manipulation of task demands that may affect these specific relationships, e.g., switching response locations (i.e., category 'A' = right button), may impair II CL (or demonstration of previously learned II categorisation performance). However, RB learning is considered to concern explicit hypothesis testing, possibly allowing the development of verbalisable category structure (Ashby & Valentin, 2005). In contrast, it is not thought to involve procedural learning and therefore such (response location) manipulations are unlikely to affect performance on such tasks. Recent evidence has suggested that this appears to be the case (Ashby, Ell, & Waldron, 2003; Maddox, Bohil, & Ing, 2004).

Finally, the involvement of executive processes (WM, selective attention) in RB but not II CL gives rise to the, possibly counterintuitive, prediction that performance will be less impaired on II relative to RB tasks when an additional task (requiring WM and executive attention) is performed concurrently. Despite II categorisation often involving more complex stimuli (and hence considered to be more complex tasks), the learning of such categories is not thought to require executive processes and a concurrent task of this type should not interrupt II learning. In contrast, although RB tasks are often considered to be less complex, a concurrent task involving WM or selective attention (or both) will decrease available resources; thereby leading to poorer RB learning performance. These exact effects were demonstrated in a study by Waldron and Ashby (2001) which found that RB, but not II, performance was impaired when concurrently performing an executive task (i.e., involving WM and attention) compared to single task (i.e., RB or II CL) performance. In a subsequent study (Maddox, Ashby, Ing, & Pickering, 2004) a further dissociation between the two systems dependency upon executive attention was revealed. A reduction in the time available for the processing of categorisation feedback was shown to impair RB but not II performance, suggesting that RB, but not II, CL was dependent upon sufficient and effortful attention to feedback. Taken together, these findings suggest that (explicit) attentional processes and working memory are critical for successful RB, but not II, CL.

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[2] As summarised in Pickering & Gray (2001), '3-factor' learning refers to the 3 components which are necessary for synaptic modification to occur: 1) activation of the presynaptic terminal (e.g., stimulus input), 2) depolarisation of the of the postsynaptic (striatal) neuron (e.g., associated response) and 3) an appropriately timed, purportedly dopaminergic, reinforcement signal. Consequently, only in the presence of all 3 factors is the synapse strengthened (i.e., the association between input and response).

Personality and Category Learning

The potential use of the CL paradigm to explore personality related differences in cognitive function was first explored in detail by Pickering and Gray (2001). The Ball and Zuckerman (1990) study, discussed in the previous chapter, involved learning to select the correct target from two possible stimuli; in essence a form of CL. Based upon the neurobiological COVIS model (Ashby et al., 1998; Ashby & Waldron, 1999), Pickering and Gray (2001) utilized this result as the basis to explore predictions from a neural network simulation of BAS function. Further discussion of the neural network modelling data is not pertinent to the current debate. It is however worth reviewing two key results from the Ball and Zuckerman (1990) study. Firstly, high sensation seekers were able to learn the task more quickly and secondly, the predicted interaction between this trait and reinforcement conditions did not occur; suggesting that this difference in performance was mediated by factors other than individual differences in sensitivity to reinforcement parameters (e.g., selective attention).

Given the description of the Ball and Zuckerman (1990) task (in the previous chapter p. 28) along with the discussion of different forms of CL above, it can be considered that the learning involved was most likely RB in nature. Therefore, the lack of the proposed association between personality and the reinforcement manipulation would appear consistent with the CL literature, in particular the COVIS model, as learning of RB categories is thought to be reliant upon explicit processes – and not thought to be dependent upon reinforcement (cf. the procedural/implicit system). Furthermore, superior performance on RB tasks may arise from enhanced attentional processing which may subsequently facilitate the quicker discovery of the appropriate stimulus dimensions and category rule; this may support Ball and Zuckerman's suggestion that high sensation seekers were able to learn the task more quickly as a result of superior selective attention.

The utility of the CL paradigm was further discussed by Pickering (2004). Building on the Ball and Zuckerman (1990) result, two further studies were reported which appeared to support the suggestion that, possibly by way of a relationship with superior selective attention, particular personality traits may be associated with enhanced learning on a subset of CL tasks (i.e., RB). The first study used a simple RB task in which one dimension (height of rectangle) of a two-dimensional stimulus (position of an internal line segment was the second dimension; which was irrelevant) determined category membership. This study included a measure of novelty seeking (The Tridimensional Personality Questionnaire, Cloninger, 1989) and two of the subscales, impulsivity and disorderliness, were found to be significantly positively related to overall performance. In addition, high-impulsives were found to perform better than low-impulsives in all but the first block of the task (there were 6 blocks in all; each block consisted of a random presentation of all of the stimuli).

The same stimuli were used in a subsequent study which included an additional methodological manipulation. In the first phase the lateral position of the internal line segment defined the category structure (with the height of the rectangle being irrelevant). The second phase consisted of an unannounced switch of category structure, now determined by the height of the rectangle (with the position of the internal line segment being irrelevant). The personality measures used included the psychoticism scale (EPQ-P) from Eysenck's personality questionnaire (Eysenck, Eysenck, & Barrett, 1985) as well as the Unusual Experiences scale (reflecting positive schizotypy) from the OLIFE (Mason et al., 1995). Psychoticism (EPQ-P) was significantly positively related to overall performance (phase 1 and 2 combined), although this result appeared to be driven primarily by performance in the first phase (relationship was significant for the first phase only). In contrast, the positive schizotypy measure was significantly related to poorer performance only in the second phase of the task, i.e., after the switch of category structure. Including a measure of extraversion (EPQ-E) did not affect the independent contributions of EPQ-P and positive schizotypy in predicting task performance.

These three studies demonstrated superior learning of (nominally) RB categories was related to personality; sensation seeking, novelty seeking (especially impulsivity) and EPQ-P respectively. As will be discussed in the following chapter, some researchers (e.g., Pickering, 2004; Pickering & Gray, 2001) believe that the aforementioned personality measures represent a cluster of related traits. Given the discussion of the possible link between impulsivity (and putatively related traits e.g., novelty/sensation seeking) and selective attention in the previous chapter, together with the proposed role of executive attention in RB CL, the results from these initial studies suggest that the CL paradigm may indeed be a beneficial strategy to further explicate these relationships and underlying mechanisms.

From the preceding discussion of the CL literature, it would appear unlikely that the relationships between performance and personality observed in the three studies just described were mediated by reinforcement or reward processing mechanisms. However, as examined above, the learning of other category structures (i.e., II tasks) may be critically dependent upon such processes. Consequently, it has been noted (Pickering, 2004; Pickering & Gray, 2001) that there exists a high degree of overlap between the neural structures and function implicated in both the implicit system of the COVIS model and the BAS (discussed in chapter 1). From this basis a simple hypothesis arises (to summarise Pickering, 2004): Individuals with a more reactive BAS may be more sensitive to signals of reward (e.g., positive reinforcement), hence such individuals may show superior levels of performance in CL that is contingent upon appropriate feedback such as the reinforcement-based learning of II category structures.

The prediction that BAS function (as assessed by putatively BAS-related personality traits) would relate to the learning of specific category structures (i.e., II), through the mechanism of reward-based (i.e., trial and error) learning, was assessed in a study by Pickering (reported in Pickering, 2004). This study used a within-participants design to assess whether differences in categorisation ability were dependent upon the manner of acquisition i.e., whether learning involved reinforcement (reward) processes or not. This study used a probabilistic categorisation task in which there were four cue cards (dimensions), and two possible categories of 'weather' outcomes (in this case 'sun' or 'rain'). The design was such that, across the whole task, two of the four cue cards were moderately associated (.64) with sun, with the remaining two associated (to the same degree) with the alternate weather outcome (rain). Participants were trained on this task using standard feedback (i.e., predict weather - sun or rain; receive feedback i.e., correct/incorrect and actual outcome - rain or sun), with an additional enhancement of positive feedback by financial rewards (10 pence) for each correct response (prediction). Learning was assessed in a subsequent test phase in which all possible stimuli were shown (individually) and participants responded without receiving any feedback.

Using an identical design, with modified stimuli (four new cue cards which now related to two different, fictitious, diseases), a paired-associate version of the task was created. No reinforcement or feedback was given during the training phase. Instead, on each trial, the cue cards were simply presented together with the actual outcome (disease). Therefore, it is likely that learning in this version of the task was mediated by systems other than those implicated in the BAS or implicit system of COVIS. Learning was assessed in the same way as the reinforcement based task. (The study employed a fully counter-balanced design i.e., half of the participants performed the reinforcement task first, followed by the paired-associate version; half of each task type used the 'weather' stimuli, with the other half employing the 'disease' stimuli).

The results demonstrated a double-dissociation between personality and task type; EPQ-P was significantly related to better performance on the paired-associate version of the task, yet unrelated to performance in the reinforcement version. The complementary pattern of results was found for extraversion (a combined measure including EPQ-E); no relationship with performance on the paired-associate version was found, yet superior performance on the reinforcement task was associated with extraversion. (Learning in either version of the task was unrelated to positive schizotypy, and the results reported above remained if this measure or the un-associated trait, e.g., EPQ-E in paired-associate task, were partialled out). Therefore, as predicted, the results do appear to support the possibility of BAS (as indexed by the extraversion measure[3]) mediated differences in performance on tasks that appear reliant upon reinforcement/reward based learning. However, as discussed in chapter 1, this result may further add to the literature endorsing extraversion (cf. impulsivity) as the trait which reflects BAS function.

Tharp (2003) also explored the relationship between personality and II categorisation performance. This study employed a task modelled on an experiment by Maddox, Filoteo, Hejl and Ing (2004). The stimuli were single lines that varied in length and angle of orientation (as presented on a computer screen). Determination of the stimulus category required integration of information from both stimulus dimensions and consequently the rule that defined the category structure was not easily verbalisable. The distribution of the stimuli across the two dimensions is shown in figure 2.1 below. The optimal (II) rule is indicated by a dashed line on the figure (i.e., the optimal decision bound). It can be clearly seen that 4 of the 100 stimuli shown on the figure (each stimulus was presented twice in the experiment) would be incorrectly classified even with the application of the optimal decision bound (i.e., optimal accuracy was 96%). However, it is clear that the use of uni-dimensional rules (e.g., classifying stimuli based upon whether their length was greater than, or less than, 'x' pixels) would yield sub-optimal performance.

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[3] As discussed previously, the nature of the true BAS related trait is a matter of a debate (e.g., Pickering & Gray, 2001; Smillie, Pickering et al., 2006). No particular position regarding this debate is taken in the current thesis and both impulsivity (and related traits, including ImpASS) and extraversion are viewed as potential candidates. Accordingly, previous research in which the BAS was discussed (and possibly indexed) in terms of either impulsivity (ImpASS, etc) or extraversion is considered. This thesis does not attempt to directly address the issue of which trait (or traits) may most accurately reflect BAS function, although any data which may usefully add to this debate is highlighted.

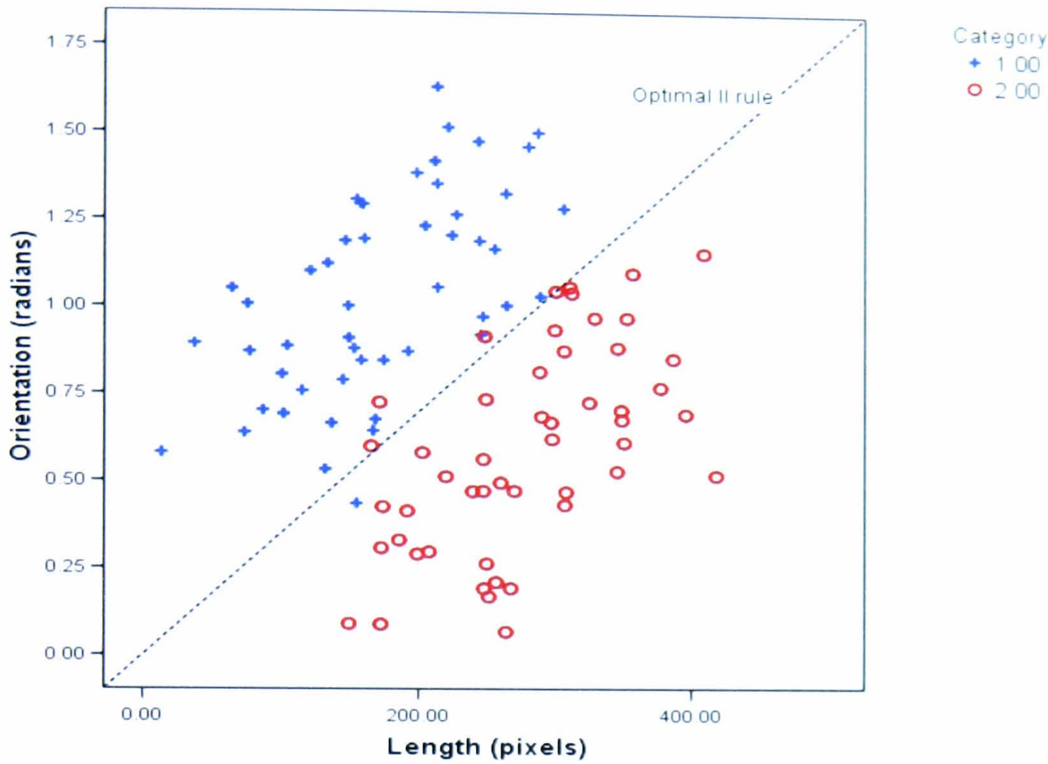

Figure 2.1: *Scatter plot of the stimuli used by Tharp (2003) showing the length and orientation of the stimuli across the two categories*

The task followed a traditional reinforcement learning (trial and error) paradigm; participants were presented with a single stimulus and asked to categorise it to one of two possible categories; appropriate feedback was then given (i.e., 'error' or 'correct') including a financial reward (2 pence) for each correct response. As a further aid to possible reward related facilitation of learning on the task, the participant's current total of accumulated winnings was displayed on screen throughout the task.

From the previous demonstration of a positive relationship between a putatively BAS related trait (extraversion) and learning on an II task, it was predicted that a correspondent finding may be observed in the present study. However, extraversion was not significantly related to performance on the two-dimensional II task. In fact, both schizotypy and a combined measure of traits related to impulsivity (including the SSS, EPQ-P and the Impulsive Nonconformity measure from the OLIFE) were significantly *negatively* related to performance upon this task. In multiple regression, the combination of these two measures accounted for a significant proportion of variance in the number of correct responses, yet neither personality measure accounted for significant unique variance on this performance measure.

To further explore performance on the II task, discriminant function analysis was used in an attempt to provide a basic model of each participant's category (assignment) responses. Hence, this analysis was performed individually for each participant, with their category responses (i.e., category '1' or '2') as the DV and the stimulus dimension values as the predictors (line length and angle of orientation). The loadings for the two predictor variables (indicating the extent to which each dimension appeared to be weighted, or used, in the categorisation decisions) were then used to calculate an index which reflected the degree to which one dimension was used more than the other in the participant's category assignments. The index ranged from 0, indicating that both dimensions were weighted equally (a two-dimensional strategy), to 1, indicating that only one of the dimensions appeared to be considered (a uni-dimensional strategy).

A significant negative correlation between participants' response strategy indices and categorisation performance ($r = -.51$, $p < .001$) demonstrated that better performance was indeed related to a response strategy that considered both of the stimulus dimensions. Furthermore, a histogram plot of the II strategy index (figure 2.2 below) suggested a possible bi-modal distribution with approximately 40% of participants tending towards a two-dimensional response strategy (index at or below .4) while 53% appeared to apply more uni-dimensional response strategies (index of .66 or above). In support of the correlation between response strategy index and performance reported above, the participants with a greater tendency towards two-dimensional response strategies (i.e., index at or below .4) performed significantly better than those who tended towards a uni-dimensional strategy (i.e., index of .66 or above; $t_{42} = 3.132$, $p = .003$), obtaining on average 9% more correct categorisations.

The combined 'impulsivity' measure was found to be significantly related to the strategy index, indicating a greater tendency towards a uni-dimensional strategy. A trend was also observed for schizotypy and extraversion (although the latter trait was unrelated to performance). Further regression analyses revealed that the strategy index was by far the largest predictor of performance on the task, and that both the impulsivity measure and schizotypy were most likely related to poorer performance through their association with strategy used.

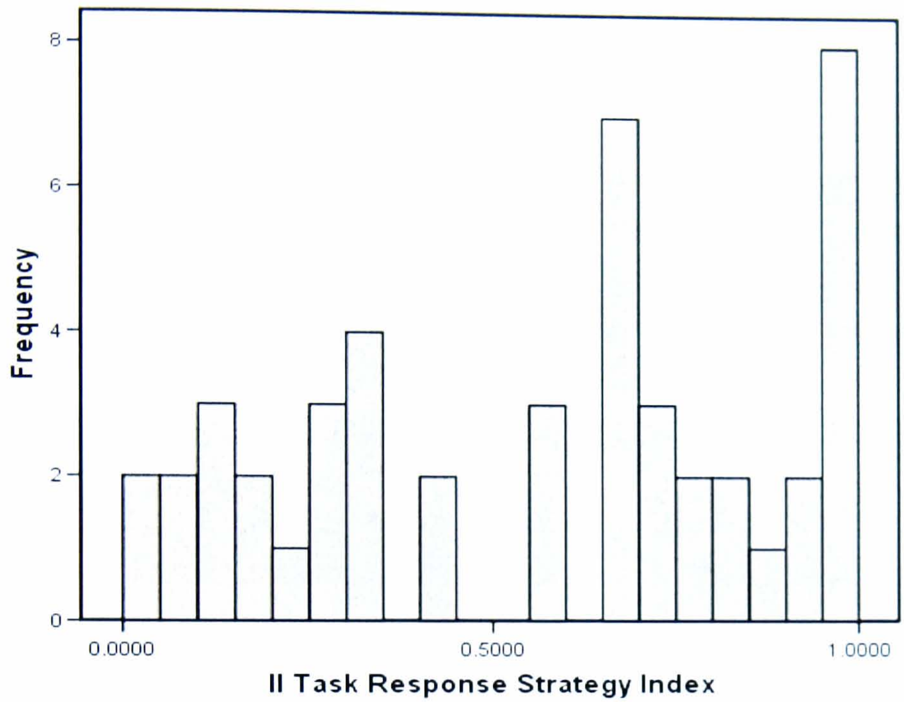

Figure 2.2: *Frequency distribution of the Response Strategy Index*

The association between impulsivity and poorer performance on the task just described may be of wider relevance to the current discussion. The result demonstrated that impulsivity was associated with poorer performance on an II task in which the information from both features of a two-dimensional stimulus needed to be integrated for successful performance. Furthermore, the analysis of the response strategy index suggested that the association with poorer performance on the task may have arisen as a result of the use of (inappropriate) uni-dimensional strategies. While this result is of interest in its own right, and is suggestive of an association between this personality domain and inferior performance on II tasks, it is of particular appeal given the previous association between impulsivity-related traits and *superior* performance upon RB CL tasks.

As discussed above, Pickering (2004) described two experiments in which impulsivity-related traits (i.e., novelty seeking and EPQ-Psychoticism) were associated with superior learning of RB category structures. These results appeared to support previous work by Ball and Zuckerman (1990) which showed an association between sensation-seeking and superior performance on a

RB style categorisation task. In addition, it was suggested that these traits, putatively linked to impulsivity, may have been related to better performance on the task by way of an association with superior selective attention; an enhanced ability to detect or attend the relevant dimension from a multi-dimensional stimulus may be beneficial for learning on such tasks in which a single dimension determines category membership.[4]

Consequently, the present result, in which impulsivity was related to poorer performance and greater use of inappropriate uni-dimensional rules on the II task (which required attention to, and integration of, both dimensions of two-dimensional stimulus), may be attributable to similar processes purported to be involved in the RB tasks. Hence, the association with superior ability or tendency to prefer uni-dimensional strategies may provide a plausible mechanism for both *inferior* performance on the II task just described, and the *superior* performance on the previous RB tasks as discussed by Pickering (2004).

The Tharp (2003) result presents a timely reminder about the nature of the COVIS theory. This model describes two systems which compete for dominance during the learning of novel categories. It is suggested that the verbal system is likely to be dominant in the initial stages as explicit rule hypotheses are tested (Ashby et al., 1998). If this system fails to learn the category structure the implicit system may become dominant. This leads to a variety of possible effects. For example, during the learning of an II category structure, an individual may initially start using RB strategies. The time course for the progression towards the use of the II system (or II strategy) may depend on a variety of factors (for example the number of simple rules which may be tested or the individual's perception of whether an explicit rule is in fact possible – which may be influenced by the nature of the stimuli). Indeed, in certain circumstances, it may be observed that individuals persist with a RB strategy even when this may be sub-optimal (e.g., Ashby et al., 1998; Maddox et al., 2003; Maddox, Filoteo et al., 2004). Conversely, it may be possible that a participant relies on the II system if a suitable rule can not be found, even though one may exist.

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[4] The relevant stimulus feature in the Ball and Zuckerman (1990) study comprised 2 dimensions. However, as the values on these dimensions were in a fixed pairing (i.e., Target: a large letter T cf. distractor: a small letter X) it could be suggested that participants had to discover this single fixed feature of a multi-dimensional stimulus.

Accordingly, it is important to appreciate that although the underlying category structure (i.e., RB or II) may give rise to expectations regarding the way in which CL skills may develop, it does not imply any exclusivity in the manner in which an individual attempts to learn how to categorise a set of stimuli. One approach with which to tackle this issue is the assessment of participants' learning strategies. For example, the method of modelling participants' response strategy applied by Tharp (2003) appeared to be a useful and valid technique of determining whether participants were using uni-dimensional or two-dimensional strategies. Thus, the modelling of participants' response strategies may not only help to elucidate processes which may underlie performance but also demonstrate differential associations between personality and strategy use during CL.

The type of response modelling analyses applied to participants' data may be dependent upon the theoretical model of CL under consideration; one potentially useful example is briefly considered here. Inherent in the application of Decision Bound Theory (DBT, e.g., Ashby, 1992; Maddox & Ashby, 1993) is the proposal that perceptual stimuli are represented in multi-dimensional space (cf. figure 2.2) and that individuals can learn to partition the perceptual space into distinct response regions that are associated with specific category responses (cf. figure 2.2; the category-specific response regions lie either side of the optimal decision bound, represented by the dashed line). These models assume that the use of a decision bound during categorisation of a stimulus involves both perceptual and decisional noise (i.e., associated with the judgement of a stimulus' true location within the perceptual space and application of the associated decision bound, e.g., see Maddox, 2002). More detailed discussion of DBT models is deferred until the following study chapters. However, it is pertinent to reiterate the distinction that these models make between perceptual and decisional components; consequently these models emphasize the role of attentional processes (i.e., attention to stimulus features in order apply the decision bound) which may subsequently influence CL performance.

The association between personality and performance on the CL tasks described previously also appears to reflect the importance of attentional processes. For example, the Tharp (2003) results would seem to emphasize the role of attentional process during the learning of II structures. Impulsivity was associated with the degree with which participants appeared to use either a single or both dimensions of two-dimensional stimuli during CL. This measure of strategy use may have reflected the relative attention afforded the stimulus dimensions. Despite the fact that the task involved an II category structure, the result again suggested that certain features of learning performance may be mediated by differences in attentional function, which in turn appears related to particular personality domains. Furthermore, as discussed above, such an attentional style may also underlie the apparent association between this trait and performance on RB tasks.

The crucial role of attention in the selection of relevant, and suppression of irrelevant, stimulus information in CL is further discussed by Kruschke (2005). Many theories of CL emphasize (the learning of) attentional allocation as a core component, resulting in a variety of mathematical models of categorisation, such as the DBT briefly described above. However, unlike the associated COVIS model, many theories do not distinguish between distinct types of category or systems and subsequently are often referred to as 'single system' theories of CL. The ALCOVE (Attention Learning COVEring map) model is one such implementation (Kruschke, 1992). This connectionist model is closely associated with an exemplar theory of category representation; the Generalised Context Model (GCM, Nosofsky, 1986, 1991). This theory proposes that the perceptual properties of a stimulus (e.g., length, colour etc) are represented in multi-dimensional space. Classification of a stimulus is based upon the similarity (i.e., distance) with all stored stimulus exemplars (e.g., a novel stimulus is compared to all the exemplars of existing categories, categorisation of the novel stimulus is subsequently based upon the relative 'similarity' to the known exemplars). A core feature of this type of model is the ability to learn to selectively attend relevant stimulus features through error-driven learning. Consequently, the attentional weightings of any dimensions (or dimension) which are salient for categorisation are increased, thus amplifying the importance of these dimensions in similarity calculations. Therefore, while debate regarding the validity of various CL theories is ongoing (e.g., Ashby & Ell, 2002a; Ashby & Ell, 2002b; Nosofsky & Kruschke, 2002, for a brief review of the cognitive neuroscience of CL see Keri, 2003), the role of attention appears to be a common and integral feature.

Summary

The aim of the current chapter was to demonstrate the potential utility of the CL paradigm in the investigation of personality and cognition. The CL literature provides an impressive theoretical and empirical background encompassing a range of methodologies; from neuropsychological research to mathematical modelling; neuro-imaging studies to purely behavioural experiments. This comprehensive foundation has yielded a range of well developed tasks and experimental methods; for example the ability to contrast highly similar, yet distinct forms of CL (cf. II and RB), using highly matched tasks and the application of mathematical modelling of participants' performance. The neurobiological basis of CL theory is also appealing. In light of the proposed association between specific personality traits (i.e., extraversion, impulsivity and positive schizotypy) and dopaminergic function the purported role of the dopaminergic systems in the COVIS model is of particular interest. The importance of attentional processes in CL is evident in numerous theories of categorisation and is also pertinent to the current research programme. Finally, although somewhat limited, the initial exploration of possible associations between personality and CL is encouraging and suggestive of independent influences which may impact upon CL performance (e.g., impulsivity may be associated with enhanced or decreased CL ability depending on whether task performance is likely to be facilitated or inhibited by a preference for uni-dimensional rules; extraversion may be associated with enhanced performance on CL tasks which are dependent upon reward-based learning).

Chapter 3

Personality Data

AIMS

There are three key aims of this chapter. Firstly, a brief review of the personality dimensions of interest to the current investigation will be presented, with a focus upon the trait level of description. Following this, the personality inventories applied in the ensuing studies will be introduced. Finally, the rationale and approach taken to the assessment of key personality dimensions in this research (through the extraction of key personality factors from data accrued across a variety of established personality measures) will be illustrated.

Review of Personality Traits

Extraversion and Neuroticism

Across the various manifestations of personality trait theory, two dimensions appear consistent: extraversion and neuroticism. Both traits are found in the influential 'big three' (Eysenck, 1967; Eysenck & Eysenck, 1975; Eysenck et al., 1985) and 'big five' (Costa & McCrae, 1992, 1995; Goldberg, 1981, 1993; see John & Srivastava, 1999) factor models as well as identical or conceptually similar constructs in many other contemporary personality theories. For example, Zuckerman's alternative five factor model (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993; Zuckerman, Michael Kuhlman, Thornquist, & Kiers, 1991) contains the factors 'sociability' and 'neuroticism-anxiety', while Tellegen's higher order dimensions of 'positive emotionality' and 'negative emotionality' (Tellegen, 1982, 1985) can both be considered, to some extent, comparable to the conceptual constructs of extraversion and neuroticism (e.g., for a comparison of Tellegen's personality model and the 'big five' model see Church, 1994).

In addition to the credence afforded to these dimensions from their widespread appearance in a variety of personality measures, differences in the conceptual foundations of these theories may also add weight to their validity. Many personality models have arisen from the 'lexical' approach, which attempts to determine meaningful personality dimensions from the statistical extraction of clusters of behavioural descriptors that appear in everyday language (see Saucier & Goldberg, 2001). The big five models (e.g., Costa & McCrae, 1992; John, Donahue, & Kentle, 1991) are exemplars of this method. In contrast, other personality theories have followed Eysenck's (1967) biological approach, whereby personality dimensions are construed within a nomological framework including biological and psychophysiological substrates (Matthews et al., 2003; Zuckerman et al., 1993). The theories of Zuckerman and Tellegen, mentioned above, can also be considered to follow this latter perspective.

Despite such theoretical and other subtle (e.g., descriptive) differences between models which incorporate apparently equivalent dimensions, there does appear to be some general level of convergence. For example, table 3.1 below shows trait descriptors associated with extraversion in the big three (Eysenck, 1967; Eysenck & Eysenck, 1975; Eysenck et al., 1985) and a big five measure (Costa & McCrae, 1992). The five facets appearing above the dashed line (in italics) would generally appear to be congruent across the two different measures, despite some lexical differences in specific labels used (e.g., sociable as opposed to gregariousness etc). However, it is also evident that there are more descriptors associated with extraversion in the big three (nine cf. 6) and in addition some of the descriptors used in the big five do not appear in the big three (e.g., warmth).

Table 3.1: *Trait descriptors of extraversion from the 'Big Three' and 'Big Five' personality models**

Big Three	Big Five
Sociable	*Gregariousness*
Active	*Activity*
Assertive	*Assertiveness*
Sensation Seeking	*Excitement Seeking*
Carefree	Warmth
Dominant	Positive emotions
Surgent	
Venturesome	
Lively	

Note. Each descriptor of extraversion appearing above the dashed line appears to have a somewhat correspondent counterpart in the alternate model (i.e. the adjacent descriptor); those below the dashed line do not. The table also highlights the unequal numbers of descriptors in the two models.

*(adapted from Matthews et al., 2003)

However, at the broad trait level, the extraversion construct would appear to be widely endorsed by a number of personality models. Additional consensus is also beginning to appear in relation to possible causal mechanisms underlying the trait. The link with dopaminergic function discussed in the first chapter (e.g., Depue & Collins, 1999), receiving support from a variety of researchers employing a diverse range of methodologies (e.g., Chavanon et al., 2007; Cohen et al., 2005; Reuter, Netter, Toll, & Hennig, 2002; Wacker et al., 2006; Wacker & Stemmler, 2006).

Another issue related to this dimension was also briefly discussed in the first chapter; the relationship between extraversion and impulsivity. It was noted that Depue and Collins (1999) considered impulsivity to be emergent (from the interaction of extraversion and constraint), yet distinct from, extraversion. Additionally, it is often considered that the revision of Eysenck's personality questionnaire (Eysenck et al., 1985) reduced the degree of impulsivity associated with the extraversion dimension, instead aligning impulsivity more with the psychoticism dimension (Diaz & Pickering, 1993; Rocklin & Revelle, 1981). Further discussion of impulsivity and related traits will appear below.

As mentioned at the beginning of this section, the neuroticism-emotional stability dimension (referred to simply as neuroticism) is another trait which appears fairly consistently across a range of different measures and theoretical positions, a key facet being the relation with anxiety. This dimension was only briefly mentioned in the first chapter as it not thought to be directly (or at least not as clearly) related to the processes that are of current interest (e.g., systems that may be involved in the development of novel stimulus-category associations - CL).

However, in addition to the prominence of this trait there is the potential benefit of accounting for any variance in performance with which it may be related, whether this may be by direct (e.g., overlap between the neural substrates of neuroticism and CL, cf. previous discussion of extraversion) or indirect association (e.g., possible interference related to test anxiety). Two possible influences which could specifically impact upon categorisation performance were discussed by Matthews et al. (2003). Firstly, it has been proposed (e.g., Eysenck, 1992; Eysenck & Calvo, 1992) that elevated levels of neuroticism (or anxiety) may decrease the availability of executive cognitive resources (e.g., WM or attentional), hence performance on cognitively demanding tasks may be impaired (e.g., Ashcraft & Kirk, 2001). It is therefore possible that for some CL tasks (i.e., those contingent upon such executive functions) variation in neuroticism may affect performance. Additionally, a great deal of research has explored neuroticism and attentional bias in relation to emotive stimuli (e.g., see Matthews et al., 2003). Numerous studies have demonstrated that anxiety is related to the increased attentional processing of threatening stimuli. While the issue of negative affective valence on anxiety related differences in stimulus processing is likely to be largely irrelevant in the present thesis, it is interesting to note the way in which such differences in selective attention have been further dissected into discrete mechanisms (e.g., the shifting towards, as opposed to disengagement of, attention to threatening stimuli, Fox, Russo, Bowles, & Dutton, 2001).

While it may be considered that neuroticism is not generally directly related to our current interest, a recent paper has explored anxiety related influences upon categorisation. However, the article by Dean, Keim, Clark and Hyatt (2007) explored state (as opposed to trait) anxiety. In addition, the paradigm employed in (and area of interest of) the study was quite different to that discussed in the previous chapter. This study involved dividing a presented list of objects into categories which were not pre-defined (unsupervised CL). Hence, one focus was upon the number of categories formed by the participants, and whether this was affected by anxiety (as well as other features such as the saliency of the stimulus features). It is unclear how performance on this task might relate to performance on the types of CL task described previously. However, while the literature relating neuroticism and CL may be sparse (or virtually non-existent), for the reasons described above it would seem pertinent to include this personality dimension in the forthcoming analyses.

Impulsive Anti-social Sensation Seeking (ImpASS)

In addition to sociability and neuroticism-anxiety (two factors resembling extraversion and neuroticism), Zuckerman et al. (1991) included an additional 3 factors in their five-factor model: Impulsive Un-socialised Sensation Seeking (ImpUSS), Aggression-Hostility (Agg-Host) and Activity. It has been noted (e.g., Zuckerman et al., 1993) that Eysenck's psychoticism factor/scale emerges as a prominent marker for the ImpUSS factor, and subsequently that the dimension has often incorporated this term (Pickering, 2004; Zuckerman et al., 1993). As noted previously, the construct of impulsivity has proven to be somewhat less convergent across various trait theories and its inclusion in the ImpUSS factor may therefore warrant further attention. In the preceding chapters, impulsivity was often considered to be related to other traits (e.g., sensation/novelty seeking) and therefore to observe such a cluster of traits emerging as a higher-order personality factor may support this view and lend support to the consideration of this trait cluster in the current thesis.

As discussed in the opening chapter impulsivity has been proposed to reflect the functioning of the BAS (Gray, 1970). In addition, and in correspondence with the relationship with Zuckerman et al.'s (1991) ImpUSS factor, it has further been suggested Esyenck's psychoticism dimension may also reflect BAS function (e.g., Pickering & Gray, 1999). Upon reflection of observed correlations between psychometrically defined impulsivity and other behavioural traits such as sensation seeking and antisocial tendencies, Pickering and Gray (1999) suggested that 'impulsive sensation seeking' might be a more appropriate label for the trait associated with BAS function. In a subsequent paper, Pickering and Gray (2001) further refined their taxonomy of the BAS related trait as Impulsive Anti-social Sensation Seeking (ImpASS); at face value, highly concordant with Zuckerman et al.'s core ImpUSS cluster. (Indeed Pickering, 2004, explains the preferred use of 'anti-social' as opposed to 'un-socialised' merely upon the basis of the possible misinterpretation of a causal nature underlying the un-socialised term, i.e., environmental influences).

The affiliation of anti-social behaviour with this cluster has been supported in a recent review by Cale (2006). This meta-analysis considered the relationship between anti-social behaviour and a broadly defined 'big three' personality dimensions (i.e., reflecting extraversion/sociability, neuroticism/emotionality, and impulsivity/disinhibition cf. Eysenck's extraversion, neuroticism and psychoticism). The results of the analyses found that anti-social behaviour was most strongly related to impulsivity(/disinhibition) and least related to extraversion/sociability. This then would appear to be convergent with the purported relationship between Eysenck's psychoticism and ImpUSS/ImpASS cluster. The validity of the Eysenck's psychoticism dimension as a measure of psychosis proneness (cf. criminality measure) was criticised from the outset (e.g., Bishop, 1977; Block, 1977) and the current result reported by Cale may provide additional support for the assertion that the psychoticism scale largely reflects anti-social aspects of behaviour as distinct from schizotypal/psychotic traits (Mason & Claridge, 2006; Pickering, 2004; Pickering & Gray, 2001).

Eysenck's psychoticism scale may, therefore, provide a useful index of the anti-social component of the ImpASS cluster. Furthermore, additional personality measures, for example Zuckerman's (1979) Sensation Seeking Scale (discussed below), may be more representative of other aspects of the cluster (Pickering, 2004). Consequently, if inter-individual variation in BAS functioning is thought to relate to this trait cluster (i.e., as a putative causal component of impulsive behaviour), the assessment of BAS function may also be pertinent to the measurement of the ImpASS dimension. As mentioned in the opening chapter, however, determination of the true BAS related trait is ongoing (e.g., see Smillie, Pickering et al., 2006), with some researchers firmly espousing extraversion (cf. impulsivity) as the appropriate trait (e.g., Depue & Collins, 1999). This then raises additional concerns regarding the appropriate assessment of BAS function, in terms of applicable measures of BAS-associated behavioural tendencies.

While many researchers tend to adopt a variety of established inventories depending on their viewpoint (e.g., indexing BAS function from measures of psychoticism/sensation seeking or measures of extraversion), a few specific BAS measures have been developed. The most widely used inventory appears to the 'Behavioural Inhibition/Activation System Scales' (BIS/BAS, Carver & White, 1994, i.e., including assessment of the second system of RST). While the BAS scale is often cited as an index of BAS function, and subsequently has been viewed as loading upon the ImpASS cluster (e.g., Pickering, 2004), the measure is not without issues. For example, Smillie and Jackson (2005) failed to find any relationship between the BAS (subscales) and putatively BAS mediated task performance. However, the BAS inventory may yet provide some useful insight. For example, Carver and White's BAS measure consists of three inter-related factors: Drive, Reward-Responsiveness and Fun-Seeking (D, RR and FS respectively). Recent work suggests that while these factors are somewhat divergent, they can yet help delineate the impulsivity related features of the BAS (associated with FS) from reward-related function (associated with D and RR, and partially with FS); which may be more aligned with extraversion (Smillie, Jackson et al., 2006).

In the preceding chapter a number of results indicating a possible relationship between traits associated with ImpASS measures and CL performance were discussed. In this regard the issue of the true BAS related trait is not as crucial (for the present thesis) as the general consensus/observation that the traits of ImpASS and extraversion are somewhat distinct. Furthermore, it was also suggested that the mediatory effect of these ImpASS traits on CL performance occurred in tasks in which the involvement of the BAS was unlikely to have played a major role (Pickering, 2004). Instead, one possibility was that the association with performance may have reflected attentional processing (Pickering, 2004; Pickering & Gray, 2001). In contrast, an additional study found that extraversion (but not ImpASS) was related to CL in a task where BAS mediation (though reward-related processing) was more likely (Pickering, 2004). Hence, further consideration of these traits in respect to CL may help elucidate distinctive associations between ImpASS, extraversion and performance on tasks which may be differentially dependent on BAS functioning.

Schizotypy

This personality dimension, thought to reflect behavioural similarities and possible susceptibility to symptoms of schizophrenia, was discussed in the opening chapter. The multi-faceted nature of this domain was also briefly alluded to by the consideration of a popular inventory of this dimension; the OLIFE (Mason et al., 1995). This questionnaire measure contains four scales, the first three of which, unusual experiences (UnEx), introvertive anhedonia (IntAnh), and cognitive disorganisation (CogDis) appear to directly map onto schizophrenia symptom clusters. As suggested in the first chapter the fourth dimension, impulsive nonconformity, does not appear to directly relate to schizophrenia symptomatology. Rather this feature may associate more closely to behaviours seen in particular personality disorders (Pickering, 2004). Furthermore, Pickering (2004) suggests that this dimension is more in line with the ImpASS trait cluster described above. This is further evidenced by the fact that the measure of this facet includes eight items from Eysenck's psychoticism measure.

The heterogeneity of the OLIFE measure, however, is fully acknowledged by the authors (see Mason & Claridge, 2006). The inclusion of the impulsive nonconformity scale, for example, was based upon both empirical and theoretical grounds. Relative to a more narrowly defined schizotypy construct – which may be sufficiently characterised by the UnEx, IntAnh and Cog Dis scales – the OLIFE is thought to represent a fully dimensional model of psychosis-proneness which encompasses the view that pathology associated with both schizophrenia (and related disorders) and bipolar disorder may share a common aetiology (Mason & Claridge, 2006). Furthermore, it is advised that the OLIFE measure is applied in accordance with this multi-dimensional view of distinguishable sub-components; the summing of the 4 scales to provide a single measure is not advised and it is unclear as to what such a measure would represent.

The multi-dimensional nature of the OLIFE measure gives rise to a related issue; the potential association between the sub-components of schizotypy (e.g., as measured by the OLIFE) and other 'personality' traits as demonstrated, for example, by the purported overlap between the ImpNon component and ImpASS cluster. Indeed, schizophrenia has previously been shown to be related to elevated neuroticism and lower levels of extraversion (Berenbaum & Fujita, 1994). Similar associations have been observed between 'big-five' personality traits (including neuroticism and extraversion) and both positive (cf. UnEx) and negative schizotypy (cf. IntAnh) measures (Ross, Lutz, & Bailley, 2002).

From a simple descriptive viewpoint, it may be suggested that the CogDis and IntAnh subscales of the OLIFE inventory may be, on some level, likely to be associated with the personality traits neuroticism and extraversion respectively. For example, Claridge et al. (1996) provided further support for the four component structure of schizotypy (i.e., UnEx, IntAnh, Cog Dis and ImpNon) in a large scale (n = 1095) study in which a variety of schizotypy measures and personality measures (including the EPQ) were factor analysed. As noted by Boyle (1998), however, in their study Claridge et al. referred to the CogDis factor as 'Cognitive Disorganisation with Anxiety', clearly demonstrating an association between this component of schizotypy and a personality trait resembling neuroticism.

In an extension of Claridge et al.'s (1996) analyses (which retained additional scales assessing 'delusions'), Boyle (1998) reported a five factor solution which included two schizotypy factors (positive and negative) along with three more general personality factors (cf. extraversion, neuroticism and psychoticism). Crucially, Boyle suggested that 'neurotic personality traits' may be a more suitable label for Claridge et al.'s CogDis factor. Additional evidence for an association between neuroticism and facets of schizotypy is found in a review of the association between deficits in latent inhibition (LI) and schizotypy (Braunstein-Bercovitz, Rammsayer, Gibbons, & Lubow, 2002). While attenuated LI may have been viewed as a potential marker of psychosis-proneness, Braunstein-Bercovitz et al. suggest that, instead, the LI deficit may arise from the association between schizotypy and elevated state/trait anxiety.

The IntAnh scale of the OLIFE describes 'a schizoid, withdrawn, socially isolated individual with a long-term inability to experience pleasure' (Mason, Claridge, & Clark, 1997, p. 138) and is considered to assess negative schizotypy symptoms. The descriptive label of this scale (i.e., *introvertive* anhedonia) may suggest a possible (inverse) relationship with trait extraversion. However, in the Boyle (1998) analysis described above, separate factors for extraversion and negative schizotypy were reported. Interestingly, however, the negative schizotypy factor loaded mainly upon the *physical* anhedonia (cf. *social* anhedonia) scale. While the social anhedonia scale also loaded upon the negative schizotypy factor it was in fact (marginally) more strongly (negatively) related to the extraversion factor.

A similar finding, which used a big-five model of personality (NEO-PI-R, Costa & McCrae, 1992), was reported by Ross et al. (2002). Extraversion was found to be significantly (negatively) correlated with (and the best predictor of all the 'big-five' dimensions of) social anhedonia. These results, therefore, suggest that extraversion may indeed be somewhat associated with negative schizotypy measures, particularly with facets related to social anhedonia. This may be of particular relevance to the current application of the OLIFE measure, specifically the IntAnh scale, given that this component is suggested to predominantly assess social anhedonia (Mason et al., 1997; Nunn & Peters, 2001).

The preceding discussion would appear to suggest that 3 of the 4 OLIFE schizotypy factors (i.e., IntAnh, CogDis and ImpNon) may be somewhat associated with higher-order personality dimensions (e.g., Eysenck's extraversion, neuroticism and psychoticism scales) and, therefore, may be likely to load upon such factors if combined in factor analysis. Consequently, the positive schizotypy component, UnEx, might appear to be a somewhat more distinctive. This aspect is further demonstrated by the consideration of items which comprise the scale, which describe 'perceptual aberrations, magical thinking, and hallucinations' (Mason & Claridge, 2006, p. 206). While Ross et al. (2002) reported that positive schizotypy symptoms were significantly predicted by a combination of 'big-five' traits (positively associated with neuroticism and openness and negatively associated with agreeableness) it was also noted that the strength of the association between the big-five model of personality and positive symptoms was significantly lower than the association between the big-five and negative symptoms. Furthermore, it was concluded that 'positive symptoms, as continuous indicators of psychotic-like experiences, are not adequately assessed using the NEO–PI–R' (Ross et al., 2002, p. 67).

Additionally, the positive component (e.g., UnEX) often appears to be the most prominent in terms of the association between schizotypy and cognitive functioning. For example, as reported in the opening chapter, higher scores on the UnEx scale of the OLIFE were associated with greater incidental learning (Burch et al., 2006) and decreased distractor cueing effects (Steel et al., 2002). The positive schizotypy component also appears to be of primary importance in respect to the observed impairments in LI (Evans et al., 2007; Gray, Fernandez, Williams, Ruddle, & Snowden, 2002; Tsakanikos & Reed, 2004). Consequently, in regards to the assessment of schizotypy, the positive schizotypy component is of particular interest and an index of this dimension would be most beneficial for the current research programme.

An additional schizotypy measure (The Schizotypal Personality Questionnaire, Raine, 1991) was also applied in the later studies of the thesis and is briefly discussed in the following section.

Personality Questionnaire Measures

Five personality questionnaires were applied in all of the studies of the thesis. An additional schizotypy measure was applied in all but the first study. These questionnaires are briefly summarised below.

Big Five Inventory (BFI)

Table 3.2: *Big Five Inventory (John et al., 1991)*

Big Five Inventory (BFI)	
Extraversion	BFI-E
Neuroticism	BFI-N
Conscientiousness	BFI-C
Agreeableness	BFI-A
Openess	BFI-O

The BFI was developed to provide a concise measure of the 'big-five'. This self-report measure uses a 5 point Likert scale (ranging from agree strongly to disagree strongly) and consists of 44 items. These items are short phrases which complete the question fragment 'I see myself as someone who…', with each phrase based upon key adjectives thought to reflect the 5 factors (e.g., talkative and energetic are thought to be descriptors of extraversion, hence two of the items are 'Is talkative' and 'Is full of energy'). Possibly the most developed and renowned big-five measure is the 240-item NEO Personality Inventory-Revised (NEO PI-R, Costa & McCrae, 1992). In a review of the measurement of the big-five traits, John and Srivastava (1999) suggest that this measurement scale is most appropriate when a detailed assessment of each trait at the facet level is required and contact time with the participant is not an issue. While a shortened version (60-items) of the NEO PI-R is available (Costa & McCrae, 1992), the items of the BFI are thought to be shorter and easier to understand (Benet-Martinez & John, 1998) and after additional assessment John and Srivastava (1999) suggest that the BFI is a comparable measure of the core features of the big-five traits. Thus the BFI scale was included to provide additional measures of extraversion and neuroticism for inclusion in the subsequent factor analysis. Additionally, it was proposed that the conscientiousness scale may also provide a measure for the ImpASS factor; for example, the conscientiousness subscale of the NEO-PI-R has previously been shown to be inversely related to Esyenck's psychoticism scale (Costa & McCrae, 1995; Zuckerman et al., 1993).

Eysenck Personality Questionnaire - Revised

Table 3.3: *Eysenck Personality Questionnaire – Revised (Eysenck et al., 1985)*

Eysenck Personality Questionnaire – Revised (EPQ-R)	
Extraversion	EPQ-E*
Neuroticism	EPQ-N*
Psychoticism	EPQ-P*

*revised version used, abbreviated as EPQ for brevity

The EPQ-R assesses the proposed orthogonal traits of extraversion, neuroticism and psychoticism; as proposed by Eysenck's biologically based personality theory (Eysenck, 1967). The questionnaire consists of 106 items, comprising short statements to which the respondent may reply yes or no. The scores on the three scales range from 0 to 23, 0 to 32 and 0 to 24 for the three traits (as listed above) respectively. A further 21 items comprise the Lie scale, initially included to assess the degree to which participants may falsify their responses in line with what may be considered the 'correct' response (i.e., to fake 'good', Eysenck et al., 1985). This scale, along with two additional subscales (Addiction and Criminality; which can be calculated with the use of the final 6 items), were not used in the following analyses.

Sensation Seeking Scale

Table 3.4: *Sensation Seeking Scale V (Zuckerman, 1979)*

Sensation Seeking Scale (SSS)	
Thrill and Adventure Seeking	TAS
Experience Seeking	ES
Disinhibition	D
Boredom Susceptibility	BS
Summed SSS subscales score	*SSS*

The SSS employs a forced-choice format whereby one of two contrasting statements must be chosen (e.g., 'I like 'wild' uninhibited parties' cf. 'I prefer quiet parties with good conversation'). While various concerns regarding the validity of the measure (e.g., limitations of the forced-choice method and use of some outdated language) have been highlighted, this remains a popular instrument (for a recent discussion see Gray & Wilson, 2007). This scale consists of 40 items (i.e., 80 statements), which can further be classified into the four subscales listed above (TAS, ES, D and BS), each comprising of 10 separate items. The summation of these four subscales provides a global index of sensation seeking. In the forthcoming analyses only this overall measure (SSS) will be employed.

Behavioural Inhibition Scale/Behavioural Activation Scale

Table 3.5: *Behavioural Inhibition/Activation Scales (Carver & White, 1994)*

Behavioural Inhibition/Activation Scales (BIS/BAS)	
Behavioural Inhibition Scale	BIS
Drive	BAS-D
Fun Seeking	BAS-FS
Reward Responsiveness	BAS-RR
Summed Behavioural Activation Scale	*BAS*

The BIS and BAS scales are putative measures of two systems proposed by Reinforcement Sensitivity Theory (RST, Gray, 1970, 1981, 1991; Pickering et al., 1997); the Behavioural Inhibition System (BIS) and Behavioural Activation System (BAS). The questionnaire contains 20 items that provide a measure of two the BIS and three putatively BAS related factors (Drive, Fun-Seeking and Reward Responsiveness). The items use a 4-point Likert response scale ranging from 'Disagree Strongly' to 'Agree Strongly'. This instrument was specifically created to assess the sensitivity of the two emotional-motivational systems (BIS/BAS) of Gray's theory of personality (described briefly in chapter 1). As discussed above, the BAS scales may differentially reflect reward related BAS function (possibly associated with extraversion) and impulsivity facets (e.g., Smillie, Jackson et al., 2006). The BIS is proposed to be causally related to anxiety (e.g., Gray, 1991); the BIS scale is therefore predicted to be associated with other anxiety/neuroticism measures.

Oxford-Liverpool Inventory of Feelings and Experiences

Table 3.6: *Oxford-Liverpool Inventory of Feelings and Experiences (Mason et al., 1995)*

Oxford-Liverpool Inventory of Feelings and Experiences (OLIFE)	
Unusual Experiences	UnEx
Cognitive Disorganisation	CogDis
Introvertive Anhedonia	IntAnh
Impulsive Non-conformity	ImpNon

As described previously, the OLIFE is a measure used to assess schizotypal traits and produces scores on four distinct but inter-related subscales listed above (UnEx, CogDis, IntAnh and ImpNon). The standard measure also includes the Schizotypal Personality scale (Claridge & Broks, 1984) as well as the Lie and Extraversion scales (Eysenck & Eysenck, 1975). The inventory contains 159 items requiring a yes/no response. The extraversion scale from the OLIFE, which consists of original EPQ extraversion items, was used as a measure of retest reliability ($r = .938$, $p < .001$, $n = 245$). (In the following analyses an average of the EPQ-E and OLIFE extraversion measures, EPQmn, was occasionally applied).

The Schizotypal Personality Questionnaire

This questionnaire was administered in later studies as an additional index of schizotypy. In contrast to the dimensional approach of the OLIFE scale, which parallels the 'personality trait' view, the creation of the SPQ was specifically based upon the clinical diagnostic criteria (DSM-III-R, American Psychiatric Association, 1987) for schizotypal personality disorder. Consequently, the inventory evolved to provide a self-report measure of the nine schizotypal traits. The measure consists of 74 items, each requiring a 'yes' or 'no' response. As listed in the table below, it contains 9 subscales which can further be classified into 3 factors: Cognitive-Perceptual, Interpersonal and Disorganised (not unlike the core OLIFE scales; UnEx, IntAnh and CogDis respectively) in addition to an overall schizotypy score. The suspiciousness subscale (Susp*) appears in both the Cognitive-Perceptual and Interpersonal factors. However, it is unclear how this particular subscale relates to the OLIFE factors.

Table 3.7: The Schizotypal Personality Questionnaire (Raine, 1991)

The Schizotypal Personality Questionnaire (SPQ)		
Factors	**Subscales**	
Cognitive-Perceptual	Ideas of Reference	IoR
	Odd beliefs / Magical Thinking	OddBel
	Unusual Perceptual Experiences	UPE
	Suspiciousness	Susp*
Interpersonal	Excessive Social Anxiety	ESA
	No Close Friends	NCF
	Constricted Affect	CA
	Suspiciousness	Susp*
Disorganised	Odd Behaviour	OddBeh
	Odd Speech	OddSp
Combined Score		SPQ

Analysis of Questionnaire Data

This section outlines the approach taken to the assessment and description of personality during the thesis. Our general interest concerned higher order traits defined at the level of the 'super factor', generally following the 'big three' framework (i.e., extraversion, neuroticism and ImpASS) as well as the consideration of schizotypy measures. It was decided to endorse broadly defined personality dimensions by consideration of numerous questionnaire measures, described above, which putatively assess the same constructs (e.g., BFI-E and EPQ-E). This approach may establish more inclusive and reliable assessment of the dimensions concerned. Additionally, the use of a single set of personality factors, as opposed to numerous different personality scale measures, will help reduce the number of comparisons made in later analyses.

Adopting this logic, it was therefore decided to employ factor analysis with the personality data obtained. Principal Axis Factorisation was employed to obtain factors that encompassed only shared variance across the different scales. Following the tradition of several biologically based personality theorists (e.g., Eysenck, Zuckerman, Gray and others) it was decided to extract orthogonal factors, which in may help to maximally distinguish the dimensions. Furthermore, the extraction of orthogonal factors may help in the interpretation of later regression analyses in which more than one of the personality factors is included as predictors. The following analyses represent the attempted extraction of the following dimensions: extraversion, ImpASS, neuroticism and (positive) schizotypy.

Factor Analyses

Table 3.8 below summarises the predicted loading of particular personality scale components onto the four key constructs (a minus sign in brackets following a component indicates that it is predicted to be negatively related to the factor). The questionnaire subscales in brackets are from the SPQ. These were available only for the second stage of analyses (stage 2) reported below.

Table 3.8: *Predicted loading of the questionnaire subscales on the four anticipated factors*

Extraversion	ImpASS	Neuroticism – Anxiety**	Positive Schizotypy
BFI-E	EPQ-P	BFI-N	UnEx*
EPQ-E	SSS	EPQ-N	(IoR)*
IntAnh (-)	ImpNon	BIS	(OddBel)*
		CogDis	(UPE)*
BAS*	BFI-C (-)*		

** To emphasize the *trait* as opposed to *state* nature of this dimension, this factor will simply be labelled as neuroticism for the remainder of the thesis.

Questionnaire subscale components appearing above the dashed line in table 3.8 were strongly predicted to load upon the respective factors. The factor loading of the components below the dashed line were less confidently predicted. In the case of the BAS it was expected that this measure may load sizeably onto more than one factor, particularly extraversion and ImpASS. The likely strength of the (inverse) relationship between BFI-C and ImpASS was not strongly predicted.

Stage 1 (n = 249)

The first set of factor analyses were performed upon the personality data collected across all 5 studies presented in the thesis and comprised a total sample size of 249 participants. Data screening did not reveal any univariate or multivariate outliers. The correlation matrix for the 13 variables entered is shown in the appendix (B.1, p. 306). In addition to numerous correlations which exceeded .30, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .752 – greater than the level required for good factor solution (.6, Tabachnick & Fidell, 2001). Finally, consideration of the initial squared multiple correlations among the variables did not suggest any multi-collinearity.

Using the components listed in the table above, an initial factor analysis was performed using Principal Axis Factoring. An orthogonal extraction method was used (Varimax) and the number of factors extracted initially based upon eigenvalues greater than one (and additional consideration of a scree plot).

A 3 factor solution resulted, encompassing the first 3 of the 4 proposed factors (i.e., extraversion, neuroticism and ImpASS). Neither the BAS nor BFI-C measures were particularly well explained by the solution (extraction communalities < 0.3) although they did moderately load onto the factors as predicted (see appendix B.2, p. 307). Given that only one measure of positive schizotypy (UnEx) was entered into the analysis, the failure to extract a 4 factor solution was not unsurprising. Additionally, as UnEx was not explained well or clearly defined by the solution, it was decided to pursue a 3 factor solution and remove this measure from the subsequent analyses. The remaining measures generally followed the predicted pattern and were therefore retained for further analysis.

Subsequent analyses (appendix B.3 – B.4, p. 308 – 309, respectively show results with BFI-C and BAS removed individually) showed that the BAS measure did not load onto a single factor, but rather was split across both extraversion (e.g., 0.386) and ImpASS (e.g., 0.273) and was not well accounted for by the extracted factors (extraction communality < .27). Similarly, while BFI-C loaded moderately (inversely) upon the ImpASS factor (e.g., -0.407) it was again not explained well by the solution (extraction communality < .22). It was therefore decided to remove these two measures.

The key output from a final 3 factor solution, which used all of the measures from table 3.8 except those marked with an asterisk (*), is shown below. Factor scores were saved for each participant using the regression method (e.g., Tabachnick & Fidell, 2001) provided in the SPSS computer package. Hence, the mean of the scores on each of the 3 factors extracted was 0, with a standard deviation approximately equal to 1 (.95, .99 and .90 for the neuroticism, extraversion and ImpASS factors respectively).

Table 3.9: *Initial and extraction communalities (Squared Multiple Correlations) for the 3-factor solution (PAF_1)*

	Initial	Extraction
BFI: Extraversion	.629	.581
BFI: Neuroticism	.631	.653
BIS	.553	.629
EPQ-Psychoticism	.449	.594
EPQ-Neuroticism	.718	.804
OLIFE: Cognitive Disorganisation	.662	.670
OLIFE: Introvertive Anhedonia	.498	.462
OLIFE: Impulsive Non-conformity	.543	.721
Sensation Seeking Scale	.395	.405
EPQ-Extraversion	.737	.983

Extraction Method: Principal Axis Factoring.

From table 3.9 above it can be seen that SSS and IntAnh were least well accounted for by the extracted factors (.405 and .462 respectively), although as will be discussed later both variables appeared to load clearly onto the factors as predicted. The SMCs for the remaining variables were all well above .55, with EPQ-E very highly explained by the factors (.983).

Table 3.10: Loadings of the 10 scales on the extracted for the Varimax rotated 3-factor solution (PAF_1)

	Factor		
	N	E	ImpASS
EPQ-Neuroticism	**.878**	-.153	.100
BFI: Neuroticism	**.781**	-.205	
BIS	**.769**		-.183
OLIFE: Cognitive Disorganisation	**.754**	-.241	.209
EPQ-Extraversion	-.150	**.962**	.189
BFI: Extraversion	-.160	**.729**	.156
OLIFE: Introvertive Anhedonia	.188	**-.653**	
OLIFE: Impulsive Non-conformity	.228	.171	**.800**
EPQ-Psychoticism			**.767**
Sensation Seeking Scale		.206	**.596**
Factor score variance	**.893**	**.981**	**.816**

* Loadings below .1 are omitted

Overall, the three extracted factors were well defined by the variables (bottom row of table 3.10) and accounted for 65% of the variance (the three factors accounted for 26.8%, 20.8% and 17.3% of the variance in the variables respectively). Consideration of the rotated factor matrix (table 3.10) revealed that the variables loaded onto the factors as predicted. The first factor extracted was therefore labelled neuroticism (N), with EPQ-N, BFI-N, BIS and CogDis all loading above .75 onto this factor (in addition, any cross loadings were below .25). The second extracted factor was very highly defined by EPQ-E (.962), with both BFI-E and IntAnh also loading well onto this factor as predicted (.729 and -.653 respectively). These three scales did not load above .2 onto any other factor and this factor clearly represented extraversion (E). ImpNon and EPQ-P both loaded highly onto the final factor (.8 and .767 respectively), SSS also loading highly (.596). This would therefore appear to support the ImpASS label for the third factor (ImpASS). Again, no significant cross loadings were observed.

Stage 2 (n = 166)

In the later studies of the thesis an additional schizotypy scale (SPQ) was also administered. Three of the subscales of this measure are thought to assess the same underlying construct as that measured by the OLIFE UnEx scale, i.e., reflecting positive schizotypy. These are Ideas of Reference (IoF), Odd Beliefs or Magical Thinking (OddBel) and Unusual Perceptual Thinking (UPE). These are 3 of 4 subscales that comprise a factor of the SPQ titled Cognitive/Perceptual (the fourth subscale, suspiciousness, does not appear to be related to UnEx/positive schizotypy, Cochrane, 2005). The robust positive correlations between these subscales and UnEx are shown in table 3.11 below.

Table 3.11: *Correlation between OLIFE positive schizotypy subscale and 3 components of the SPQ Cognitive/Perceptual subscale (n = 166)*

		SPQ: Ideas of Reference	**SPQ: Odd beliefs or Magical Thinking**	**SPQ: Unusual Perceptual Thinking**
OLIFE: Unusual Experiences	Pearson Correlation	.621(**)	.581(**)	.691(**)
	Sig. (2-tailed)	.000	.000	.000

** Correlation is significant at the 0.01 level (2-tailed).

Owing to the significant correlations shown in table 3.11 above, it was therefore decided to run a further factor analysis with these 3 additional SPQ subscales in order to try and establish a fourth factor of positive schizotypy. These four measures (OLIFE: UnEx and SPQ: IoR, OddBel and UPE) were therefore added to those measures used in PAF_1. The results of this analysis (PAF_2), with a sample size of 166, are shown below.

This factor solution again appeared sound, with all variables relatively well explained by the four extracted factors (all extracted communalities greater than .4; table 3.12). The factor variance variances (table 3.13) show that the extracted factors were also well defined by the variables (SMCs range from .777 to .943) and in combination explained almost 65% of variance in the variables entered.

Table 3.12: Initial and extraction communalities (Squared Multiple Correlations) for the 4-factor solution (PAF_2)

	Initial	Extraction
BFI: Extraversion	.666	.623
BFI: Neuroticism	.658	.674
BIS	.594	.617
EPQ-Psychoticism	.465	.584
EPQ-Neuroticism	.734	.786
EPQ-Extraversion	.785	.942
OLIFE: Cognitive Disorganisation	.737	.742
OLIFE: Introvertive Anhedonia	.545	.525
OLIFE: Impulsive Non-conformity	.590	.729
Sensation Seeking Scale	.418	.449
OLIFE: Unusual Experiences	.717	.851
SPQ: Ideas of Reference	.439	.413
SPQ: Odd beliefs or Magical Thinking	.513	.467
SPQ: Unusual Perceptual Thinking	.575	.673

The rotated factor matrix again reveals that N was the first extracted factor (with the same four variables loading upon it EPQ-N, .861; BFI-N, .797; BIS, .766; CogDis, .73) and accounted for 19.5% of the variance. With a total of 4 measures (3 SPQ subscales and UnEx) the second factor now appeared to be positive schizotypy (and accounted for 17.6% of the variance), with very high loadings for both UnEx and UPE (.868 and .79 respectively) and also good loadings for the remaining two SPQ subscales used (OddBel, .661; IoR, .57). Extraversion (E) clearly emerged as the third factor, with EPQ-E again a key marker (loading .92) along with BFI-E (.748) and IntAnh (-.703), and accounted for 15.3% of the variance. The final factor was again ImpASS, indicated by high loadings of ImpNon, EPQ-P and SSS (.751, .726 and .606 respectively) and accounted for 12.4%. The highest cross loading of any of the variables is ImpNon, which in addition to the ImpASS loading (.751), also loads upon the positive schizotypy factor (.309). As all other cross loadings are below .3, this would therefore appear to represent a valid structure/solution.

Table 3.13: Loadings of the 14 scales on the extracted for the Varimax rotated 4-factor solution (PAF_2)

	Factor			
	N	Positive Sz.	E	ImpASS
EPQ-Neuroticism	**.861**	.133	-.149	
BFI: Neuroticism	**.797**		-.185	
BIS	**.766**			-.165
OLIFE: Cognitive Disorganisation	**.730**	.286	-.270	.232
OLIFE: Unusual Experiences	.223	**.868**		.217
SPQ: Unusual Perceptual Thinking		**.790**		.205
SPQ: Odd beliefs or Magical Thinking		**.661**	.132	.104
SPQ: Ideas of Reference	.220	**.570**		.184
EPQ-Extraversion	-.178	.172	**.920**	.184
BFI: Extraversion	-.106	.160	**.748**	.165
OLIFE: Introvertive Anhedonia	.172		**-.703**	
OLIFE: Impulsive Non-conformity	.206	.309	.167	**.751**
EPQ-Psychoticism		.212		**.726**
Sensation Seeking Scale		.143	.239	**.606**
Factor score variance	**.887**	**.875**	**.943**	**.777**

* Loadings below .1 are omitted

Assessment of Stage1 and Stage 2 Factors

As shown in table 3.14 below, the corresponding factors that were extracted from both stage 1 and stage 2 (i.e., N, E and ImpASS) were understandably extremely highly correlated (minimum $r = .972$, $p < .001$, $n = 166$). Additionally OLIFE UnEx was naturally very highly correlated with the positive schizotypy factor ($r = .928$).

Table 3.14: *Correlation between stage 1 and stage 2 N, E and ImpASS factors and UnEx and positive schizotypy factor (n = 166)*

		Neuroticism (PAF 2)	Extraversion (PAF 2)	ImpASS (PAF 2)	Positive Schizotypy (PAF 2)
Neuroticism (PAF 1)	Pearson Correlation	.991(**)	-.019	.020	.150
	Sig. (2-tailed)	.000	.810	.798	.054
Extraversion (PAF 1)	Pearson Correlation	-.053	.985(**)	.039	.130
	Sig. (2-tailed)	.499	.000	.617	.094
ImpASS (PAF 1)	Pearson Correlation	.001	.041	.972(**)	.316(**)
	Sig. (2-tailed)	.994	.598	.000	.000
OLIFE: Unusual Experiences	Pearson Correlation	.237(**)	-.012	.246(**)	.928(**)
	Sig. (2-tailed)	.002	.877	.001	.000

** Correlation is significant at the 0.01 level (2-tailed).

It was therefore decided that the stage 1 factor scores would only be used for the participants of study 1 (chapter 4, who did not provide SPQ data), together with raw OLIFE UnEx scores as an index of positive schizotypy. The remaining studies use the 4 factor scores from stage 2. Thus although these two personality data sets use marginally different factor components, the correlations above suggest that they can be considered as equivalent. (The relationship between these factors and the standard personality measures used, i.e., E factor and EPQ etc, are shown for the PAF_2 solution in the appendix; B.5, p. 310 – 311,). For the analyses presented in the ensuing chapters, these factors will be referred to simply as E, ImpASS, N and positive schizotypy, or positive schizotypy (UnEx) where appropriate.

Chapter 4

Study 1 - Comparing Rule-Based and Information-Integration Category Learning

INTRODUCTION

Background

The opening chapter introduced the theme of the possible mediating role of personality on cognitive performance. A small number of purportedly fundamental, notionally biologically based, personality traits were discussed in relation to particular aspects of cognitive function, with a focus upon learning and attentional effects. Possible processes through which such modulatory relationships may be evidenced were briefly explored along with some general consideration of plausible underlying neural mechanisms (e.g., dopaminergic based reinforcement learning). The second chapter described a potentially beneficial paradigm with which these relationships may be further scrutinized, highlighting appealing features of the CL paradigm including the variety of well established tasks and associated behavioural and neuropsychological theory.

In the preceding chapters consideration was also given to the limited literature concerning CL and personality. Performance on a number of RB type tasks was found to relate to the ImpASS cluster of traits. In addition, it was suggested that this association may occur through a relationship with attentional processes. Positive schizotypy was also observed to show associations with performance in such tasks. In particular, this domain was related to learning associated with the modulation of attention and response contingencies (i.e., after an unannounced switch of the dimension determining category structure), building upon a substantial background of research relating this personality dimension and attentional processing. Reinforcement based learning effects in II CL were also reported, which suggested a relationship between extraversion but not ImpASS (EPQ-P) and this mode of learning. In contrast, in a structurally identical task, ImpASS traits were found to relate to learning purportedly mediated by episodic memory (paired-associate CL task). However, further discussion highlighted the potential difficulties in the comparison of performance upon distinct CL tasks (e.g., a participant may approach an II task with a RB strategy), although the potential utility of the assessment of participants' response strategies in such circumstances was also put forward.

The general aim of the first study was to provide the first simultaneous comparison of personality related effects on the performance of RB and II CL tasks. Each participant performed both the RB and II CL tasks in a counter-balanced design. Furthermore, both the stimuli and procedure used in the tasks were identical; the sole manipulation was the structure of the categories. The present CL tasks had been previously employed by Ashby et al. (2003) and Waldron and Ashby (2001). In the Ashby et al. (2003) study, the two task variants were used to examine CL deficits in Parkinson's disease. In support of the functionally separable CL systems hypothesis the study found that, relative older controls, patients with Parkinson's disease were impaired on RB but not II CL tasks. The Waldron and Ashby (2001) study used dual task methodology to compare interference effects of concurrent tasks upon RB and II CL. Support for multiple CL systems was again provided when the results demonstrated that interference, caused by a concurrent numerical Stroop task, occurred on the RB but not the II CL task. Both studies appear to have benefited from the ability to control certain aspects of the comparison tasks (i.e., the stimuli used and aim of the participant, to reach a criterion number of correct responses, were identical in both cases).

From the preceding discussions it is apparent that WM may be involved in RB categorisation. The role of various memory systems in CL has been discussed extensively by Ashby and O'Brien (2005). It was suggested that some category structures may encourage the use of explicit memorisation (e.g., involving declarative memory) if a more simplistic rule can not be found. The low number of stimuli used in the present study may suggest a possible avenue for the involvement of episodic memory processes in the acquisition of the appropriate category-response assignments. Additionally, Pickering (2004) reported a relationship between personality and enhanced learning of categories through paired-associate learning. It would therefore seem pertinent to include measures of both WM and declarative memory processes in the current study.

An additional aim of the WM task was to attempt to provide a measure of general intelligence. A substantial amount of literature demonstrates the close association between these two constructs (e.g., Ackerman, Beier, & Boyle, 2002; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Unsworth & Engle, 2005) and although investigation of the precise nature of this relationship and underlying mechanisms is ongoing, there exists "little doubt that WM measures are significantly associated with measures of general intelligence" (Ackerman et al., 2002, p.587). Therefore, although the present research programme may have benefited from the assessment of general intelligence as an important individual difference which may have contributed to CL performance, it is felt that WM span measures would provide a useful proxy for general intelligence. Furthermore, as discussed previously, WM ability has been implicated in some forms CL (e.g., RB) and thus it is possible that this (purported) component of general intelligence may be a most important measure. (A measure of general intelligence was included in some of the later studies when feasible. Due to procedural complications the results are reported for study 3 only).

General Hypotheses

The general aim of this first study was to assess the occurrence of differential relationships between key personality traits and learning performance upon the distinct CL tasks. The design of the study would hopefully enable the exclusive attribution of any observed differences to the manipulation of the category structures. Performance on the RB task would be considered to be heavily reliant upon executive processes and in particular appropriate allocation of attention towards relevant stimulus features. Consequently, personality traits previously shown to be connected with attentional processes may be predicted to relate to performance upon the RB task. From previous studies, ImpASS traits may be expected to relate to superior performance upon the RB CL task, possibly through a relationship with enhanced selective attention. Additionally, positive schizotypy may also be associated with performance upon this task, especially when an unannounced switch of category rule occurs. In contrast, performance upon the II CL task may be more dependent upon reinforcement based learning, hence traits related to reward processing may be expected to correlate with performance on this task. As described previously, extraversion has been previously associated with such learning. Finally, following work by Tharp (2003), assessment of response strategies may also reveal distinct performance differences related to personality (e.g., Impulsivity was related to greater uni-dimensional strategy use in an II task involving two-dimensional stimuli).

METHOD

The current study (along with all further studies presented in this thesis) was approved by the Psychology Department's Ethics committee (Goldsmiths, University of London). All participants received an initial briefing regarding the nature of the testing session and their right to withdraw from the study at any point (without explanation). All participants were offered the opportunity to receive both a verbal and written debriefing after completion of the experimental session.

Participants

A sample of 82 participants, age range 18 to 49 years (mean age = 23.2, SD = 7.0), took part in the study. Of these, 57 (16 males and 41 females) took part in order to gain course credit (1st year BSc Psychology undergraduates). The additional 25 participants (all males) were mostly recruited from other departments within Goldsmiths, University of London and were non-psychology students. Those not participating for course credit received payment of £12. All participants' spoken English was sufficiently fluent to enable completion of the personality questionnaires. However, clarification of any terms in the questionnaires was given if requested.

Design

Personality Questionnaires

In this study participants completed the EPQ-E, OLIFE, BFI, SSS and the BIS/BAS scales. As described in the preceding chapter, three personality factors (extraversion, ImpASS and neuroticism) were obtained from these results. In addition the Unusual Experiences (UnEx) scale from the OLIFE was used as an index of positive schizotypy. The following analyses will henceforth simply refer to these four factors as: E, ImpASS, N and UnEx within the results section and extraversion, ImpASS, neuroticism and positive schizotypy (UnEx) in other sections.

CL Tasks

The CL tasks applied in this study were modified versions of those devised by Ashby et al. (2003) and Waldron and Ashby (2001). Two distinct CL tasks were created from the same set of stimuli, shown below in figure 4.1. The 16 unique stimuli are composed from 4 binary valued dimensions: Background colour (blue/yellow), Inner shape(s) (circle(s)/square(s)), Shape colour (red/green), Shape numerosity (1/2). Figure 4.1 (left panel) shows the stimuli divided into two categories; those with blue backgrounds above the horizontal line and those with yellow below. This category structure forms the basis of a simple RB CL task, with a verbalisable optimal categorisation rule: i.e., category 'A' items have a blue background, category 'B' have a yellow background. In addition, the remaining three stimulus features are irrelevant; each value on each dimension occurs equally as often in category A as it does in category B (e.g., half of the category A items contain 2 inner shapes, the other half contain only 1 inner shape).

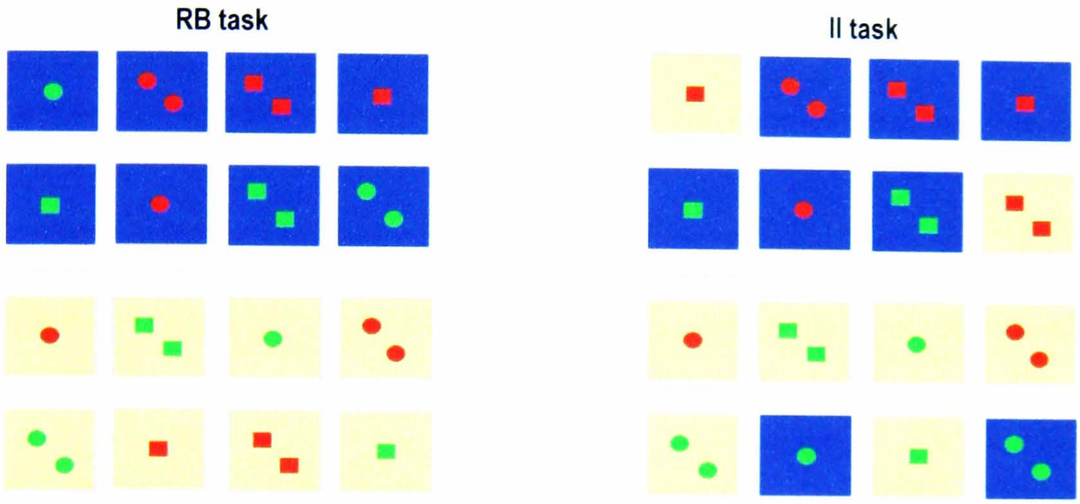

Figure 4.1: *Stimuli used in the RB and II CL tasks; category 'A' stimuli are shown above the grey line, category 'B' items below in each example*

In addition to RB category structures, the same stimuli were also employed in the creation of II category structures. Figure 4.1 (right panel) presents one example (as applied in the current study). This category structure is obtained by arbitrarily assigning numerical 'values' of 1 and -1 to each of the pairs of possible perceptual values on the four dimensions (e.g., blue background = 1; yellow background = -1, etc). In this example, blue backgrounds, square inner shapes and red inner shapes are assigned the value 1 (with the complementary perceptual dimension values assigned the numeric value of -1). The numerosity dimension is again irrelevant to category structure, and has no assigned numerical value (≡ 0). The stimuli are defined as category 'A' (i.e., those above the line) if the sum of the 3 relevant dimensions (i.e., all except numerosity) is greater than zero. Therefore, the sum of the dimension values for category 'B' stimuli, those below the line, is less than zero. (As an example, the top left stimulus of figure 4.1 (right panel) has a yellow background (-1), with a single (0) red (1) square (1). Hence, the sum of the dimension values is 1, and the stimulus is category 'A').

Although the mathematical description is quite straightforward (i.e., if the dimension values are *a*, *b* and *c*, then the mathematical description is simply: if sum $(a,b,c) > 0$, category = 'A'; elseif sum $(a,b,c) < 0$, category = 'B'), it is difficult to provide a simple verbalisable rule which encapsulates this category structure. A second indicator of the II structure is that the information from the dimensions needs to be integrated at a pre-decisional stage (i.e., the values of the relevant dimensions are combined before deciding on the category. In contrast, a conjunctive rule allows for decisions to be made for each dimension, then combined).[1]

However it is suggested that participants often apply sub-optimal rules in such tasks (e.g., Ashby et al., 1998). Therefore, although the category structure may be II, inappropriate RB strategies may be applied (especially during the initial stages of learning, e.g., Ashby et al., 1998). Additionally, as will be discussed in the following analyses, it is important to be aware of other strategies which may be employed with the present stimuli (e.g., due to the low and fixed number of exemplars, memorisation strategies may be partially successful). However, the key distinction between the task variants concerns the number of relevant dimensions; optimal categorisation requires the consideration of 1 relative to 3 dimensions in the RB and II versions of the task respectively.

Procedurally, the CL tasks employed a standard trial-and-error learning paradigm. Participants attempted to learn to correctly classify the presented stimuli into either category 'A' or 'B' (by pressing the appropriately labelled key on the keyboard). The stimuli were presented one at a time, and remained displayed until a category response had been made. Appropriate feedback was given after each trial to inform the participant whether they had correctly or incorrectly categorised the stimulus. Through the use of the trial-by-trial feedback, participants attempted to learn the category structure in order to maximise response accuracy (both the RB and II version of CL tasks are considered deterministic; the optimal response criteria achieves 100% accuracy). Performance on the tasks was assessed by a trials-to-criterion (TTC) measure; the number of trials taken before a run of 'x' correct consecutive responses was achieved ('x' being 8 or 10 in the published studies listed above).

[1] This can be demonstrated by the following example. The II structure above means that any value on the relevant dimensions is possible in either category; i.e., for category A stimuli, background colour can be blue or yellow, inner shape(s) red or green etc so it is only the integration of this information that determines the category. However, for a conjunctive rule, e.g., category A stimuli must contain red squares, it is possible to make a decision on each of these dimensions independently (i.e., if the inner shapes are green the stimulus is not from category A).

The stimuli described above were utilised in the present study. The RB task used the category structure shown in figure 4.1 (and described above). The first phase consisted of a maximum of 200 trials. The stimuli were presented individually (1 stimulus per trial) in a fixed randomised order (i.e., the same random order for each participant). The task continued until either the TTC had been achieved (in the present study we used an increased TTC of 16 consecutive correct responses) or the maximum trial limit had been reached. At this point there was an unannounced switch of the category rule, with the new categories determined by the inner shape; square(s) indicated category 'A' stimuli, circle(s) category 'B' – background colour, along with inner shape colour and numerosity, was now irrelevant. Participants were not forewarned of this possibility, and there was no other indication (e.g., pause in the task, extra instructions etc) that the categories had changed other than the resultant change in feedback contingencies (i.e., reflecting the change in category structure). This second phase of the RB task continued until either the TTC (16 consecutive correct responses for the new category structure) was achieved or the trial limit (reset to 200 trials at the beginning of the second phase) was reached.

At the beginning of the second phase (i.e., after the unannounced switch of category rule) a fixed order of the 16 stimuli were presented. This was constructed specifically so that for the first 4 trials, using the old dimension, or either of the remaining 2 irrelevant dimensions, as the category rule would yield a response accuracy of 50%. This was repeated for the whole cycle of stimuli, i.e., the remaining 12 stimuli. This meant that all participants were presented with the same stimuli for the first few trials (i.e., 16, a complete set of the stimuli) after the rule switch. Had this not occurred, the stimuli presented immediately after the rule switch would simply depend on how many trials the participant had taken to reach the criterion; which subsequently determined at which point along the fixed stimulus presentation order the participant had reached. Thus, this may have introduced an unwanted degree of variance in the post rule-switch trials (e.g., as the stimuli presented would otherwise be random, it is quite possible that a variable number of the first few trials may not indicate any change in the category structure (i.e., the old (background colour) and new (inner shape) rule dimension values may co-occur – blue backgrounds and squares/yellow background and circles – obscuring any change in feedback contingencies and subsequently category structure). The use of the fixed presentation order for the first 16 trials helped to clearly indicate the change in category structure. Following these 16 initial stimuli, subsequent stimulus presentation reverted to the random fixed order.

The category structure used in the II task was as shown in figure 4.1 (right panel) and described above. This task consisted of a maximum of 200 trials (which were again in a fixed randomised order of presentation). The same learning criteria of 16 consecutive correct responses (i.e., leading to a TTC measure) was used, yet unlike the RB task only one II category structure was applied (i.e., there was no switch of category structure for the II task). Hence, the task finished when either participants achieved the learning criterion or the trial limit had been reached.

WM Task

The WM task was a measure of memory scanning ability (Sternberg, 1966). For each trial, participants were required to memorise a set of letters, displayed for 2.5 seconds. After each set, 'yes-no' testing of set members and foils was conducted. The first four trials used 4-letter sets and were considered practice, while the next 10 experimental trials used 6-letter sets. Participants scored a point for every target or non-target correctly identified and hence each (experimental) trial was scored out of 12.

Paired Associate Task

Episodic memory was assessed by the use of a visual paired-associate memory task (henceforward referred to as PA memory). This is a widely used method of assessment for this facet of declarative memory, which can be viewed as a system primarily involved in the creation of associative memories (see Mayes, Montaldi, & Migo, 2007, for a recent review). The basic task involves the presentation of a series of unrelated word pairs (e.g., dive – main). In a subsequent test phase, participants are given the first word of the pair (i.e., the cue; dive) and have to attempt to recall the word with which it was paired (i.e., the target; main). In the present study, the presentation and subsequent test phase for the paired word list was repeated three times. In addition, a surprise recall test, after a fixed delay of approximately 30 minutes, was also given.

Procedure

Participants completed a consent form which included a broad outline of the tasks involved in the study as well as the participant's right to withdraw from the study at any point (and other related information). Basic participant details (i.e., age, gender) were also recorded. The study was performed over two sessions each lasting approximately 45 minutes. The sessions took place at an interval of approximately one week. The details of the two sessions are shown in table 4.1 below.

Table 4.1: Task order for session A and session B

Session A	Session B
Paired-associate memory task	II CL task
RB CL task	BIS/BAS questionnaire
BFI questionnaire	WM task
Paired-associate recall task	

The session order (AB, BA) was counterbalanced across participants. Those participants who were paid for their participation completed the remaining questionnaires (EPQ, OLIFE, SSS) in their own time (i.e., between the two sessions). Those partaking in order gain course credit had previously completed these questionnaires.

Session A

The PA memory task was presented on the computer. The participants were instructed that they would be presented with a series of pairs of unrelated words, one pair at a time, and shown an example. The participants were asked to try and memorise each pair and informed that their memory would be tested by trying to remember the second word of the pair when the first was presented. In addition, the participants were told that although the presentation of the word pairs may seem rapid, their performance would likely be better than expected. Finally, participants were forewarned that they would see the word pairs several times. After any additional clarification required from the experimenter, the 12 word pairs were presented.

The first test phase then began with instructions presented by the computer. Participants would be presented with the first word from a pair and then had to type in the second word using the keyboard. Again, an example was shown. Participants were encouraged to guess even if they were unsure. Participants moved onto the next word by pressing the return key. Each response was recorded by the computer. After memory for all 12 word pairs had been tested, participants were informed that the presentation stage would be repeated. The second presentation of the word pairs was followed by a second test phase, and participants were told to proceed in the same manner as the previous test phase. The presentation-test phase sequence was then performed for a third and final time. The same 12 pairs of words were used throughout the experiment, and for each participant. During the presentation stage, each pair of words remained on screen for 2 seconds.

Participants then took part in the RB CL task. Instructions were presented via the computer. Participants were informed that they were required to classify presented stimuli into two categories. On each trial a (single) stimulus would be presented and remain on the computer screen until either the button labelled "A", for category 'A' or the category 'B' button (labelled "B") had been pressed (using either the left- or right-index finger respectively). The participants were advised to begin by guessing the category of each stimulus as at the start of the task they would not know the category to which each stimulus belonged. The participants were subsequently informed that feedback ('CORRECT' or 'WRONG' displayed on the screen in green or red respectively) would be given after each trial and also received a demonstration of both forms of feedback. Finally, the participants were told that the computer would stop the task when the categories had been sufficiently 'learned'. As both of the CL tasks were to be performed by all participants, additional instructions were given on the second session which indicated that new (different) categories would have to be learned if the task had been performed previously, and that some categories may be harder to learn than others.

After a verbal affirmation from the participant that the task instructions had been understood, the experimenter left the room and the participant commenced the task by pressing the space bar on the computer keyboard. The task proceeded as described above (i.e., continuing until 16 consecutive correct responses had been made or the maximum trial limit of 200 had been reached; followed by an unannounced switch of category rule, from background colour to inner shape(s)). The stimuli were presented centrally on a 17inch CRT monitor with a black background. The stimulus remained on screen until the participant had pressed one of the two possible response keys (the 'D' key on the keyboard labelled as "A", for category 'A', and the 'K' key on the keyboard labelled as "B", for category 'B'). After each response the stimulus was immediately wiped from the screen and the accuracy feedback was presented centrally for 1 second at which point the screen was cleared and the next trial began. Responses and reaction times were recorded for both the RB and II CL tasks.

After completion of the RB CL task (and the II CL task in session B) participants were given a list of questions in an attempt to ascertain how they had attempted to learn the preceding task. This data will not be formally presented as part of the thesis.

Participants then completed the BFI questionnaire. The surprise recall test of the paired associate memory task then occurred next, approximately 30 minutes after the end of the original presentation of the task. If the participant had completed the BFI before this time additional questionnaires were issued (merely as fillers) in order to create the appropriate delay. For the surprise PA recall test, participants were reminded of the earlier task which they had performed and informed that their memory for the word pairs was to be tested one final time. The participants were asked to proceed exactly as they had done in the previous test phases.

Session B

The II task was presented in the exact same manner as the RB task; the task procedure and instructions were identical. The only differences between the tasks were as described above (i.e., the different category structure and use of only one set of categories cf. the two category structures used in the RB task). Subsequent to the completion of the task, the participants were issued with an identical set of questions regarding performance on the task.

Before proceeding to the final task of this session, participants were asked to complete the BIS/BAS scales questionnaire. The WM task was then performed. This was again presented on the computer. The task followed the format described above and the instructions were presented via the computer. Participants were informed that they would be asked to memorise a small set of letters after which they would then be shown a series of single letters and for each one decide whether it was a member of the 'memorised set' or not. Further instructions revealed that this process would be repeated a number of times, with a new set of letters on each occasion and followed by a subsequent presentation of single letters. Additionally, participants were informed that initially there would be some practice sets containing only 4 letters. This would then be followed by the real (test) sets containing 6 letters. The participants were again asked to verbally clarify that they understood how to perform the task.

Participants initialised the task by pressing the spacebar on the keyboard. The screen was then cleared and the instructions "Memorise this set of letters" appeared in green at the top of the screen with the set of letters presented beneath in white (on a black background). The set of letters remained on screen for 2.5 seconds before the disappearing. The test phase then began. The following question was presented at the top of the screen in green font: "Was this in the last set of letters which you memorised?", with a single letter displayed underneath (approximately in the centre of the screen) in a white font. The probe letter remained until a response had been made (either the key labelled 'Yes' or key labelled 'No' – '\' and '/' keys respectively). At the time of response the screen was again cleared and appropriate feedback given: "Correct!" was displayed in the centre of the screen for a correct hit or a correct rejection, while "Wrong!" was displayed if a false positive or incorrect rejection was made. The feedback remained displayed for one second before the next probe was presented in the centre of the screen. This test phase continued until all probes had been evaluated by the participant. If the letter set was a practice set, then 4 letters were to be memorised, and the probe trials consisted of the 4 members of the letter set as well as 4 foils (letters not from the previous letter set) presented in a random order. For the real letter sets 6 letters were to be memorised; with the member letters and 6 additional foil letters presented in the test phase.

The task consisted of 4 practice letter sets (i.e., 4 letters) followed by 10 'real' letter sets (i.e., 6 letters). The letters presented (both as members of the letter sets and as foils) were randomised, but fixed across participants. The letters 'i' and 'o' were excluded from inclusion in the task because of the possible confusion of these letters with the digits '1' and '0'. Participants' responses and reaction times were recorded for each trial.

RESULTS

The results section will comprise three parts. Firstly, raw performance measures on the two CL tasks and the two memory tasks will be considered. Secondly, the personality data will be presented and explored in relation to performance on the various tasks. Finally, a more detailed analysis of performance on the II CL task will be performed through the consideration of formal modelling of participants' response strategies.

Task Performance

RB CL Task

The key dependent variables for the RB task were the number of trials taken to reach the learning criterion (16 consecutive correct responses) for the first and second category rule (TTC1 and TTC2 respectively). The minimum number of trials required to reach the learning criterion, in either first or second category rule phase (RB1 and RB2 respectively), was therefore 16 trials. If a participant failed to reach the learning criterion within the 200 trial limit, the TTC measure was calculated as the minimum number of trials which would have been required to reach the criterion from that point (i.e., if the participant had made 7 consecutive correct responses at the point of the 200^{th} trial then the minimum number of trials in which the criterion would have been reached would be 209, as 7+9 = 16. Hence, if the participant had made an incorrect response on the 200th trial their TTC would be 216). Descriptive statistics for the TTC measures in the two phases are shown in table 4.2 below.

Table 4.2: *Descriptive statistics (mean and standard deviations) for the trials taken to reach the criterion in the first (TTC1) and second rule phase (TTC2)*

	Mean	SD
TTC1	49.646	50.146
TTC2	76.963	55.030

The mean number of trials taken to reach the criterion was approximately 50 (SD = 50.146) for the first rule, which was significantly less than the 77 (SD = 55.030) trials for the second rule ($t_{(82)} = -4.160$, $p < .001$).[2] Only 5 of the 82 participants failed to reach the criterion in the first phase (i.e., TTC1 > 200), while 6 participants were able to reach the criterion in the minimum possible trials (i.e., TTC1 = 16). In the second phase a similar number of participants failed to reach the criteria within the 200 trials (6 participants), while 2 participants managed to achieve the criterion in 20 trials.

Both TTC measures appeared were significantly positively skewed (z's > 5.191; p's < .0001), especially TTC1. In order to compare these measures (i.e., participant's TTC across the two phases) a log transformation was applied to counter the effects skewing. These transformed variables will be used for the remaining analyses. While there was a significant moderate positive correlation between the (log transformed) TTC measures ($r = .332$, $p = .002$, $n = 82$) it appears that this may have been due in part to extreme scores. Subsequent removal of any (original) scores above the maximum trial limit (i.e., 200) reduced the correlation between the measures to a trend ($r = .201$, $p = .086$, $n = 73$).[3] Although a degree of overlap exists, it seems possible that, to some extent, the two measures reflect subtly different aspects of performance (e.g., the TTC2 measure probably includes an additional performance component not present in the first phase of the task; the ability to inhibit a previously learned rule).

As reported above, the present CL tasks have been applied in previous studies (i.e., Ashby, Noble et al., 2003; Waldron & Ashby, 2001). These studies employed learning criteria of 10 and 8 consecutive correct responses respectively (cf. the current criterion of 16). In order to make a comparison with performance in the previous studies, each participant in the present study received two recalculated TTC scores (as if the lesser criteria, i.e., 8 and 10, had been applied). The previous studies reported the mean TTC scores based only upon participants that were able to attain the criterion within the trial limit. Therefore, any participants showing a TTC greater than 200 (with any of the 3 criteria applied) were excluded. The recalculated means and number of participants meeting the learning criterion at the three levels is shown in table 4.3 below (calculated for the first rule only – RB1).

Table 4.3: *Number of learners, mean and standard deviations of TTC by different learning criteria (RB1)*

Criterion	Number of learners (max 82)	Mean TTC	SD
8	79	29.5	31.846
10	78	31.8	32.191
16	77	39.1	28.620

The re-calculated scores barely impacts upon the numbers of participants classified as learners. Removal of 'non-learners' reduces the mean TTC1 for the current criterion (i.e., 16) by approximately 10 trials (40 cf. 50). Comparison of these mean TTC measures and the previous studies is shown in figure 4.2 below.

2 This comparison was unaffected by the use of the log transformed TTCs – see below – and/or exclusion of non-learners, i.e., TTC > 200

3 This pattern remains whether the measures are transformed or not. However, while the transformed TTC2 variable was not significantly skewed, the transformed TTC1 was and remained so even after the removal of participants that did not reach the learning criterion

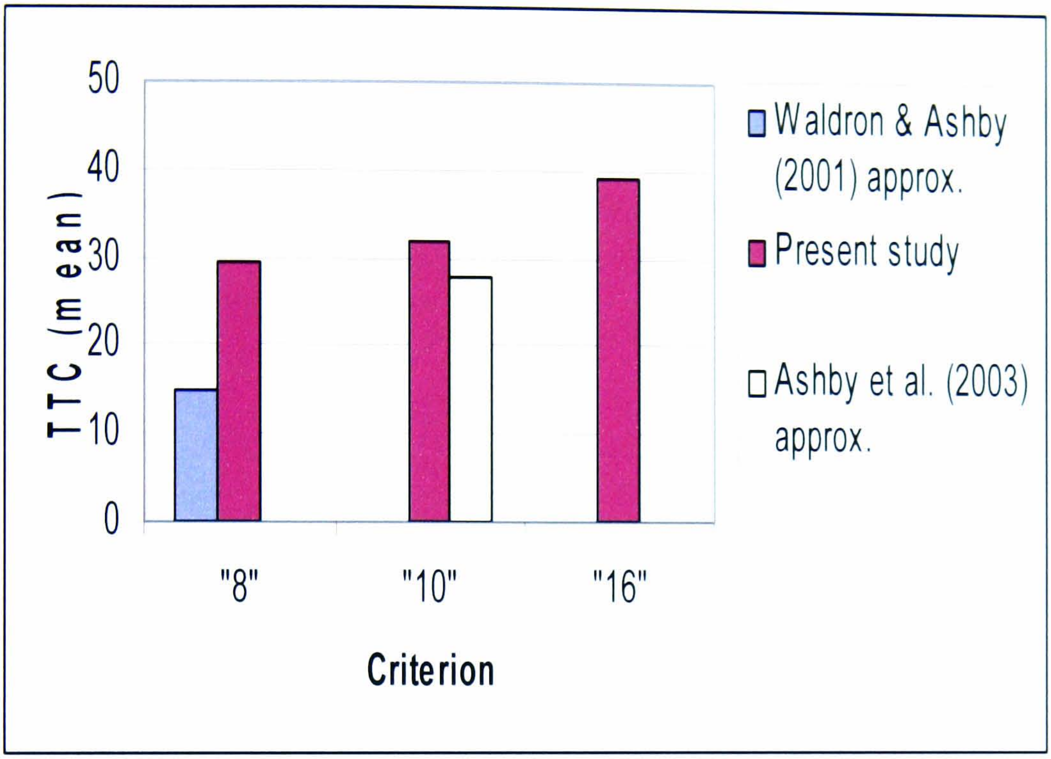

Figure 4.2: *Mean number of trials taken to reach criterion across different studies (and criteria applied to present data)*

Naturally if either the 8 or 10 consecutive correct trials criteria had been applied in the present study the mean number of trials taken would have been reduced (as represented in the figure above). These adjusted mean TTC measures for the present data appear to be reasonably comparable to the previous studies, although there does appear to be a degree of discrepancy with that of the Waldron and Ashby (2001) study (TTC = 8). These discrepancies are most likely due to procedural differences between the studies. For example, in the Ashby et al. (2003) study the participants were shown examples of the stimuli and informed of the dimensions prior to the start of the experiment. Additionally, the value above is calculated as an average across two different rule phases. In contrast to the present study, participants were forewarned that the categories may occasionally change during the course of the experiment. The Waldron and Ashby (2001) study had an initial session in which two RB and two II categories were learned. This was considered a practice session. The following week an additional four rules were learned (two of which had RB structure) and these were the basis of the mean TTC presented above. Hence, it could be suggested that these participants had greater levels of experience of the stimuli and task.

To compare the possible effects of the counterbalancing manipulation in the present study, a mixed design 2 (CB condition) x 2 (RB phase) ANOVA was performed with (log transformed) TTC as the DV (also participants who failed to achieve the criterion in the RB1 phase were removed to minimise the skewness of the TTC1 measure). The main effect of the CB group was not significant ($F_{(1, 75)} = .734$, $p = .391$). Interpretation of the significant main effect of RB phase ($F_{(1, 75)} = 56.353$, $p < .001$) was qualified by a significant interaction ($F_{(1, 75)} = 4.143$, $p = .021$). Figure 4.3 below suggests that overall more trials were needed to reach the criterion for the second rule, yet the greater number of trials required in the second phase was largest for the group who had previously performed the II task (CB2).[4]

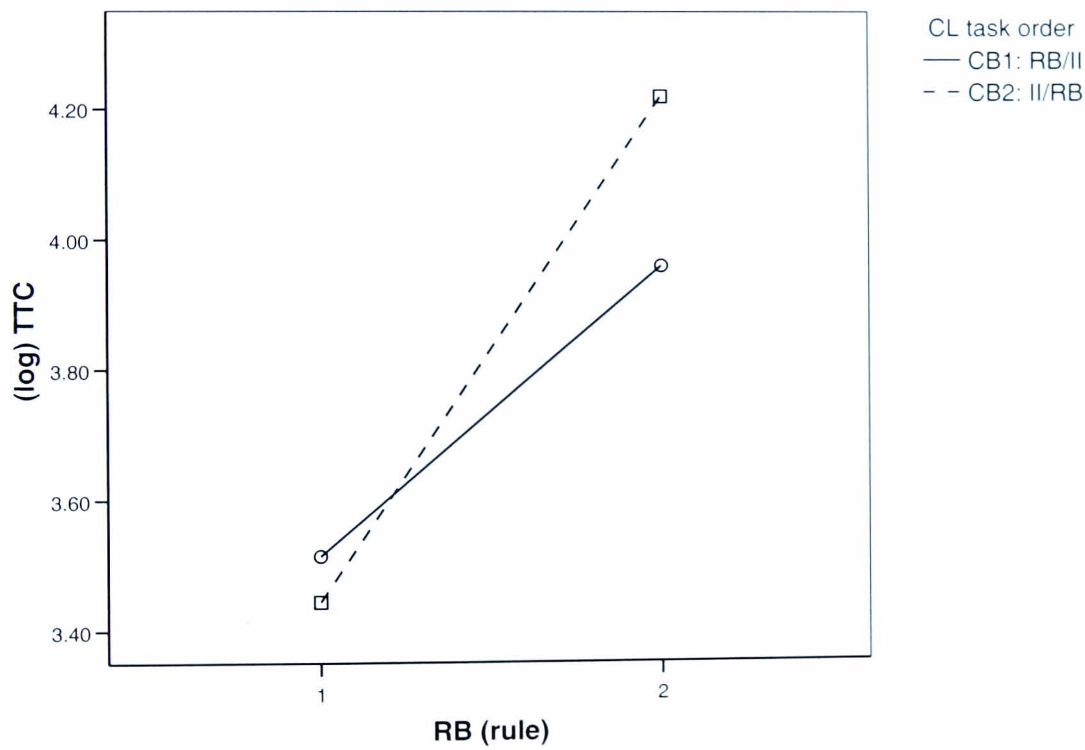

Figure 4.3: *Mean TTC for RB1 and RB2 phase by CB group*

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[4] This result was unaffected if the raw TTC measures were used or non-learners included

II CL Task

Although only consisting of one phase (200 trials), the procedure for the II task was otherwise identical to that of the RB task. Hence the key measure was again the number of trials taken to reach the criterion (TTC). The category structure of the II task was more complex than that of the RB task (e.g., requiring the consideration of 3, as opposed to only 1 of the 4 dimensions) and consequently performance was much poorer. Despite the fact that half of the participants had previously been exposed to the stimuli (in the RB task – discussed in more detail below) only 13 of the 82 participants (~16%) were able to attain the criterion within the 200 trials allowed (range 63 – 186 trials). Unsurprisingly the mean TTC score was 200 trials (SD = 34.715). Because of the number of participants scoring between 200 and 216 the distribution of this variable was negatively skewed.

Performance was again considered in respect to the previous studies; the proportion of participants classified as non-learners by the three different criteria is shown in figure 4.4 below.

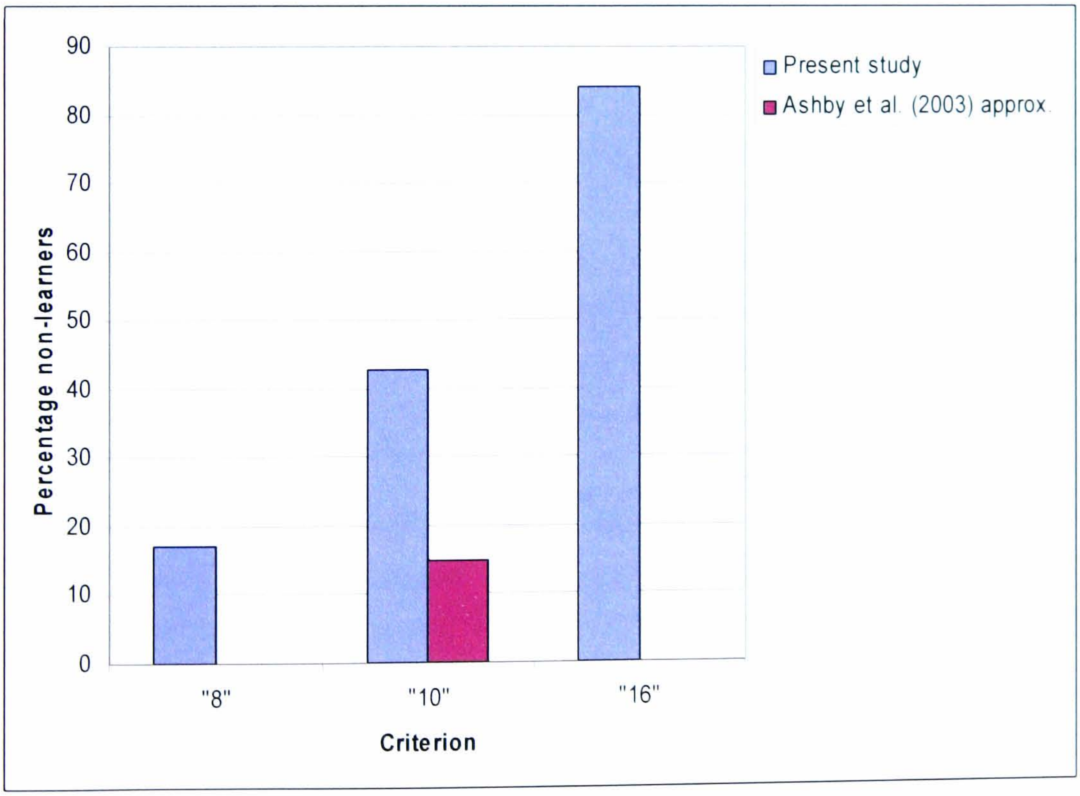

Figure 4.4: *Percentage of non-learners in the Ashby et al. (2003) and present study assessed by different criteria*

The 84% of participants (n = 69) that failed to reach the criterion in the present study can be seen in the last column of figure 4.4. In contrast, approximately half of these participants would have been classified as learners had the 10 consecutive correct trials criterion been applied. Of the 47 participants who were able to attain 10 consecutive correct responses in the present study, only 13 (<30%) were able to maintain this for a further 6 correct responses. This demonstrates that the criterion applied has a significant impact upon those classified as learners. Indeed, had the criterion been 8 consecutive correct responses, fewer than 20% of participants would have failed to show 'learning' of the II category structure. Clearly then the different criteria appear to index distinct levels of 'learning' on the task.

Despite some procedural differences described above, it is unclear why the proportion of non-learners in the Ashby et al. (2003) appears to be so much lower than the present study (the current figure, 43%, is closer to that of the older controls and patients with Parkinson's disease; approx. 47% and 51% respectively from the Ashby et al. study). One effect which may have been present is that of the counterbalancing of the CL task order. In the Ashby et al. (2003) study, the older control group and patients with Parkinson's disease learned 3 RB rules in the first session followed by 2 II rules in the second session. One possible explanation is that the prior experience of the RB task facilitated performance on the subsequent II task.

Indeed, in the current data it appears that previous performance of the RB task (CB1) may have facilitated performance on the II task, with more than two-thirds of participants achieving the criterion coming from this group (9 cf. 4). However, no such advantage is observed if the less stringent 10 consecutive correct trials criterion is applied, with approximately 40% of participants from both groups still unable to learn the categories within 200 trials (41.5% and 43.9% classified as non-learners from the CB1 and CB2 groups respectively).

Due to the highly non-normal distribution of scores upon the TTC measure for the II task, it was decided to assess performance by additionally considering the proportion of correct trials. The mean proportion of correct trials was 63.33% (SD = 9.476, range 45% – 84%), and scores upon this variable appeared normally distributed. An independent samples t-test revealed no significant difference in the percentage of correct trials between the two CB groups ($t_{(80)} = .640$, $p = .524$).

CL Task Comparison

Because of the highly skewed distribution of the TTC measure for the II task, comparison of performance across the two CL tasks was achieved through the consideration of the RB (log) TTC measures and percentage of correct trials on the II task. If performance on both tasks was expected to be related, a negative correlation between these two measures would be predicted (i.e., fewer trials needed to reach criterion and a higher proportion of correct responses are indicative of better performance on the RB and II tasks respectively). After the removal of any participants that failed to reach the criterion in the respective RB phases, RB1 (log TTC1) performance was significantly negatively related to II performance ($r = -.234$, $p = .041$, $n = 77$) while a trend was observed between RB2 (log TTC2) and II performance ($r = -.200$, $p = .083$, $n = 76$).

PA Memory Task

The PA memory task performance afforded two key dependent variables: total study-phase score (comprised of the 3 x 12-word sets) and delayed recall test score (12 words). Each correctly recalled word scored one point (hence the maximum scores were 36 and 12 respectively). These two measures were highly correlated ($r = .962$, $p < .001$, $n = 82$) and were subsequently combined to form a composite PA memory score (mean = 17.6, SD = 9.8, range 0 - 43). There were no significant differences between the CB groups on PA memory measures.

Overall PA memory performance was not significantly related to the percentage of correct trials on the II task. There was no significant difference in PA memory between those participants who reached the II TTC within 200 trials and those (the majority) that did not.

PA memory was not significantly correlated with performance on the RB task (r's < .130, n = 77/76; RB non-learners excluded). However, comparison of high and low RB1 performers (grouped by lower and upper terciles of the TTC1 measure respectively) demonstrated a trend for those with lower TTC1 scores (i.e., better performance) scoring more highly on the PA memory task ($t_{(50)} = 1.945$, $p = .057$ – equal variances not assumed). No such pattern was observed in the analoguous comparison between RB2 performance and PA memory ($t_{(53)} = .504$, $p = .616$).

WM Task

The percentage of correct responses on the test phase of the WM task was calculated as an overall percentage accuracy measure (i.e., hits + correct rejections). Mean performance was 83% (SD = 9.6%, range 47 - 98) and the distribution was significantly negatively skewed. The removal of the only participant who performed at 'below chance' (47%) levels on the test trials (after having achieved 97% on the practice trials) reduced the skew to acceptable levels. (This did not significantly affect any results presented below). As was predicted, WM was positively related to PA memory ($r = .204$, $p = .034$, $n = 81$, 1-tailed). There were no significant differences between the CB groups on WM performance.

Performance on the II task was significantly positively related to WM ($r = .334$, $p = .002$, $n = 81$). An independent-samples t-test revealed that the successful learners of the II task (i.e., TTC < 201; n = 13) performed significantly better on the WM task than the non-learners ($t_{(29)} = -4.421$, $p < .001$, equal variances not assumed). The means and standard deviations for the two groups are shown in table 4.4 below.

Table 4.4: *WM performance (mean percentage of correct trials and standard deviations) for the II learners/non-learners*

II 'Learners'	**N**	**WM (mean)**	**SD**
No	68	82.45	8.790
Yes	13	90.06	4.877

WM was weakly related to better performance (lower TTC) on the RB task, although the association did not reach significance for either the first or second phase ($r = -.150$, $p = .200$, $n = 75$; $r = -.115$, $p = .325$, $n = 76$).

Personality and Task Performance

The personality measures were used to create factor scores (E, ImpASS and N) as described in the previous chapter. The extracted factors were orthogonal, yet this study contained only a subset of the participants involved in this analysis. Correlations confirmed that scores on these three measures were unrelated. Additionally, the measure of positive schizotypy (UnEx) was found to be moderately positively related to all three factors. The three factors combined were able to account for 20% of the variance in UnEx. Both E and N accounted for significant unique variance, while ImpASS fell just short of a significant contribution. Age was not significantly related to any of the three personality factors. However, it was significantly negatively correlated with UnEx ($r = -.323$, $p = .004$, $n = 80$).

Personality differences across gender were assessed by four independent-samples t-tests. Males were lower on E, although the difference just failed to reach significance ($t_{(80)} = -1.914$, $p = .059$). Males were, however, significantly higher on the ImpASS measure ($t_{(80)} = 2.808$, $p = .006$). Females scored more highly on N, yet this difference did not reach statistical significance ($t_{(80)} = -1.326$, $p = .189$). No difference was observed on the UnEx measure ($t_{(78)} = -.003$, $p = .998$). Males were significantly older than the females ($t_{(71)} = 2.925$, $p = .005$; equal variances not assumed), with a mean age difference of just over 4 years (25 cf. 21). Although the CB groups had broadly equal proportions of males and females (CB1: 21 males, 20 females; CB2: 20 males, 21 females), the CB2 group were just over 3 years older on average ($t_{(71)} = -2.104$, $p = .039$ – equal variances not assumed).

Performance on the PA memory task was unrelated to any of the personality measures, although a trend of a weak positive correlation with UnEx was observed ($r = .199$, $p = .077$, $n = 80$). Despite two previous studies demonstrating a positive relationship between ImpASS and PA memory (e.g., as summarised in Pickering, 2004), there was no hint of a correlation in the present data ($r = .011$, $p = .922$, $n = 82$). Additionally, gender and age were unrelated to performance on this task.

Performance on the WM task was unrelated to personality or age. However, males performed slightly but significantly better (with a mean of 86%) relative to females (mean = 82%; $t_{(79)} = 2.224$, $p = .029$).

Performance on the first phase of the RB task was generally unrelated to personality (NB as noted earlier, the distribution of the TTC measures were somewhat skewed potentially hampering the assessment of these performance measures). However, the largest correlation occurred with E, which was related to better performance on the task, i.e., fewer trials to reach the criterion ($r = -.189$, $p = .099$, $n = 77$). Gender was also unrelated to performance on the task, while there was a weak trend for older participants having performed better ($r = -.201$, $p = .079$, $n = 77$).

Neither E nor age was related to performance on the second phase of the RB task (r's < .045). However, N was significantly related to poorer performance in the second phase ($r = .267$, $p = .020$, $n = 76$) while a weak trend was also observed for ImpASS ($r = .194$, $p = .093$, $n = 76$). A weak relationship with better performance was also observed for UnEx ($r = -.194$, $p = .100$). No other relationships were observed.

The proportion of correct responses on the II task was generally unrelated to personality. However, N was moderately negatively correlated with this performance measure ($r = -.227$, $p = .046$, $n = 78$), while males performed significantly better than females (attaining on average 6% more correct responses; $t_{(78)} = 2.865$, $p = .005$). The predicted relationship between E and performance on the II task was not observed ($r = -.046$, $p = .692$, $n = 78$).

As reported above, only a small proportion of participants were able to meet the II learning criterion of 16 consecutive correct responses. Independent-samples t-tests were performed to assess personality differences between learners and non-learners. As would be predicted from the correlations reported above, learners on the II task scored lower on neuroticism, although this just fell short of statistical significance ($t_{(78)} = 1.875$, $p = .065$). Additionally there was a trend for the non-learners scoring more highly on extraversion ($t_{(78)} = 1.785$, $p = .078$). There were no differences in age or other personality factors between learners and non-learners. There was however a significant association between gender and learning on the task, with 10 of the 13 successful learners being male ($\chi^2 = 4.479$, $p = .034$).

<u>Overall CL Performance – RB Task</u>

Performance on the RB task was generally unrelated to the variables measured in the present study. The two variables most strongly associated with performance on the first phase of the RB task were E and age; both associated with better performance on the task. In regression, these to factors accounted for a marginally non-significant ($F_{(2, 70)} = 2.935$, $p = .060$), 7.7% of the variance in (log)TTC1. Neither E nor age contributed a significant unique proportion of variance to the model. The addition of any of the remaining personality factors (ImpASS, N and UnEx) did not improve the model.

Poorer performance on the second phase of the RB task was related to higher levels of N, and weakly associated with higher levels of ImpASS. A relationship, albeit very weak, with better performance was observed for positive schizotypy (UnEx). These 3 factors were entered into a regression and accounted for a significant 20.6% of the variance in (log)TTC2 ($F_{(3, 69)} = 5.977$, $p = .001$). All three factors contributed significant unique variance to the model (N: $t_{(69)} = 3.007$, $p = .004$; ImpASS: $t_{(69)} = 2.238$, $p = .028$; UnEX: $t_{(69)} = -2.975$, $p = .004$).

<u>II Task</u>

Poorer performance on the II task was related to N, while both better WM and being male were related to better performance on the task. In regression, these 3 factors accounted for a significant 21.1% of variance in the proportion of correct trials on the task ($F_{(3, 74)} = 6.589$, $p = .001$). WM contributed the greatest proportion of unique variance on this measure (8%; $t_{(74)} = 2.750$, $p = .007$). Gender also contributed a significant proportion of unique variance to the model (4.5%; $t_{(74)} = -2.043$, $p = .007$), while the unique contribution of N was not significant (<2%; $t_{(74)} = -1.263$, $p = .211$). The addition of any of the remaining personality factors (E, ImpASS, and UnEx) did not improve the model.

Response Strategy

As discussed at the beginning of the chapter, one key issue which needs to be considered when assessing categorisation performance concerns the variety of possible strategies which a participant may employ. This is especially important when examining performance on more complex II tasks, such as the one used in the current study. It is quite possible that a number of participants employed sub-optimal rule-based strategies during the II task. Indeed, the fact that so few participants reached the performance criterion indicates that most were adopting a sub-optimal strategy. It is possible that many participants were responding on the basis of the value upon one dimension for example. The ability to ascertain an individual's response strategy will help to give a more accurate assessment of the relationship between personality and performance when such differences in strategies employed are also able to be considered. For example, observed performance differences may partly occur due to a relationship between personality and preference for particular strategy types. In the following section the assessment of such 'response' strategies will be evaluated for the II CL task only.[5]

To explore performance on the II CL task more thoroughly, formal modelling of participants' categorisation was performed. A discriminant function for category response (H) was constructed such that:

$$H = w1*B + w2*S + w3*C + w4*N$$

where 'B', 'S', 'C' & 'N' represent the respective stimulus dimensions (**B**ackground colour, **S**hape, (shape) **C**olour and **N**umerosity), with possible values of '1' or '-1' (depicting the binary perceptual dimensions). The relative weightings for each dimension are therefore given by w1 – w4.

The decision bound parameter, 'd', defines the criterion by which a category response is calculated from the discriminant function (H). Assuming an unbiased decision bound (i.e., d=0; no bias/preference for responding either category 'A' or 'B'), a participant's response set can be described as:

Respond category 'A' if $H > d$; else respond category 'B' if $H < d$
(guess if $H = d$)

A noise parameter is also present in the model, jointly accounting for two factors; perceptual and criterial noise. In reality we assume negligible perceptual 'decoding' noise; i.e., the assessment of the value on any given dimension (e.g., colour of the background – yellow or blue) should be relatively free from error, particularly with the current set of stimuli. In addition the noise associated with the placement (or application) of the criterion (for any given decision) is thought to come from a zero mean Gaussian distribution (variance = σ^2). Therefore, the combined noise parameter also has mean = 0 (variance = σ^2).

It is therefore possible to model a participant's categorisation 'strategy' during a task by using maximum likelihood estimates to ascertain values for the weighting parameters (and associated variance parameter) that are most likely to be correct, i.e., the parameter values that would come closest to generating the observed category responses produced by an individual subject. Modelling was performed using constrained non-linear regression, which applies maximum likelihood estimation and additionally enables constraints to be set on the parameters. The regression is an iterative process and attempts to minimise the loss-function (-2 Log-Likelihood), in other terms reducing the discrepancy between the recorded responses and those of the model, by varying the parameters (within the specified constraints).

[5] This method was not applied to the RB data for the following reasons 1) individuals are less likely to employ complex strategies at the start of a CL task, therefore participants likely to learn RB structure before applying II rules; 2) number of trials needed for such analysis is likely to be insufficient

The final solution then provides an overall loss-function for the specific model applied. This enables the various models to be compared statistically (in terms of the relative fit) by contrasting the associated loss-functions, using log-likelihood ratio test statistics.

This method allowed the assessment of a variety of response strategy models. The most general decision bound model has 4 free parameters: 3 of the 4 dimension weightings (with the remaining dimension weighting fixed at 1 so that the relative weightings of the other dimensions can be compared) and the variance-noise parameter. This model would therefore assess the most absolute form of an II strategy, with the possibility of all dimensions being weighted equally (therefore of equal importance in respect to the resulting category response). However, in the current context (involving stimuli with binary valued dimensions) it was not possible to determine whether the information from the dimensions implicated from the model were combined in an II- or RB-like fashion (see appendix C.1 for more details, p. 312). Consequently, this model would simply reflect the use of a multi-dimensional response strategy (i.e., involving all 4 dimensions), yet would not imply whether this was of an II or RB form.

In contrast, simple RB models (i.e., involving a single dimension) were also applied. For example, if only one dimension were to determine responses, the associated dimension weighting (e.g., w1) would be set to 1. The remaining 3 dimension weightings (i.e., w2 – w4) are therefore constrained to equal zero, with variance (noise) as the only free parameter.

Three multi-dimensional models (MD; i.e., using 2, 3 or 4 dimensions) were applied. Four single dimension models (SD) were also fitted to the data. These models reflected the use of a single dimension (e.g., using dimension 1, or dimension 2 etc). All the model variants were fitted to each participant's data individually. Further details of the models fitted to the data can be found in the appendix (C.2, p. 314).

For each participant a loss-function was found for every model. If it was statistically possible to determine the model with the lowest loss-function (by a chi-square comparison at *df* equal to the difference in the number of free parameters in the models — provided the models were nested), then the participant was 'confidently' classified (as using either a SD or MD strategy). If it was not possible to statistically determine the most likely model then the participant's strategy was classified as 'probable' (SD or MD), selecting the model with the lowest loss-function. Details of this process can again be found in the appendix (C.3, p. 315).

Response Strategy Modelling Analyses

The distribution of participants across the four different classifications of strategy use (i.e., confident or probable, SD or MD strategy) is shown in figure 4.5 below. The response strategy of one participant was unclassifiable and is omitted from the data below.

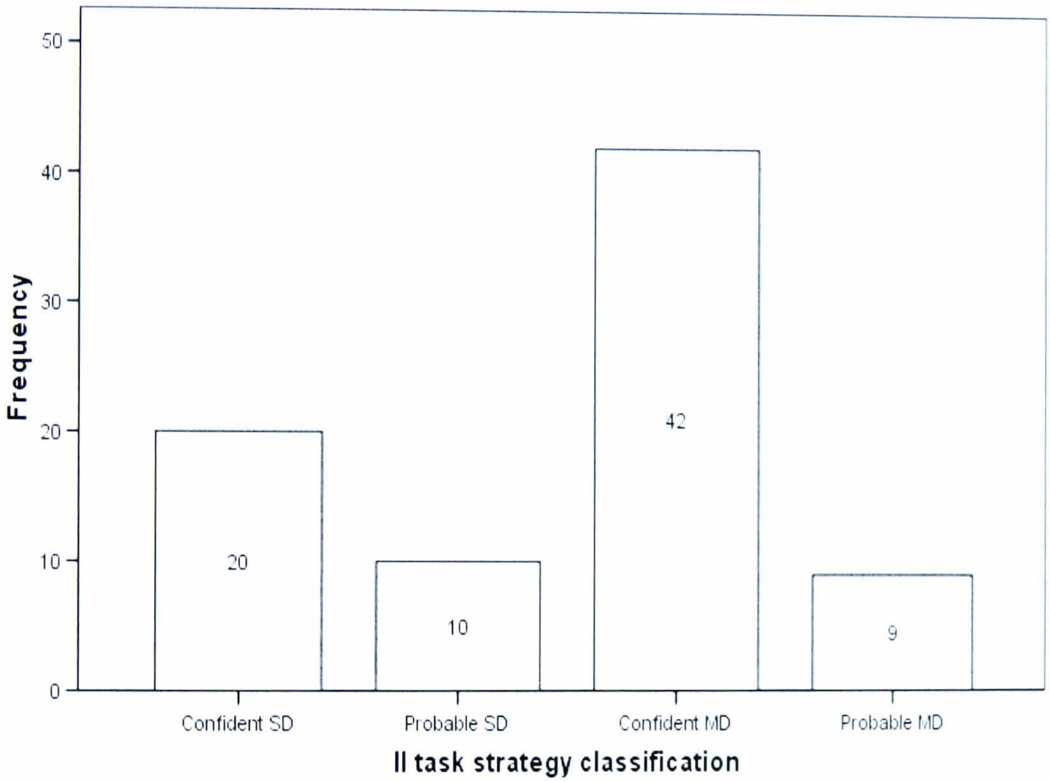

Figure 4.5: *Frequency of strategy use classifications for the II CL task*

Over 60% percent of participants appeared to be using an MD response strategy. To assess whether participants using this strategy performed better on the task than those using SD strategies, a one-way between-groups ANOVA was conducted with the response strategy groups comprising a 4 level factor. Additionally, a pre-planned contrast was performed to compare the MD groups with the SD groups (i.e., confident and probable combined). The main effect of strategy group was highly significant ($F_{(3, 77)} = 33.304$, $p < .001$) and the pre-planned contrast was also highly significant ($t_{(77)} = 5.804$, $p < .001$), indicating that those using MD strategies performed significantly better than those using SD strategies attaining almost 10% more correct responses.

As reported above, few participants were able to meet the learning criteria in the II CL task. In order to account for differences in performance on the task related to the degree of learning, participants were classified as learners or non-learners on the basis of whether they achieved more than chance levels of correct trials (from the binomial distribution this equates to 56% or above). Applying this criterion, 63 of the 82 participants were classified as learners of the task. The 19 non-learners comprised 10 from the CB1 group and 9 from the CB2 and included the one participant with an unclassified response strategy. Only 4 of the remaining 18 participants were classified as using an MD strategy (at the 'probable' level of confidence).

Removal of the non-learners from the analysis above did not alter the findings, those classified as using MD strategies still performed significantly better than users of SD strategies ($t_{(59)} = 1.768$, $p = .041$; 1-tailed prediction). Likewise, comparing learners from the different strategy groups for those confidently classified (i.e., confident MD cf. confident SD) also displayed the same difference but more robustly ($t_{(55)} = 4.386$, $p < .001$).

A final assessment of performance considered the possible effect of the CB condition across learners using MD or SD strategies, and non-learners. Therefore, a between participants design, 2 (CB group) by 3 (MD learners/SD learners/non-learners) ANOVA was performed (confident and probable classifications were ignored for the learners) with percentage of correct trials as the DV. A significant main effect for the strategy/learner – non-learner factor ($F_{(2, 76)} = 70.315$, $p < .001$) confirmed the previous analyses demonstrating that those participants using MD strategies performed better than those using SD strategies (and by definition, both groups performed better than the non-learners). The absence of a main effect of the CB condition ($F_{(1, 76)} = .181$, $p = .672$) or interaction ($F_{(2, 76)} = 1.011$, $p = .369$) suggests that this factor did not influence performance on this task.

Personality and Strategy Use

Differences between participants who used SD as opposed to MD strategies were assessed by independent samples t-tests for continuous variables and chi-square tests of association for gender and CB group. For the first set of comparisons non-learners are included together with learners. However, in an attempt to highlight any specific differences between the groups only those who were 'confidently' classified as using SD or MD strategies were included. Comparisons were made for the four key personality factors, memory measures, as well as for age, gender and CB. There was a significant association between gender and strategy use, specifically females were associated with the greater use of SD strategies ($\chi^2 = 5.522$, $p = .019$). Given the earlier correlations observed between gender and personality, it is not unsurprising that their were trends for higher N ($t_{(60)} = 1.805$, $p = .076$) and lower ImpASS ($t_{(60)} = -1.741$, $p = .087$) scores in those using a SD strategy. No other relationships were observed.

If the 5 participants who were classified as non-learners were removed from the SD group (there were no non-learners in the MD group), there were some subtle differences in the comparisons reported above.[6] The association with gender just failed to reach significance ($\chi^2 = 3.637$, $p = .057$). The observed trends for N and ImpASS also failed to appear ($t_{(55)} = -1.117$, $p = .269$; $t_{55)} = 1.251$, $p = .216$). However, the SD group were now significantly higher on E than the MD group ($t_{(26)} = 2.085$, $p = .043$; equal variances not assumed). Additionally, there was a significant association between SD strategy use and the CB2 group (who performed the II task in the first session; $\chi^2 = 4.108$, $p = .043$).

Factors Predicting Strategy Use

From the preceding analyses a variety of variables appeared to be associated with strategy employed on the II CL task. Logistic regression was used to predict strategy use from these key variables. Initially for participants whose strategy was confidently classified (irrespective of performance), gender, and CB group were entered as factors predicting whether a SD or MD strategy was employed.

This initial main effects model was significantly better than the intercept only model ($\chi^2_{(2)} = 7.190$, $p = .027$) and not significantly different from the saturated model ($\chi^2_{(1)} = .150$, $p = .699$). However, the removal of gender significantly deteriorated the -2 log-likelihood of the model ($\chi^2_{(1)} = 5.589$, $p = .018$), while the removal of CB did not ($\chi^2_{(1)} = 1.560$, $p = .212$). Subsequently it was observed that a model with only gender was significantly better than the intercept only model ($\chi^2_{(5)} = 5.631$, $p = .018$) and that females were just under 4 times (3.8; $CI_{95,}$ 1.21 – 12.20) more likely than males to employ a SD strategy on the task.

The addition of any of the four personality traits (as covariates) did not significantly improve the model, although a trend was observed for N ($\chi^2_{(1)} = 2.739$, $p = .098$), with increasing levels associated with increased likelihood of employing a SD strategy. Furthermore, the addition of participants whose strategy use was not confidently classified did not alter this general pattern of results.

[6] Naturally after the removal of these participants it is difficult to judge whether changes in the significance of the comparisons reflect changes due to decreased power from the lower sample size, or reflects an aspect of the cluster of non-learning participants

Overall II CL Performance

In an earlier analysis, it was observed that performance on the II task (percentage of correct trials) was most related to WM and gender, as well as N. However, it was predicted that overall performance on the II task would be most related to strategy employed. From the analyses above, strategy used appeared most related to gender although other variables (e.g., N, CB, ImpASS and E) may also be associated with strategy use. It is therefore possible that gender may relate to performance partially by association with strategy employed.

In a multiple regression, strategy employed (binary coded to reflect the use of SD or MD strategies) accounted for 32.9% of the variance in performance on the II task ($F_{(1, 76)} = 37.232$, $p < .001$). The personality trait that would add most to the model at this point was the positive schizotypy measure (UnEx). Inclusion of the predictor at this stage would significantly add to the model ($t_{(77)} = -2.042$, $p = .019$) and account for an additional 7.1% of the unexplained variance in II performance (i.e., squared partial correlation). If WM was instead entered at this point, it would contribute an additional 4.4% of the unexplained variance in II performance, although this just reached a trend ($t_{(76)} = 1.855$, $p = .067$). None of the remaining variables would contribute more than 4% if entered at this point.

A final, hierarchical regression was performed with strategy employed in the first step, followed by UnEx and WM in the second step of the model. Naturally, the initial model was as described above. The addition of the two predictors in the second step of the model contributed a significant additional 7.6% to the model ($F_{(2, 74)} = 4.730$, $p = .012$) which in total accounted for 40.5% of the variance in II performance ($F_{(3, 74)} = 16.782$, $p < .001$). Positive schizotypy was related to poorer performance on the task and uniquely contributed a significant 4.7% to the model ($t_{(74)} = -2.048$, $p = .019$). In contrast, WM was related to better performance on the task, although the unique contribution of 2.8% variance in II performance just reached a trend ($t_{(74)} = 1.871$, $p = .065$).

DISCUSSION

The aim of this first study was to explore the association between personality and performance upon two distinct CL tasks. In both of the tasks the aim of the participant was to learn to correctly classify presented stimuli. The stimuli used in each task were identical; only the structure of the categories across the two tasks was manipulated. Previous work relating personality and CL, together with a theoretical background from the general CL literature, lead to the expectation of a divergent pattern of association between the various personality traits and performance on the two tasks. The results of the study will be considered in relation to each of the two CL tasks separately, before a final summary.

Summary of RB Performance

Performance on the RB CL task was generally very good. Few participants failed to reach the learning criteria and performance appeared to be in line with previous studies. The number of trials required to reach the learning criteria in the two phases of the RB task appeared to be weakly related and likely reflects the differences in the two phases of the task. For example, the unannounced shift of category structure in the second phase requires the ability to inhibit a previously learned and successful category rule while seeking to discover the new category structure.

Contrary to the predictions arising from previous studies, ImpASS was not associated with superior performance on the RB task. In fact, ImpASS was associated with poorer performance on the second phase of the task. Two previous studies reported by Pickering (2004) had demonstrated a significant positive association between purportedly ImpASS traits and performance on RB CL tasks; in one study the relationship with performance appeared to be driven primarily by superior performance in the (analogous) first phase of the task. Naturally, however, the use of individual personality scales (i.e. novelty seeking – not used in the present study – and EPQ-P) in the Pickering (2004) studies, compared to the use of a composite ImpASS measure in the present study, may be one factor which complicates the comparison of these results.

One key difference between the present RB task and those reported by Pickering, concerns the nature of the stimuli. In the previous studies the stimuli were comprised of two-dimensions compared to the four-dimensional stimuli used in the present task. More crucially, however, the dimensions were multi-valued (height of a rectangle and position of an internal line) rather than binary valued dimensions used here. In the present study participants had to determine the correct dimension (e.g., colour of the background) and then ascertain the appropriate category-response assignment (i.e., is a blue background category A or category B). However, in the previous studies, in addition to establishing the rule dimension (e.g., the height of the rectangle) and correct category-response assignment (i.e., are tall or short lines category A), the participants had to derive and apply a category decision bound (i.e., what height discriminates category members; at what point is a rectangle tall rather than short). In contrast, with the binary valued dimensions in the present study, determination and application of a categorical dimension boundary could be considered to be 'error-free' (i.e., the background colour of a stimulus was either yellow or blue. Additionally, there is no reason to expect a participant to make 'perceptual' errors in the application of this decision bound). This leads to the possibility that ImpASS was associated to performance in the previous studies due to a superior ability in assessing the correct category decision boundary, or a superior application of the criterion, or a combination of both processes. This may be one possible explanation for the lack of a positive association with performance in the present study.

However, the previous discussion does not generate a simple hypothesis to account for the association between ImpASS and poorer performance on the second phase of the task. In addition, the study by Ball and Zuckerman (1990) also reported a positive association between ImpASS traits and superior performance on a RB type learning task. There are subtle differences between the task used by Ball and Zuckerman and those used in the both the present study and previous studies described by Pickering (2004). For example, in the Ball and Zuckerman task, participants were presented with two stimuli on each trial and were required to select the target stimulus (the other being a distractor). This can be considered a form of categorisation (i.e., the participant must learn to correctly choose the target on each trial). However, the presentation of two stimuli on each trial may have affected the mechanisms involved in the categorisation process (i.e., the comparison of the dimension features of the two stimuli on each trial), that in turn may have affected the cause of the association between the personality trait and performance.

Another possible area of influence on the performance on the second phase of the RB task appears to have been the previous experience of the stimuli for some of the participants (i.e., those who performed the II task in the first session). Participants that had performed the II task in their first session (i.e., prior to the RB task in the second session) required a greater number of trials to reach the criterion in the second phase of the RB task, relative to those participants that performed the RB task in the first session. It is only possible to speculate likely causes of this effect. However, it may be possible that previous experience of the stimuli, in a task in which performance was poor (and may therefore have been considered highly complex, frustrating, or both), influenced the subsequent assessment of the sudden change in category rule. For example, those with prior experience of the II task may have felt that highly successful performance on the task (involving these stimuli) was not possible and may have been more accepting of, or more frustrated with, the sudden increase of incorrect responses (at the switch of category rule). Subsequently, this may have impacted on their ability, or motivation, to adjust to the change in response contingencies and discover the new category structure.

While such speculation must be considered with caution, it is clear that this situation did not exist in the studies reported by Pickering (2004); participants were naive to the stimuli used in the RB tasks. Therefore, it is plausible that prior experience of the stimuli in a complex (II) task may have been an additional factor involved in the relationship between ImpASS and poorer performance on the second phase of the RB task observed in the present study. (Interestingly, although not reported in the previous results, the association with ImpASS and slower learning of the second category rule on the RB task did appear to be driven primarily by those participants that had previously performed the II task).

The issues just discussed may also apply to other results observed in respect of the RB task. The relationship between positive schizotypy (UnEX) and enhanced learning of the second RB category was also unexpected. The study reported by Pickering (2004) found that positive schizotypy was related to poorer overall performance on the RB task, especially on the second phase after an unannounced change in the category rule. Again, differences in the design of the task and study procedures could be pursued for a possible explanation of the divergent results. However, while the present result appears inconsistent with that discussed by Pickering, it would seem entirely consistent with previous literature demonstrating an association between schizotypy and decreased latent inhibition (i.e., quicker learning of an association between an outcome and a stimulus previously learned to be irrelevant, e.g., see Pickering & Gray, 2001).

Extraversion was found not to be significantly related to performance on the RB task, although there was a weak association with better performance on the first phase. While a relationship with performance on the task was not strongly predicted, the direction of the association is concordant with the idea that extraversion may relate to better performance on tasks that are driven by reinforcement learning.

It is important, however, to note a significant caveat in the ability to speculate on the specific mechanisms which may underlie any observed association between BAS-related traits (such as extraversion) and performance on such tasks. As discussed previously, an individual with a more reactive BAS may experience superior reward-driven learning (i.e., in standard trial-and-error paradigms; where the emphasis is upon producing rewarded cf. unrewarded – but not punished – responses). However, in addition to this learning or reinforcing component, BAS activation also gives rise to motivational effects; increased arousal and invigoration of ongoing behaviour (particularly toward the reward eliciting stimulus, e.g., Pickering & Gray, 2001). Hence, it is possible that either, or both, of these components may contribute to BAS-mediated behaviour and, for example, facilitate learning performance. Consequently, in circumstances in which an association between a BAS-related trait and performance occurs, it is not necessarily possible to distinguish between these causal processes unless this issue has been specifically addressed in the experimental design (e.g., see Pickering, 2004; Pickering & Gray, 2001; Smillie, Dalgleish, & Jackson, 2007). In the present thesis it is thought that the nature of the tasks is predominantly rewarding, thus, although the effects of these underlying mechanisms may be indistinguishable, they should not be in opposition. Hence, further tests can be designed to delineate these processes should reliable associations between BAS like traits and performance arise (the focus of the present research programme).

An additional relationship that was not predicted showed that neuroticism was associated with poorer learning of the second category rule in the RB task. It would seem that a reasonable post-hoc interpretation of this result would be that participants with higher levels of neuroticism experienced a greater level of anxiety when the first category rule suddenly appeared to be an invalid strategy (i.e., when the change in category structure had occurred). It is therefore possible that such an increase in anxiety levels lead to the subsequent impairment in the learning of the new rule, inhibition of the previous rule, or both.

A final interesting point to note is the apparent lack of a significant relationship between performance on the RB task and WM. This may have been because the executive requirements of the RB task (notwithstanding the unannounced switch of rule in the second phase) were too simplistic to be much affected by 'normal' levels of variance in WM observed in the current sample (e.g., the stimuli were comprised of 4 binary-valued dimensions, it may not be very demanding to hold a particular uni-dimensional rule in memory. Therefore, normal variation in WM, i.e., within general population, may be unlikely to show a relationship in the present task). An additional factor may have been the problematic distribution of the TTC1 measure, which may have reduced the power with which to detect a possible association with WM.

Summary of II Performance

In contrast to the RB task, learning of the II category was markedly poor. Just over 15% of participants were able to achieve the learning criterion, while the average proportion of correct responses was a modest 63% (cf. 50% chance level). It would therefore seem clear that few participants were applying the optimal rule. Again in contrast to the RB task, the application of less stringent learning criteria (i.e., 8 and 10 consecutive correct trials) drastically increased the numbers of participants classified as 'learners'. However, the number of 'non-learners' in the current study was still above that of the previous study by Ashby et al. (2003). It seems most likely that this reflected differences in the amount of experience of the task/stimuli in the Ashby et al. study.

Due to the markedly uneven distribution of learners and non-learners (by the 16 consecutive correct responses criterion), the majority of analyses of II task performance considered the percentage of correct trials on the task. By this measure neuroticism was moderately related to poorer performance. Additionally, better performance was somewhat related to being male and having better WM. However, in regression WM was the most important predictor followed by gender (the unique contribution of gender was not significant). The strong relationship between WM and performance on the purportedly II task is surprising given that the learning of such category structures is not thought to engage (or require) such executive processes.

This situation may partly arise due to the suggestion discussed previously; that the design (i.e., structure) of a CL task does not imply any exclusivity in the methods by which a participant attempts to learn a category structure. Indeed, the poor performance on the task may reflect the fact that many participants were not 'fully applying' the implicit system of the COVIS model (i.e., not relying upon implicit, procedural learning). One factor which may have influenced this was the length of the task; the number of trials may have been insufficient to allow the implicit system to 'dominate' learning of the category structure. This may also provide an explanation for the lack of a relationship with extraversion and task performance; if participants were not relying up the implicit system to learn the appropriate category responses (i.e., in a procedural fashion), then the predicted association with extraversion would not be expected to occur (at least in respect to the functioning of this system). In contrast, superior WM abilities appear to have helped facilitate performance even though sub-optimal strategies may have been employed.

An additional feature of the analyses of II task performance concerned the assessment of response strategies. Those classified as using MD strategies (i.e., using 2 or more dimensions), as opposed to SD strategies, performed significantly better on the task. Of the 62 participants whose strategies were confidently classified, just under a third (20) appeared to be using SD strategies (the inclusion of probable classifications increases the proportion of SD strategy use to 37%). This further supports the issue mentioned previously that participants may use sub-optimal rules or strategies on any given task. In addition, the MD strategies in this task are themselves possibly RB in nature (e.g., conjunctive rules).

Females appeared significantly more likely to use SD strategies. Accordingly, both higher levels of neuroticism and lower levels of ImpASS (both significantly associated with being female) were found to be associated with increased SD strategy use. However, gender was found to be the most significant predictor of strategy use.

Unsurprisingly, strategy employed was the most significant predictor of response accuracy on the II task. Both WM and positive schizotypy (UnEX) explained variance in II response accuracy over and above strategy employed. As described above, WM was associated with higher accuracy levels. Despite no previous association with performance, or strategy used on the task, positive schizotypy (UnEx) accounted for a significant proportion of the variance in response accuracy and was associated with poorer performance. This was a novel and unexpected finding. One approach which may be helpful in the consideration of a possible cause of the observed association could be prompted by the findings of impaired distractor cueing effects in relation to schizotypy (as discussed in chapter 1). As discussed by Steel et al. (2002), one of the various hypotheses put forward to account for the association between schizotypy and decreased distractor cueing effects suggested that high-schizotypy individuals may exhibit poorer associative learning mechanisms. Such processes may be crucial for the learning of stimulus-category contingencies, especially with multi-dimensional stimuli. Alternatively, it was suggested that stimulus representations may be more fragmented in patients with schizophrenia (and by association individuals scoring more highly on schizotypy). Such an account may also be expected to influence learning in the present task and the use of different numbers of dimensions. However, these proposals are highly speculative and should be considered tentatively.

The relationship between WM and performance on the II task is an intriguing finding and, as discussed above, supports the view that participants can employ a range of strategies to perform a particular task. To this end the use of formal models of participants' response strategies appears to have been a useful tool with which to further consider aspects of task performance.

Although the use of such techniques must adopt a degree of caution (for example, the method employed was not able to distinguish between II and conjunctive rules), in the present study their application enabled a degree of confidence regarding the use of uni-dimensional and multi-dimensional rules.

Conclusions

In summary, the study provided some interesting results, although not necessarily as predicted from previous research. In particular, performance on the RB task revealed associations with ImpASS and positive schizotypy (UnEx) in the opposite directions to those which were expected (i.e., ImpASS was predicted to relate to superior performance, while positive schizotypy was predicted to relate to impaired performance). Tentative suggestions were made as to the possible causes of these discrepancies, with a particular emphasis on the subtleties of task design. These issues may be pertinent for consideration in the design of future studies. The predicted association between extraversion and performance on the II task also failed to appear and it was suggested that this may have reflected the use of strategies other than those associated with the implicit CL system. In support of this, WM was found to be related to performance on the II tasks, yet not significantly related to performance on the RB task. The use of formal modelling of participants' response strategies was also pursued and appeared to be a valuable tool in the exploration of performance on the II task.

Chapter 5

Study 2 - The Impact of Irrelevant Stimulus Information during Speeded Categorisation

INTRODUCTION

Background

The preceding chapter explored the association between personality and performance upon two distinct CL tasks; RB and II. One key difference between the two forms of CL task concerned the number of stimulus dimensions that needed to be attended in order to obtain optimal categorisation performance. In the II task, classification of each stimulus was dependent upon the integration of information from 3 of the 4 stimulus dimensions. In contrast, in the RB task, 3 of the 4 dimensions were irrelevant; optimal performance required attention to be given to only one of the stimulus features.

The importance of effective allocation of attention towards relevant dimensions in such tasks is therefore self-evident and has been a recurrent theme in the thesis thus far; it is suggested that inter-individual variation in selective attention may be one mechanism through which personality mediated differences in cognitive function may arise. Furthermore, it is not difficult to see how such mechanisms could impact upon performance in related tasks. For example, if the previous RB task had involved a reaction time component (i.e., speeded classification), one simple hypothesis might be that superior selective attention abilities would facilitate rapid responding (e.g., by inhibiting the processing of irrelevant, possibly distracting, stimulus information).

One example, briefly discussed in the opening chapter, considered the association between positive schizotypy and performance on a task thought to be critically reliant upon selective attention. Building upon work with schizophrenia patients, the study by Steel et al. (2002) explored the effect of nominally irrelevant distractor cues on reaction time (RT) during a simple classification task. In the experiment, the target feature of a stimulus (the central letter, either an 'M' or a 'C', of a letter triad) was flanked by two letters (either X's or Y's). On each trial participants had to respond to the individually presented stimulus by pressing the appropriate key as quickly as possible.

In approximately 90% of the trials, the target letters were flanked by the same letters (i.e., XMX and YCY). These trials were referred to as 'valid' trials, as the flanker letters (Y's and X's) were appropriate cues (i.e., the same flanker-target pairing occurred in 90% of trials) to the category of the stimulus (i.e., M or C) and their associated responses. In the remaining trials the target-flanker pairings were reversed (i.e., YMY and XCX) and these trials were referred to as 'invalid', as the flanker letters were now inappropriate cues to the category of the stimuli/responses.

On invalid trials, it was predicted that the mismatch between the central target letter (e.g., M and its response) and the response more strongly associated with the flanker letters (i.e., Y, associated with C and the alternate response) would lead to slowed response times (relative to the valid trials). Therefore, the crucial measure was the difference in response times between the valid and invalid trials. This was termed the distractor cueing effect (DCE); the more the invalid flanker letters affected responses, the greater the DCE. Previous studies with schizophrenia patients had reported a decreased DCE (Jones et al., 1991, cited in Steel et al., 2002).

The key finding reported in Steel et al. (2002) was the demonstration of a significant negative relationship between positive schizotypy (UnEx) and the overall DCE ($r = -.340$, $p = .042$, $n = 36$). While the relationship between positive schizotypy (UnEx) and the DCE for the right- and left-hand were not of significantly different strengths (Williams $T2_{(33)} = 1.13$, $p = .130$), the correlation was significant only for right-hand responses ($r = -.370$, $p = .026$). This result was concordant with the previous studies which demonstrated reduced DCE for right-hand responses in acute-phase schizophrenia patients (Jones et al., 1991, cited in Steel et al., 2002).

Additional findings, not reported in the original paper, are analyzed here (raw data provided by Alan Pickering). There was a significant positive relationship between extraversion (as measured by the EPQ) and increased DCE for left-hand responses ($r = .401$, $p = .015$). The effect appeared to be lateralised for the left-hand; no significant relationship was observed for the DCE overall ($r = .170$, $p = .322$) and the relationship between extraversion and the DCE for the right-hand ($r = -.073$, $p = 673$) was significantly different from that of the left-hand (Williams $T2_{(33)} = 2.51$, $p = .009$).

Multiple regression analyses were performed for the right- and left-hand DCE separately, entering positive schizotypy (UnEx) and extraversion as predictors. The regression model accounted for 13.7% of the variance in the right-hand DCE, although this proportion just failed to reach significance ($F_{(2, 33)} = 2.629$, $p = .087$). However, positive schizotypy made a significant unique contribution to the model ($t_{(33)} = -2.248$, $p = .031$).

In contrast, the regression model accounted for a significant proportion of variance (20.4%) in the DCE for left-hand responses ($F_{(2, 33)} = 4.233$, $p = .023$). Unlike the model for the right-hand effect, positive schizotypy did not account for significant unique variance ($t_{(33)} = -1.342$, $p = .189$) whereas extraversion, although not contributing significant unique variance in the model for the right-hand, did account for a significant proportion of variance in the effect shown in the left-hand ($t_{(33)} = 2.217$, $p = .010$).

In summary, there were independent effects of positive schizotypy and extraversion on the observed DCE. Positive schizotypy was related to decreased DCE, especially for the right hand. In contrast, greater levels of extraversion were related to increased DCE, but this appeared lateralised for the left hand. However, one important issue related to the design of the study, concerned the relative number of valid and invalid trials. Approximately 90% of the trials were of the 'valid' stimuli; the remaining 10% comprising the 'invalid'. Hence, the two trial types differed not only in the 'validity' of the distractors but also in their novelty (the valid trials more familiar than the more novel invalid trials). Thus, interpretation of the effect of the invalid cues was confounded with any possible effects associated with the relative novelty of these stimuli (i.e. both of these factors may be predicted to increase response times for the invalid probes).

Aims

The goal of the present study was to re-examine the association between personality and DCE. A key aim was to remove the possible influence of novelty effects from the assessment of the DCE. To this end, an equal number of valid and invalid probe stimuli were used (this is discussed in more detail in the ensuing method section) thereby ensuring novelty effects were matched for both trial types. The design of the study was influenced by the CL literature explored in the preceding chapters. The stimuli used in the present task were similar to those used in the previous study (chapter 4) and comprised 4 binary valued dimensions. As in the Steel et al. (2002) study participants classified the presented stimuli on the basis of a single feature (dimension) of the stimuli (cf. the RB task in chapter 4). For a greater analogy with the Steel et al. study (in which participants were informed how to categorise the stimuli (i.e., they were instructed to respond with a specific key if the central letter was 'M' etc) the 'learning' component of the present study was minimised by presenting the participants with a strong hint as to the category structure (i.e., they were told which was the relevant dimension).

A subset of the (16) possible stimuli were used in an initial phase of the task. The stimuli were selected so that the 3 nominally irrelevant dimensions created the appropriate distractor effects. In this phase, each value of the 3 irrelevant dimensions was more strongly associated with one of the two categories/responses (e.g., yellow backgrounds were more closely associated with category A, whereas blue backgrounds were more closely associated with category B). Therefore, in comparison with the Steel et al. (2002) study there were 3, as opposed to 1, dimensions that were partially valid indicators of the stimulus category. Furthermore, in combination these 3 dimensions also formed a congruent II rule that was 100% predictive of the stimulus category. In a subsequent phase, two types of novel probe were introduced in which the values of the 3 irrelevant dimensions were either congruent or incongruent with the actual category of the stimulus. The DCE was subsequently assessed by the comparison of the response times to these distinct probe types. Therefore, the primary aim of the present experiment was to explore whether a DCE could be induced by the presence of a nominally irrelevant II category structure during RB categorisation involving a separate dimension. (A DCE could be induced through the 'learning' of any combination of the 3 irrelevant dimensions; it was not assumed that the DCE would arise only if the full II structure was learned).

A subsidiary aim of the study was to explore the role of feedback on the DCE. This was considered especially pertinent in light of the methodology employed. In chapter 2 the role of feedback was considered in respect of the distinct RB and II CL systems. It was noted that an appropriately timed feedback signal was crucial for learning involving the implicit system which may be employed for the learning of II category structures (or more specifically, the appropriate behavioural response). In contrast, such feedback is not necessarily critical for learning RB category structures. Exploring the role of feedback in the current context may therefore provide a useful insight into the nature of the processes involved in the DCE. Absence of the DCE in a condition where trial by trial by feedback is not given may suggest a vital role for a dopaminergic reward signal (e.g., Schultz, 1998, 2006) in the development of associations between the irrelevant stimuli dimensions and category structure (or more accurately appropriate response). Furthermore, due to the proposed association between dopaminergic function and major personality traits (i.e., extraversion, ImpASS and positive schizotypy), the feedback manipulation may also influence the relationship between personality and the magnitude of the DCE.

In summary, the primary aim of the study was to explore a new paradigm with which to concurrently investigate the DCE and the association between this phenomena and specific personality traits. The design of the present experiment would also help to confirm that the results reported by Steel et al. (2002) were most likely due to a genuine DCE as opposed to novelty effects. The observed association between positive schizotypy, extraversion and the DCE could also be reassessed. ImpASS has been linked with enhanced performance on CL tasks involving categories that are defined by a uni-dimensional rule. One suggestion has been that such individuals benefit from superior selective attention. Therefore, it may be possible that this trait cluster will demonstrate an association with performance on the current task specifically via a reduced DCE. Finally, the role of feedback in the development of the DCE and association with personality would also be considered.

METHOD

Participants

A sample of 140 participants, age range 18 to 48 years (mean age = 23.62, SD = 5.78), took part in the study. The data was collected over two separate testing periods; a summer and autumn session. During the summer session, 64 participants (32 males and 32 females) were recruited from various departments within Goldsmiths, University of London and the local area, and in the main, were non-psychology students. These participants received a payment of £13 for taking part in the study. A further 76 participants (10 males and 66 females) were recruited in the autumn session and took part in order to gain course credit (1st year BSc Psychology undergraduates). Apart from the difference in the distribution of gender across the two samples, the participants in the summer study were slightly but significantly older than those in the autumn session (26.67 cf. 21.05 years; $t_{(128)} = 6.538$, $p < .001$). All participants' spoken English was sufficiently fluent to enable completion of the personality questionnaires. Clarification of any terms in the questionnaires was given if requested.

Design

Personality Questionnaires

In this study participants completed the EPQ-E, OLIFE, BFI, SSS, BIS/BAS scales and the SPQ. As described in chapter 3, four personality factors (extraversion, ImpASS, positive schizotypy and neuroticism) were obtained from these results. The following analyses will henceforth simply refer to these four factors as: E, ImpASS, positive schizotypy and N.

Incidental Learning Reaction-Time Task (RT task)

The concept of the present study partially evolved from the CL tasks employed in the previous chapter. The stimuli in the present study consisted of 4 dimensions, each dimension taking one of two possible values (i.e., matching the basic features of the stimuli used in study 1). In the initial phase of the task participants learned to categorise 6 (of the possible 16) stimuli. These stimuli formed two categories, with each category consisting of 3 of the stimuli. The category structure was RB and determined solely by the value on one of the four stimulus dimensions (cf. RB CL task used in study 1). The construction of the training stimuli is illustrated in the first three rows of table 5.1 below, with '1' and '-1' indicating the value of each of the 4 dimensions (I – IV) for each stimulus. Table 5.1 demonstrates that the first dimension determined category membership; 'category A' stimuli had a value of -1 on the dimension while 'category B' stimuli had the complementary value (1) on this dimension.

Table 5.1: *Reaction Time Task Stimuli**

	Category A				Category B			
	I	II	III	IV	I	II	III	IV
Training	-1	1	-1	-1	1	-1	1	1
Training	-1	-1	1	-1	1	1	-1	1
Training	-1	-1	-1	1	1	1	1	-1
Incongruent	-1	1	1	1	1	-1	-1	-1
Congruent	-1	-1	-1	-1	1	1	1	1

*Each row represents one stimulus from category 'A' and its complementary stimulus from category 'B'. Each column (I – IV) reflects a different stimulus dimension; the shaded dimension is the target dimension.

This subset of the 16 possible stimuli was chosen because the remaining, nominally irrelevant stimulus dimensions (i.e., dimensions II – IV) formed a congruent II category structure that was equally predictive of the stimulus-category membership for the 6 training stimuli (i.e., if the sum of the values on dimensions II – IV is greater than 0 then the stimulus is category B; if the sum of these values is less than 0 then the stimulus is category A). Additionally, it can be seen that within this subset of the stimuli, each value on a particular dimension is more closely associated with one of the two categories. For example, the values '-1' on each dimension occur in 2 of the 3 training exemplars from the category A stimuli, whereas the complementary pattern is seen for the value '1' and category B stimuli. Therefore, the key issue was whether any incidental 'learning' of the association between the values on the 'irrelevant' dimensions (i.e., dimensions II – IV) and the categories (or responses) would occur while a participant was classifying the stimuli based upon the value of a separate dimension (i.e., dimension I).

A series of pilot studies lead to a slight modification of the stimulus dimensions used in the creation of the stimuli for the present study (e.g., the numerosity dimension was removed owing to possible Spatial Numerical Association of Response Codes (SNARC) effects, Dehaene, Bossini, & Giraux, 1993). The dimensions used in the present study were: shape of the background (circle/square), colour of the background (blue/yellow), size of inner triangle (small/large) and orientation of inner triangle (upwards/downwards). Figure 5.1 demonstrates one version of the stimuli used in which the size of the inner triangle determined category membership (cf. table 5.1).

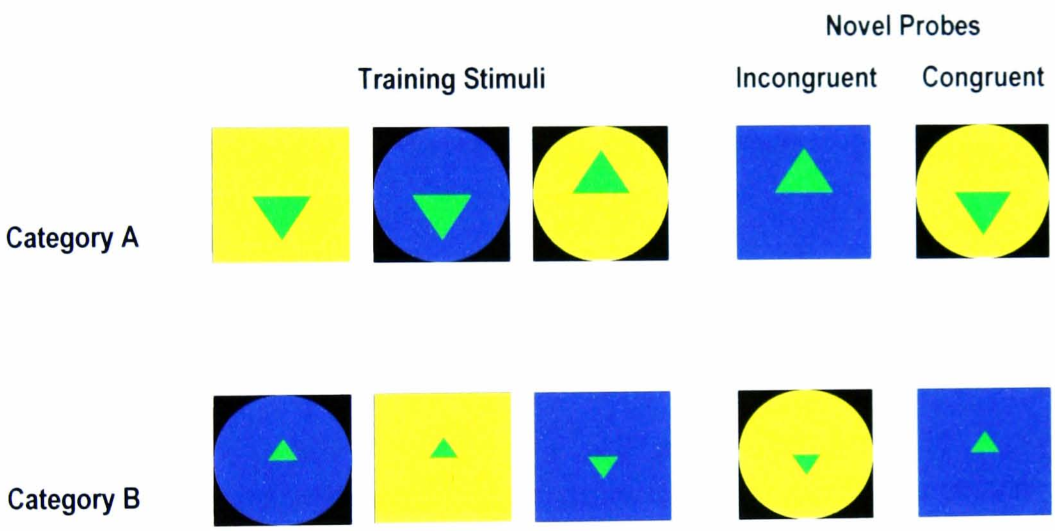

Figure 5.1: *Example of the Reaction-Time task stimuli*

The initial phase of the task was designed as a training phase in which the participants were to learn the simple category structure and focus upon responding as quickly and accurately as possible in categorising (i.e., category A or B) each stimulus presented. The basic instructions followed the same format used in the previous study with one key alteration. The participants were given a strong hint regarding the category structure; more specifically, they were told the feature or dimension critical for determining the category to which each stimulus belongs. For example, in one condition the shape of the stimulus background (either a circle or square; discussed in more detail below) determined category membership. The hint given to the participant was therefore: "The categories are related to the shape of the background". This hint was given in the instructions presented on the computer and repeated verbally by the experimenter prior to beginning the task.

As in the previous study, appropriate feedback was given after each category response (i.e., participants responded by pressing either the category 'A' or 'B' key (using the left- or right-index finger respectively) and received visual, 'correct' or 'wrong', and auditory feedback). Therefore, given that only two background shapes and two response alternatives (i.e., A or B) were available, it was theoretically possible to learn the category structure in two trials. In the RB CL task used in study 1, participants required an average of 40 trials to reach the learning criterion of 16 consecutive correct responses. Therefore, given the hint regarding the category relevant dimension used in the current study, it would be expected that participants would be able to learn the category structure in many fewer than 40 trials. In order to establish fluent responding on the task (e.g., for stable RTs) the initial training phase consisted of 120 trials (i.e., 20 presentations each of the 6 training stimuli, in a fixed random order for each participant). The fixed number of presentations would help to ensure that each participant received an equal experience of the stimuli and additionally allow sufficient time for any possible associations between the irrelevant dimensions and the category structures (or category responses) to develop.

In the training phase participants were asked to focus upon fast and accurate responding once they had successfully established the appropriate category structure (and response). To assess whether any incidental learning of the association between category responses and the irrelevant dimensions had occurred, 4 novel probes were introduced in the test phase. The probe stimuli were interspersed among repeated presentations of the 6 original training stimuli. There were two novel probes per category; an incongruent and congruent probe. The structure of the probe stimuli can be seen in table 5.1 above (below the dashed line). The incongruent probes were so named because the category most strongly associated with the 3 irrelevant dimensions (i.e., II – IV), whether considered individually or combined using the II rule described above, was now incongruent with the actual category of the stimulus. In contrast, the values on dimensions II – IV of the congruent probes matched the actual category of the stimulus.[1]

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[1] For example, the value on dimension I of the incongruent category A stimulus is '-1'; defining the stimulus as a member of category A. The values on the remaining 3 dimensions are all '1'. From the stimuli used in the training phase, this value is more strongly associated with category B stimuli/responses (for dimensions II – IV). Additionally, combining the information from these dimensions, using the II rule described in the text, would also arrive at the opposite classification i.e., the sum of dimensions II – IV = 3; therefore the category as determined by the II rule is B)

The test phase of the task consisted of 264 trials. The first 24 trials of the test phase comprised 4 occurrences of each of the 6 training stimuli in order to re-establish fluent responding. Each of the 4 novel probe stimuli were presented 6 times during the remaining 240 trials; occurring on average every 10 trials. The probe stimuli were interspersed among the training stimuli (each of which were presented 36 times). The stimuli were presented in the same randomised order for every participant.

The incidental learning of any association between the irrelevant dimensions and the category structure, or category responses, would give rise to the following predictions. The RTs to the incongruent probes are predicted to be slowed due to the interference caused by the values on the irrelevant dimensions indicating a conflicting category response to the one that was required. In contrast, this category response interference would not occur for the congruent probes. It may even be possible that RTs are facilitated as the values on the irrelevant dimensions are all most strongly associated with the actual category of the stimulus. However, it is conceivable that the novelty of the probe may induce a slowing effect which might thus obscure such a faclitatory effect.

In line with the Steel et al. (2002) study, the critical behavioural measure was the difference in RTs across the incongruent and congruent probes; with a larger difference indicative of a greater effect of the irrelevant dimensions and subsequently greater incidental learning. A key benefit of the present design was the ability to disambiguate the effect of the congruency of the nominally irrelevant dimensions from novelty effects. In the Steel et al. (2002) study the stimuli with 'invalid' (incongruent) distractors were presented much less frequently than those with 'valid' (congruent) distractors and therefore the comparison of RTs between these stimuli conflated novelty and congruency effects. In the current study, both probe types were novel, and therefore any differences in RTs could be confidently attributed to congruency effects. Other features of the stimuli were also balanced across the task (i.e., each possible value on the four dimensions was presented equally), with the same combination of values on the irrelevant dimensions used to create the incongruent and congruent probes for both categories (i.e., '-1' on dimensions II – IV were used for the congruent category A probe and incongruent category B probe stimuli).

An additional experimental manipulation was made in order to explore the secondary hypothesis discussed in the introduction. A version of the task was created in which feedback was not given during the training phase (non-FB version). Every attempt was made to make the non-FB condition as analogous as possible to the FB condition. Apart from the removal of feedback during the training phase the only other alteration was to the instructions provided. The participants were given the same hint regarding the relevant dimension. The instructions emphasized that no feedback would be given during the task and that participants were to establish a consistent method of assigning the stimuli to either category A or to category B (based upon the dimension specified in the hint: e.g., "The categories are related to the shape of the background") and maintain this method for the duration of the experiment.

In the FB version of the task, the reinforcement contingencies ensured that the response-category assignments were the same for each participant (e.g., stimuli with circular backgrounds are category A, those with square backgrounds are category B). However, in the non-FB version of the task, two 'correct' category-response assignments were possible: participants could either assign stimuli in the same way as those in the FB condition (e.g., as described in the preceding sentence) or the assignment (category A and B) could be reversed (i.e., with square backgrounds indicating a category A and circular backgrounds a category B stimulus for the current example). This did not alter the instructions given for the critical test phase, which was identical in both the FB and non-FB versions, participants were simply required to continue categorising the stimuli in exactly the same manner as they had been during the training phase. The critical behavioural measure was therefore identical in both versions.

<u>WM Task</u>

The WM task was identical to that used and described in the preceding chapter.

Procedure

Participants completed a consent form which included a broad outline of the tasks involved in the study as well as informing the participant of their right to withdraw at any point (and other related information). Basic participant details (i.e., age, gender) were also recorded. As the critical task employed reaction time methodology, only right-handed participants were recruited. All participants described themselves as predominantly right-handed.

Participants were recruited jointly with another experimenter, and the testing sessions comprised a mixture of the two independent studies. (Participants were informed that the two studies were unconnected and that the joint recruitment was simply for practical reasons). As mentioned in the introduction, the data for this experiment were collected across two separate study sessions (summer and autumn). Participants who took part during the summer study completed two separate testing sessions on different days within one week. Each session lasted approximately 70 minutes. The RT task was performed in one session, followed by two of the personality questionnaires (SSS and BIS/BAS scales) and a final experiment (discussed in the following chapter). The WM task was conducted in the remaining session along with the BFI and SPQ questionnaires (and other tasks related to the co-joint study). The order of these two sessions was counterbalanced. The remaining questionnaires (EPQ and OLIFE) were completed between the two testing sessions in the participants' own time.

Testing in the autumn study was conducted within a single session, lasting approximately 75 minutes. The RT task was performed in the session along with the WM task (and an additional experiment related to the co-joint study). Additionally, the BIS/BAS scales and the BFI personality questionnaires were completed during the session. The remaining personality questionnaires (SSS, SPQ, EPQ and OLIFE) had been previously completed by the participants for course credit (i.e., all participants in the autumn study were 1st year psychology undergraduates).

RT Task

The stimuli used in the task were described previously. The type of category structure to be used in the experiment involved a single dimension. A partial counterbalancing of the dimension used to define the category structure was applied, with 2 of the possible 4 dimensions used as the category dimension in the present study. In CB1, the size of the inner triangle determined the category of each stimulus. Category A stimuli contained a large triangle, whereas category B stimuli contained a small triangle (this particular category structure is as shown above in figure 5.1). In a second condition (CB2), the shape of the stimulus background was used. Category A stimuli had a circular background, whereas category B stimuli had a square background (Naturally, this refers to the FB version of the task, the category labels, A and B, could be reversed in the non-FB version).

As described above, two different versions of the task were performed; a standard version with response accuracy feedback during training (FB) and a version with no feedback (non-FB). All participants in the summer study took part in the FB version; half of the participants were in the CB1 condition, with the remaining participants in the CB2 condition. In the autumn study, 33 participants took part in the CB1 condition, which used a FB version. A further 43 participants took part in the CB2 condition using the non-FB version of the task. This distribution of participants is summarised in table 5.2 below.

Table 5.2: *Distribution of participants taking part in the in CB1 and CB2 conditions, FB and non-FB versions of the task across the two testing sessions*

	Summer	Autumn	
	FB	FB	non-FB
CB1	33	32	-
CB2	31	-	44

The instructions for the task were presented via the computer and reaffirmed verbally by the experimenter prior to the start of the task. The participants were informed that they were required to classify presented stimuli into two categories. On each trial a (single) stimulus would be presented and remain on the computer screen until either the keyboard key labelled 'A' ('z' key covered with an appropriately marked sticky label), for category A, or the key labelled 'B' ('/' key again covered with a sticky label), for category B, had been pressed. Initially, as the category of each stimulus would be unknown, the participants were advised to guess. In the FB condition, participants were subsequently informed that visual and auditory feedback ('CORRECT' or 'WRONG' displayed on the screen in green or red, together with a pleasant or unpleasant sound, respectively) would be given after each trial. A demonstration of both types of feedback was given. All participants (in both the FB and non-FB versions) were informed that their task was to assign each stimulus as quickly and accurately as possible to the correct category. Finally, participants were given the category rule 'hint'. For example, the CB1 hint group were informed that:

"The categories are related to the size of the small shape in the centre of the display".

As described in the method section above, the instructions given to participants in the non-FB version required some minor alterations (i.e., no feedback would be used and therefore participants needed a different explanation of how to 'correctly' categorise the stimuli). The instructions followed the same general format, although the participants were informed of the category 'hint', that the categories were related to the background shape of the stimuli (i.e., all non-FB participants were in the CB2 condition), on more than one occasion. In contrast to the FB version, in which participants were able to use the feedback to guide their category responses, the participants were informed that no feedback would be given during the task and were simply instructed to establish a method of consistently assigning the stimuli to either category A or category B ("based upon the shape of the background"). The percentage of correctly assigned stimuli would be displayed to the participant at the end of the (training) session. The final instructions, describing the aim of task (to assign each stimulus as quickly and accurately as possible to the correct category), and a final reminder of the category 'hint', were identical to those in the FB version. In both the FB and non-FB versions the instructions were summarised verbally by the experimenter before the participant proceeded to perform the task.

The stimuli were presented centrally on a 21 inch CRT monitor with a black background. The stimulus remained on screen until the participant had pressed one of the two possible response keys. After each response the stimulus was immediately wiped from the screen. For those in the FB condition, the accuracy feedback was presented centrally for 1 second simultaneously with the appropriate feedback sound. In the non-FB version, the screen remained clear for one second.

The training phase consisted of 120 trials. At the end of the training phase the experimenter re-entered the testing room. The percentage of correct trials was displayed upon the screen (for participants in the non-FB version, the percentage was calculated under the assumption that the appropriate dimension was being used). At this point the experimenter asked the participant how they had been deciding to respond category 'A' or 'B' for each stimulus (i.e., the participant's category 'rule', although this term was not used). The combination of the self-reported strategy of the participant, along with the displayed percentage of correct trials, enabled the experimenter to ascertain whether the correct category rule had been used. Provided that the participant had described an appropriate method of categorisation (corroborated by the percentage of correct trials) the experiment continued to the test phase. If the participant described an inappropriate categorisation strategy (e.g., using the incorrect dimension, or using more than one dimension), the experimenter explained the correct category rule (e.g., if the stimulus contained a large triangle it belonged to category 'A', otherwise, if the stimulus contained a small triangle it belonged to category 'B') and instructed the participant that this rule should be used for the following phase.

The instructions for the test phase were presented by the computer. The participants were informed that the task was continuing in exactly the same manner as before the break and to continue to allocate the stimuli to either category A or B in exactly the same way (i.e., using the method just described to the experimenter, provided that they had described the appropriate category rule). Emphasis was again placed upon responding as quickly and as accurately as possible, with the prospect of obtaining a ticket to enter a (£25) prize draw; provided responses were sufficiently accurate and rapid (to be monitored by the computer). Participants were additionally advised that a small number of response errors were acceptable and to ignore any that were made; the emphasis again upon responding quickly and accurately.

Response feedback was not given during the test phase (in any version of the task). Participants were instructed to continue to assign the each stimulus to the appropriate category. In addition, participants were advised to respond in the normal way to any new stimuli that may occasionally be presented. After a final reminder to focus upon fast and accurate responses, participants were warned that upcoming session would be longer than the previous (i.e., training) session and to try not to get frustrated.

WM Task

The WM task was administered in the same manner as the previous study.

RESULTS

CB1 (n = 65)

Participant Data

The personality measures were used to create factor scores (E, ImpASS, positive schizotypy and N) as described in chapter 3. The extracted factors were orthogonal, yet this study naturally contained only a subset of the participants involved in this analysis (of the 65 participants who took part in this condition, 2 did not have a complete set of personality data and hence are excluded from the following personality correlations; hence, n = 63). Correlations confirmed that scores on these four measures were unrelated. Age was also unrelated to all personality factor scores except ImpASS, with which there was a significant negative correlation (r = -.300, p = .017, n = 63). There were no significant gender differences in levels of positive schizotypy or E. However, males scored significantly higher on ImpASS ($t_{(61)}$ = 2.285, p = .026) while females scored more highly on N ($t_{(61)}$ = -3.321, p = .002). Males were also 3 years older than the females on average, although this difference just failed to reach significance ($t_{(63)}$ = 1.904, p = .062).

WM performance was positively related to ImpASS ($r = .359$, $p = .004$, $n = 63$) but unrelated to age or any other personality factors. There was no significant difference in WM between males and females.

Training Phase

Six participants made more than 20 response errors (range 22 - 44) during the last 100 trials of the training phase of the task. Participants that did not appear to have applied the correct category rule during the training phase were instructed as to the appropriate strategy for classifying the stimuli. These participants performed well during the test phase, making 10 or fewer errors. However, in case poor response accuracy during the training phase may have affected subsequent performance in the test phase, the inclusion of this group of participants was monitored.

Test Phase

Owing to equipment failure, the data was not recorded for one participant (hence, initial $n = 64$). The first 24 trials of the test phase were retraining trials involving the 6 stimuli presented in the training phase. These trials were removed from the following analyses. Additionally, any incorrect responses, or reaction times greater than 1 second, were removed from further processing.[2] Almost 70% of the participants made 5 or fewer incorrect responses on the last 240 trials (91% making 10 or fewer errors). One additional participant was removed after making more than 59 (25%) errors. A further 5 participants (7.8%) made between 11 and 22 errors. Any possible effect of including/excluding these participants was monitored.

To establish whether the key experimental manipulation appeared to have been effective (i.e., whether mean RTs for the maximally incongruent probes were slower than those to the maximally congruent probes) a 2 (probe type) x 2 (response hand) repeated-measures ANOVA was performed on mean RT (in ms). A significant main effect of probe type was observed (incongruent, $M = 511$, $SE = 12$; congruent, $M = 494$, $SE = 11$; $F_{(1, 62)} = 7.206$, $p = .009$). There was no main effect for response hand ($F_{(1, 62)} = 1.679$, $p = .200$) or interaction ($F_{(1, 62)} = .227$, $p = .635$). Figure 5.2 below demonstrates that the maximally incongruent probes were indeed slower than the congruent probes, for both the left and right hand.

Pre-planned contrasts assessing the difference in RTs between the probe types were performed for each hand separately. A trend was observed for the left-hand ($t_{(62)} = 1.393$, $p = .168$) while the contrast for the right hand fell just short of reaching statistical significance ($t_{(62)} = 1.961$, $p = .054$; both contrast were 1-tailed, Bonferroni corrected for two comparisons).

Surprisingly, the left hand appeared quicker than right hand responses, although as described above, this difference was not significant. In summary, the pattern of RT results suggests that the experiment appeared to work as intended. The incongruent probes produced slower responses than the congruent probes.

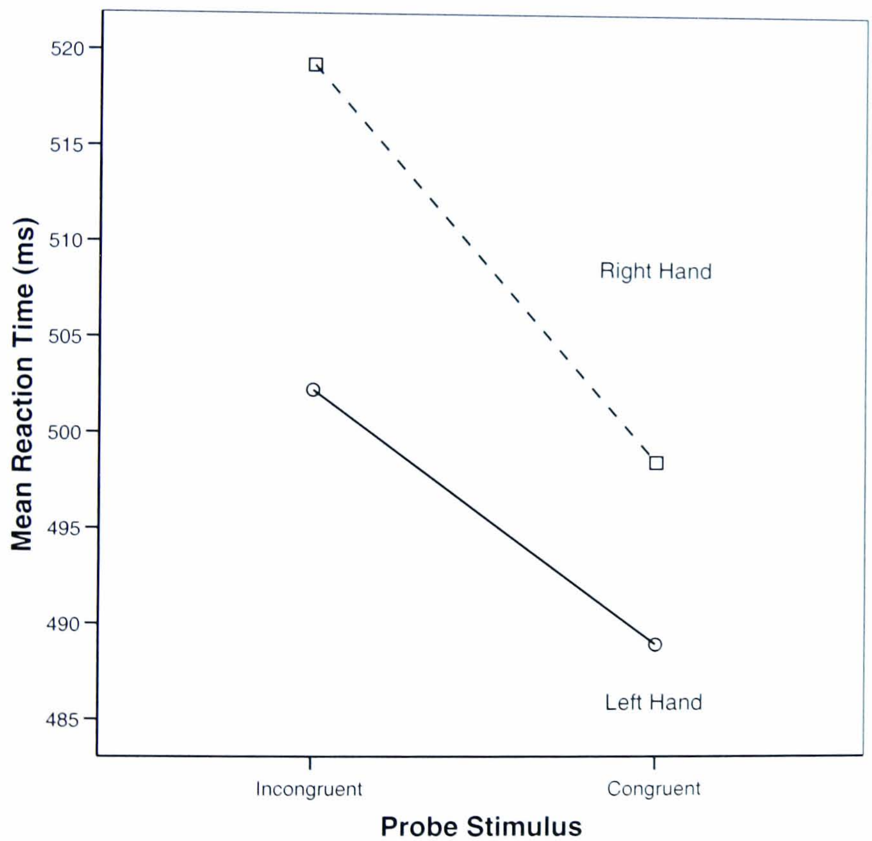

Figure 5.2: *Mean reaction times to incongruent and congruent probes, by response hand*

[2]To monitor the effect of the filtering incorrect and slow responses, the number of the critical probe trials removed by the process was assessed. For the majority of cases (88%) the mean reaction time for each of the 4 probes was based upon all 6 occurrences. In all other cases, except one, the mean reaction time was based upon 5 occurrences. Only in one instance were 2 occurrences of a probe stimulus removed by the filter; the resulting mean probe RT was therefore calculated using 4 occurrences.

Personality and the DCE (CB1)

Three key performance variables were considered in relation to the personality factors and individual differences variables. A composite measure (an aggregate of left and right hand responses) of the difference between the incongruent and congruent probes was calculated, and referred to as the distractor cueing effect (DCE). This measure was also calculated for the left and right hand individually (DCE: LH / DCE: RH).

The three DCE measures were unrelated to age, gender or WM.

The correlations between personality and the DCE measures are shown in table 5.3 below (the sample size, n = 61, reflects the exclusion of the participants with missing questionnaire or missing/poor task data).

Table 5.3: *Correlation between personality and the DCE (n = 61)*

		DCE	DCE (Left Hand)	DCE (Right Hand)
Extraversion	Pearson Correlation	-.066	.137	-.204
	Sig. (2-tailed)	.614	.294	.115
Positive Schizotypy	Pearson Correlation	-.262(*)	-.050	-.269(*)
	Sig. (2-tailed)	.042	.702	.036
ImpASS	Pearson Correlation	.003	.010	-.006
	Sig. (2-tailed)	.984	.937	.962
Neuroticism	Pearson Correlation	-.137	.073	-.232
	Sig. (2-tailed)	.291	.575	.072

* Correlation is significant at the 0.05 level (2-tailed).

The overall DCE was negatively related to positive schizotypy. This appeared to be primarily driven by the relationship with right hand responses, although comparison of the correlations for the left and right hand individually suggested the relationship across hands were not of significantly different strengths (Williams $T2_{(58)} = 1.105$, $p = .137$). Extraversion was unrelated to the overall DCE. However, the relationship across hands was significantly different (Williams $T2_{(58)} = 1.710$, $p = .046$). The left hand effect was positively, while the right hand effect was negatively, related with extraversion. Neuroticism was related to less DCE for the right hand, although this only reached a trend. The difference between the effect for the left and right and their relationship with neuroticism just failed to reach significance (Williams $T2_{(58)} = 1.529$, $p = .066$). The DCE appeared unrelated to ImpASS.

To compare the current results with those of the Steel et al. (2002) study, two separate multiple regression analyses were performed for the left- and right-hand DCE. These first analyses included only the E and positive schizotypy factors. The result of the regression for the right-hand DCE was broadly in line with the Steel et al. findings; the model accounted for a significant 10.2% of the DCE variance ($F_{(2, 58)} = 3.296$, $p = .044$). The unique contribution of positive schizotypy just failed to reach significance ($t_{(58)} = -1.978$, $p = .053$), while the unique contribution of E was not significant ($t_{(58)} = -1.386$, $p = .171$). (N did not significantly add to this model; $t_{(57)} = -1.685$, $p = .097$).

The model did not account for a significant proportion of variance in the DCE for left-hand responses ($R^2 = .023$; $F_{(2, 58)} = .686$, $p = .508$).

These results demonstrate a close replication of the published results from the Steel et al. (2002) study. Positive schizotypy was again related to decreased DCE overall, and the effect appeared, as in Steel et al., to be more strongly associated with right-hand responses.

However, the unpublished relationship between E and increased DCE in left-hand responses was not observed (although consideration must be given to the different measures of extraversion, the correlation between the left-hand DCE and this trait across the two studies was not significantly different; z-score = 1.316, p = 0.188). Extraversion appeared to be more strongly associated with decreased DCE for right-hand responses in the present study (although this relationship did not account for a significant proportion of unique variance when entered in a multiple regression with positive schizotypy).

CB2 (n = 75)

Participant Data

Owing to poor performance on the test-phase of the task (and in one case an equipment failure leading to the loss of data), the data from 4 participants are excluded from the following analyses (the exclusion criteria are described in more detail below). Correlations confirmed that scores on the personality factors were unrelated in this sample. Age was also unrelated to all personality factor scores although a trend for a negative relationship with extraversion was observed ($r = -.228$, $p = .053$, $n = 71$). There were no significant gender differences in levels of positive schizotypy or extraversion. However, males scored significantly higher on ImpASS ($t_{(69)} = 3.193$, $p = .002$) while females scored more highly on N ($t_{(69)} = -2.939$, $p = .004$). Males were also significantly older than the females (by on average 4 years; $t_{(69)} = 2.908$, $p = .005$).

Of the CB2 sample, 42 performed in the non-FB condition (autumn session) while the remaining 29 participants performed in the standard FB version of the task (summer session). There were proportionally more females in the non-FB (35) condition relative to the FB condition (17), and the non-FB were also significantly younger (on average 7 years younger; $t_{(69)} = -7.451$, $p < .001$). There was also a trend for lower scores on ImpASS for this group ($t_{(69)} = -1.789$, $p = .078$). However, no other differences in personality or WM performance were observed.

WM (n = 75)

WM performance was unrelated to age or any other personality factors. This is surprising given the high positive correlation found between WM and ImpASS in the CB1 group ($r = .359$, $p = .004$, $n = 63$). The strength of this particular correlation in the present condition (CB2; $r = -.054$, $p = .647$, $n = 75$), was significantly different to that of the CB1 group (z-score = 2.459, $p = 0.014$). Further exploration of the relationship between WM performance and ImpASS across the entire study, appeared to suggest that the significant correlation observed for the CB1 group was primarily driven by the participants who took part in the autumn session. However, it is unclear why the same pattern did not emerge for the CB2 group; in fact there was a negative correlation between WM and ImpASS for those participants that took part during the summer session. These correlations are shown in table 5.4 below. Unsurprisingly, the correlation for the sample as a whole was positive, although not statistically significant ($r = .137$, $p = .108$, $n = 138$).

Table 5.4: *Correlation between WM performance and ImpASS across the different sub-samples*

	CB1		CB2	
	Summer	Autumn	Summer	Autumn
Pearson Correlation	.085	.594	-.238	.065
Sig. (2-tailed)	.636	.001	.197	.674
N	33	30	31	44

The correlation between WM and ImpASS was repeated for the two (recruitment) sessions (i.e., summer and autumn) individually. ImpASS was significantly positively correlated with WM in the autumn sample ($r = .298$, $p = .010$, $n = 74$). In contrast, the correlation between WM and ImpASS in the summer sample was not statistically significant ($r = -.079$, $p = .536$, $n = 64$); consequently the correlations across the two samples were of significantly different strengths (z-score = -2.214, $p = 0.027$).

There was no significant difference in WM between males and females, between the task conditions (CB1/2) or between study sessions (summer/autumn). However, participants from the summer session were significantly higher on ImpASS ($t_{(136)} = 2.452$, $p = .015$) relative to those from the autumn session (however, the participants from the autumn session were predominantly female undergraduate psychology students. Thus, the lower ImpASS scores in this session seems likely to reflect the composition of this group; i.e., males scored more highly on this trait).

Training Phase

Thirteen participants had performed incorrectly or poorly during the training phase. For example, these participants may have used the wrong dimension to classify the stimuli and were subsequently given the appropriate rule to use in the test phase by the experimenter. However, 4 of these participants took part in the FB condition. These participants committed a relatively high number of errors during the training phase. The effect of including or excluding such participants from further analyses will be considered in more detail below.

Test Phase

A technical error resulted in the loss of data for one participant. Performance accuracy was again based upon the critical trials of the test phase (i.e., after the initial 24 retraining trials). 73% of the participants made 5 or fewer incorrect responses on the last 240 trials (89% making 10 or fewer errors). A further 3 participants were excluded after making 51 (21%) or more errors (hence, n = 71). (5 participants, made between 12 and 20 errors. There did not appear to be any significant effects of including/excluding these participants from the following analyses).

An additional factor introduced from the design was variability in the category-response assignment (i.e., square backgrounds are either A or B) for those in the non-FB condition. Of the remaining 42 participants (after the exclusions discussed above) in the non-FB version, 25 used the identical category assignment to those in the FB condition (in both the training and test phases). A further 11 participants used the reversed category assignment. The remaining 6 participants had used an incorrect rule in the training phase and were subsequently given the actual category rule for the test phase, matching the category assignment of the FB condition.

The first 24 'retraining' trials of the test phase were removed from the following analyses. Additionally, any incorrect responses, or reaction times greater than 1 second, were removed from further processing.[3]

CB2 Feedback Condition (n = 29)

The first set of analyses was performed for those in the FB condition only. Firstly, the DCE was examined by considering the differences in mean RTs for the incongruent and congruent probes. A 2 (probe type) x 2 (response hand) repeated-measures ANOVA was performed. A significant main effect of probe type was observed (incongruent, M = 471, SE = 16; congruent, M = 452, SE = 15; $F_{(1, 28)} = 4.793$, $p = .037$). There was no main effect for response hand ($F_{(1, 28)} = .003$, $p = .958$) or interaction ($F_{(1, 28)} = .447$, $p = .509$).

The mean RTs for the probes by response hand are shown in figure 5.3 below. Pre-planned contrasts assessing the difference in RTs between the probes were performed for each hand separately. The difference in mean probe RTs for the left hand was significant ($t_{(28)} = 2.167$, $p = .034$) while the contrast for the right hand was not ($t_{(28)} = .857$, $p = .381$; both contrasts were 1-tailed, Bonferroni corrected for two comparisons).

[3]The number of the critical probe trials removed by the filtering process was assessed. For the majority of cases (82%) the mean reaction time for each of the 4 probes was based upon all 6 presentations, with a further 15% of cases having 4 presentations. In only 8 of the 284 cases was the mean probe RT based upon only 4 presentations, while for one case 3 presentations were filtered out.

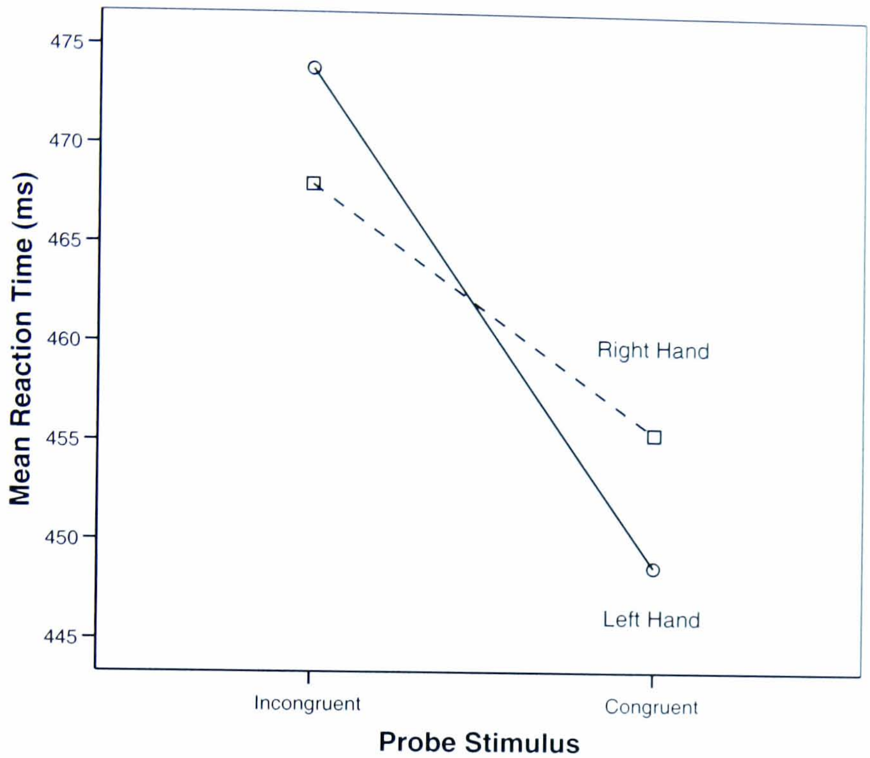

Figure 5.3: *Mean Reaction Time to Incongruent and Congruent Probes, by Response Hand (CB2 FB)*

CB2 Non-feedback Condition

A subsequent ANOVA was performed to include the participants in the non-FB version of the task, resulting in a 2 (probe type) x 2 (response hand) x 2 (FB) design. As discussed above, the feedback manipulation gave rise to the situation whereby participants were able to choose their own category-response assignment. 31 participants used the same category assignments as the FB condition (although 6 of these had performed incorrectly during the training phase, and were 'given' the category-response assignment for the test phase), while 11 participants used the reversed pattern of category-response assignment. The first analysis included just the 31 participants that used the identical category-response assignment as those in the FB version.

The means and standard deviations for the two probe types by hand and FB condition are displayed below.

Table 5.5: *Mean reaction times and standard deviation for probe trials across the FB conditions*

	Mean RT (ms), SD (in brackets) Feedback			
Probe	**No**		**Yes**	
	Left	**Right**	**Left**	**Right**
Incongruent	450 (77)	440 (87)	474 (79)	468 (101)
Congruent	433 (60)	445 (70)	449 (87)	455 (90)

The mean RTs for the probes were quicker in the non-FB condition, although the main effect was not significant ($F_{(1, 58)} = 1.106$, $p = .297$). There were no significant interactions between the FB condition and the stimulus type ($F_{(1, 58)} = 1.289$, $p = .261$), the FB condition and response hand ($F_{(1, 58)} = .002$, $p = .967$) or three way interaction ($F_{(1, 58)} = .147$, $p = .703$). This suggests that performance in the non-FB was comparable to that in the FB condition. Analogous with the previous ANOVA, there was a significant main effect of stimulus type (incongruent, M = 458, SE = 10; congruent, M = 445, SE = 9; $F_{(1, 58)} = 5.902$, $p = .018$) yet no significant main effect of hand ($F_{(1, 58)} = .014$, $p = .907$) or interaction between hand and stimulus type ($F_{(1, 58)} = 2.043$, $p = .158$).

Pre-planned contrasts were again performed to assess the difference in RTs between the probes for each hand separately. The difference in mean probe RTs for the left hand was significant ($t_{(58)} = 3.058$, $p = .003$) while the contrast for the right hand was not ($t_{(58)} = .476$, $p = .636$; both contrasts were 1-tailed, Bonferroni corrected for two comparisons).

This general pattern of results was relatively unaffected by the exclusion of 1) participants who performed poorly on the test phase, 2) participants who had performed incorrectly during the training phrase in the non-FB condition and were given the category response assignment to use in the test phase or 3) the combination of these exclusion criteria. One interesting effect of removing the participants described in number 2 above, was the trend for a significant main effect of the FB condition ($F_{(1, 52)} = 3.377$, $p = .072$). As reported above, this appears to suggest that probe response times may have been quicker for those in the non-FB condition.

Finally, as described above, 11 participants in the non-FB condition applied the reversed category-response assignment. A 2 (probe type) x 2 (response hand) repeated-measures ANOVA for this group of participants found a trend for slower incongruent relative to congruent probes ($F_{(1, 10)} = 3.515$, $p = .090$) while right hand responses were quicker than left hand responses ($F_{(1, 10)} = 12.058$, $p = .006$). There was however no significant interaction ($F_{(1, 10)} = 1.652$, $p = .228$).

Pre-planned contrasts found a weak trend for slower incongruent relative to congruent probes in the left hand only ($t_{(10)} = 1.791$, $p = .104$; 1-tailed, Bonferroni corrected for two comparisons). Despite the fact that the stimulus-response assignments were reversed in this group (i.e., the incongruent probe stimulus for the left hand in this group was the incongruent probe stimulus for the right hand in the standard response-category assignment etc), the DCE effect again appeared to be stronger for the left than right hand. Tentatively, this appears to suggest that the difference in DCE observed across hands would seem to be driven by the hand used rather than any specific feature or features of stimuli across the two categories, although due consideration must be given to the small sample size for these comparisons.

The inclusion of these participants, after appropriate recoding (i.e., aligning response hand, not actual stimuli), with the other CB2 participants in the analyses reported above did not significantly alter the results, although there was a trend for a probe stimulus by hand interaction ($F_{(1, 69)} = 2.988$, $p = .088$). This suggests that DCE was greater for the left hand in the CB2 condition as demonstrated by figure 5.4 below.

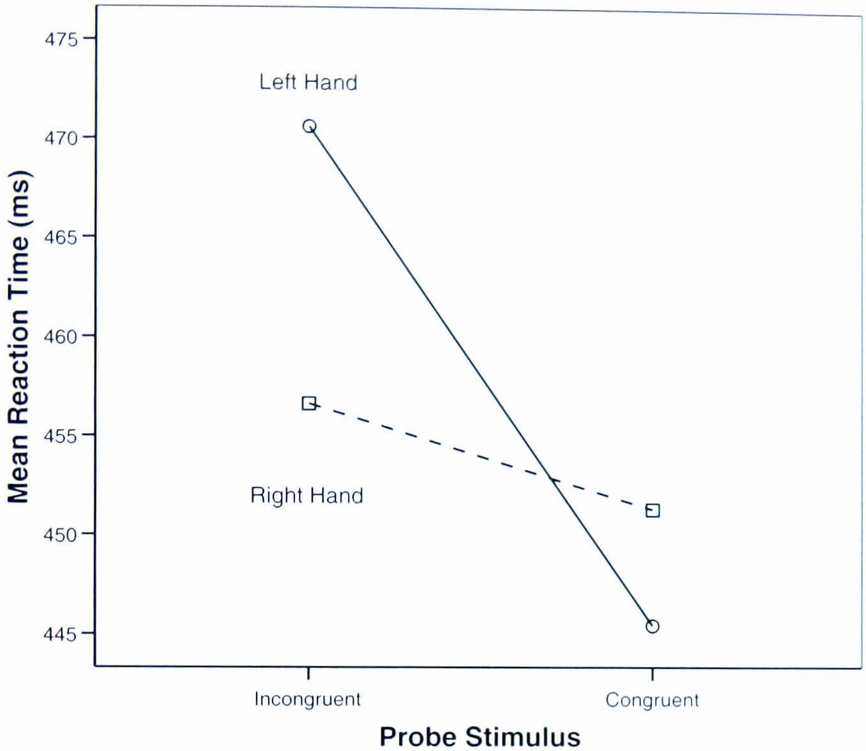

Figure 5.4: *Mean Reaction Time to Incongruent and Congruent Probes, by Response Hand (CB2; FB and non-FB condition)*

Comparison of CB1 and CB2

A mixed design 2 (probe type) x 2 (response hand) x 2 (CB) ANOVA was performed to compare performance across the two CB conditions. The participants in the non-FB version of the task were excluded. As would be expected, a significant main effect of probe type was observed ($F_{(1, 90)} = 10.586$, $p = .002$) demonstrating the DCE across both CB versions. There was also a main effect of the CB condition ($F_{(1, 90)} = 4.620$, $p = .034$), and consideration of the mean overall RTs for the CB1 (.502, SE = .011) and CB2 (.461, SE = .016) groups revealed that the latter made significantly faster responses. (Inclusion of the non-FB participants did not alter the overall results, although there was a trend for a significant interaction between response hand and CB condition.)

Summary of Behavioural Effects for CB2

The pattern of RT results suggests that the experimental manipulation again appeared to work as intended, and was consistent with the previous result with the CB1 group although responses in the current condition appeared to be quicker overall. Additionally, the FB manipulation did not appear to influence the overall pattern of results. While incongruent probes appeared to be slower than the congruent probes overall, it appeared that the effect may have been more pronounced for the left hand. Such a pattern was not seen in the CB1 group, which if any anything appeared to show a greater effect for the right hand.

Personality and the DCE (CB2 FB condition)

Age and gender were not significantly related to the DCE for those participants in the FB condition. The correlation between WM and the combined DCE measure was positive although not statistically significant ($r = .182$, $p = .346$, $n = 29$). However, better WM was positively related to the DCE, but for the left-hand only ($r = .417$, $p = .024$; this relationship was significantly different from the negative correlation, $r = -.112$, $p = .564$, observed for the right-hand; Williams $T2_{(26)} = 1.998$, $p = .028$). The relationship between the DCE and the personality factors is shown in table 5.6 below.

Table 5.6: *Correlation between personality and the DCE for participants in the FB condition (n = 29)*

		DCE	DCE (Left Hand)	DCE (Right Hand)
Extraversion	Pearson Correlation	-.015	.239	-.209
	Sig. (2-tailed)	.937	.213	.276
Positive Schizotypy	Pearson Correlation	-.145	-.103	-.095
	Sig. (2-tailed)	.452	.595	.623
ImpASS	Pearson Correlation	.126	.256	-.050
	Sig. (2-tailed)	.514	.181	.795
Neuroticism	Pearson Correlation	-.069	.032	-.110
	Sig. (2-tailed)	.722	.868	.569

Despite the lack of any significant correlations, the relationship between positive schizotypy and the DCE was not significantly different to that observed in the CB1 condition (DCE, z-score = 0.518, p = 0.605; DCE: LH, z-score = -0.226, p = 0.821; DCE: RH, z-score = 0.765, p = 0.444). This was also true for the relationship between extraversion and the DCE (DCE: LH, z-score = 0.448, p = 0.654; DCE: RH, z-score = -0.0221, p = 0.982). Therefore, the overall pattern of results appears to be in general concordance with CB1 condition and consequently the Steel et al. (2002) data.

Owing to the small sample size and magnitude of correlations reported above, further detailed analyses involving the DCE, positive schizotypy and extraversion were not performed for this sample. However, in addition to the unexpected correlation between WM and increased DCE (for left-hand responses) a similar, albeit non-significant, relationship was observed with ImpASS. These two variables were entered into a regression predicting the DCE for the left hand. The resultant model was highly significant and accounted for 30.3% of the variance ($F_{(2, 26)} = 5.642$, p = .009). Both predictors contributed significant unique variance in the model (WM, t = 2.974, p = .006; ImpASS, t = 2.191 p = .038). The addition of positive schizotypy and extraversion did not improve the model.

Personality and the DCE (CB1 and CB2 FB condition)

The relationships between personality and the DCE observed for the participants in the CB2 FB condition appeared to be comparable to those observed in the CB1 condition. Consequently, the correlations were repeated for the CB1 and CB2 (feedback condition only) combined (table 5.7 below).

The correlations observed between the DCE and positive schizotypy in the present sample (i.e., participants involved in the FB version of the task, CB1 and CB2 combined) provided a close replication of Steel et al.'s (2002) published results (see introduction, p. 37). There was a significant negative relationship between positive schizotypy and the overall DCE (r = -221, p = .037). As seen in the published findings, the relationship between positive schizotypy and the DCE for the right- and left-hand were not of significantly different strengths (Williams $T2_{(87)} = .872$, p = .192), although the correlation was significant only for right-hand responses (r = -.207, p = .050).

Table 5.7: Correlation between personality and the DCE for participants in the FB condition, CB1 and CB2 combined (n = 90)

		DCE	DCE (Left Hand)	DCE (Right Hand)
Extraversion	Pearson Correlation	-.046	.165	-.201
	Sig. (2-tailed)	.668	.120	.057
Positive Schizotypy	Pearson Correlation	-.221(*)	-.066	-.207(*)
	Sig. (2-tailed)	.037	.536	.050
ImpASS	Pearson Correlation	.037	.072	-.019
	Sig. (2-tailed)	.727	.498	.858
Neuroticism	Pearson Correlation	-.113	.041	-.173
	Sig. (2-tailed)	.287	.700	.103

* Correlation is significant at the 0.05 level (2-tailed).

As discussed in the introduction, an additional unreported finding was an association between extraversion and an increased DCE for left-hand responses. Although the analogous association in the present sample was not statistically significant, the correlation was positive ($r = .165$, $p = .120$). Additionally, a negative association was observed between this trait and the DCE for right-hand responses ($r = -.201$, $p = .057$). In line with the unpublished Steel et al. data reported earlier, the relationship between extraversion and the DCE was significantly different across hands (Williams $T2_{(87)} = 2.286$, $p = .012$).

To further compare the Steel et al. data with the present data, 2 multiple regression analyses were performed for the right- and left-hand DCE separately, entering positive schizotypy and extraversion as predictors. The regression model accounted for a significant 8.3% of the variance in the right-hand DCE ($F_{(2, 87)} = 3.926$, $p = .023$). Positive schizotypy, associated with reduced DCE, made a significant unique contribution to the model ($t_{(87)} = -2.002$, $p = .048$). In addition, the unique contribution of extraversion, also associated with reduced DCE, just failed to reach statistical significance ($t_{(87)} = -1.943$, $p = .055$). With the exception of the near-significant contribution of extraversion, this result is a close replication of the result reported previously for the DCE in right-hand responses.

In contrast to the Steel et al. data, the regression model did not account for a significant proportion of variance (3.2%) in the DCE for left-hand responses ($F_{(2, 87)} = 1.431$, $p = .245$). Naturally, this may have been somewhat expected following the non-significant positive correlation between extraversion and the DCE for left-hand responses (a weak trend was found for extraversion in the current regression; $t_{(87)} = 1.571$, $p = .120$). Unlike the model for the right-hand effect, positive schizotypy did not account for significant unique variance ($t_{(87)} = -.641$, $p = .523$).

In summary, the findings from the combined sample of participants who took part in the FB version of the present task appeared to demonstrate a fairly close replication of the Steel et al. data. In particular, positive schizotypy was again associated with decreased DCE. Similarly, the effect appeared lateralised for right-hand responses. As with the earlier analysis of the Steel et al. data, extraversion was positively associated with an increased DCE in left-hand responses, however, the strength of the present relationship was not statistically significant. Furthermore, in common with positive schizotypy, extraversion was associated with decreased DCE for right-hand responses. This maintained the apparent lateralisation (i.e., divergent direction of correlations) of the association between extraversion and the DCE.

Personality and the DCE (CB2 non-FB condition)

The following considers only those participants that used the standard response-category assignment in the non-FB version ($n = 25$). In contrast to the FB condition, WM was negatively, although not significantly, related to the left-hand DCE ($r = -.312$, $p = .129$, $n = 25$). The relationship between WM and left hand DCE was therefore significantly different across the FB groups (z-score = 2.647, $p = 0.008$). The DCE was not significantly related to age or gender (consequently there were no significant correlations between the DCE and age or gender across the two groups).

The association between personality and the DCE appeared somewhat different in the non-FB condition relative to the FB group. However, it should be noted that this group was predominantly female ($n = 22$). Unlike the FB version, extraversion was positively related to the DCE for both left- and right-hand responses, although neither correlation was significant ($r = .056$, $p = .790$ and $r = .286$, $p = .166$ respectively). The left-hand DCE was significantly negatively correlated with positive schizotypy ($r = -.457$, $p = .022$), and this was significantly different to the (positive) relationship observed for right-hand responses ($r = .297$, $p = .149$; Williams $T2_{(22)} = -2.859$, $p = .005$). Neither ImpASS nor N was related to the DCE.

Further analyses were not pursued due to the limited sample size and moderate correlations. Brief exploratory analysis suggested that the strength of some of the correlations were highly susceptible to the influence of extreme values on the DCE measures.

Personality and the DCE (CB2)

The following analysis considers only those participants that used the standard response-category assignment in the non-FB version ($n = 25$) as well as the participants from the standard FB condition ($n = 29$). The relationships between personality and other individual differences are considered below for the two groups in combination (i.e., $n = 54$).

Gender and WM were not significantly related to the DCE. Age was moderately positively correlated with the DCE but only for right hand responses ($r = .293$, $p = .032$). The DCE was not significantly related to personality; the largest correlation occurring between positive schizotypy and the DCE for left-hand responses ($r = -.224$, $p = .104$; remaining r's < .186). The correlations for positive schizotypy and E are shown in table 5.8 below.

Table 5.8: *Correlations between positive schizotypy, extraversion and DCE (n = 54)*

		DCE	DCE (Left hand)	DCE (Right hand)
Extraversion	Pearson Correlation	.033	.185	-.114
	Sig. (2-tailed)	.813	.180	.411
Positive Schizotypy	Pearson Correlation	-.122	-.224	.034
	Sig. (2-tailed)	.381	.104	.806

However, the relationship between positive schizotypy and the DCE measures were not of significantly different strength from those observed in CB1 (DCE, z-score = 0.759, $p = 0.448$; DCE: LH, z-score = -0.926, $p = 0.354$; DCE: RH, z-score = 1.614, $p = 0.107$). Additionally, the relationship between E and the DCE for left- and right-hand responses were also not of significantly different strengths from those observed in the CB1 condition (DCE: LH, z-score = 0.257, $p = 0.797$; DCE: RH, z-score = 0.481, $p = 0.630$).

DISCUSSION

The current experiment was inspired by research by Steel et al. (2002) that reported an association between positive schizotypy and decreased DCE (especially in relation to right-hand responses). Further analysis of the data (not reported in the published paper) also demonstrated a statistically independent association between extraversion and increased DCE, although this appeared to be lateralised for left-hand responses. Consequently, the aim of the present study was to examine the relationship between specific personality traits and the effects of nominally irrelevant stimulus information during a speeded classification task (cf. DCE). The behavioural task employed was adapted from the study described in the previous chapter and was subsequently considered from the perspective of the CL paradigm. One important feature of the present design, in relation to the Steel et al. (2002) study, was the ability to delineate DCE from novelty effects (i.e., the DCE in the present study was calculated by the comparison of congruent and incongruent probes that were 'equally' novel). Hence, the effect of distractor congruency was not confounded with (stimulus) novelty. A secondary aim of the study was to explore the possible role of reinforcement in the DCE, and subsequently whether reinforcement may influence the association between personality and the DCE.

The initial discussion will focus upon the first study condition (n = 65) in which the participants categorised the stimuli depending on the size of the inner triangle. Before summarising the results of the present study it is pertinent to consider some of the differences between the experimental design of the present task and the target study (Steel et al., 2002). The Steel et al. task comprised of a single phase in which 192 trials were presented. There were four different stimuli; the 'valid' and 'invalid' stimuli of each category. The valid stimuli were each presented 88 times, while the invalid stimuli were each presented 8 times across the task. Participants were given exact instructions as to how to perform the task (i.e., which target letter required which response) and were instructed to ignore the distractor letters. Accuracy feedback, in the form of short tones (high pitch indicating a correct response; low pitch indicating an incorrect response) was provided after each response.

In contrast, the present task consisted of two phases; an initial training phase (120 trials) followed by a subsequent test phase (264 trials). The stimuli consisted of 4 (as opposed to 2) binary valued dimensions and in contrast to the stimuli used in the Steel et al. study, the dimensions were not lexical characters but shape, colour etc. The training phase involved 6 distinct stimuli (an equal number from the two categories). Participants did not receive exact instructions as to the category structure, although a strong hint regarding the relevant dimension was given. There was no instruction to ignore the remaining dimensions. Participants were instructed to learn the appropriate category assignments through trial-and-error (i.e., using the feedback) and then focus upon fast and accurate responses. Four distinct novel stimuli (probes) were additionally introduced in the subsequent test phase; for each category a probe with congruent, and a probe with incongruent, values on the nominally irrelevant dimensions (cf. valid/invalid stimuli). No feedback was given during the test phase of the task, participants were simply instructed to carry on responding in the manner they had been for the previous phase. Additionally, participants were given an incentive (the chance to win a prize-draw ticket) to encourage fast and accurate responding during the test phase.

The experimental manipulation in the present study appeared to be successful; response times for the congruent probes were significantly faster than the incongruent probes. The difference in response times between the two probe types was subsequently calculated as a measure of the DCE. Despite the differences between the two tasks, described above, the results of the present study were remarkably similar to those reported by Steel et al. (2002). Positive schizotypy was again significantly related to decreased DCE and in parallel with Steel et al. the effect appeared somewhat stronger for right-hand responses. In combination with extraversion, these two personality factors accounted for a significant proportion of variance in the DCE (right-hand), although the unique contribution of positive schizotypy just failed to reach statistical significance (the unique contribution of extraversion was not significant).

In the Steel et al. (2002) study extraversion was significantly related with increased DCE for left-hand responses. This relationship was not found in the present study although it may be tentatively suggested that the non-significant positive association in the present study was not significantly different from that of the published study. Accordingly, extraversion and positive schizotypy did not account for a significant proportion of variance in the DCE for left-hand responses.

The results of the first condition of the RT study therefore appear broadly in line with the previous published study by Steel et al. (2002), particularly in relation to positive schizotypy and the DCE. Despite the various methodological differences, positive schizotypy was again related to decreased DCE, especially for the right-hand.

Further examination of the association between positive schizotypy, extraversion and the DCE was considered by the additional inclusion of the participants from the CB2 condition (FB version). This gave a total sample size of 90 participants. The CB2 condition had shape of the background as the rule-relevant dimension. The results strengthened the replication of the basic published results of Steel et al. (2002); positive schizotypy was significantly correlated with decreased DCE, especially for the right hand. Furthermore, in combination with extraversion, positive schizotypy uniquely accounted for a significant proportion of variance in the DCE for right-hand responses (cf. the unpublished results, see p. 118). Unlike the Steel et al. (unpublished) data considered previously, extraversion was also related to decreased DCE in right-hand responses and just failed to uniquely account for a significant proportion of variance in the regression analyses.

In line with the results of the CB1 group, the combined data failed to demonstrate a significant association between extraversion and increased DCE for left-hand responses, although the observed correlation was positive. However, the direction of the association between extraversion and the DCE was of significantly different strengths across hands; thus replicating the pattern observed in the Steel et al. data.

The results from the combined data, involving different samples and different task variants, provide further support for the basic result reported by Steel et al. (2002). Consequently, the concordant findings observed across these qualitatively distinct paradigms afford a degree of confidence in the legitimacy of an association between positive schizotypy and reduced DCE (particularly for right-hand responses). What is more, the design of the current task removed the possible confound of stimulus novelty, allowing greater confidence that the published results reflected a true DCE and was not an artefact related to the design of the task (i.e., novelty of the 'invalid' stimuli). Finally, in the present sample, extraversion was more strongly associated with a decreased DCE for right-hand responses relative to the (positive) association with the DCE for left-hand responses. In contrast, the Steel et al. data revealed a significant association between extraversion and the DCE for left-hand responses. However, in both studies the relationship between extraversion and the DCE across hands was significantly different, clearly suggesting a degree of lateralisation between this trait and the DCE.

The primary aim of the present experiment was to re-examine the relationship between personality and the effects of task irrelevant, and potentially distracting, stimulus information. Additionally, the role of feedback on these effects was also considered. Accordingly, the present study did not attempt to directly address the more general question of the possible mechanisms that may underlie the DCE (this subject is considered further below). This issue was considered in more detail by Steel et al. (2002), wherein a variety of possible explanations of the phenomena and their relevance to the reduced DCE observed in schizotypy (and schizophrenia) are discussed. Intriguingly, however, the behavioural manifestation of the DCE appeared to develop equally well in the absence of trial-by-trial feedback. This may provide a potentially useful result in the determination of the processes likely involved in the DCE.

The role of feedback was considered in a subsequent condition of the RT study (CB2). Participants either performed in a standard feedback version of the task (FB) or in a non-feedback version (non-FB) in which (trial-by-trial) response accuracy feedback was not given during the training phase. In addition, the rule dimension in the CB2 condition was the shape of the background (either circle or square, cf. the size of the triangle in the CB1 condition). The basic experimental manipulation again appeared to be successful with responses to the congruent probes being significantly quicker than the respective incongruent probes. Crucially, the FB manipulation did not appear to influence this general (behavioural) result. The DCE was evident despite the absence of trial-by-trial feedback in the training session of the non-FB condition. Furthermore, the size of the DCE was not significantly different in the non-FB condition compared with the FB condition.

The lack of any clear behavioural effects attributable to the FB manipulation (in terms of the key DCE measure) may be informative with regard to the proposed mechanisms thought to underlie the effect. A number of possible accounts of the DCE were discussed by Steel et al. (2002), including that of Miller (1987) who originally reported the DCE phenomenon. Miller's account suggested that, in addition to the development of stimulus-response (S-R) associations involving the category (or response) relevant dimension, individuals may also form S-R associations with distractor features (although it is quite possible that S-R associations involving the 'irrelevant' features are less prominent than the S-R associations involving the target dimension). Consequently, the slowing of RTs on invalid (or incongruent) trials reflects the competition between the opposing S-R associations (i.e., the distractor dimensions are associated with the opposite response to that of the target dimension). However, in the present study the basic DCE was observed whether explicit trial-by-trial FB was present or not. Consequently, this would imply that the formation of S-R associations is possible without the requirement of explicit FB (and associated reinforcement). If this assertion is correct, then it would seem unlikely that dopaminergic reinforcement plays a significant role in modulating the development of S-R bonds.

Although the DCE appeared consistent (in magnitude) in both the FB and non-FB conditions, the possibility remains that the effect was related to qualitatively distinct mechanisms in each case. Before consideration of one alternative to the S-R account, it is worth briefly considering evidence from the present study which may offer tentative support for this proposition. Firstly, in the FB version of the CB2 condition, WM was significantly related to an increased DCE in left-hand responses. In combination with ImpASS, WM uniquely accounted for a significant proportion of variance in the DCE for the left-hand (ImpASS also contributed a significant unique proportion of variance). In contrast, the association between WM and the DCE in left-hand responses was significantly different for those participants in the non-FB condition, wherein WM was related (albeit non-significantly) with a reduced DCE. This divergent pattern of association may suggest that WM exerts a differential influence on the DCE in the FB and non-FB conditions.

A similar divergent pattern of associations was observed for the relationship between positive schizotypy and the DCE. Positive schizotypy was significantly related to an overall reduced DCE for participants in the FB condition (CB1 and CB2 combined). However, the association was strongest (and significant only) for right-hand responses. Conversely, in the non-FB condition, positive schizotypy was significantly related to a decreased DCE for left-hand responses. Furthermore, this latter association was significantly different from the positive (albeit non-significant) relationship with the DCE in right-hand responses for the non-FB condition. Accordingly, the combined impact of these results (i.e., the association between WM, positive schizotypy and the DCE across the FB conditions) may provide tentative support for the notion that different processes may be involved in DCE dependent on the presence or absence of response accuracy FB during the learning.

It is possible, therefore, that the DCE arises through qualitatively distinct mechanisms, dependent on the FB manipulation. One alternative to the S-R account described above, which may provide an explanation for the effect in either condition – or perhaps only the non-FB condition – might suggest that the DCE occurs through the development of stimulus-stimulus (S-S) associations between the target and irrelevant features of the stimuli. The unitization of one, or all, of the nominally irrelevant stimulus features with specific values on the target dimension could give rise to the DCE if the similarity between category exemplars and the novel probes were of different magnitudes for the congruent and incongruent probes. Specifically, the DCE would arise if the congruent probes were more similar to the training exemplars than the incongruent probes, thereby facilitating faster responses.

A simple model of stimulus 'similarity' that can that can provide support for this account can be found in the appendix (D, p. 316-318). The model demonstrates that the congruent probes are indeed more 'similar' to their respective training stimuli (relative to the training stimuli of the opposite category) in comparison to the incongruent probes and, therefore, provides a viable account of the DCE phenomenon. Furthermore, the model can be extended to include a plausible explanation for the association between positive schizotypy and decreased DCE. This relationship could arise if individuals scoring more highly on positive schizotypy tended to encode only the target dimension and fewer than 3 of the remaining stimulus dimensions. For example, if high schizotypes tended to encode only 2 dimensions on a particular (probe) trial (one dimension being the target) it can be shown that, although present, the size of the DCE is predicted, based on the 'similarity' model, to be much reduced compared to the situation in which all 3 irrelevant dimensions are encoded.

In addition this analysis also provides a degree of support for the earlier suggestion that the DCE could still arise even if only a subset of the dimensions are encoded (naturally, however, the magnitude of the effect would be expected to be reduced relative to the DCE resulting from the encoding of all stimulus dimensions). During the training phase the 3 irrelevant dimensions formed a category congruent II rule. However, each individual (perceptual) value on the 3 dimensions was partially predictive (66%) of the stimulus category. Therefore, it was also possible that the DCE was induced by a single irrelevant dimension or a combination of 2 of the 3 irrelevant dimensions. Indeed, it may be that in each of the particular conditions used in the present study (i.e., CB1/2) one or more of the irrelevant dimensions may have been more salient in respect to the current target dimension. For example, in the CB1 condition participants' classification of the stimuli depended on the size of the inner triangle. Consequently, the relevance of the triangle's orientation (pointing upwards or downwards), an irrelevant dimension, may have been particularly salient (as it is more integrally connected to the target feature). In contrast, the background colour may have been more prominent for the CB2 condition in which the shape of the background was the relevant dimension. Furthermore, it is possible that the individual dimensions were not equally salient; for example the different colours used for the background dimension may have been particularly prominent in either condition. However, the general pattern of results indicated that performance generally matched expectations (in behavioural terms). Therefore, while it is possible that the number and type of irrelevant dimensions had some impact on the DCE (and possibly the association with personality), it would appear that the overall influence was probably relatively minor.

The preceding discussion presented a possible mechanism by which the DCE could arise. Furthermore, a plausible account for the association between positive schizotypy and decreased DCE was suggested. However, the model does not provide a simple account of the potential, independent, contribution of extraversion to variance in the DCE. Nonetheless, it is possible to construct alternative models which are able to accommodate dissociable components that each contribute to observed variance in the DCE. One such model, developed by Pickering and Tharp (unpublished), is outlined in figure 5.5 and briefly considered below.

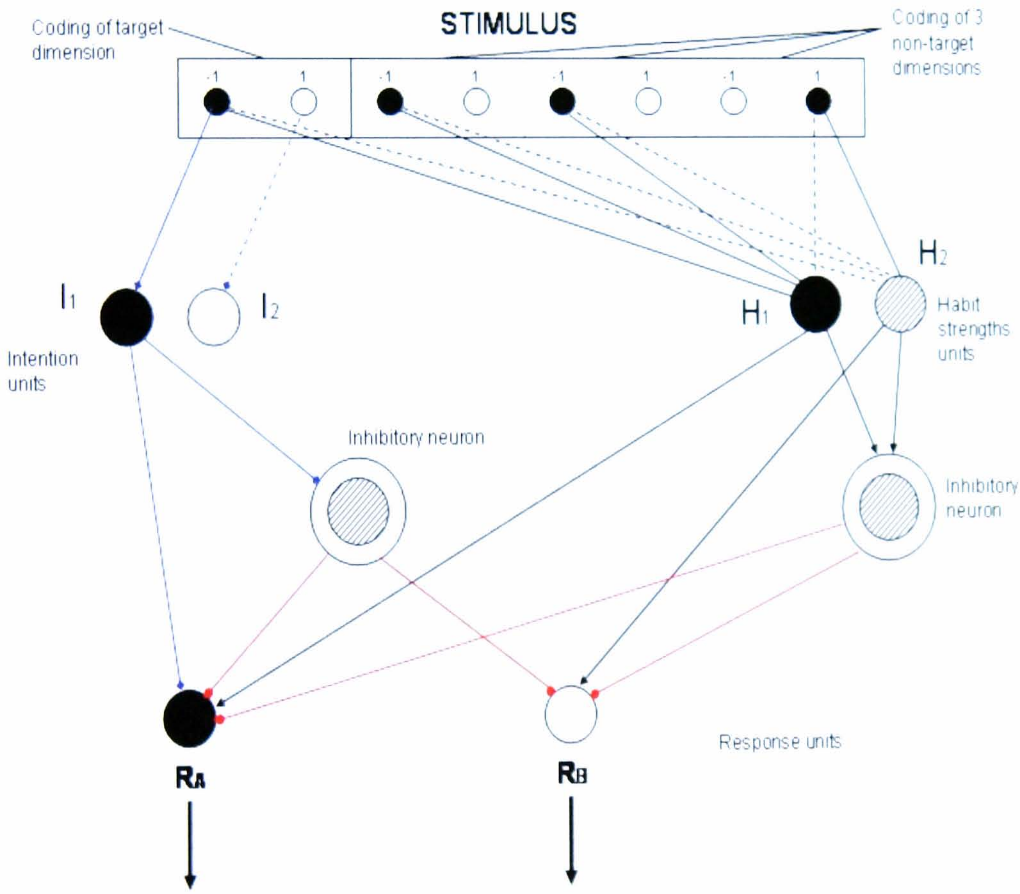

Figure 5.5: *Neural network model representation of possible inhibitory, associative and intentional processes involved in the DCE**

*Filled circles are *activated* nodes, unfilled circles are *un-activated*. Solid black lines represent active connections, dashed black lines are un-activated connections. Red connections are inhibitory, blue connections are excitatory.

In contrast with the preceding similarity based model, in which there were individual representations of each stimulus exemplar, the current model individually codes each of the possible stimulus values alongside the degree of association, or habit strength, with each of the two possible responses. Consequently, the 8 stimulus nodes, representing the possible values on the 4 stimulus dimensions, are differentially associated with the two responses (via the habit strength nodes). The strength of these connections (broadly) reflects the degree of co-occurrence between the stimulus feature and response. Consequently, the current value on the target dimension (category 'A' value) in figure 5.5 can be seen to be strongly connected to the appropriate habit and associated response node (and unconnected with the complementary habit and response node). Furthermore, the relative strengths of the connections between the remaining dimension values and the habit nodes can be seen to reflect the differential association between these values and the two responses (accordingly, value '-1' on dimension 2, is more strongly connected with habit node 'A', reflecting the appropriate category 'A' response, as this feature occurs in 2 out of 3 category 'A' training stimuli – and only 1 out of 3 category 'B' training stimuli).

In the current study a strong hint regarding the target dimension was given to all participants. This aspect of the task is reflected in the intention units. In addition to the activation of the respective habit node, each value of the target dimension activates the appropriate intention node. Consequently, if the stimulus contains a large triangle (for example) the intention would be to make a category 'A' response. Conversely, if the target has the complementary value (i.e., a small triangle), the intention would be to make the opposite response. The structure of the model attempts to incorporate the intention units as a reflection of top-down control processes such that a response threshold will not be exceeded unless there is appropriate input from the intention node as well as the appropriate habit strength input.

The model follows the framework of a simple neural network. Crucially, activation of either the intention or habit nodes (or both) subsequently activates inhibitory control neurons which inhibit all responses. Previous research has suggested particular features of schizophrenia and/or schizotypy arise from impaired or reduced inhibition (e.g., Frith, 1979; Peters et al., 1994). Consequently, one method of modelling the association between positive schizotypy and the DCE is to reduce the output of the inhibitory neurons. Simulating this in the present neural network does indeed give rise to a reduction in the size of the DCE, as observed in the current behavioural experiment.

Furthermore, the model also has the capacity to address additional, independent processes which may impact on the DCE. For example, the attentional component, reflecting the relative proportion of attention toward the target dimension and nominally irrelevant dimensions, can also be considered. Increasing the relative weighting of the attention given to the non-target dimensions led to an increase in the DCE. Thus, the possible association between extraversion and increased DCE, observed in the behavioural studies, can be modelled in the current neural network by increasing the breadth of attention towards the nominally irrelevant dimensions of a multi-dimensional stimulus. Tentative support for an association between extraversion and a greater 'weighting' of the non-target dimensions is provided in a study by Althaus et al. (2005) that found extraverted children demonstrated a greater perceptual sensitivity to irrelevant information in a selective attention task.

The preceding sections demonstrated the utility of applying a variety of simple models in the exploration of the underlying mechanisms possibly involved in the DCE. However, neither of the models presented were able to provide any explanation of the apparent effects of response hand in the present study. One suggestion for the observed handedness effects is that the processes involved in the task are themselves lateralised in the brain. For example, Marsolek (1999) describes two neural subsystems thought to underlie visual object recognition. The *abstract-category subsystem* enables the visual system to map divergent input shapes (e.g., different views of the same object) onto the same output representation. This system is thought to be suited to feature-based processing (cf. the neural network model described above) and considered to relate to the function of the left-hemisphere. In contrast, the *specific-exemplar subsystem* is thought to operate more effectively in the right-hemisphere and benefit from global stimulus processing (cf. exemplar/similarity model above).

Consequently, dependent on the actual nature of the processing required in the present task (i.e., feature-based or more holistic stimulus processing), one may expect that inter-individual variation in the functioning of the relevant system is more likely to be observed in the respective (i.e., contra-lateral) hand of response (notwithstanding the differences between (object) recognition and performance on the present task which may partially reflect recognition processes – i.e., of the relevant stimulus features, training exemplars etc). Therefore, if the neural network model presented previously is somewhat representative of the type of processes engaged in the RT task (and these processes are indeed related to the function of the abstract-category subsystem), this may provide a possible explanation for the association between positive schizotypy and decreased DCE that appears somewhat specific to right-hand responses. Recent research exploring hemispheric differences in categorisation (and affect) has been reported (Ramon, Doron, & Faust, 2007). Despite conceptual differences with the present study (e.g., Ramon et al.'s categorisation task involved 'known' categories as opposed to the learning of novel stimulus-category associations), this comparable finding supports the possibility that the apparent lateralisation of performance does indeed reflect a real phenomenon and suggests the possibility for further research.

Another alternative explanation for the apparent lateralisation of the association between personality and the DCE is the possibility that variation in the personality traits themselves may reflect lateralisation of brain function. As summarised in Steel et al. (2002), and equally applicable for the current data, the finding that the association between decreased DCE and positive schizotypy was significant only for right-hand responses may suggest that some aspect of the association between this trait and the behavioural phenomenon is lateralised in the brain (i.e., in the left-hemisphere). (Although, it is possible that the effect for the left-hand may have been masked by the association between extraversion and increased DCE for the left-hand). However, Steel et al. cited previous research by Nalcaci, Kalaycioglu, Cicek, and Budanur (2000) which found a similar association between a measure of positive schizotypy and hemispatial inattention only for responses made with the right hand.

One factor which may influence the apparent lateralisation of the effect could be the reported association between schizophrenia/schizotypy and reduced dominance of the left-hemisphere for language (e.g., Leonhard & Brugger, 1998). One possibility may be that participants verbalise the current category rule (e.g., square background, respond 'A' etc) and reduced dominance of the left-hemisphere in this verbalisation may give rise to the decreased DCE for the right-hand responses (although this suggestion does not provide a specific mechanism through which this may occur). In addition, a recent study by Fisher, Heller, and Miller (2007) discussed the association between schizophrenia/schizotypy and the increased reliance upon the right-hemisphere and activation of (semantic) associations and maintenance of context. Furthermore, it was suggested that right-hemispheric function gives rise to processing involving 'less attention to detail' in an ongoing task; consequently, in the present context, this may lead to a reduced effect of the distractors (although again, this would not provide a clear explanation of why the effect was only significant for right-hand responses).

The association between extraversion and the DCE, which appeared to be weakly related to increased DCE for left-hand and decreased DCE for right-hand responses, may also be suggestive of hemispheric differences in the phenomenon (and/or the impact of extraversion). While a number of studies appear to demonstrate an association between lateralised hemispheric brain function and extraversion, by way of EEG (e.g., Fink, 2005; Fink, Grabner, Neuper, & Neubauer, 2005) or fMRI measures (e.g., Canli et al., 2001), it is again difficult to derive a clear explanation of the current effect (cf. positive schizotypy). Furthermore, the association between extraversion and the DCE appeared less consistently across the various tasks. Consequently further speculation of the possible causes of the effect is not presented and it is clear that further experimentation is required in order to determine the basis of the apparent handedness effects in the present study.

A further result of interest concerns the significant association between ImpASS and superior WM performance observed in the sample of participants from the autumn study (n = 63). The role of WM in particular forms of CL has been discussed in the preceding chapters. The explicit system of the COVIS model of CL (Ashby et al., 1998; Ashby & Waldron, 1999) prescribes WM as a core component in the learning of RB category structures. For example, RB CL is thought to be dependent upon explicit hypothesis testing of candidate category rules (i.e., reflecting the underlying category structures). Consequently, WM may be considered crucial to the active maintenance of the current rule being tested as well as preserving the status of rules applied previously. Superior WM ability, therefore, may facilitate the learning of RB category structures.

It was noted previously, and considered in more detail by Pickering (2004), that ImpASS related personality traits have been associated with superior performance on a number of nominally RB CL tasks. Therefore, if the current association between this trait and WM is indicative of a genuine superiority in WM function, this may suggest a viable mechanism through which ImpASS may impact upon some forms of CL; specifically those in which enhanced WM may facilitate performance (i.e., RB tasks). However, it was also noted that the association between ImpASS and WM appeared somewhat variable. For the sample of participants recruited in the summer session variation in ImpASS was not significantly associated with WM performance. In fact, the strength of the association was of a significantly different strength to that observed in the autumn sample. While it is apparent that there were differences between the two samples (e.g., the autumn sample were all psychology students and predominantly female whereas the autumn sample comprised a broader range of participants i.e., non-students, non-psychology students, equal gender ratio etc) it is unclear how these qualitative differences between the samples would have generated the observed differences in the relationship between ImpASS and WM. Consequently, a degree of caution is required in the previous assertion that ImpASS may be related to performance in particular forms of CL by way of an association with WM function.

Given the degree of association between attentional processes and WM (e.g., see Awh, Vogel, & Oh, 2006) the significant positive association between ImpASS and WM (in the sample of participants in CB1) is also intriguing given the subsequent lack of an observed association with the DCE. For example, it has been shown that superior WM ability is associated with enhanced attentional control (e.g., Kane, Bleckley, Conway, & Engle, 2001). Thus, it may have been expected that ImpASS (by way of the association with superior WM) would be associated with the magnitude of the DCE (e.g., enhanced attentional control may decrease the processing of the irrelevant dimensions and hence decrease their influence). In fact, no association between the DCE and ImpASS (or WM) was found in this sample. This may suggest that the DCE is instantiated through mechanisms other than those associated with attention and WM (e.g., associative learning). However, while there appears to be a great deal of overlap between the constructs of attention and WM, the exact nature of this relationship "depends upon the specific variety of attention or working memory that is considered" (Awh et al., 2006, p. 201). Thus, such speculation must be considered tentatively. Furthermore, as mentioned above, the association between ImpASS and WM (and indeed WM and the DCE) was somewhat variable across the different samples, which again urges caution in the interpretation of the association between ImpASS, WM (and attention) and performance on the task.

In summary, the present study appeared to provide a degree of support for an association between specific personality traits and the DCE during speeded categorisation. In support of the results reported by Steel et al. (2002), positive schizotypy appeared to be somewhat associated with *decreased* interference from irrelevant dimensions. In particular the result appeared related to decreased effects of irrelevant dimensions upon right-hand responses. In contrast, extraversion was moderately associated with *increased* effects for the left hand, as well as some suggestion of an association with decreased effects for the right hand. An additional finding suggested that the size of the DCE was not dependent upon trial-by-trial feedback. This result spurred the consideration of the processes through which the DCE may occur. Two plausible models of distinct mechanisms were briefly presented and should help to develop further experimentation regarding this issue (e.g., whether the DCE is driven by S-R or S-S associations, or whether the inhibitory and facilitatory components of the DCE implied by the neural network can be substantiated). Finally, brief discussion of the apparent lateralisation of the association between the effect and personality was provided.

Chapter 6

Study 3 - Flexibility in Classification Strategy during Rule-Based Category Learning

INTRODUCTION

Background

The CL paradigm was employed in a study by Maddox, Baldwin and Markman (2006) that explored the effect of regulatory focus on cognitive flexibility during RB CL. Briefly, regulatory focus (e.g., Higgins, 1997) is a broad theory related to basic motivational systems involved in the pursuit of positive outcomes and avoidance of negative outcomes. Higgins (1997) proposed that distinct processes are involved with the regulation of behaviour associated with these two forms of approach and avoidance goals. Thus a distinction can be made between a *promotion focus*, in which the individual is alert to the gains associated with an outcome, and a *prevention focus* in which the individual is sensitive to the potential losses related to an outcome. Therefore, regulatory focus can be distinguished from the raw motivational contingency or general utility associated with an outcome. One example, discussed by Higgins (2000; 2005), considers the attainment of an 'A' grade for a piece of coursework; a desirable outcome. However, one individual may pursue this goal from the perspective that the grade is a positive achievement or accomplishment (promotion focus). In contrast, another individual may consider the grade to be a requirement that they *should* obtain and therefore wish to avoid missing out on the grade (prevention focus).

Additionally, the manner in which a particular goal is pursued may also vary; eagerness may be associated with a promotion orientation whereas vigilance may be associated with a prevention focus (Higgins, 1997, 2000). In relation to the example given above, the individual focusing on the positive achievement of attaining an 'A' grade may study a wider variety of course material (eagerness) in order to reach the goal, whereas the individual with a prevention orientation may focus upon on not missing any essential requirements of the course (vigilant) in order not to 'lose out' on the 'A' grade (Higgins, 2005). This distinction between a particular motivational orientation (regulatory focus) and mode of achieving a specific goal lead to the concept of 'regulatory fit' (Higgins, 2000). Regulatory fit occurs when the manner in which a goal is pursued matches the regulatory focus or orientation of the individual concerned; consequently the 'experience' of regulatory fit enhances the 'value' of the individual's current behaviour. This proposal leads to a number of hypotheses (see Higgins, 2000). Two of these are pertinent to the present discussion. Firstly, individuals are more likely to pursue goals in a manner that is consistent with their regulatory focus (e.g., eagerness and promotion focus). Secondly, motivation towards the current goal will be enhanced by a higher regulatory fit. Therefore, this suggests that regulatory focus/fit may have predictable effects on goal directed behaviours.

The previous discussion suggests that individuals vary in their orientation towards a particular style of regulatory focus. This trait-like predisposition toward a promotion or prevention focus is referred to as 'chronic' focus (e.g., Higgins, 1997). In addition to dispositional factors, regulatory focus can also be influenced by situational variables (Higgins, 2000). This was the approach taken by Maddox, Baldwin et al. (2006) in their exploration of the effect of regulatory fit on cognitive flexibility. In their study, Maddox, Baldwin et al. operationalised cognitive flexibility as the ability or willingness to engage in different strategies during a CL task. It was hypothesized that a higher level of regulatory fit would lead to a greater degree of cognitive flexibility. One of the 3 experiments reported involved a CL task in which cognitive flexibility was considered to be crucial for the discovery of the optimal classification (category) rule and allow the participant to attain the performance criterion. The stimuli were comprised of 3 dimensions. Any one of these dimensions could be used individually to obtain a reasonably high level of categorisation accuracy on the task. For example, one of the dimensions was length, and categorisation of the stimuli using this dimension (i.e., long and short stimuli) with the appropriate criterion could achieve accuracy levels of 83% (this level of accuracy could also be achieved using either of the remaining 2 dimensions). However, the goal of the task was to achieve performance accuracy of 90% (on the last block of trials). This level of performance was obtainable only with the use of the correct (conjunctive) category rule that involved 2 of the 3 dimensions. Hence, while a reasonable level of performance could be achieved with a variety of uni-dimensional rules, successful performance on the task would require the optimal rule to be discovered and applied; hence cognitive flexibility should facilitate better performance on the task.

The manipulation of regulatory fit was achieved by varying regulatory focus and the reward structure used in the task. In the promotional focus condition, participants were aiming to reach the performance criterion in the last block of trials in order to receive a ticket for a prize-draw. In contrast, a prevention focus was induced for a separate group of participants by informing them that they would lose their prize-draw ticket if they failed to reach the performance criterion. To complete the regulatory fit manipulation two different reward structures were used in each of the conditions described above. Firstly, a 'gains' reward structure was used in which participants received 2 points for every correct classification and no points for an incorrect classification. Therefore, in the promotion condition, participants were focused upon obtaining as many points as possible and regulatory fit was subsequently 'high'; and should lead to enhanced performance upon the task. In contrast, regulatory fit was 'low' for those participants in the prevention focus condition as there was a mismatch with the reward structure (gains); subsequent performance should therefore be inhibited. For the 'loss' reward structure, participants would lose 3 points for every incorrect classification yet lose only 1 point for correct classifications (the aim in this task was to lose 58 or fewer points). Hence, with this reward structure, regulatory fit would be high for those participants in the prevention focus condition, yet low for those in the promotion focus condition. Performance on the task would therefore be expected to be facilitated and inhibited respectively.

The analyses revealed overwhelming support for the predictions. Participants for which regulatory fit was 'high' did indeed perform better (e.g., reached the criterion level of performance earlier) on the task relative to those participants for which regulatory fit was low. Additionally, formal modelling of participants' responses (akin to those described in chapter 4) was performed in order to assess the range and changes in strategies applied throughout the task. These analyses suggested that regulatory fit was specifically related to earlier switching from uni-dimensional to conjunctive rules and consequently better task performance. In order to ascertain whether these performance differences were specifically related to regulatory fit and increased cognitive flexibility or merely reflected superior CL performance, two further studies were performed in which it was arranged that cognitive flexibility would be detrimental to task performance. As predicted, the results confirmed that regulatory fit was related to increased cognitive flexibility, as participants for which the regulatory fit was 'high' performed more poorly than those for which it was regulatory fit was low (i.e., greater regulatory fit lead to increased cognitive flexibility, which was detrimental to performance on these tasks. The opposite result would of course be expected if greater regulatory fit simply facilitated 'learning' in categorisation tasks in general).

The study just described examined the interface between motivation and cognition, more specifically, the effect of regulatory focus/fit upon classification learning. However, the notion that there are basic systems which underlie approach and avoidance behaviours is common to a variety of motivation/emotion/personality theories. A clear comparison can be made with RST (Gray, 1970, 1981; Pickering et al., 1997) described in chapter 1. The possible connection between RST, motivation and learning has been discussed previously. As noted by Maddox, Markman and Baldwin (2006), the function of the BAS would appear to be most clearly associated with aspects of the regulatory focus hypothesis. For example, a more reactive BAS may predispose an individual to be more sensitive or reactive to actual or potential rewards. Hence, there would appear to be the possibility for a high degree of theoretical and functional overlap between high BAS function and a greater orientation towards a promotion focus; consequently similarities in behavioural outcomes may also exist.

Accordingly, the possible effects of regulatory fit upon learning, due, for example, to convergence between regulatory focus (i.e., promotion/prevention focus) and situational/task demands (e.g., enhanced cognitive flexibility), may also be expected to occur in respect to BAS function. Furthermore, the postulated hypothesis that variation in BAS function underlies variation in fundamental personality dimensions leads to the supposition that regulatory fit may be indexed by the appropriate BAS-related trait measure (possibly ImpASS or E) and subsequently relate to learning (and other behavioural effects) in a predictable fashion. This notion is supported by data discussed by Cunningham, Raye and Johnson (2005) which suggested that individuals with a greater tendency towards a promotion focus were slightly more extraverted (as well as open to experience) than those with a lesser promotion focus tendency.

However, the primary interest with the Maddox, Baldwin et al. (2006) study described above concerns the issue of cognitive flexibility and classification learning performance. One theme of this thesis has been to consider the relationship between personality and possible attentional processes that may be involved in CL. For example, through its direct association with schizophrenia, schizotypy has long been associated with impaired selective attention. This is one possible cause of the data discussed previously (Pickering, 2004) that showed that an association between positive schizotypy and poorer performance on a RB task. Positive schizotypy was more strongly associated (numerically at least) with impaired performance after an unannounced switch of the category rule had occurred; this may be construed to suggest some degree of cognitive *in*flexibility in CL is associated with this trait.

A number of studies, described in the introductory chapters, have lead to the proposal that one way in which ImpASS may influence CL performance is through a distinct attentional or strategic style. For example, in the study by Tharp (2003), described in the second chapter, ImpASS traits were related to poorer performance on a task that required attention to information from both dimensions of a set of two-dimensional stimuli. Furthermore, these traits were related to the greater use of (inappropriate) uni-dimensional strategies. In addition, as discussed in chapter 2, this trait cluster has also been related to the enhanced learning of (nominally) RB categories in a number of other studies (e.g., Pickering, 2004). This again may be suggestive of an attentional or strategic style that is more suited to the learning of category structures in which a simple rule (e.g., possibly involving a single dimension) needs to be acquired.

Such an attentional, or strategic, style would likely be detrimental to performance on the task utilised by Maddox, Baldwin et al. (2006). ImpASS traits may therefore be expected to be related to poorer performance on the task in which cognitive flexibility is considered to be the critical factor required for the successful attainment of the optimal categorisation strategy. Such a deficit may be particularly evident in this task. Simple, uni-dimensional strategies yield relatively highly levels of performance, yet must be abandoned in favour of the more complex strategy, involving the consideration of two of the stimulus dimensions, in order to successfully achieve the performance criterion.

Aims

The primary aim of the current study was to explore the relationship between personality and CL performance on a task that is dependent upon cognitive flexibility. The task used in the present study was identical to the one described in the first experiment reported by Maddox, Baldwin et al. (2006). However, the manipulation of regulatory focus and reward structure was not applied. In the current study, all participants took part in the promotion focus condition (i.e., all participants attempted to obtain enough points to receive a prize-draw ticket). In addition, a 'gains' reward structure was used (i.e., participants received points for correct classifications and no points for incorrect classifications). Therefore, there was a high degree of regulatory fit between the situational characteristics and reward structure associated with the task. Crucially, this aspect of regulatory fit was not manipulated by the experimenter, and was therefore identical for each participant.

A number of predictions were therefore considered. Firstly, general performance on the task was predicted to relate to cognitive flexibility. As discussed above, it was therefore predicted that higher levels of ImpASS may relate to poorer performance on the task as a result of reduced cognitive flexibility (especially as the task required a complex two-dimensional rule).

It was possible that positive schizotypy may relate to poorer performance on the task. In addition to a possible relationship with cognitive flexibility described above, results from the Tharp and Pickering study (discussed in chapter 2) showed positive schizotypy (together with ImpASS) was related to poorer performance on a CL task requiring a two-dimensional strategy. Furthermore, in the II task reported in chapter 4, positive schizotypy accounted for a significant proportion of variance in the number of correct responses and was related to poorer performance on the task. Hence, in addition to cognitive inflexibility (suggested by poorer CL after an unannounced switch of category rule), it is possible that positive schizotypy may relate to poorer CL performance in tasks that involve more complex (e.g., multi-dimensional) category structures. Both processes may therefore lead to impaired performance on the current task.

Regulatory fit was not manipulated experimentally in the present study. However, variation in the degree of regulatory fit may have occurred by way of individual differences in regulatory focus orientation. A strong promotion focus was established in the task together with a matching reward structure, heightening the degree of regulatory fit inherent in the task. As described above, a degree of overlap may exist between BAS function and a predisposition toward a stronger promotion focus. Consequently, it may be suggested that a greater degree of regulatory fit would occur for 'high-BAS' as opposed to 'low-BAS' individuals, and therefore it would be predicted that such individuals are more likely to perform well on the task, as a greater degree of regulatory fit appears to facilitate cognitive flexibility and therefore learning on this particular task.

As has been discussed previously, the nature of the 'true' BAS-related personality trait is a matter of debate. One candidate trait is extraversion and consequently it may be expected that this trait would relate to better performance on the task. Impulsivity, and ImpASS related traits, has also been linked with BAS function. This provides an interesting proposition. ImpASS may be associated with a greater orientation towards a promotion focus. Consequently, performance on the task may be facilitated by a greater regulatory fit for those individuals that score more highly on ImpASS. However, as discussed above, due to an association with decreased cognitive flexibility, higher levels of ImpASS were predicted to relate to poorer task performance. Hence, higher levels of ImpASS could be predicted to lead to enhanced or inhibited performance on the task (or alternatively, the combined effects may lead to no association with performance).

Finally, no strong predictions were made for a relationship between neuroticism and performance on the task. WM was assessed in the study as it is considered to perform an important role in RB CL. In an attempt to consider possible IQ related effects upon cognitive flexibility, a measure of fluid intelligence was also included in the present study.

METHOD

Participants

The participants who took part in this study were described in the preceding chapter. This opportunity sample comprised the 32 male and 32 female participants recruited in the summer session, obtained from the college and local area, with a mixture of (mostly non-psychology) students and non-students. The age range was 18 to 39 years (mean 26.7, SD 4.4). All participants were chosen to be right-handed, due to the design of the RT task described in the previous chapter. As detailed in chapter 5, participants received a minimum payment of £13 for participation as well as the opportunity to win a further £2 and also entry to a £25 prize draw (dependent on performance on particular tasks). All participants' spoken English was sufficiently fluent to enable completion of the personality questionnaires. Clarification of any terms in the questionnaires was given if requested.

Design

Personality Questionnaires

In this study participants completed the EPQ-E, OLIFE, BFI, SSS, BIS/BAS scales and the SPQ. As described in chapter 3, four personality factors (E, ImpASS, positive schizotypy and N) were obtained from these results. The following analyses will henceforth simply refer to these four factors as: E, ImpASS, positive schizotypy and N.

Conjunctive RB CL Task (Conjunctive RB Task)

This task was identical to the one used by Maddox, Baldwin et al. (2006) discussed in the introduction (subsequently the task description and procedure closely follows that presented in the aforementioned paper). The stimuli were single lines that varied upon 3 dimensions: length, angle of orientation and (horizontal) position (as presented on the computer screen). Each stimulus belonged to one of two categories. The stimuli were created such that any of the 3 dimensions could be used individually, in a uni-dimensional RB fashion, to obtain reasonable categorisation performance. However, perfect performance was attainable through the use of a conjunctive rule involving the length and orientation of the stimulus (i.e., stimulus position was nominally task irrelevant). The nature of this rule, and associated optimal decision bound, can be seen in figure 6.1 below which shows a scatter plot of the stimuli across the two relevant dimensions of length and orientation (shown in raw dimension units). Therefore, the optimal response strategy is to respond 'category 2' if the stimulus is long (i.e., greater 150 units) *and* orientation is steep (i.e., greater 150 units); otherwise respond 'category 1'.

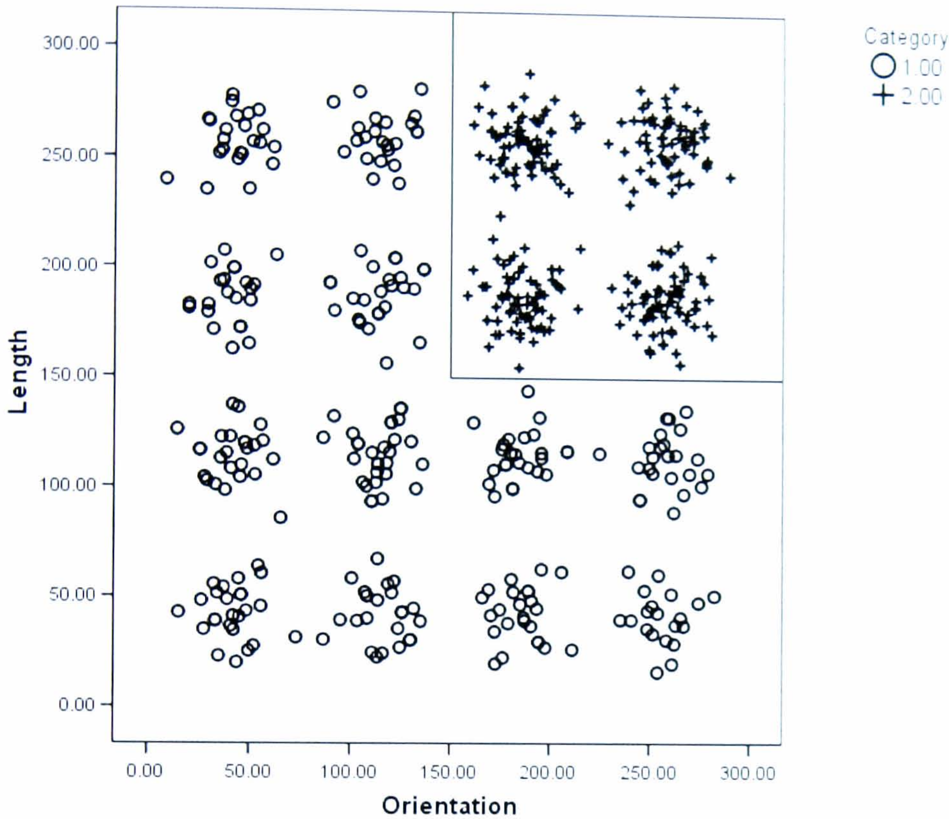

Figure 6.1: *Scatter plot of the stimuli across the length and orientation dimensions with the optimal decision boundary for the two-dimensional conjunctive rule*

The category structure was deterministic, hence correct application of the optimal rule would lead to 100% accuracy. However, as mentioned above, the use of any of the 3 dimensions individually would also lead to reasonable accuracy. The most accurate uni-dimensional rules for the two relevant dimensions (occurring at the same cut-off point as the optimal conjunctive rule, i.e., 150 units) would yield an accuracy rate of 83%. Additionally, the most accurate uni-dimensional rule for the remaining dimension (position) would also yield a response accuracy of 83%. Crucially, as will be discussed further below, the participants were attempting to achieve a performance criterion of 90% accuracy or above. Hence, although the simple uni-dimensional rules would lead to relatively high accuracy levels, only the use of the optimal (conjunctive) rule would enable the participant to achieve the desired performance criterion.

The general aim of the task was to assess how well participants were able to modify their category response strategies from reasonably successful and simple uni-dimensional rules, to the more complex yet optimal conjunctive rule. Therefore, the task would benefit if participants initially focused upon uni-dimensional rules. After a series of pilot studies, Maddox, Baldwin et al. (2006) observed that the position dimension appeared to be the most salient feature of the stimuli. Accordingly, this dimension was chosen to be the irrelevant dimension.

Working Memory Task

The design and procedural information for the WM task was described in the preceding chapter.

Fluid Intelligence Task (WAIS-III matrices)

To obtain a measure of fluid intelligence the matrix reasoning task from the Wechsler Adult Intelligence Scale III (WAIS, Wechsler, 1997) was administered. This task involves the presentation of a matrix with a missing component. Based upon the pattern of components within the matrix, participants are required to select the appropriate component to fill in the missing cell of the matrix. There are 5 possible alternatives for each of the 26 matrices presented. In the present study the raw scores (i.e., number of correct responses) were simply summed for each participant.

Procedure

The general testing procedure was as described in the preceding chapter. To recap, participants completed two separate testing sessions on different days within one week. Each session lasted approximately 70 minutes. The RT task was performed in one session, followed by two of the personality questionnaires (SSS and BIS/BAS scales). The present task was the final experiment of this session. The WM task was conducted in the second session along with the BFI and SPQ questionnaires. The order of these two sessions was counterbalanced across participants. The remaining questionnaires (EPQ and OLIFE) were completed between the two testing sessions in the participants' own time.

Conjunctive RB Task

Instructions for the task were presented via the computer. The participants were informed that the task would involve learning to classify a series of pictures. The pictures would consist of a single line that varies in length, the direction it is orientated, and its location on the screen. The participants were asked to categorize each presented stimulus to one of two possible categories by pressing the appropriate response key (labelled 'A' and 'B'). After each response the computer would inform them of whether the response had been correct. Additionally, if the incorrect category had been chosen, the computer would display the correct category for the stimulus. Participants were informed not to worry about making incorrect responses and focus upon the correct categorisation of subsequent stimuli. Initially the participant may rely upon guessing, however as the task proceeded, the accuracy would be likely to increase. The participants were instructed that an equal number of stimuli from the two categories would be presented.

Subsequently, participants were informed that the task would consist of a number of blocks of trials (the exact number was not given). For each correct response two points would be received, whereas no points would be received for incorrect responses. If the participant was able to reach at least 86 points over the last block of trials then they would receive two tickets for entry into a £25 draw. This last point was strongly emphasised in order to encourage the participant to work hard at the task. The experimenter then verbally clarified any additional questions before leaving the testing room. The participant began the experiment by pressing the space bar.

On each trial a single stimulus was presented on the computer screen, comprising a single white line displayed on a black background. The stimulus was situated in vertically central position within a white box. The length of the stimulus, angle of orientation and horizontal position (within the borders of the white box) varied on each trial (as described in appendix E.1, p. 319). Additionally, a rectangular point meter was displayed in white on the right-hand side of the screen. At the start of each block of trials the point meter was set to zero (unfilled). The base of the point meter was labelled zero (i.e., 0), with the performance criterion of 86 points indicated by a horizontal line across the point meter. To indicate whether the current level of performance was sufficient to obtain the prize-draw tickets (i.e., as if the current block was the last block of trials), the area of the point meter above the performance criterion was labelled 'Yes', whereas below, the region was labelled 'No'.

Each stimulus remained on the screen until an appropriate response had been made. At this time visual feedback was presented below the stimulus presentation box. If an incorrect response had been made the feedback text read "No, the correct category was A/B" (as appropriate). Following a successful category response, the word "Correct" was displayed. After 300ms, the point meter was updated. If the correct response had been made the degree of fill of the point meter increased by the appropriate proportion to represent an increment of two points. To emphasize the increase in the points total, the region of the increment flashed for 600ms. The auditory feedback, comprising the sound of a cash-register ('kerching'), was presented simultaneously. After a pause of 100ms, the new points total was shown both graphically and in text on the point meter for a further 300ms. For incorrect responses a 'buzzer' sound was played for 600ms followed by a 100ms pause. The point meter remained unchanged on the screen. For both correct and incorrect responses, the stimulus display was cleared, followed by an inter-trial-interval of 250ms. The point meter remained on screen throughout this period.

At the end of each block of trials a summary of the participants' performance over the preceding block was given. For all except the final block trials, if the performance criterion had been reached (or exceeded), the participant was congratulated and informed that had that been the last block of trials then they would have earned 2 tickets for the prize draw. If they had not attained the performance criterion within the block, the participant was encouraged to keep trying and informed that they would not have earned the tickets for the prize draw had that been the last block of trials. Naturally, on the final block of trials all participants were thanked and informed as to whether or not they had obtained the prize draw tickets.

RESULTS

*(These analyses are based on the results from 63 of the participants due to equipment failure which resulted in the data from 1 participant not being saved)

General Performance

The performance criterion for this task was 90% accuracy or above. 29 (46%) participants met or exceeded this criterion on the last block of trials. Only 4 participants failed to reach the performance criterion in any of the 12 blocks. The frequency distribution of the number of blocks in which the criterion performance was attained is shown below. The mean was 4 blocks, demonstrating the relative difficulty of the task; fewer than a quarter of participants were able to achieve the performance criterion in more than half of the blocks.

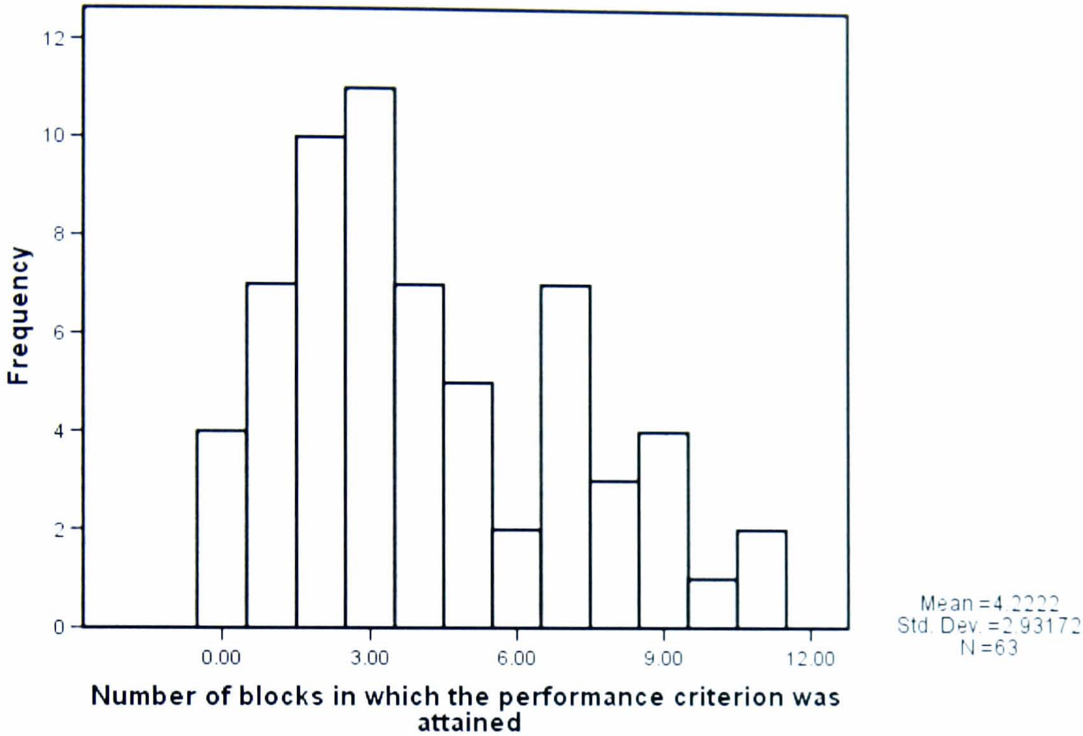

Figure 6.2: *Frequency distribution of the number of blocks in which participants reached the criterion level of performance*

A plot of accuracy rates also demonstrates a clear linear pattern of generally improving performance over blocks 2 – 12. Performance in the first block appears relatively high before dropping to the lowest level in block 2. Performance then appears to steadily increase until approximately block 8, at which point average performance appears to level off. As discussed in the introduction, this pattern of performance was predicted from the design of the task. It was envisaged that participants would initially apply uni-dimensional RB strategies and subsequently perform well on the task as the use of any individual dimension would yield relatively high levels of accuracy. However, as the bonus target could be reached only by the application of the correct two-dimensional rule, performance was predicted to drop as participants attempted to establish a more successful response strategy. Subsequently, participants' performance may be expected to level-off somewhat towards the end of the task as optimal (or near optimal) performance was achieved. It was therefore predicted that performance over the entire task would follow a cubic trend (convex downwards followed by convex upwards).

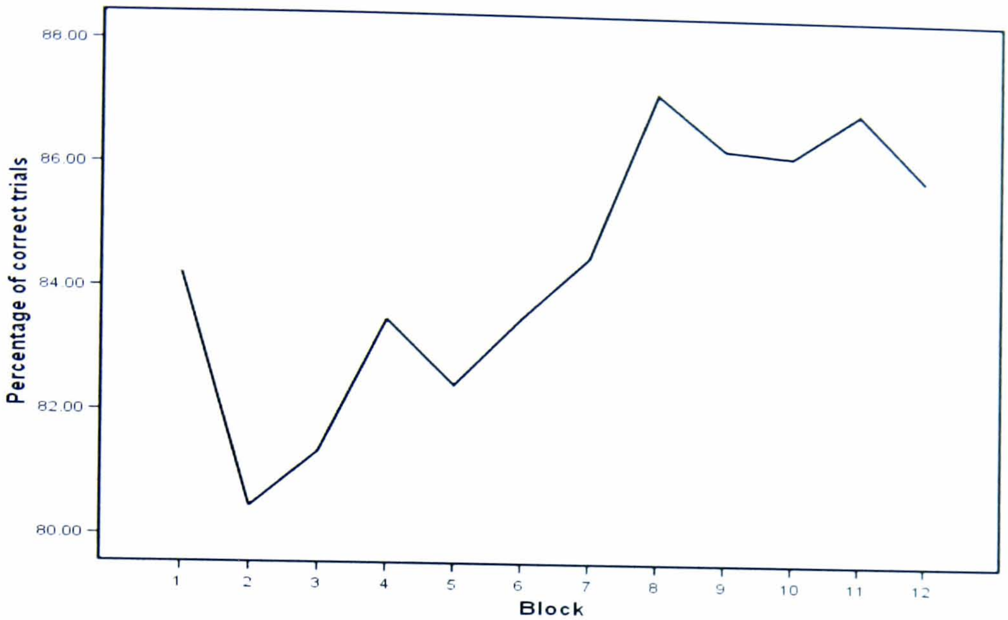

Figure 6.3: *Mean number of correct trials by block*

Performance and Individual Differences

WM was not significantly related to the personality factors (all r's < .09). However, performance on the fluid intelligence task (WAIS matrices) was significantly negatively related to positive schizotypy (r = -.260, p = .038), but no other significant relationships were observed (r's < .09). Mean percentage accuracy on the conjunctive RB task was not significantly related to age, gender or performance on the WAIS task. There was a weak positive relationship with working memory which still fell well short of statistical significance.

Table 6.1: *Correlation between the mean percentage of correct trials (across the task) and individual differences measures (excluding the personality factors)*

		Age	Gender	WAIS	WM
Percentage correct trials (mean)	Pearson Correlation	-.068	.080	.028	.170
	Sig. (2-tailed)	.598	.531	.828	.182

ImpASS was strongly associated with poorer overall accuracy. None of the remaining personality factors were significantly related to overall performance, with extraversion showing the next strongest relationship.

Table 6.2: *Correlation between the mean percentage of correct trials (across the task) and personality factors*

		Extraversion	**ImpASS**	**Neuroticism**	**Positive Schizotypy**
Percentage correct trials (mean)	Pearson Correlation	.126	-.398(**)	.043	-.051
	Sig. (2-tailed)	.324	.001	.740	.692

** Correlation is significant at the 0.01 level (2-tailed).

Various methods were employed to explore the relationship between performance and personality, specifically ImpASS. A median split was applied to group participants into high and low ImpASS groups (the high group had only 31 participants). To facilitate comparison with the Maddox, Baldwin et al. (2006) study, the first analysis involved assessing the first block in which the performance criterion was exceeded. Hence scores ranged from 1 to 12, with 13 being used to code for those participants who did not reach the criterion performance in any block (i.e., the minimum number of blocks that would have been required). The low ImpASS group achieved their first criterion level performance after 2.65 blocks on average. This was significantly earlier than the high ImpASS group, that achieved the criterion after an average of 4.38 blocks ($t_{(49)} = -2.47$, $p = .017$ *equal variances not assumed).

To explore accuracy performance over the task a mixed design, block (12) by ImpASS group (2), ANOVA was performed on the percentage of correct trials in each block. There was a significant main effect of block ($F_{(11, 671)} = 6.889$, $p < .001$), with a significant linear trend of increasing accuracy over blocks ($F_{(1, 61)} = 28.784$, $p < .001$). There was also a significant main effect of ImpASS group ($F_{(1, 61)} = 5.827$, $p = .019$) with the low ImpASS group performing better than the high ImpASS group (estimated marginal means 86.0% and 82.7% respectively). The graph below demonstrates that with the exception of the 1st block, the low ImpASS group on average scored higher than the high ImpASS group. There was however no significant interaction between the two factors ($F_{(11, 671)} = 1.476$, $p = .136$).

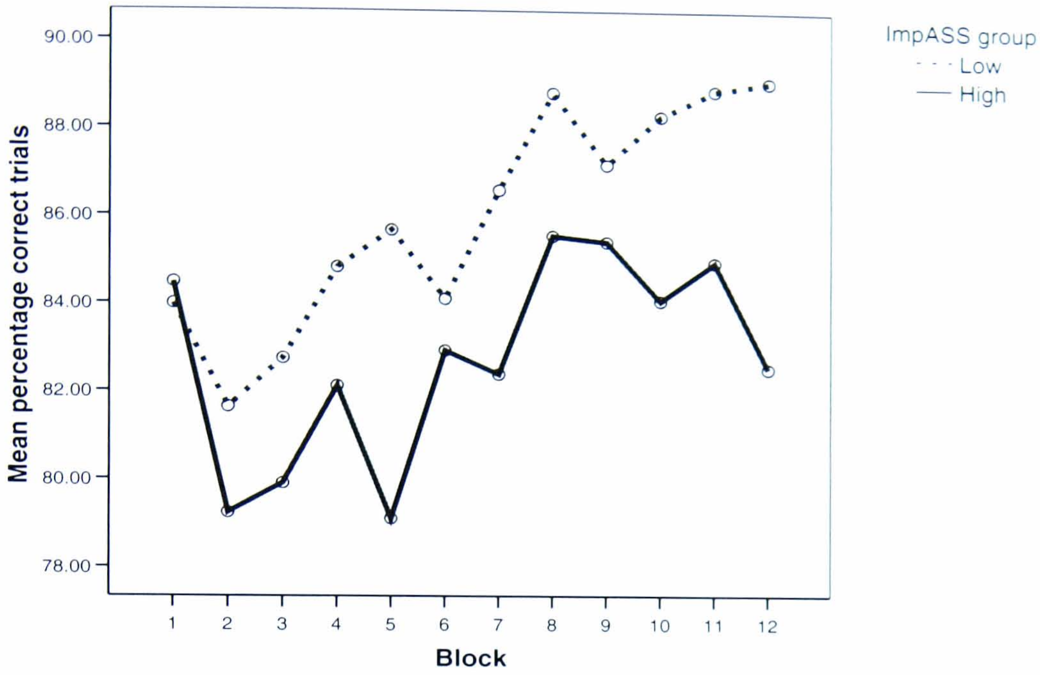

Figure 6.4: *Mean number of correct trials by block for the high and low ImpASS subgroups*

Despite the significant main effect of ImpASS group, inspection of figure 6.4 above suggested that the high and low ImpASS groups may not have differed on performance in the first block of trials, and therefore the main effect may have been driven by performance on blocks 2 – 12. This was confirmed by a significant interaction between ImpASS group and a contrast of performance on the 1st block with the remaining 11 blocks ($F_{(1, 61)} = 4.286$, $p = .043$ – uncorrected post-hoc comparison).

For an alternative exploration of accuracy performance over the task, a repeated measures ANCOVA was performed on the percentage of correct trials in each block, with block number (12 levels) as the factor and ImpASS as the covariate. There was a significant main effect of block ($F_{(11, 671)} = 7.089$, $p < .001$). A significant linear contrast ($F_{(11, 61)} = 34.238$, $p < .001$), and inspection of figure 6.3 shown previously, shows that performance levels generally increased throughout the task. The figure also suggests an initial dip in performance after the 1st block, followed by steady increases in accuracy before possibly reaching a plateau (or even slightly decreasing) over the final blocks. As predicted previously, this pattern is confirmed by a significant cubic trend ($F_{(11, 61)} = 13.040$, $p < .001$) for score by block.

There was also a significant main effect of the covariate ImpASS ($F_{(1, 61)} = 11.456$, $p = .001$) as well as a significant interaction between block and ImpASS, indicating that the main effect of block was qualified by the level of ImpASS. The linear and cubic contrasts were again significant for the block by ImpASS interaction term ($F_{(11, 61)} = 5.635$, $p = .021$ and $F_{(11, 61)} = 6.811$, $p = .011$ respectively). To characterise the relationship between performance over the blocks and ImpASS a linear trend score was first calculated for each participant. This was achieved by multiplying the linear contrast coefficients for each level of the block factor by each participant's individual score on that block. The linear trend score therefore reflects the degree to which a participant's scores follow a linear pattern over the 12 blocks (higher magnitude scores indicate a greater linear increase or 'slope', and positive and negative values indicate the direction of the relationship). The relationship between linear trend score and ImpASS is shown in figure 6.5 below.

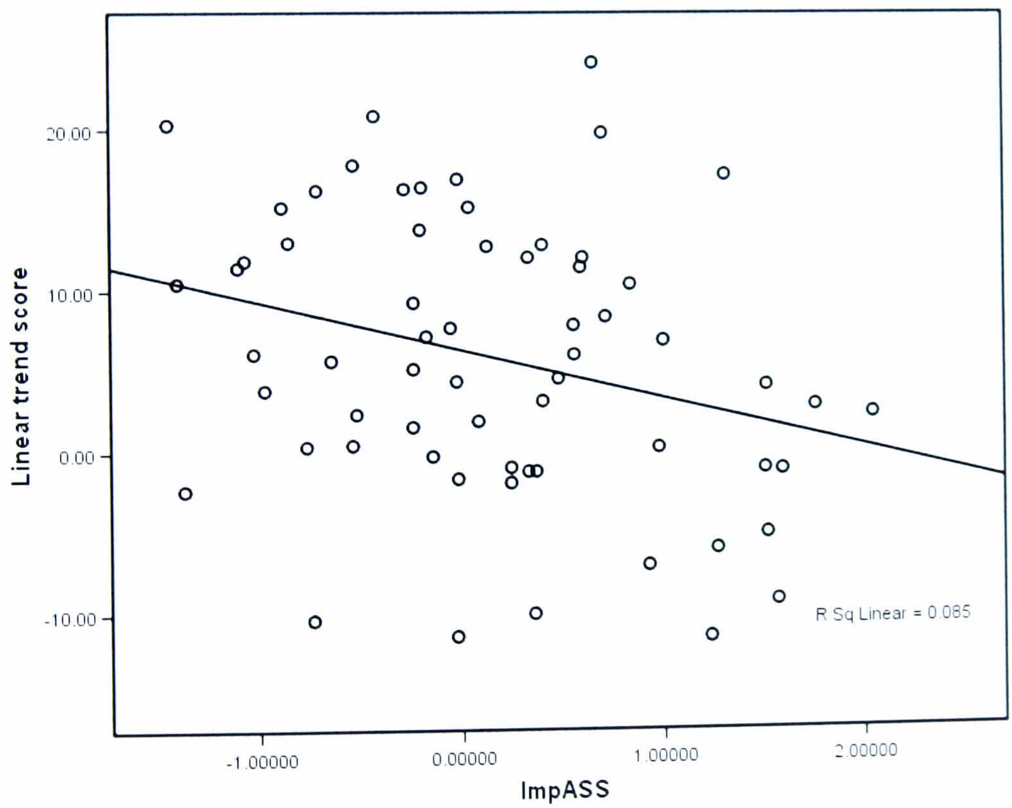

Figure 6.5: *Scatter plot of ImpASS and linear trend score (best fitting linear regression line shown)*

This demonstrates a significant negative relationship (r = -.291, p = .021) between ImpASS and the linear trend score. This means that lower scorers on ImpASS showed a stronger positive linear performance trend, whereas higher scorers were associated with less of this trend (and possibly a weak negative linear performance trend).

The same process was repeated for the significant cubic contrast of the interaction term. The relationship was again significantly negative (r = -.317, p = .011) and is shown below in figure 6.6. From the general pattern of results across the task (i.e., figures 6.3 and 6.4), and cubic trend co-efficients calculated by SPSS, the cubic trend can be seen to be negative as opposed to positive. The significant negative correlation between ImpASS and the cubic trend score therefore indicates that individuals scoring more highly on ImpASS demonstrated more of a cubic trend. Taken together with result described above, this suggests that participants that scored more highly on ImpASS showed a greater drop in performance after the first block of trials and greater drop in performance levels across the last few blocks of trials relative to participants that scored lower on ImpASS that showed a greater general (i.e., linear) increase in performance across the task.

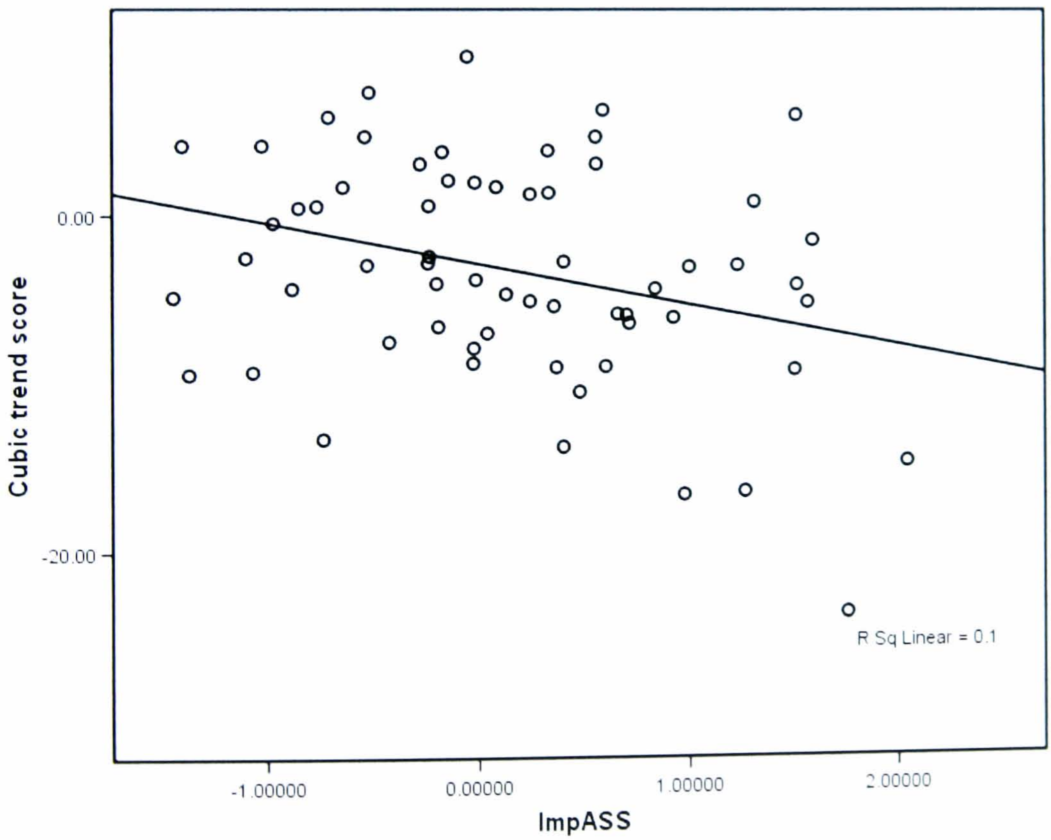

Figure 6.6: Scatter plot of ImpASS and cubic trend score (best fitting linear regression line shown)

Participants in this task were attempting to reach the performance criterion in the last block of trials in order to win an entry into a £25 prize-draw. As mentioned above, 29 of 63 participants were able to reach or exceed this criterion on the last block of trials. A logistic regression was performed with success in the last block of trials as the binary dependent variable (1 – yes, 0 – no). ImpASS was entered as a (continuous) predictor together with extraversion, the personality factor with the next strongest relationship with overall accuracy levels. This 2 parameter model was a significantly better fit to the data compared to the intercept only model ($\chi^2_{(2)} = 14.607$, $p = .001$), and was not significantly worse than the saturated model ($\chi^2_{(60)} = 72.333$, $p = .132$). Both effects contributed to the model which was significantly poorer if either effect was removed (ImpASS $\chi^2_{(1)} = 7.329$, $p = .007$; E $\chi^2_{(1)} = 9.009$, $p = .003$). Inspection of the parameter table revealed that a for each unit increase in ImpASS (and recall that ImpASS is a standardised variable as it was extracted by factor analysis) the odds of *not* reaching the performance criterion increased by 2.5 (95% C.I. = 1.22 – 5.14). In contrast, participants were 2.27 (95% C.I. = 1.25 – 4.10) times more likely to reach the criterion for each unit increase in extraversion. No other personality or individual differences variables were able to provide significant additional contributions to this model. [1]

Together the accuracy analyses suggest that higher levels of ImpASS were related to 1) overall poorer levels of accuracy, 2) a greater number of blocks taken to reach the performance criterion 3) a smaller linear trend of increasing performance over blocks (compared to a greater positive linear trend for lower levels of ImpASS) and 4) decreased likelihood of reaching the criterion performance in the last block of trials. In addition, in the final block of trials, higher levels of extraversion were related to an increased likelihood of achieving the criterion.

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[1] The data revealed a distinct covariate pattern. However, the analysis was similar if repeated using quartiled variables: If ImpASS and E were quartiled then used as covariates the model was still a significantly better fit than the intercept model ($\chi2(2) = 1.922$, $p = .003$), and was not significantly worse than the saturated model ($\chi2(13) = 17.598$, $p = .173$). Both effects contributed to the model which was significantly poorer if either effect was removed (ImpASS $\chi2(1) = 5.195$, $p = .023$; E $\chi2(1) = 6.656$, $p = .010$). Inspection of the parameter table revealed that for each quartile increase in ImpASS the odds of not reaching the performance criterion increased by 1.82 (95% C.I. = 1.09 – 3.04). In contrast, participants were 1.98 (95% C.I. = 1.18 – 3.32) times more likely to reach the criterion for each quartile increase in extraversion.

Response Strategy Modelling

The analyses presented above clearly indicate a deleterious effect of ImpASS on task performance as well an increased likelihood for more extraverted individuals to have achieved the performance criterion in the final block of trials. In an attempt to understand a possible cause for this relationship, a series of decision bound models were fitted to each individual participant's data (i.e., responses) to determine the most likely response strategy. This is analogous to the type of response modelling procedure described in chapter 4 (and identical to the approach pursued by Maddox, Baldwin et al., 2006). However, the use of stimuli with continuous-valued dimensions in the present study enabled more sophisticated mathematical models of an individual's response criterion to be applied (e.g., Ashby & Maddox, 1993; Maddox & Ashby, 1993).

The models were applied to each individual participant's data, for each block of the task separately. The parameters for each model (i.e., decision criteria and 'noise') were estimated using maximum likelihood methods. Hence, for every participant, a likelihood ratio statistic was created for each of the models, for each of the 12 blocks of trials. The best fitting model in each block was assessed by the comparison of the **A**kaike **I**nformation **C**riterion (AIC, e.g., Motulsky & Christopoulos, 2003), which was calculated on the basis of the number of free parameters and estimated likelihood of each model. Therefore, the model with the lowest AIC value was considered the best fitting model. Further details of the modelling procedure can be found in the appendix (E.2, p. 320).

Three categories of model were fitted to the data as described below. Each of these models was fitted to each participant's data individually. The models were fitted on a block by block basis to allow the examination of changes in strategy used over the task.

1 - Uni-dimensional Rule Models

The uni-dimensional models describe the situation in which a participant assigns a criterion to one of the three stimulus dimensions and categorises each stimulus depending on whether the value on that dimension (e.g., length) exceeds or falls below the criterion. Hence, three different models were possible, depending on whether the dimension used was the length, orientation or position of the stimulus. This model had two parameters that were free to vary; the criterion placement (estimated from the data) and noise.

In addition to these models a further set of three uni-dimensional rules were applied. These models were identical to the models just described except that the criterion was fixed at the optimal point (i.e., the value that would maximise response accuracy if using such a strategy – note that this is distinct from the actual optimal task strategy, to be discussed below). Hence these models had only parameter that was free to vary (i.e., noise). Owing to the design of the category structure the optimal criterion, if using either length or orientation, had a numeric value of 150 (see figure 6.1 in the procedure section, p. 166). From Signal Detection Theroy (e.g., Stanislaw & Todorov, 1999) the numerical value for the position dimension was 325 (i.e., this is simply the midpoint between the means of the two categories on this 'irrelevant' dimension).

2 – Two-dimensional Conjunctive Rule Models

These models describe the situation in which the participant uses a conjunctive rule that involves applying separate criteria on two of the dimensions in order to assess category membership (e.g., if the stimulus is above value 'x' on dimension 1 *and* above value 'y' on dimension 2, then the stimulus is category B, otherwise the stimulus is category A). As described above, the stimuli were constructed such that those stimuli which exceeded the criteria on length and orientation (both set at 150) belonged to category B, with all other stimuli belonging to category A. Hence, the remaining value on the position dimension was irrelevant.

The first set of models of this type had 4 parameters that were free to vary; the criteria for the two dimensions (2) as well as the associated noise parameters (2). Three different models of this type were applied for each combination of the 3 dimensions. Obviously 2 of these 3 combinations (i.e., 'length and position' and 'orientation and position') were inappropriate to the task. An additional model derivation was applied where the criteria were again fixed to the optimal settings. This was only used for the appropriate combination of dimensions (i.e., length and orientation), and hence the criteria were both fixed to 150, with the resulting model having 2 (noise) parameters which were free to vary.

Based on Maddox, Baldwin et al. (2006), the conjunctive models described above were also fitted using only one noise parameter (i.e., the noise parameter was assumed to be equal for both dimensions). These two model types were therefore identical to the two models described above except for using one fewer free parameter in ach case.

3 - II Models

These models describe the situation in which participants appeared to use II strategies (as discussed earlier). The key difference is that the information, from the dimensions which are used to classify the stimuli (e.g., length and orientation), is combined at a pre-decisional stage. In contrast on conjunctive rule models, a decision is made on each dimension and then the decisions are combined to come to a classification.

Firstly, two-dimensional II models were applied. These models involved combining the information from 2 of the 3 stimulus dimensions. Hence, 3 different versions were fitted for each combination of 2 dimensions. These models describe a linear decision bound (straight line) in the two-dimensional stimulus space defined by the 2 dimensions used. The models therefore had 3 parameters which were free to vary; intercept, slope and noise.

Finally, a 3 dimensional II model was applied, which was simply an extension to include the use of all 3 dimensions. These models therefore describe a decision boundary (plane) in the 3-dimensional space defined the 3 stimulus dimensions. This model therefore has one additional free parameter (additional slope coefficient) for the 3rd dimension. However, the data from this model will not be presented.

Modelling Results

The best fitting models were classified into 3 distinct categories:

Type 1) uni-dimensional rules

Type 2) incorrect two-dimensional rules (either RB or II)

Type 3) correct two-dimensional rules (either RB or II)*

*Of the 756 possible model fits (i.e., 63 participants by 12 blocks), 701 provided a good fit to the data as described and defined in the modelling procedure. Of these, only 9 were attributed to a two-dimensional II rule combining the relevant 2 dimensions. The modelling procedure is likely to have more power to distinguish between dimensions used relative to whether the dimensions were used in an II as opposed to a conjunctive rule fashion. For this reason (and the low number of fits attributed to this II model) it was decided that it would be most appropriate to include these as type 3 models as described above. This maintained the key distinctions between the model types; use of a single dimension or two dimensions combined and whether incorrect or correct dimensions were combined. To support this view it was observed that in all of 9 cases in which a two-dimensional *II rule* combining the relevant 2 dimensions was the best fitting model, the next best fitting model was the correct two-dimensional *conjunctive rule* (i.e., both classified as type 3). This grouping has been used in subsequent analyses presented below. Any results that appear to be affected by this classification are highlighted.

The models fitted the data well and on average (calculated across the entire task) the three model types accounted for 82.6%, 82.7% and 87.6% of responses respectively (best fitting models only). The distribution of the different model types for each block is shown below, the 3 categories are represented by the black, grey and white bar segments respectively.

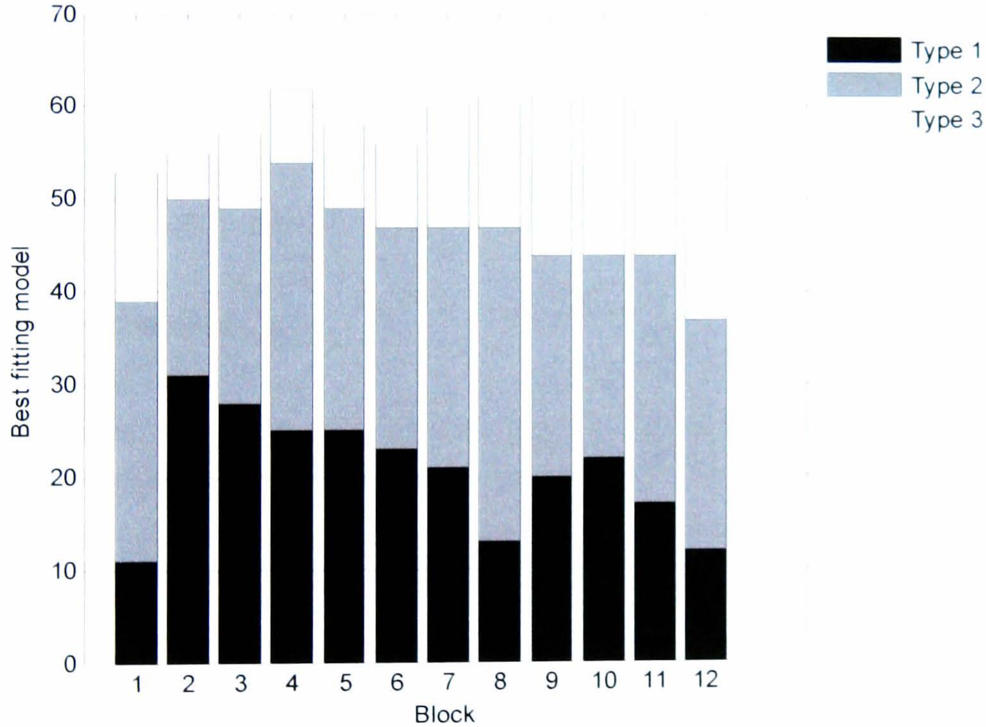

Figure 6.7: *Frequency of the best fitting model types by block*

Figure 6.7 suggests that there appears to be a general trend of decreasing uni-dimensional rule use over blocks 2-12 coupled with a gradual rise in the use of the correct conjunctive rule. In all blocks, the mean percentage of correct trials for those using the correct two-dimensional rules (type 3) was higher than that of those using incorrect two-dimensional rules (type 2), which was in turn higher than those using uni-dimensional rules (type 1). Detailed results are not presented here, however, in every block except the first, pre-planned contrasts revealed that those using the correct two-dimensional rules (i.e., type 3) performed significantly better than those using incorrect two-dimensional rules. (Those using the uni-dimensional rules were significantly worse than those using incorrect two-dimensional rules in 3 of the 12 blocks, with a trend observed in a further 3 blocks).

The number of best fitting two-dimensional models (i.e., type 2 and type 3) in the first block of trials may appear surprisingly high. However, this is not too unexpected. There are a number of reasons why it would be predicted that there is likely to be a greater amount of variation, or noise, in the modelling of response strategy during the first block of trials (e.g., during this first block participants are familiarising themselves with the stimuli and it is likely that initial guessing rates are high, also a variety of different response strategies may be employed etc.). The two-dimensional models may be more able to account for such performance.

The model fits therefore match the data as expected, both in terms of performance levels and frequency of occurrence over the task. On a final note, the claim that the (irrelevant) position dimension appeared to be the most salient of the 3 dimensions appeared to be somewhat validated. Across the task as a whole, 63% of all the best fitting models involved the use of the position dimension (33% using this dimension in a uni-dimensional rule).

Strategy and Personality

Further analyses were performed to clarify the possible relationships between personality and response strategy use as indexed by the best fitting models. For each participant the proportion of blocks in which a uni-dimensional was the best fitting model was calculated. Hence, if all blocks (in which there was a good fitting model) were best described by a uni-dimensional model this proportion would equal 1. This ratio was highly (negatively) correlated with performance on this task in terms of both percentage of correct trials ($r = -.693$, $p < .001$) and likelihood of achieving criterion level of performance in the last block ($r = -.482$, $p < .001$). ImpASS was positively related to a greater proportion of uni-dimensional strategy use ($r = .327$, $p = .009$). Again there was a weak negative association with extraversion ($r = -.163$, $p = .201$), which was significantly different from the relationship between ImpASS and the proportion of uni-dimensional strategy use (Williams $T2_{60} = 3.008$, $p = .002$). WM was also negatively related to this measure ($r = -.231$, $p = .069$). Multiple regression was used with ImpASS, E and WM as predictors. The model accounted for a significant 18.1% of the variance in the proportion of uni-dimensional strategy use ($F_{(3, 59)} = 4.431$, $p = .008$). ImpASS was related to a higher degree of uni-dimensional strategy use and accounted for a significant proportion of unique variance (10.6%) in the model. WM and E were both negatively related to uni-dimensional strategy use, yet the unique contributions of 3.8% and 3% of the DV variance respectively, were not significant ($t_{(59)} = -1.664$, $p = .101$; $t_{(59)} = -1.461$, $p = .149$).

An additional method of assessing strategy use across the task yielded similar results. Using the model types described above, a crude measure of average strategy use was calculated by calculating each participant's mean strategy type score. Hence, lower scores would indicate a tendency towards uni-dimensional rules while higher scores would reflect the use of the (correct) two-dimensional strategy. WM was weakly positively correlated ($r = .208$, $p = .101$) with this measure. ImpASS was again the only personality factor significantly to related to this measure ($r = -.372$, $p = .003$) and in the direction that would be predicted form the accuracy results. Again there was a weak positive association with extraversion ($r = .191$, $p = .133$). These 3 variables were used in a multiple regression to predict mean strategy type employed. The model was highly significant, accounting for 21.5% of the variance in the mean strategy type ($F_{(3, 59)} = 5.376$, $p = .002$). ImpASS was related to a lower mean strategy type, indicating a proportionally higher degree of uni-dimensional strategy use, and contributed a unique 14% of variance to the model ($t_{(59)} = -3.245$, $p = .002$). In contrast, E was related to a higher mean strategy type, although the unique contribution to the model just failed to reach significance (4.2%; $t_{(59)} = 1.783$, $p = .080$). WM was also related to higher mean strategy type although this did not contribute a significant proportion of unique variance to the model (4.2%; $t_{(59)} = 1.459$, $p = .150$).

Two variables were created that coded the first block in which 1) a two-dimensional rule was used and 2) the correct two-dimensional conjunctive rule was used. Hence, these variables ranged from 1 – 12, with a value of 13 indicating that this type of rule had never been used. Non-parametric tests revealed that the high-extraversion group used a two-dimensional strategy earlier than the low extraversion group ($U = 362.5$, $p = .028$; on average just over 1 block earlier – mean number of blocks 1.35 cf. 2.50). No other significant relationships were observed with this measure.

There were 25 participants who did not use the correct rule at any point during the task. This group were significantly higher on ImpASS compared to the group of 38 participants who did use the correct conjunctive rule at some point during the task ($t_{(61)} = 5.139$, $p < .001$). Additionally, those that did not use the correct rule at any point scored lower on the WM task ($t_{(61)} = -1.968$, $p = .054$).

The low ImpASS group used the correct rule earlier than the high ImpASS group, after a mean of 5.75 blocks compared to 9.77. As the distribution of this second variable was again highly non-normal, a non-parametric test was used to compare the first use of the correct rule between the high- and low-ImpASS groups and found the difference to be significant ($U = 271$, $p = .001$). In contrast, the high-extraversion group used the correct rule after 6.4 blocks on average ($SD = 5.26$) which was earlier than the average of 9.0 blocks taken by the low-extraversion group although this just failed to reach significance with the non-parametric comparison ($U = 363$, $p = .057$). No other relationships were observed with this measure.

Multinomial logistic regression was used to predict strategy (type 1, 2 or 3) during the last block of trials. ImpASS and extraversion were entered as continuous predictors.[2] This 2 parameter model was a significantly better fit to the data compared to the intercept only model ($\chi^2_{(4)} = 14.015$, $p = .007$), and was not significantly worse than the saturated model ($\chi^2_{(106)} = 104.354$, $p > .05$). Both effects contributed to the model which was significantly poorer if either effect was removed (ImpASS $\chi^2_{(2)} = 7.977$, $p = .019$; Extraversion $\chi^2_{(2)} = 6.841$, $p = .033$). For each unit increase in ImpASS the odds of using an uni-dimensional relative to the correct two-dimensional rules increased almost three-fold (2.95; $CI_{95,}$ 1.04 – 8.32). A similar situation was seen for the use of incorrect two-dimensional rules relative to the correct two-dimensional rules, with an odds ratio of 2.96 for each unit increase in ImpASS ($CI_{95,}$ 1.23 – 7.10). However, as would now be expected, extraversion was related to a decreased likelihood of using a uni-dimensional rule relative to the correct two-dimensional rules. For each unit increase in extraversion the odds of using the correct strategy relative to a uni-dimensional strategy more than doubled (2.55; $CI_{95,}$ 1.17 – 5.59). The same pattern was seen for the odds ratio between using the correct two-dimensional rules relative to incorrect two-dimensional rules, and increase of 1.41 for each unit increase in extraversion. However, the 95% confidence interval for this odds ratio embraced 1 (0.71 – 2.81) and therefore did not reach significance. (The addition of WM did not improve the model).

In summary, the model fitting results suggest that higher levels of ImpASS were related to 1) a greater proportion of uni-dimensional rule use, 2) first using the correct rule at a later point (or not all) during the task, 3) an increased likelihood of using uni-dimensional rules as opposed to two-dimensional rules in the last block of trials. Furthermore, the relationship between ImpASS and the overall use of uni-dimensional strategies (i.e., 1 and 3 above) was statistically independent of other variables (e.g., extraversion and WM).

[2] A sparse covariate pattern was observed in the data, with 66.7% of cells having zero frequencies. However, the same general pattern of results was observed if the two predictors were first quartiled

In addition, extraversion was often found to exhibit the inverse relationship to these measures. Extraversion was weakly positively related to a lesser proportion of uni-dimensional rule use, and this relationship was significantly different and independent from that of ImpASS and uni-dimensional rule use. The high extraversion group first used a two-dimensional significantly earlier in the task relative to the low extraversion group and a similar trend was observed for the earlier use of the correct two-dimensional rules. Finally, higher levels of extraversion were significantly associated with a decreased likelihood of using uni-dimensional relative to the correct two-dimensional strategies in the last block of trials.

DISCUSSION

The present study examined the association between personality and performance on a CL task that was dependent upon cognitive flexibility for successful performance. The use of simple, uni-dimensional rules lead to reasonable yet sub-optimal levels of accuracy. However, the criterion level of performance was attainable only with the application of a two-dimensional conjunctive rule. The task appeared to work as intended. For example, initially it was expected that individuals adopt simple RB strategies (i.e., uni-dimensional rules) before attempting more complex category rules. Performance in the first block was approximately at the level that would be expected if a uni-dimensional strategy had been employed. A drop in mean performance levels in the second block of the task suggests that participants may have abandoned the partially successful, yet sub-optimal, uni-dimensional rule to pursue alternatives. Additionally, a general linear trend of improving accuracy rates across the task was observed, suggesting that participants modified and improved their classification strategy as they gained more experience of the task.

ImpASS was significantly related to poorer overall accuracy levels, and those participants scoring more highly on this trait attained the criterion level of performance (i.e., 90%) significantly later in the task. Additionally, the comparison of low- and high-ImpASS participants (i.e., the median split groups) found that the high-ImpASS individuals performed less accurately than the low-ImpASS participants in all but the first block of trials. One possible explanation for this result might be that most participants applied uni-dimensional rules in the first block of trials and therefore performance levels would be expected to be similar. However, in the subsequent blocks of the task the observed detriment in performance associated with the high-ImpASS group could be attributable to reduced cognitive flexibility. This may be interpreted as support for the proposal that ImpASS is associated with an attentional or strategic preference for simple rules.

Further support for an association between ImpASS and reduced cognitive flexibility was found with the demonstration of a significant relationship between higher levels of ImpASS and a lesser degree of improvement in response accuracy across the task (i.e., relative to the stronger positive linear trend associated with lower levels of ImpASS). Therefore, if later successful performance on the task is primarily related to cognitive flexibility this suggests that greater levels of ImpASS are indeed associated with poorer cognitive flexibility. In addition, higher levels of ImpASS were associated with a greater (negative) cubic performance trend across the task (i.e., a greater drop in performance after block 1 and less improvement, and possibly deterioration, across the final blocks of the tasks). This pattern of results is best illustrated by figure 6.4. In a further demonstration of poorer performance on the task, each unit increase in ImpASS was associated with a 2.5-fold increase in the likelihood of failing to achieve the criterion level of performance in the final block of trials.

Analysis of response accuracy demonstrated a clear association between ImpASS and poorer performance. However, consideration of the response strategies employed in the task enabled a further examination of possible causes for the observed differences in performance. Crucially, ImpASS was related to a greater proportion of uni-dimensional strategy use over the 12 blocks of the task and, independently of other factors (discussed below), accounted for over 10% of the variance in this measure. In addition, higher levels of ImpASS were associated with an increased likelihood of using an incorrect strategy in the final block of the task. Unsurprisingly, the high-ImpASS participants used the correct two-dimensional rules significantly later in the task relative to the low-ImpASS group. Furthermore, participants who did not use the correct two-dimensional strategy at point during the task scored more highly on the ImpASS factor. The results of the modelling analyses are therefore highly consistent with the performance accuracy data and suggest that the association between ImpASS and inferior performance on the task, associated with decreased cognitive flexibility, was indeed most likely related to the use of inappropriate strategies. The main prediction of the study appears to have been strongly validated by the data. ImpASS was associated with poorer performance on the task, and the predicted association with reduced cognitive flexibility was apparent with the greater use of simple (i.e., uni-dimensional) rules.

Although not significantly related to the general performance measures, in the final block of trials, extraversion (independently from the influence of other factors) was significantly associated with an increased likelihood of achieving the performance criterion. Therefore, despite no clear association with general accuracy levels across the task, extraversion was related to better performance in the crucial phase (i.e. final block of trials) of the task and was thus suggestive of an association with higher levels of cognitive flexibility. In agreement with this result, extraversion was related to 1) a reduced proportion of uni-dimensional strategy use, 2) the earlier use of a two-dimensional strategy, 3) the earlier use of the correct two-dimensional rule and 4) the increased likelihood of using the correct two-dimensional rules in the final block of trials.

In direct contrast to ImpASS, therefore, higher levels of extraversion appeared to be related to superior cognitive flexibility. The most obvious explanation is that this trait is simply related to increased cognitive flexibility. However, the mechanism through which this association may have occurred is unclear. For example, the design of the task was such that a high degree of regulatory fit occurred between the two main situational factors; i.e., the promotion focus (attempting to win a prize-draw ticker) and the 'gains' reward structure. As discussed in the introduction, individuals are thought to vary in their chronic focus, i.e., their predisposition toward a promotion/prevention focus. Hence, in the present study, those individuals with a stronger promotion focus orientation would be predicted to experience a greater regulatory fit and consequently, following the arguments of Maddox, Baldwin et al. (2005), cognitive flexibility would be enhanced. It was additionally suggested that extraversion may reflect a stronger promotion focus. Therefore, one possibility is that a higher degree of regulatory fit existed for the more extraverted individuals, which subsequently facilitated greater cognitive flexibility.

This result is therefore consistent with the proposition that trait extraversion relates to variation in BAS function. As discussed previously, the BAS is thought to be responsive to reward and signals related to reward. Hence, the BAS may be more likely to be engaged in an environment in which there is potential for reward, especially one in which 'approach' behaviour is required (i.e., promotion focus – to gain a prize-draw ticket) and the signals are primarily rewarding (i.e., a 'gains' reward structure). As the level of reward was not manipulated in this study (i.e., the current experiment did not contain a 'punishment' condition in which, for example, a 'prevention focus' and 'loses' reward structure was used) it is not possible to draw conclusions regarding the influence of the BAS. However, it is interesting to speculate that performance on the current task may be facilitated for individuals with greater BAS reactivity. This facilitation could be due to a motivational component (akin to the idea of a match, or increased regulatory fit, between the 'situation' and 'trait'). For example, one consequence of BAS activation is thought to be the intensification of current 'approach' behaviours towards the BAS activating stimulus. This may motivate the pursuit of better performance strategies, a process that could lead to increased cognitive flexibility. Alternatively, the facilitation of cognitive flexibility could result from a more direct learning or cognitive component. For example, this may arise from enhanced strength, or processing, of the reinforcement signals required to learn the category structure. Alternatively, BAS activation may increase the amount of attentional resources directed toward the rewarding task. Both processes could potentially result in increasing cognitive flexibility and consequently performance on the task. Naturally, in the current study it is not possible to determine which of these mechanisms may have been involved. However, as discussed below, future studies may be able to disentangle these different processes.

In contrast, there were no a-priori reasons to suggest that ImpASS would be related to a decreased promotion focus orientation. It is therefore hard to explain the poorer performance on the task in terms of reduced cognitive flexibility resulting from a lesser degree of regulatory fit. In fact, if ImpASS is considered to be a valid index of BAS function the opposite prediction would have been made. Hence, it would appear most likely that ImpASS was *directly* related to reduced cognitive flexibility (as it applies in this instance – i.e., the ability to abandon 'reasonably' successful uni-dimensional rules in favour of more complex two-dimensional rules) as opposed to an *indirect* result of a mismatch between trait related (i.e., reduced promotion focus) and situational (i.e., situational promotion focus/'gains' reward structure) factors. Accordingly, the current result may add tentative support to the postulate that extraversion, as opposed to ImpASS, is the 'true' BAS related trait (although again caution must be applied in the absence of reward/punishment manipulation).

Working memory is considered to be crucial for the learning of RB category structures and may be especially important for the acquisition of more complex category rules. While not significantly associated with overall accuracy (or successful attainment of the prize-draw ticket), WM was related to aspects of strategy use. For example, participants who did not use the correct two-dimensional rules at any point during the task scored lower on WM. In addition, lower WM performance was also associated with a higher proportion of uni-dimensional strategy use. Crucially, however, the relationships between personality and performance described above were independent of any effects associated with WM. Importantly, this suggests that ImpASS and extraversion were more predictive of performance, in terms of both accuracy and strategy use, on the task.

Performance on the task did not appear to be related to positive schizotypy. This trait had been previously associated with poorer performance on a task requiring the integration of two-dimensions, as well as impaired performance on the previous II task (discussed in chapter 4) that involved 3 dimensions. Consequently, it was suggested that the relationship with poorer performance on these more complex tasks may reflect a more general 'impairment'. (This proposal may be supported by the significant association with poorer performance on the WAIS matrices task performed in this study). Therefore, it may be that performance on this particular task was not significantly influenced by processes associated with positive schizotypy (again this may be supported by an absence of a relationship between performance on the conjunctive RB task and the WAIS matrices task).

The design of the current study was somewhat distinct to those discussed in the previous two chapters (e.g., this study involved stimuli constructed from continuous dimensions and involved a conjunctive rule). Therefore, comparison with the previous results must be considered with some degree of caution. For example, the experiment in the preceding chapter employed a reaction time methodology and the requirement for 'learning' of the category rule was considered to be minimal (as participants were given a strong hint regarding the relevant dimension). It may be that the observed association between extraversion and increased distractor cueing effects (DCE) involves some processes that underlie the apparent relationship with increased cognitive flexibility in the present study. For example, increased cognitive flexibility may suggest that more extraverted individuals were better able to learn the category associations of the nominally irrelevant dimensions in the reaction time tasks; thereby leading to the increased DCE. However, ImpASS was not significantly related to the DCE in the previous chapter. In contrast, positive schizotypy was associated with increased DCE but not cognitive flexibility. As highlighted above, the differences between the two studies make comparison of the performance and personality association somewhat tentative.

However, in the first study (chapter 4), ImpASS was associated with poorer performance on the second phase of the RB task. This may be viewed as a demonstration of poorer cognitive flexibility (e.g., a reduced capacity for modulating one's response strategy in light of changing feedback contingencies). Processes that may have been associated with poorer performance in the first study may have had a comparable impact in the present study; contributing to impaired performance on the conjunctive RB task. However, in the first study neuroticism was also related to impaired performance on the second phase of the task, while positive schizotypy was associated with better performance. Neither of these personality factors was significantly associated with performance or strategy in the present study.

The results of the present study suggest many avenues for future research. A key follow-up study would involve the exploration of performance on an analogous task in which cognitive flexibility would be considered detrimental to task performance. If all other experimental conditions were identical to the present study it would be predicted that ImpASS would be associated with superior performance. Such a result would provide a powerful confirmation of an association between ImpASS and cognitive (in)flexibility. A suitable task has been performed by Maddox, Baldwin et al. (2006) and thus would provide an appropriate replication. This will be discussed further in the final summary chapter.

In addition, the relationship between extraversion and performance on a task facilitated by decreased cognitive flexibility would also be of interest. The preceding discussion considered the cause of the association between extraversion and performance to be uncertain. If extraversion is simply associated with increased cognitive flexibility then performance on the new task would be predicted to be impaired. If however, performance on the current task was influenced by motivational effects (i.e., the promotion focus, 'gains' reward structure), then performance on the task proposed in the previous paragraph may also be enhanced. This leads on to a final area of interest; the manipulation of the situational focus and reward structure applied in the task. Manipulation of these factors would further enable the examination of the causal mechanisms underpinning the association between personality and performance. This issue will again be considered in the final summary chapter.

<u>Summary</u>

Performance on the task, in respect of strategy use and overall success, appeared to be independently associated with both ImpASS and extraversion. Crucially, however, the relationships were in direct opposition; ImpASS was associated with decreased cognitive flexibility (and poorer performance) whereas extraversion was associated with increased cognitive flexibility (and greater success). In light of the theoretical background of the task, and in support of the hypotheses, it was suggested that ImpASS appeared to be directly related to reduced cognitive flexibility, manifest as a preference for uni-dimensional rules. In contrast, extraversion may be directly related to increased cognitive flexibility, or this relationship may be have been mediated by the situational factors. This study may also provide further support for the suggestion that extraversion, as opposed to ImpASS, is a more likely candidate as an index of BAS function. Implications and future research were briefly discussed.

Chapter 7

Study 4 - Selective Attention during Rule-Based Category Learning

INTRODUCTION

Background

Effective allocation of attention is considered to be a crucial component in many theories of CL and integral to the successful learning of novel stimulus-category associations. For example, the explicit system of the COVIS theory of CL (Ashby et al., 1998; Ashby & Waldron, 1999) was discussed in chapter 2. It was suggested that one key feature of the explicit system is the ability to modulate attentional focus in order to test hypothesized category structures. For example, the testing of an explicit category rule (e.g., are long lines category A?) may benefit from superior selective attention to the relevant stimulus feature (i.e., length) and simultaneous inhibition of the irrelevant features (e.g., width, orientation, position etc). Support for the role of selective attention in the learning of particular category structures data is reported by Filoteo and colleagues (e.g., Filoteo et al., 2007; Filoteo et al., 2005). Patients with Parkinson's disease were found to exhibit greater impairment in the learning of RB category structures that involved a greater number of irrelevant stimulus features (dimensions). Furthermore, patients with Parkinson's disease demonstrated impaired CL of two-dimensional stimuli when the category structure was solely determined by one dimension. In contrast, if the category structure was more complex and determined by a combination of both dimensions, performance was not impaired relative to controls.

The role of selective attention in such studies, however, was *inferred* (e.g., from the effect of irrelevant stimulus features) rather than representing a direct assessment of attentional processing. To address this issue, Rehder and Hoffman (2005) employed eye-tracking methodology in order to assess the modulation of selective attention towards stimulus features during CL. The primary aim of their study was to explore the widely held opinion that individuals learn to optimally allocate their attention to only those dimensions required for successful categorisation. By employing specially created stimuli (comprising 3 spatially separable dimensions) in a series of CL tasks, in which category structure was determined by either a single dimension, a combination of 2 or all 3 dimensions, Rehder and Hoffman were able to demonstrate that individuals did indeed learn to allocate their attention (as assessed by eye-gaze – fixations) to only those dimensions which were required for successful categorisation. Furthermore, the study allowed the consideration of two CL theories which include attentional mechanisms (ALCOVE, Kruschke, 1992; RULEX, Nosofsky, Palmeri, & McKinley, 1994)[1], and provided divergent predictions regarding the allocation of attention to stimulus dimensions during various stages of CL. For example, the assessment of eye-gaze showed that participants tended to fixate all stimulus dimensions early in the learning episode, while the restriction of attention towards only those dimensions required for successful categorisation occurred rapidly and only after categorisation errors were significantly reduced (often eliminated). The application of the eye-tracking method, therefore, appeared to be valuable tool with which to attempt a more direct assessment of attentional processes during CL and specifically the role of selective attention.

The present study follows the novel approach taken by Rehder and Hoffman (2005) in which eye-gaze, specifically fixations upon stimulus dimensions, were measured and used as an index of selective attention during CL. This study appeared to be the first to employ eye-tracking methodology in the assessment of attentional processes during CL and offered a number of unique insights (for example contrasting the predictions of two prominent computational models of CL). The ability to compare variation in attention towards stimulus features alongside variation in behavioural measures of performance (i.e., elimination of response errors) was considered to offer an invaluable assessment of the modulation of attention during CL (in addition to providing a degree of cross-validation of the method). One primary aim of their study was to assess the general assumption that individuals optimise the learning of novel categories by appropriately restricting selective attention towards only those dimensions (or features) needed for successful categorisation. This assertion was found to hold across a variety of CL tasks that demonstrated that participants did indeed allocate their attention optimally (e.g., fixating only 2 of 3 dimensions of a stimulus if the 3rd dimension was irrelevant to the category structure). Additionally it was found that most participants tended to fixate all stimulus dimensions early in the learning process, even if it were likely that the usefulness of uni-dimensional category rules were being assessed.

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[1]Detailed discussion of the **A**ttention **L**earning **COVE**ring map (ALCOVE) and **RUL**e-plus-**EX**ception (RULEX) models is not essential to the current topic. However, their consideration demonstrates the potential utility of the eye-tracking method. For example, the ALCOVE model is a connectionist exemplar model which suggests that individuals initially attend to all stimulus features and that selective attention towards individual dimensions (modified by error-feedback) occurs gradually over the course of learning ('associative' style learning). In contrast, the RULEX model suggests that individuals will first explore simple uni-dimensional rules before progressing to more complex multi-dimensional rules (plus exceptions) if required. Accordingly, the hypothesis-testing component of the RULEX model also suggests that the change in selective attention towards the relevant stimulus dimensions will occur more rapidly. As briefly summarised above, partial support was found for some aspects of both of these CL models.

General Aims

The aim of the current experiment was to explore the use of eye-tracking (ET) methodology in the examination of individual differences in selective attention during CL. To this end, a simple RB task was developed that required attention to a single dimension (of a multi-dimensional stimulus) for successful categorisation. It was hoped that the use of four-dimensional stimuli (i.e., in which 3 stimulus dimensions are irrelevant) would highlight the modulation of attention during learning of the category structure.

The focus of the present chapter is the consideration of possible relationships between personality and ET measures (i.e., detailed assessment of the data of particular relevance to the CL literature will not be presented). For example, a possible association between ImpASS and enhanced selective attention, demonstrated by superior performance on a range of RB CL tasks, has been noted throughout the thesis. The present study may allow a partial test of this assertion and other related issues may also be addressed. For example, positive schizotypy has long been associated with attentional deficits (e.g., poorer inhibition of irrelevant information leading to decreased latent inhibition). The present study may allow examination of qualitative differences in attentional processes that may relate not only to performance on the present task but also previous findings (e.g., in the chapter 2 study, positive schizotypy was associated with reduced distractor effects, possibly reflecting reduced attention towards irrelevant stimulus features). Furthermore, it has been suggested that more extraverted individuals are better able to use response feedback during the learning of novel stimulus-category associations. This pattern may be evidenced by superior learning on the present task (a trend for such a relationship was observed in study 1). Therefore any potential association between this trait and the ET measures would be of particular interest.

Application of the ET methodology enables the consideration of an additional factor, namely a psychophysical measure of selective attention, which could help to further delineate processes involved in CL and possibly their differential association with personality. Consequently, the current study allows comparison of CL performance alongside the concurrent assessment of attentional processes that may directly or indirectly be associated with performance on the task.

In comparison with the RB task presented in study 1 the present experiment also featured an unannounced switch of category structure during the task, thereby allowing variation in the modulation of attention in such circumstances to be considered. Neuroticism was associated with poorer performance on the second phase (i.e., after the unannounced switch of category rule) of the RB task in study 1. Assessment of eye-gaze during the second phase of the present study may therefore help to elucidate whether this pattern of performance is indeed associated or distinct from attentional processes.

METHOD

Participants

The present sample comprised 16 male and 16 female participants. This was an opportunity sample, with a mix of students (in the main, non-psychology) and non-students. Mean age was 25.5 (range 20 – 38 , SD = 5.1) years. All participants had normal or corrected-normal vision and were subsequently able to perform the ET task. All participants received a payment of £15 for participation (this included participation in an additional session not presented in the current thesis). The participants' spoken English was sufficiently fluent to enable completion of the personality questionnaires. Clarification of any terms in the questionnaires was given if requested

Design

Personality Questionnaires

In this study participants completed the EPQ-E, OLIFE, BFI, SSS, BIS/BAS scales and the SPQ. As described in chapter 3, four personality factors (E, ImpASS, positive schizotypy and N) were obtained from these results. The following analyses will henceforth simply refer to these four factors as: E, ImpASS, positive schizotypy and N.

RB Task

The task was a simple RB CL task in which one dimension determined category membership. Once this category structure had been learned there was an unannounced switch of the category rule to a different dimension. Full description of the task procedure appears later. The stimuli were constructed from 4 binary valued dimensions; hence there were 16 possible stimuli. Each stimulus was created using the symbols displayed in table 7.1 below.

***Table 7.1:** Binary valued dimensions used to create the stimuli**

	Possible values	
Dimension	**0**	**1**
1	#	%
2	+	=
3	?	$
4	x	o

*(A specific font was chosen, Verdana, so that each of the characters used appeared as equal as possible in overall size. This also involved changing the font size for specific characters. The standard font size was 18, but for "+" "=" this was increased to 20)

While it was possible to counterbalance the dimension used as the starting rule it was decided to select one to be used for all participants. This was mainly to reduce the possibility of numerous counterbalancing conditions coupled with the limited sample size. Dimension 1 was used as the first category rule (i.e., category 'A' stimuli contained a '#', category 'B' contained a '%'), while dimension 3 ('?' / '$') was used for the second phase.

The 4 dimensions were located at spatially separable co-ordinates (in effect forming the corners of a square). The position in which the rule dimension appeared was counterbalanced across participants. Consequently, as indicated in the table below, there were 4 different position conditions (A – D). Characters which comprised the stimulus were thus assigned according to these positions. For each participant the position of the 4 stimulus dimensions were fixed for the duration of the task.

***Table 7.2:** Stimulus dimension positions (condition A – D) for the four dimensions (1 – 4)*

A		B		C		D	
1	4	4	3	3	2	2	1
2	3	1	2	4	1	3	4

The order of stimulus was randomised but fixed for all participants. Each of the 16 possible stimuli occurred once in every block of 16 trials. The order was filtered to remove back to back presentations of identical stimuli and runs of more than 4 consecutive category A or B stimuli. When the switch of rule occurred, a fixed pattern of 16 stimuli were presented. This was constructed specifically so that for the first 4 trials, using the old rule or either of the other 2 irrelevant dimensions as the rule would give 50% correct. This was repeated for the whole cycle of stimuli, i.e., the remaining 12 stimuli (cf. study 1, RB task).

Eye-tracking Assessment

Participants were fitted with the eye-tracker headset prior to the start of the task. Eye movements were assessed using the infrared reflection technique (IRIS IR 6500 by Skalar Medical) with a sampling rate of 500 Hz. Incoming eye-movement recordings were digitised using a Brain Boxes 12-bit analogue to digital conversion card. Two separate eye-pieces were used to record horizontal (left-eye) and vertical (right-eye) eye-movement.

The stimuli were presented on a computer screen in a black font on a light-grey background (RGB 236 233 216) as illustrated in figure 7.1 below. The outline box represents the monitor screen and '•' represents the central fixation point which was a filled circle (the fixation point was presented for 500ms prior to the stimulus presentation at which point it was then cleared from the screen). The horizontal distance between dimensions was 16cm (measured on the screen) with the vertical distance being 12cm.

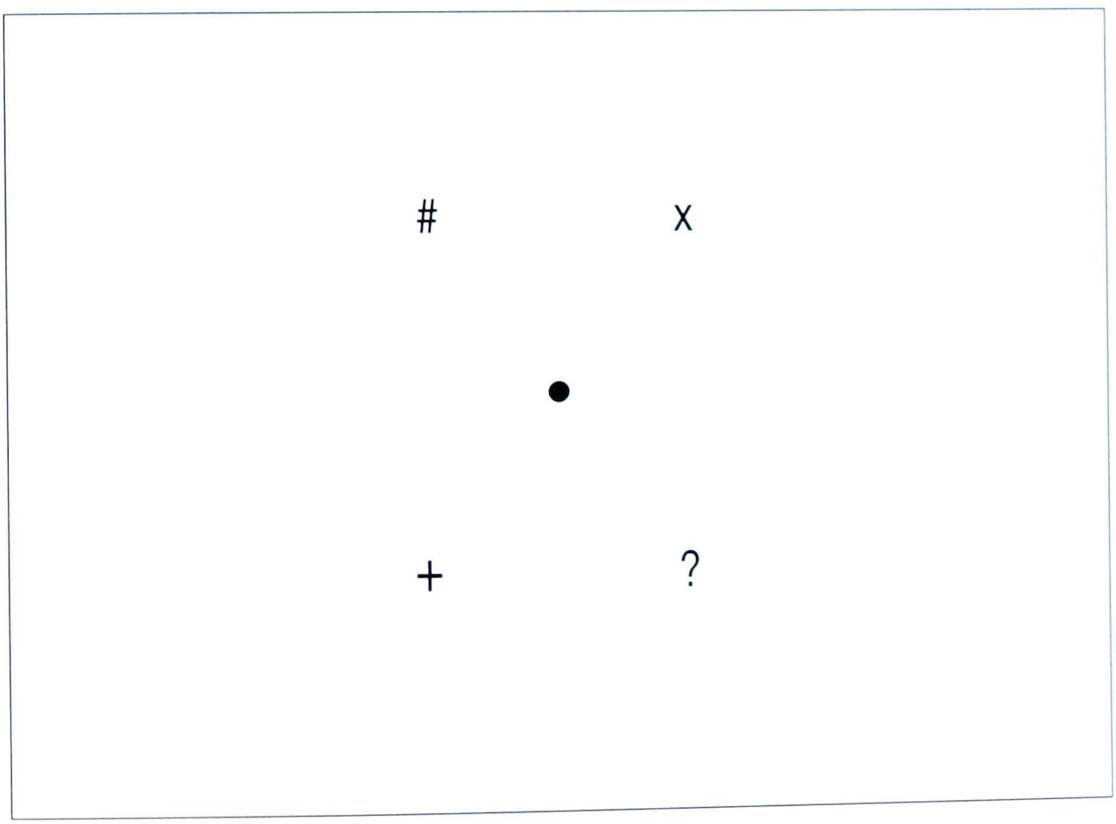

Figure 7.1: *Representation of an example stimulus as displayed on the computer monitor*

A software calibration procedure, in which participants were simply instructed to focus upon a single white dot which appeared on the screen in 4 different locations (6cm vertically above/below the central fixation point and 8cm horizontally either side of the central fixation point), was used to normalise the dimension co-ordinates to be recorded as 1 and -1 (i.e., the top-left dimension would therefore be located at -1, 1 for the X and Y co-ordinates respectively. Top-right dimension 1, 1 etc). For each sample (at 500 Hz) the eye-tracker recorded eye-gaze location based upon these normalised dimension locations. Eye-gaze recordings were taken from the moment the stimulus was presented until 2000ms after the auditory feedback was given.

Procedure

The present study was conducted within a single session. The experimental task was performed at the beginning of the session after an initial briefing. The length of the task was dependent upon the performance of the participant. The questionnaires were completed after the ET task (participants had been jointly recruited and completed some of the questionnaires in a separate session). An additional ET task was subsequently performed at the end of the session (to be discussed in the following chapter).

<u>RB CL Task</u>

The task instructions were read to the participant before setting up the eye-tracker. To summarise, participants were informed that the task involved learning how to classify simple pictures, composed of 4 symbols, into different categories. Each picture displayed belonged to 1 of 2 categories and the participants had to attempt to learn how to categorise these pictures correctly. Participants were then shown two example stimuli (not used in experiment) and instructed that similar pictures would appear on the screen, one at a time, and remain there until either the category 'A' or category 'B' button was pressed. Using the feedback that was given after each response, participants were to try and learn the categories. The feedback sounds for a correct and incorrect categorisation were also demonstrated (only auditory feedback was used during the task). Participants were informed that there were equal numbers of category 'A' and category 'B' items and that the task would continue until the categories had been sufficiently 'learned' (i.e., participants were not explicitly informed of the exact performance criterion, 16 consecutive correct responses). Therefore, participants were motivated to perform the task to the best of their ability in order to facilitate an earlier finish. Procedural information was also given (e.g., the pre-stimulus fixation point) as well as a reminder to attempt to keep as still as comfortably possible during the task (to facilitate the ET recording).

Participants were fitted with the Skalar II headset and then placed their chin onto a rest which was at a fixed height and positioned so that participants would be in a comfortable position (with the aid of an adjustable height chair) to maintain a stable poise for the duration of the task. The presentation CRT monitor was at a distance of approximately 39cm from the headrest and at a fixed height so that the participant's eyes were level with the central fixation point. The participants then performed a software calibration by simply focusing on a series of single white dots which appeared at various locations on the screen. The calibration of the equipment was repeated until the experimenter was happy with the set up. The participant then pressed any key to begin the task after the experimenter had left the room.

The task was presented on a 17inch CRT monitor with a resolution of 768 x 1024 pixels. The stimulus dimensions were located so as to give a visual angle of 23.2° horizontal and 17.5° vertical for the whole stimulus, with each dimension subtending a visual angle of approximately 1.76°. Each trial began with a central fixation point for .5 seconds, followed by the presentation of the stimulus. The stimulus remained on the screen until either the category 'A' or category 'B' key had been pressed. At this point auditory feedback was given to indicate whether the stimulus had been correctly or incorrectly categorised. The stimulus then remained on the screen for a further 2 seconds before the screen was blanked. There was then an inter-trial interval of .75 seconds after which the next trial began with the central fixation point.

The task proceeded in this way until 16 consecutive correct trials had occurred or the trial limit of 160 was reached. At this point there was an unannounced switch of category rule to a different dimension (as well as a resetting of the number of consecutive correct responses to zero). Again this second phase, with the new category structure (rule), continued until 16 consecutive responses occurred or the trial limit of 192 had been reached (i.e., the trial limit in the first phase was 160, while the trial limit of the second phase was 192 trials. Thus the maximum number of trials across the task as a whole was 352).

RESULTS

Task performance

Participant Data (n = 32)

The four personality factors were generally unrelated in this sample. However, there was a trend for a positive association between N and positive schizotypy ($r = .314$, $p = .081$; all remaining r's < .103). Age was significantly negatively correlated with E ($r = -.355$, $p = .046$) but not associated with the remaining personality factors (r's < .163). The gender groups were well matched for age and personality, although a trend for higher levels of ImpASS ($t_{(30)} = 1.790$, $p = .084$) and lower levels of positive schizotypy ($t_{(30)} = -1.616$, $p = .117$) was observed for males.

General Task Performance

The learning criterion in both phases of the task was 16 consecutive correct trials. The mean number of trials taken to reach the criterion in the first (TTC1) and second phase (TTC2) are shown in table 7.3 below.[1]

Table 7.3: *Descriptive statistics for the trials taken to reach the criterion in the first (TTC1) and second rule-phase (TTC2)*

	Mean	SD
TTC1	69.646	45.859
TTC2	80.250	54.430

One participant failed to reach the learning criterion in either the first or second phase. A further 2 participants failed to reach the learning criterion for the first rule yet achieved 16 consecutive correct responses for the 2nd rule (in 54 and 64 trials respectively). An additional 3 participants were able to reach the learning criterion for the first, but not the second category rule. The potential effects of including or excluding participants that failed to reach either of the learning criteria (i.e., non-learners) in the following analyses were monitored. Both TTC measures appeared to be sufficiently normally distributed and did not warrant any transformation (cf. study 1). Trials taken to reach the criterion on the first rule was not significantly correlated with trials taken on the second rule ($r = .221$, $p = .224$, $n = 32$; excluding any non-learners $r = -.122$, $p = .552$, $n = 26$).

[1] cf. study 1, the TTC score for those participants that failed to reach the learning criterion was simply the maximum number of trials in the respective phase. A programming glitch meant that if the trial limit was reached, the last trial was, unintentionally, repeated. Hence, maximum TTC1 and TTC2 were 161 and 193 respectively. The minimum observed values on these two measures were 17 and 22 for the first and second phase respectively

For an additional measure of performance on the task, the proportion of correct responses was also calculated. Descriptive statistics for the percentage of correct trials are shown below (for the first and second rule individually as well as a combined percentage). Again performance in phase 1 and 2 was not significantly related ($r = .239$, $p = .187$, $n = 32$; excluding non-learners $r = .162$, $p = .428$, $n = 26$).

***Table 7.4:** Descriptive statistics for the percentage of correct trials*

	Mean	SD
Rule 1	71.291	14.327
Rule 2	67.205	12.356
Overall	67.117	10.802

Age was related to a greater number of trials taken in the second rule phase ($r = .322$, $p = .072$, $n = 32$; excluding non-learners on rule 2 ($r = .400$, $p = .035$, $n = 28$), but unrelated to percentage of correct trials ($r = -.152$, $p = .405$, $n = 32$; excluding non-learners, $r = -.224$, $p = .252$, $n = 32$). Gender was not related to any of the basic performance measures (magnitude of r's < .250, p's > .215).

The four personality factors were not significantly associated with performance on the task. The greatest association was observed for positive schizotypy and fewer trials taken to reach the learning criterion on the first phase ($r = -.239$, $p = .212$, $n = 29$). The correlations between the TTC measures and personality are shown in table 7.5 below (similar, although somewhat weaker associations were observed with the percentage of correct trials measure). Power was expected to be low given the size of the personality correlations in the earlier chapter (i.e., study 1, chapter 4).

***Table 7.5:** Correlation between the TTC measures and personality (non-learners excluded)*

		Extraversion	ImpASS	Positive Schizotypy	Neuroticism
TTC1	Pearson Correlation	-.155	.006	-.239	-.100
(n = 29)	Sig. (2-tailed)	.423	.977	.212	.607
TTC2	Pearson Correlation	.039	-.132	.117	.039
(n = 28)	Sig. (2-tailed)	.845	.502	.554	.846

ET Data

The ET machine recorded eye-gaze location during each trial at a sample rate of 500 Hz. The analysis of the ET data used a simple velocity method to define fixations (e.g., Manor & Gordon, 2003; Salvucci & Goldberg, 2000). The data presented here considered the assessment of eye-gaze from the point of stimulus onset until the participant's response on each trial. For each individual trial, sample to sample velocities were calculated for each data point (i.e., the distance between the eye-gaze co-ordinates measured at two successive samples, recorded every 2ms). The program then looped through the velocity data and marked the potential start of a fixation if the velocity was below a threshold (20 °/s in the present experiment). If subsequent samples did not exceed the velocity for a saccade (200 °/s) then the 'potential' fixation continued. A fixation was marked if the duration (of samples below the saccade threshold) exceeded the minimum requirement (80 ms). After this process was completed the mean location and duration of each fixation was calculated.

All fixations occurring during the task were plotted for each individual participant. These plots were used to define the regions of the 4 dimensions of the stimuli for each participant (see appendix F.1, p. 321). It is important to note that the experimenter was not aware of the location of the actual rule dimension during this process. Subsequently, each fixation was then ascribed to one of the four dimensions (i.e., location). Fixations which did not appear to be located upon any of the stimulus dimensions were classified as outliers and were excluded from further analysis.

Following the approach taken by Rehder and Hoffman (2005), three key variables were derived from the eye-tracking data. Firstly, the number of dimensions fixated on each trial was calculated (ranging between 0-4). Secondly, the proportion of fixation time for each dimension on each trial was calculated by dividing the time fixating each individual dimension by the total time of all (dimension) fixations. Naturally, the proportion of fixation time for the rule dimension was of key interest. The final measure was the relative priority rating of each dimension (ranging from 0 - 1). This measure took into account the ordering of fixations. The first of n fixations on a trial was given a weighting of n, the second fixation $n-1$ and so on until the final fixation was weighted 1. Consequently, fixations occurring earlier in the trial received a greater weighting. The relative priority for each dimension was therefore given by summing all of the weightings for each dimension and dividing by the sum of all the weighting coefficients (i.e., sum of $1{:}n$). Again, the fixation priority of the rule dimension was of particular interest. A key issue obviously concerns the variation of these measures as the task progresses. Modelling of these key variables is discussed in due course.

Prediction of Rule Dimension (Location)

The first analysis considered the fixation time and fixation priority variables described above. As described in the preceding method section, the location of the relevant (category defining) dimension was counterbalanced across participants (i.e., for the first rule phase the target dimension was presented in the top left position for 8 of the 32 participants etc). It was predicted that once a participant had successfully discovered the relevant rule dimension, fixation time and priority towards that dimension was likely to be greater than for any of the irrelevant dimensions. Therefore, during the criterion run of 16 consecutive correct trials, it may be predicted that the relevant dimension would receive the greatest proportion of fixation time and priority.

For each of the 4 dimensions a simple summation of fixation time across the final 16 trials was calculated (for each phase independently). Following the supposition described above, the dimension that received the greatest proportion of fixation time was predicted to be the relevant rule dimension. This process was repeated using fixation priority. The relevant dimensions predicted from these ET measures were then compared to the actual rule dimension (location). Three participants were excluded due to impoverished ET data. Additionally, non-learners from each phase were also excluded. This simple method, of estimating the location of the rule dimension from a participant's eye gaze during the criterion run of correct responses, appeared to be largely successful. The proportions of correctly predicted rule dimensions are shown in table 7.6 below.

Table 7.6: *Proportion of rule dimensions correctly predicted by the ET measures.*

	Number of correctly predicted rule dimension locations (valid n)	
	Fixation time	**Fixation priority**
Rule 1	22 (28)	22 (28)
Rule 2	22 (25)	22 (25)

The results presented above would appear to provide a degree of support for the validity and accuracy of the fixation data. In the majority of cases the location of the rule dimension appeared to match the dimension (location) that received the greatest proportion of fixation time and fixation priority; this level of congruency would be unlikely if the assignment of fixations to dimension locations was inaccurate (chance level 1 in 4). Alternatively, this result would be unlikely if the postulated prioritisation of the rule dimension was incorrect. However, it is not necessarily unexpected that the congruency between the actual rule dimension and the dimension (location) predicted by the ET data was not 100% in agreement. Even if the postulate is predominantly correct and participants do prioritise the relevant dimension somewhat, it could still be possible that the rule dimension will not necessarily receive the greatest proportion of fixation time or priority (as assessed by the simple summation method described above). For example, a participant may discover the relevant dimension but then continue to assess the remaining dimensions (e.g., in terms of their association with the stimulus category). It is quite plausible that such a process may require more 'processing' time than the time required for the simple category decision.

Preliminary ET Analysis

A number of basic measures can be derived from the ET data. For example, the mean number of dimensions fixated (per trial) during the criterion run (all 16 or last 8 trials), or prior to the criterion run, or during the first *n* trials can be examined. Similar measures related to the total number of fixations can also be created. Key time periods of interest may be the initial trials, the period during which the criterion run is achieved and the corresponding periods for the second rule (which includes the rule switch period). A selection of possible analyses is presented below. Three of the original 32 participants had poor, un-assessable ET data. This data is excluded from the analyses below. Additional exclusions (e.g., non-learners) are indicated where appropriate.

<u>Number of Fixations</u>

Firstly, the mean number of fixations per trial was assessed individually for each rule phase. Neuroticism was related to a higher mean number of fixations in both phase 1 ($r = .472$, $p = .013$, $n = 27$; non-learners excluded) and phase 2 ($r = .510$, $p = .008$, $n = 26$; non-learners excluded). While E and ImpASS were not significantly related to the mean number of fixations in the first phase, the correlations were significantly different (Williams $T2_{(24)} = 1.817$, $p = .041$); E was related to fewer fixations ($r = -.266$, $p = .256$) while ImpASS was related to a greater number of fixations ($r = .242$, $p = .224$). A similar, albeit weaker, pattern was observed for the second phase (E, $r = -.108$, $p = .601$; ImpASS, $r = .268$, $p = .186$; $n = 26$) although the difference between the correlations only reached a trend (Williams $T2_{(23)} = 1.399$, $p = .088$). Positive schizotypy was not significantly related to the number of fixations in the first phase ($r = .061$, $p = .761$) and only weakly related to a greater number of fixations in the second phase ($r = .295$, $p = .145$).

The mean number of fixations per trial was also examined for the first 10 trials of the task. Interestingly, N was unrelated to the number of fixations during the early part of the task ($r = -.010$, $p = .958$, $n = 29$). ImpASS was again positively associated with a greater number of fixations ($r = .364$, $p = .052$) while E was weakly associated with fewer fixations ($r = -.146$, $p = .448$). The relationship with the number of fixations made was therefore significantly different for E and ImpASS (Williams $T2_{(26)} = 2.203$, $p = .018$). Positive schizotypy was not significantly related to this measure ($r = .057$, $p = .767$). Additionally, age was significantly related to a greater number of fixations ($r = .431$, $p = .025$), while being female was related to fewer fixations ($r = -.365$, $p = .061$). However, it was noted previously that E was negatively correlated with age, while female participants scored lower on ImpASS.

To further assess the relationship with the number of fixations in the first few trials of the task multiple regression was performed with age, gender, E and ImpASS as predictors. The model accounted for a significant 38.3% of the variance in the mean number of fixations over the first 10 trials ($F_{(4,24)} = 3.724$, $p = .017$). Age was related to a greater number fixations and uniquely accounted for a significant 13.3% of the variance ($t_{(24)} = 2.275$, $p = .032$). ImpASS was also associated with a greater number of fixations, however, the unique contribution of 9.7% of the variance just failed to reach statistical significance ($t_{(24)} = 1.937$, $p = .065$). Both extraversion and being female were associated with fewer fixations. However, neither extraversion ($t_{(24)} = -.059$, $p = .733$) nor gender ($t_{(24)} = -1.388$, $p = .178$) uniquely accounted for a significant proportion of variance in the number of fixations made over the first 10 trials.

Another factor that needs to be considered, alongside the number of fixations, is the average duration of the fixations. For example, high-ImpASS individuals may have made more fixations yet it is possible that these fixations were of a shorter duration than those who made fewer fixations (e.g., high-E participants). Accordingly, it is worth considering response times (RTs) and assessing whether fewer fixations per trial was related to faster responses. This assumption appears to be vindicated by the finding that the mean number of fixations made per trial was highly positively correlated with mean RT (phase 1, $r = .882$, $p < .001$; phase 2, $r = .934$, $p < .001$; $n = 29$).

The observed relationship between mean RTs and personality was somewhat susceptible to the influence of outlying scores (i.e., slow mean response times). However, slower mean RTs on the first phase were significantly related to ImpASS ($r = .416$, $p = .043$, $n = 24$) and being male ($r = -.414$, $p = .044$).[2]

[2] The partial correlation between ImpASS and phase 1 mean RTs allowing for gender was $r = .313$, $p = .146$, $df = 21$

Slower RTs were also somewhat related to N ($r = .259$, $p = .222$; this relationship was significant if outliers were not removed). Again although not significantly correlated with mean RTs on the first phase, E was positively related with faster responses ($r = -.105$, $p = .624$) and this association was significantly different to that observed between ImpASS and mean RTs (Williams $T2_{(21)} = 2.191$, $p = .020$).

A concordant analysis was performed for RTs over just the first 10 trials of the task. Females were associated with quicker responses ($r = -.477$, $p = .010$, $n = 28$) while higher levels of ImpASS were significantly positively related to mean RTs over the first 10 trials ($r = .484$, $p = .009$). As noted previously, males tended to score more highly on ImpASS. In multiple regression, gender and ImpASS accounted for a significant proportion of variation in RTs over the first 10 trials of the task ($R^2 = 34.3\%$, $F_{(2, 25)} = 6.522$, $p = .005$). ImpASS contributed a unique and significant 11.5% of RT variance in the overall model ($t_{(25)} = 2.094$, $p = .047$). A similar proportion of RT variance was uniquely attributable to gender (10.9%) although this proportion fell marginally short of statistical significance ($t_{(25)} = -2.035$, $p = .053$). Therefore, 11.9% of the RT variance appears to have been common to the two predictors. Although not significantly related to shorter RTs, the association with E was significantly different from that of ImpASS ($r = -.230$, $p = .239$; Williams $T2_{(25)} = 3.365$, $p = .001$). However, this factor did not contribute a significant proportion of variance if included in the regression model just described.

Similar, although somewhat weaker relationships were observed for the second phase (and overall mean RTs).

Number of Dimensions Fixated

Following on from the consideration of RTs and variation in the number of fixations made, a further measure of interest concerns the mean number of different dimensions fixated on each trial (i.e., ranging between 0 – 4). The personality measures were not significantly related to the mean number of dimensions fixated per trial across the first phase of the task. However, while the correlations were far from statistically significant, the pattern of the direction of the associations between E, ImpASS and the mean number of dimensions fixated per trial paralleled the relationships observed with the number of fixations. Thus, the correlation coefficients for the association between E and the number of dimensions fixated on each trial were negative, while those for ImpASS were positive (e.g., 1st phase mean number of dimensions fixated per trial: E, $r = -.256$, $p = .197$; ImpASS, $r = .125$, $p = .352$, $n = 27$, non-learners excluded. Further examples are shown in the appendix, F.2 p. 322).

After the exclusion of non-learners on the second phase of the task (in addition to an outlying score on the ET measure), ImpASS was significantly related to the fixation of a greater number of dimensions per trial on the second phase ($r = .430$, $p = .032$, $n = 25$).

Similar patterns were observed over the first 10 trials and last 8 trials of the second phase. Although the correlations were non-significant, ImpASS was related to a higher mean number of dimensions fixated per trial ($r = .275$, $p = .174$, $n = 26$), while the association with E was negative ($r = -.121$, $p = .558$). However, ImpASS was also correlated with a higher mean number of dimensions fixated per trial over the last 8 trials ($r = .349$, $p = .094$, $n = 24$). Again, albeit very weakly, E was negatively related to the number of fixations over this period ($r = -.060$, $p = .782$).

A trend was also observed for an association between positive schizotypy and the fixation of fewer dimensions over the last 8 trials of the second phase ($r = -.386$, $p = .062$, $n = 24$). This is potentially interesting as this trait was positively associated with the number of dimensions fixated in the first 10 trials of the phase ($r = .229$, $p = .260$, $n = 26$). A similar set of non-significant observations was made with N, which was positively associated with the number of dimensions fixated at the beginning of the phase ($r = .244$, $p = .230$, $n = 26$) while negatively associated with the number of dimensions fixated at the end of the phase ($r = -.217$, $p = .309$, $n = 24$). This pattern is in contrast to that observed with ImpASS that was associated with the fixation of more dimensions at the beginning and end of the phase.

Summary

Although a degree of caution is warranted given the small size of the present sample, there does appear to be some evidence for a divergent pattern of relationships between the personality trait measures and basic ET variables. The most consistent pattern appeared with ImpASS and the tendency for more fixations, greater response times and the fixation of more of the stimulus dimensions, particularly over the second phase of the task. In contrast, although not as strongly related to the ET variables, E demonstrated the opposite pattern of association with these measures. There were also other possible relationships such as a positive association between N and the number of fixations made throughout the task. Additionally, some consideration must be given towards the potential overlap between ImpASS and E and other participant variables (i.e., gender and age respectively) observed in the present sample.

ET Model Fitting

Model

The variation of the key ET variables across the task was considered suitable for model fitting. As mentioned above there were 3 key DVs that were derived from analysis of eye fixations during the task. Additionally, the change in accuracy rate across the task was considered. These variables are listed below.

1) Number of dimensions fixated (0-4)
2) Proportion of fixation time (0-1)
3) Relative dimension priority (0-1)
4) Error (0 if incorrect, 1 if correct)

Following Rehder and Hoffman (2005), variation in these DVs across the task could be expected to follow a sigmoid function. For example, a participant's initial accuracy level would be predicted to be at chance (i.e., .5). However, after the (simple uni-dimensional) rule has been discovered, perfect performance should be attainable (i.e., 1). The sudden change in accuracy rate, resembling an 'all-or-none' learning transition, may therefore resemble a sigmoid function. Likewise, similar patterns of variation may be observed for the ET variables (i.e., participants may rapidly switch to prioritise and fixate only the rule relevant dimension).

To characterise the changes in these DVs the following sigmoid function was used to fit the data (model parameters in italics):

$$y = \mathit{initial} + (\mathit{final} - \mathit{initial}) / (1 + \exp^{(-m^{*}(t-b))})$$

y = DV (e.g., number of dimensions fixated)

initial = initial asymptote (e.g., 4)

final = final asymptote (e.g., 1)

m = is the rate of change

b = inflexion point

t = trial

*(the 'final – initial' term describes the change between the initial and final aysmptote)

The model fitting procedure was performed using the Matlab software package. This applied an iterative least squares methodology to fit the 4 parameter model (i.e., *initial, final, m* and *b*) to the data (using the *lsqcurvefit* function). Using this nonlinear method enabled suitable constraints to be placed on the model parameters. The rate of change (*m*) parameter reflects the rapidity of the transition between the *initial* and *final* parameter values and was constrained between two limits. The lower limit is set at the point at which 95% of the change in the sigmoid function occurs over the whole task (or in this case rule phase – there were 160 trials for the 1st rule and 192 trials for the second rule). The maximum limit is given when 95% of the change occurs within a single trial.

The *b* parameter, the point of inflexion, was constrained between zero and the actual number of trials taken by each participant. The initial estimate of this parameter was simply the midpoint of each rule phase. The constraints for the two remaining parameters, *initial* and *final*, were dependent upon the DV being fitted. When model fitting the number of dimensions fixated, the range for both parameters was between 0 – 4 (zero was used to allow the possibility of no dimension fixations on a particular trial – reflecting possible error in the ET data). The starting values were '4' for *initial* and '1' for *final*. For the proportion fixation time and fixation priority DVs, the range was between 0 – 1. The starting values were '.25' and '.75' for *initial* and *final* respectively. Finally, when modelling response errors ('0' if incorrect, '1' if correct) the range was again between 0 – 1. The starting value for *initial* was '.5' to represent guessing or chance level performance. The starting value for *final* was set to just below perfect performance at '.75'.

Assessment of Model Fit

The fit of the sigmoid models were compared to a one-parameter model which was simply the mean value (intercept) of the DV being fitted. As these models are nested[3] a simple F-ratio can be calculated to assess whether the sigmoid model gives a significantly better fit to the data than the mean model. This assesses goodness of fit for each model based upon the sum of the squared deviations between the model (ŷ) and data (y). This method also takes into account the different number of parameters in the two models. The F-ratio is given by the following formula:

$$F = \frac{(SS_n - SS_a)/(SS_a)}{(DF_n - DF_a)/(DF_a)}$$

where:

SS = Sum of Squared deviations
DF = Degrees of Freedom
n = Null model (mean/intercept)

a = Alternative model (sigmoid)
DF_n = difference in the number of model parameters (4 – 1)
DF_a = error term (number of trials – 4)

Assessment of Model Parameters

It was hoped that the parameter estimates produced by the model fitting may yield interesting information related to performance on the task that subsequently can be compared with the personality factors. For example, the rate parameter (*m*) for the error rate DV may give an indication as to the type of learning, whether sudden or gradual. While the *initial* and *final* parameters for this particular DV may not be so useful, the inflexion parameter (*b*) should correspond highly to the key performance measure (trials to criterion). The key comparisons for each of the four DVs are discussed below.

Number of Dimensions Fixated

Unfortunately, after the exclusion of participants for which the sigmoid model was not a significantly better fit to the data than the intercept only model (together with non-learners on the respective phases of the task), the sample sizes were insufficient for further consideration (14 and 11 for the first and second phase respectively).

Error Rate

The rate parameter was of key interest: a higher rate possibly indicative of more rapid, all-or-none type learning (i.e., sudden reduction in errors) compared to a lower rate, reflecting more gradual learning (i.e., more steady reduction in error rates). The inflexion parameter should reflect the trials to criterion measure. The initial and final parameters were not considered, as error rates at the beginning and end of the task were likely similar for all participants (especially for the sub-group whose data was fitted well by the model).

In the first rule phase, the sigmoid model provided a significantly better fit to the data than the intercept only model in 21 of the 29 cases. The parameter estimates for the error data were predictably related to the performance measures (e.g., the correlation between the number of trials taken to reach the learning criterion and the inflexion parameter; $r = .705$, $p < .001$, $n = 21$) and are not reported.

[3] Having *initial* and *final* in the model as the mean, leads to a reduced model of 'y = initial', as the term to the right of *initial* drops out when the numerator, 'final-initial', is equal to zero

Change in accuracy level (rate parameter) was not significantly related to the personality variables (the rate parameter estimates variable was significantly negatively skewed and was appropriately transformed. Similar results were observed for non-parametric correlations using the un-transformed variable). However, positive schizotypy was related with a lower inflexion parameter estimate ($r = -.413$, $p = .063$; non-par., $r = -.526$, $p = .014$), suggesting that participants scoring more highly on this factor reduced their error rate earlier on the task. This was supported by a significant positive correlation between the mean error rate (or intercept; scored from 0, incorrect to 1, correct) and positive schizotypy ($r = .578$, $p = .006$). For this sub-group at least, positive schizotypy was associated with an earlier reduction in errors and a lower proportion of errors on the first phase of the task (however, this factor was not significantly related to the TTC measure).

In the second rule phase only 17 of the 29 participants' data were significantly better fit by the sigmoid model (cf. intercept only model). Again the model parameters demonstrated suitable correlations with the performance measures (e.g., the correlation between the number of trials taken to reach the learning criterion and the inflexion parameter; $r = .966$, $p < .001$, $n = 17$) and further details are not reported.

The rate of change in accuracy level (rate parameter) across the second phase of the task was not significantly correlated with the personality factors or the age or gender of the participants. However, there was a trend for a significant positive (non-parametric) correlation between this parameter and positive schizotypy ($r = .430$, $p = .085$, $n = 17$). This would appear to suggest that positive schizotypy was associated with a more rapid reduction in errors in the second phase of the task. There were no significant correlations between the personality variables and the inflexion parameter (p's > .121).

Rule Dimension Fixation Priority

1. Fixation priority of the valid (rule 1) dimension over the first phase

The sigmoid model provided a significantly better fit to the data than the intercept model for 25 of the 29 participants with valid ET data. Two of these participants failed to achieve 16 consecutive correct responses for the first rule and were excluded from the analyses presented below (n = 23; removal of these participants did not appear have a significant effect on the results presented below). Although not significantly related to the rate parameter estimates, the performance measures were correlated in a meaningful fashion with the remaining model parameter estimates, as shown in table 7.7 below (e.g., a higher prioritisation of the rule dimension in the final trials of the phase, final parameter, was negatively correlated with the TTC measure).

Table 7.7: *Correlation between performance and parameter estimates for the sigmoid model of rule dimension priority in phase 1 (n = 23)*

		Rate parameter	Inflexion parameter	Initial parameter	Final parameter
Trials to criterion (rule 1)	Pearson Correlation	.011	.944(**)	-.298	-.392
	Sig. (2-tailed)	.962	.000	.167	.064
Percentage correct trials (rule 1)	Pearson Correlation	.086	-.814(**)	.416(*)	.269
	Sig. (2-tailed)	.697	.000	.049	.215

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The rate parameter did not appear to be related to overall performance measures on the first phase. However, E was significantly related to a more rapid prioritisation of the rule dimension ($r = .430$, $p = .041$), while a trend was observed for positive schizotypy and a slower rate of prioritisation of the rule dimension ($r = -.360$, $p = .091$). E was also related to a higher initial priority parameter, suggesting that this trait was related to increased prioritisation of the rule dimension at the beginning of the phase ($r = .492$, $p = .017$). In contrast, E was unrelated to the final priority parameter, whereas positive schizotypy was positively related to this parameter ($r = .418$, $p = .047$), indicating a higher prioritisation of the dimension of the task at the end of the phase.

This pattern of association may suggest that high-E individuals were able to prioritise the rule dimension at a relatively early stage of the task and were subsequently able to prioritise the rule dimension more quickly (i.e., a larger rate parameter indicating a faster transition between the initial and final parameter). However, the actual size of the change between the initial prioritisation and final prioritisation may have been smaller for these participants (i.e., as the initial priority parameter was larger). In contrast, positive schizotypy was related to higher prioritisation of the rule dimension at the end of the phase (final priority parameter) and, although non-significant, was negatively associated with initial prioritisation of the rule dimension (initial parameter; $r = -.207$, $p = .343$). Additionally, positive schizotypy was associated with a slower prioritisation of the rule dimension. This may suggest that this personality factor was associated with a greater shift of prioritisation across the first phase in respect of prioritisation of the rule dimension.

To examine the change in prioritisation across the first rule phase a difference measure was calculated by subtracting the initial priority parameter from the final parameter, thus greater positive values indicated a greater increase in the prioritisation of the rule dimension from the beginning to the end of the task. As predicted positive schizotypy was positively associated with this measure ($r = .466$, $p = .025$). Although non-significant, E was negatively related to the change in rule dimension priority over phase 1 ($r = -.204$, $p = .351$) and this was significantly different from the relationship observed for positive schizotypy (Williams $T2_{(20)} = 2.327$, $p = .015$). These results support the association between E, positive schizotypy and the changes in the prioritisation of the rule dimension as described in the preceding paragraph.

No other significant relationships were observed.

2. Fixation priority of the invalid (rule 1) dimension over the second phase

The model fitting procedure was repeated for the second phase of the task. The first set of models fitted considered the fixation priority of the 1st rule dimension over the second phase of the task; the de-prioritisation of the rule dimension from the previous phase. The sigmoid model provided a significantly better fit to the data than the intercept model for only 20 of the 29 participants, two of these participants failed to achieve the learning criterion in the first phase and were therefore excluded. No significant correlations were observed within the resulting sample of 18 participants and further details of these are analyses are not reported.

3. Fixation priority of the valid (rule 2) dimension over the second phase

The final set of analyses considered the prioritisation of the second category rule dimension over the second phase of the task. The sigmoid model provided a significantly better fit to the data for 21 of the 29 participants, relative to the intercept only model. One of these participants failed to learn the second category structure and was excluded from the analyses presented below (hence $n = 20$).

Naturally, the inflexion parameter was highly positively correlated with the number of trials taken to learn the second dimension ($r = .957$, $p < .001$) while significantly negatively related to the percentage of correct trials ($r = -.694$, $p = .001$). The 3 remaining parameters were not significantly related to the performance measures (r's < .204). However, the mean prioritisation score did appear to be significantly related to performance as would be expected ($r = -.467$, $p = .038$, and $r = .670$, $p = .001$ for the TTC and percentage correct trials respectively).

Screening of the data revealed a distinct bi-modal distribution of rate parameter estimates. Participants were subsequently divided into high and low groups, reflecting more rapid and slower change in the prioritisation of the new rule dimension respectively. The 9 participants that appeared to prioritise the new rule dimension more rapidly (i.e., the high rate group) were significantly higher on ImpASS ($t_{(18)} = 2.780$, $p = .012$) and significantly lower on E ($t_{(18)} = -2.281$, $p = .035$). No other differences were observed in relation to this parameter.

Lower initial priority parameter estimates were associated with E ($r = -.461$, $p = .041$). This measure was not significantly related to ImpASS ($r = .060$, $p = .800$). In contrast, ImpASS was significantly related to lower final priority parameter estimates ($r = -.521$, $p = .018$); E was not significantly related to this parameter ($r = -.023$, $p = .922$). No other significant relationships were observed in relation to the model parameters, although age was significantly positively related to the inflexion parameter ($r = .544$, $p = .013$).

Rule Dimension Fixation Time

1. Proportion of fixation time for the valid dimension (rule 1) over the first phase

After the exclusion of non-learners, the sigmoid model provided a significantly better fit to the data than the intercept model for 18 participants for the proportion of fixation time upon the rule dimension (phase 1). There were no significant correlations between the personality factors and the model parameters, although the positive association between positive schizotypy and the final parameter estimate just failed to reach significance ($r = .496$, $p = .056$). Due to the small sample size and lack of significant correlations, further data analysis is not reported.

2. Proportion of fixation time for the invalid dimension (rule 1) over the second phase

Model fitting was again performed for the proportion of fixation time given to the first rule dimension over the second phase of the task. The sigmoid model was a significantly better fit to the data for only 16 participants. After the removal of individuals that had failed to reach the learning criterion in the first phase, this number was further reduced to 13. Subsequently, the association between the personality factors and the model parameters is not reported due to the small sample size.

3. Proportion of fixation time for the valid dimension (rule 2) over the second phase

The final model assessed the proportion of fixation time for the second rule dimension over the second phase. Excluding non-learners yielded a sample of 22. The parameter values were generally not significantly associated with personality. However, the initial proportion of fixation time parameter was significantly correlated with E ($r = -.546$, $p = .009$). The remaining personality factors were not significantly related with this parameter (r's $< .159$). E and ImpASS were weakly associated with lower *final* parameters ($r = -.263$, $p = .263$, and $r = -.285$, $p = .199$) while N and positive schizotypy were both weakly positively correlated with this parameter ($r = .208$, $p = .354$, and $r = .299$, $p = .176$).

DISCUSSION

This study employed an innovative approach in the examination of the relationship between personality and attentional processes during learning of novel stimulus-category associations. Based upon original work by Rehder and Hoffman (2005), that appears to have been the first study to have applied eye-tracking methodology within the CL paradigm, the current experiment measured eye-gaze as a proxy for selective attention. Participants attempted to learn a simple uni-dimensional category structure in order to successfully classify presented stimuli into 1 of 2 possible categories. The use of stimuli comprised of 4 spatially separable dimensions enabled the assessment of the attention given to each individual stimulus feature, including the rule dimension, throughout the learning process. An additional manipulation, involving an unannounced switch in the category structure – and consequently relevant rule dimension, allowed for differences in the modulation of attention in light of changing response contingencies to be considered.

Before further continuation of the present discussion it is worth addressing a couple of pertinent issues. One important consideration is the relatively small size of the sample (n = 32). The number of participants involved in the key analyses was further reduced after the ET data was considered; 3 participant's data was un-assessable. Further limitations on the sample size were imposed after the assessment of the model fitting data and miscellaneous data screening. The limited size of the sample available for the analyses reported in the previous section should therefore arouse a degree of caution in the confident interpretation of the results. Accordingly, the conclusions drawn from the present data are proffered somewhat tentatively and with a view to providing a possible foundation for future research.

An additional factor worthy of consideration is the interpretation of eye-gaze as a measure of selective attention. This issue is discussed in more detail in Rehder and Hoffman (2005). A central tenet of the Rehder and Hoffman study was the assertion that eye-gaze represents a legitimate means for the assessment of attentional processes (specifically selective attention) involved in CL. One validation of this hypothesis was the concordance between the attentional prioritisation of (rule) relevant dimensions and behavioural measures of learning of the category structures. Consequently this method was considered applicable for the current study. The use of eye-gaze measures in this way appeared to be further validated in the present study through a largely successful prediction of the rule dimension (despite the use of a somewhat simplistic heuristic; e.g., the dimension receiving the greatest proportion of fixation time over the final trials of the task).

Initial exploration of the raw performance measures (i.e., TTC and percentage of correct trials) did not reveal any clear association with the personality measures. Naturally, the small sample size may have been a contributory factor for this result. However, the present task is most similar to the RB task presented in study 1 in which performance again appeared to be only weakly related to personality. One feature common to both of these tasks was the use of binary valued dimensions in the creation of the stimuli. As discussed in the earlier chapter, the use of such stimuli may have been one feature that contributed to the somewhat conflicting relationships between personality and performance found (or possibly not found) in the present RB tasks in light of the previously reported associations between personality and RB categorisation (as reported by Pickering, 2004). More detailed comparisons between the two studies will be considered below. However, the inclusion of the ET measures in the present study highlights the utility of the method, enabling the exploration of individual differences in CL beyond the association with raw performance measures.

As mentioned above, the ET methodology applied in this study did appear to be somewhat validated by the successful prediction of the relevant rule dimension for the majority of participants. In spite of the somewhat simplistic manner through which this prediction was derived, this result provides a degree of confidence in the further assessment of the ET data. Although there appeared to be no clear association between personality and overall performance on the task, and despite the relatively small sample, there did appear to be some divergent relationships between personality and a variety of the ET measures.

The first set of analyses considered the raw ET measures that assessed the number and duration of fixations made during different time periods of the task as well as the proportion of the 4 dimensions that appeared to be fixated on each trial. One clear and intriguing finding that emerged from the data was a distinct pattern of relationships between extraversion, ImpASS and the ET measures. ImpASS was generally associated with a greater number of fixations, especially over the first few trials of the task, and was significantly correlated with the fixation of more of the stimulus dimensions (per trial) in the second phase of the task (with a similar trend observed for the first phase). Concordant with these findings, ImpASS was also related to slower RTs on the first phase of the task, likely reflecting the greater number of fixations made per trial. In contrast, although not generally significantly correlated with the ET measures, extraversion was consistently associated with the ET measures in the opposite manner to that observed for ImpASS (i.e., fewer fixations, smaller number of dimensions fixated per trial and shorter response times). If this pattern is a true reflection of underlying differences in attentional processes, this would provide a useful starting point for further research.

This pattern of results will be considered in more detail below. However, it is pertinent to recall that these two personality traits were somewhat related to the age and gender of the participants, which were themselves somewhat related to the ET measures (e.g., females were associated with shorter RTs over the first few trials). Therefore, these factors may also need to be addressed in future research. Additionally, both neuroticism and positive schizotypy were somewhat related to the ET data. Neuroticism was associated with a greater number of fixations on both phase 1 and phase 2 of the task. Positive schizotypy was only weakly related to the number of fixations made on the task and not significantly related to the RTs or number of dimensions fixated on each trial.

A series of models were applied to the data in order to consider the variation in the derived ET measures over the course of the task. This enabled a variety of parameters reflecting the modulation of selective attention over the task to be considered. For some participants, the model did not sufficiently describe the data that coded the number of dimensions fixated upon each trial. Subsequently this data was not assessed. This is unfortunate as this variable appeared somewhat related to ImpASS and neuroticism, and may have provided an invaluable insight into the modulation of selective attention.

The modelling of participants' response accuracy across the first phase of the task revealed an association between positive schizotypy and an earlier shift in the decrease of error rates (presumably reflecting the learning of the category rule). However, this trait was unrelated to general performance on this phase. No other findings were observed. The following discussion focuses upon the modelling of the fixation priority measure. In addition the results related to the proportion of fixation time given to the rule dimension will also be included.

A key ET variable of interest was the prioritisation of the rule dimension. The model parameter estimates for the first phase were generally related to the to the behavioural performance measures as predicted (i.e., the inflexion parameter was positively correlated with the TTC measure etc). However, the rate parameter, reflecting the number of trials taken to change from the initial to the final level of prioritisation, was unrelated to performance. Therefore, whether a participant rapidly modified their attention to the rule dimension was unrelated to performance on this task. This may suggest that any individual differences in this particular aspect of attentional modulation are unlikely to be associated with performance on the present task.

Interestingly, although not associated with performance, a more rapid change in the prioritisation of the rule dimension in the first phase was positively associated with extraversion. Additionally, this trait was associated with greater initial prioritisation of the rule dimension. Further analyses supported the proposal that, due to the greater initial prioritisation of the rule dimension, the overall change in the prioritisation was smaller for more extraverted participants. This suggests that these individuals were better able to prioritise the rule dimension earlier in the task, which likely lead to the observed relationship with a more rapid rate of prioritisation. It may be that the this pattern reflects the enhanced use of feedback in the early stages of the task allowing the greater prioritisation of the relevant dimension, although it appears that this did not necessarily have as strong an influence upon the overall learning of the category rule.

In contrast, positive schizotypy was associated with a slower change in the prioritisation of the rule dimension. Lower initial prioritisation coupled with higher final prioritisation of the dimension (and a congruent relationship with a greater proportion of fixation time at the end of the first phase) suggested that the change in the prioritisation was greater for individuals scoring more highly on positive schizotypy. This was supported by a significant association between this trait and the magnitude of the change in prioritisation of the rule dimension. Although neither trait (extraversion and positive schizotypy) was associated with performance on the first phase of the task (or on the task as a whole), these results suggest a qualitatively distinct relationship between these two traits and the modulation of selective attention across the task.

Extraversion was also associated with the rate of change of prioritisation of the rule dimension in the second phase of the task. However, in contrast to the first rule phase, more extraverted individuals demonstrated a slower prioritisation of the new rule dimension. Additionally, extraversion was associated with lower initial prioritisation (and lower proportion of fixation time) of the second rule dimension. This suggests that, in direct contrast to the first rule phase, these individuals showed greater 'difficulty' in prioritising the new rule dimension. Naturally, the key difference between the two phases is that upon commencement of the second rule-phase participants have to un-learn the initial (i.e., phase 1) rule. This may suggest that processes associated with the more rapid prioritisation in the first phase were somewhat impaired or disrupted at the beginning of the second phase. Consequently it may be speculated that the divergent association between extraversion and the prioritisation of the relevant rule dimensions is attributable to some aspect of the additional requirement to disengage attention from a previously relevant dimension, or attend to a previously irrelevant dimension, or both.

Unlike the relationship observed for extraversion, ImpASS was associated with a more rapid change in prioritisation of the new rule dimension in the second phase. In addition, this trait was related to a lower final prioritisation of the second rule dimension. This appears to be somewhat congruent with the previous association between this trait and the fixation of more stimulus dimensions. This tendency may have facilitated the initial prioritisation of the new rule dimension at the beginning of the second phase and additionally account for the lower prioritisation of the dimension at the end of the phase (concordant with the general fixation pattern observed for ImpASS). This continues the distinct and contrasting relationships observed between these two traits (extraversion and ImpASS) and the ET measures.

It is worth noting that the attempt to model selective attention towards the first rule dimension over the second phase of the task was not as successful as the standard models (i.e., 1st rule dimension over the first phase etc). This is perhaps not surprising as it is not necessarily expected that the de-prioritisation of a previously relevant dimension proceeds simply in the reverse manner to the proposed all-or-none learning (i.e., sigmoid function) of the initial rule. Indeed, it is quite possible that attention to the original rule dimension decreases gradually over the time course of the second phase.

As mentioned above, the task in the present thesis most similar to the current experiment is the RB CL task from study 1. However, while it may be useful to compare the present data with task, it was noted that there was a general lack of significant relationships between personality and performance on the RB task in study 1. However, the trait most strongly associated with performance on the previous RB task was extraversion. In fact, in combination with age, extraversion just failed to account for a significant unique proportion of variance in the number of trials required to learn the category in the first phase of the task (although the overall regression model was significant).

Thus, extraversion was associated with superior performance in the first phase of the original RB task. It is interesting to speculate how the observed relationship with an earlier (and more rapid) prioritisation of the relevant rule dimension in the first phase of the present study may provide possible corroboration of this previous finding. The association between extraversion and the greater initial prioritisation of the relevant rule dimension would most certainly be compatible with the trend towards quicker attainment of the learning criterion in the previous study. Likewise, the decreased initial prioritisation (and slower change in prioritisation) of the second rule dimension (in the second phase) may also provide a partial explanation for a lack of a positive association between this trait and performance on the second phase of the previous RB task. As suggested above, this may partially reflect the additional requirement of inhibiting a previously learned rule in the second phase of the task.

In the previous RB task, a weak correlation between ImpASS and poorer performance on the second phase of the task was observed. This association cautions the appropriate interpretation of the relationship between ImpASS and the model parameters observed for the second phase of the present task. It was noted that ImpASS was related to a more rapid change in the prioritisation of the new (i.e., phase 2) rule dimension. However, this does not necessarily translate into more rapid learning of the new category rule. For example, ImpASS was related to the fixation of a greater number of dimensions across the second phase of the task including the fixation of more of the 4 dimensions during both the first few trials and final few trials of the second phase. This pattern likely facilitated a more rapid change in the selective attention towards the relevant dimension as the change in prioritisation, from the initial to the final level, for the relevant rule dimension was smaller.

Furthermore, it is quite possible that a general style of attending more of the stimulus dimensions hindered performance on the second phase of the task. Attending more of the stimulus dimensions may not be the most efficient or effective strategy when the unannounced switch of category rule occurred. Attempting to assess the association between all four of the stimulus dimensions and the feedback may dilute the ability to discern the new rule dimension. In the present example, an alternative strategy may have been more efficient for the re-learning of the category structure in the second phase (e.g., as the rule was again uni-dimensional the consideration of each dimension individually may have resulted in the quicker learning of the new category structure). The relationship between ImpASS and attention towards more stimulus dimensions in the present study may have been one contributory factor in the weak association observed between this trait and poorer performance in the second phase of the RB task in study 1.

At this point it may be worth briefly reflecting upon the current relationship observed between ImpASS and selective attention. Ball and Zuckerman (1990) postulated that an association between sensation-seeking (a trait associated with ImpASS) and enhanced performance on a RB-like classification task may have been related to superior selective attention. This proposition was further considered by Pickering and colleagues (e.g., Pickering, 2004; Pickering & Gray, 1999). The relationship between ImpASS traits and superior learning of (nominally) RB categories was further supported in additional studies reported by Pickering (2004). Therefore, it may have been predicted that ImpASS would be associated with the opposite pattern of attentional style (i.e., focusing upon fewer dimensions etc) to that which was observed in the present study.

In the previous chapter (study 3) ImpASS was associated with reduced cognitive flexibility and poorer performance on a task in which attention upon 2 of the 3 stimulus dimensions was required for optimal performance. Furthermore, formal modelling of participants' response strategies suggested that ImpASS was related to an increased use of uni-dimensional rules (response strategies). These results appear somewhat difficult to reconcile with the current data suggesting that individuals scoring more highly on ImpASS appeared to attend more of the stimulus dimensions. Such an attentional style may have been expected to facilitate performance on the previous task.

However, as discussed in the previous chapter, it is important to consider methodological differences between the different tasks. For example, one key distinction can be drawn between the types of stimuli used. The stimulus dimensions in the present study were not only categorical (as opposed to continuous in the study 3 task) they were also spatially separable. It may therefore be possible to exclude attention to a particular dimension in the present task whereas in the previous task selective attention to the individual stimulus features was somewhat unattainable (e.g., it would be difficult to 'attend' the length of the single line without some degree of attention towards the angle and horizontal position of the line). It is difficult to assess the impact that such differences may have on attention and learning upon the two tasks. However, one key issue for future studies would be to consider selective attention during RB CL involving stimuli comprised of continuous as opposed to discrete valued dimensions.

Selective attention during CL involving a task more comparable to that used in the previous study (study 3) will be considered in more detail in the following chapter. However, one key issue that must also be considered is that the tendency to attend more stimulus features (i.e., as observed for high-ImpASS individuals in the present study) does not necessarily equate to the likelihood of incorporating the information from these dimensions in making category responses. Consequently, the findings in the present study do not imply that the high-ImpASS participants were applying more complex multi-dimensional rules, but simply that they appeared to attend a greater number of the stimulus features. This would appear to be in line with the findings of Rehder and Hoffman (2005) which suggested that participants tended to fixate all stimulus dimensions in the initial stages of CL, despite evidence suggesting that uni-dimensional rules were being applied (and assessed).

Positive schizotypy was associated with a greater change in the prioritisation of the rule dimension over the first phase of the task. In addition, this trait was positively (although non-significantly) related to the proportion of fixation time afforded to the rule dimension in the final stages of both the first and second phase of the task. This would appear to suggest that this trait was related to an increased level of selective attention towards the relevant rule dimension once the appropriate dimension had been discovered. This result appears to be highly congruent with the association between positive schizotypy and decreased distractor cueing effects reported by Steel et al. (2002; discussed in the previous chapter). The attentional style reported in the present study would provide a suitable mechanism through which the distractor effect would be reduced in the previous study.

Positive schizotypy was also found to be related to decreased interference from irrelevant dimensions in the RT study presented earlier (chapter 5). Again this result appears highly compatible with the present association between the trait and increased selective attention to the relevant rule dimension. Furthermore, the stimuli in the RT experiment (described in chapter 5) involved stimuli with dimensions that were somewhat inseparable (i.e., it may have been difficult to attend and assess the size of the inner triangle without some degree of processing of the colour of the stimulus background). This may tentatively suggest that the ability to focus upon the relevant dimension of a stimulus (and consequently the reduction of attention given to nominally irrelevant dimensions) is also applicable in situations where the stimulus features are not entirely spatially separable.

Furthermore, this result may offer a useful insight regarding the association between positive schizotypy and latent inhibition (LI). The current data may be considered somewhat incompatible with certain attentional explanations. For example, one theory of LI proposes that the phenomenon arises as the result of the inhibition of the processing of the stimulus (or stimulus feature) that is initially irrelevant (e.g., see Gray & Snowden, 2005). The association between positive schizotypy and reduced LI has therefore been suggested to result from poorer inhibitory mechanisms. In contrast, the present data suggested that positive schizotypy was associated with a greater prioritisation of the relevant stimulus dimension (relative to the irrelevant dimensions, in the first phase). Assuming inhibitory processes, relevant to LI, are also involved in this 'prioritisation' of relevant stimulus features, then this result may not appear to be fully concordant with the idea that positive schizotypy is linked to impaired inhibition.

Following the example of Rehder and Hoffman (2005), the present study provided a crucial step in the assessment of individual differences in selective attention during CL. The current task involved stimuli comprising four dimensions. However, only one of these dimensions defined the category structure thereby allowing for the possibility of selectively attending only one of the four stimulus features. The modulation of selective attention was further considered by an unannounced change in the category structure during the task that required attention to a previously irrelevant dimension.

Despite the relatively small sample size of the present study, there did appear to be some interesting relationships between personality and the measures of selective attention. Most notably a divergent pattern of association between extraversion, ImpASS and the ET measures was observed. Although unrelated to performance, extraversion was related to a greater prioritisation of the rule dimension in the initial stages of the task, possibly suggestive of a superior ability to utilise response feedback to guide attention to the relevant dimension. In contrast, ImpASS appeared generally related to a more broad attentional style and was associated with more fixations and the fixation of more of the stimulus features across the task. This result may be somewhat surprising given the previous association between ImpASS and the suggested facilitation of RB CL through superior selective attention. Implications of the present results were discussed and the possibility for future research in this area seems clear.

Chapter 8

Study 5 - Cognitive Flexibility and Selective Attention during Rule-Based Category Learning

INTRODUCTION

Aims

The motivation for the present experiment arose as a result of the findings from the preceding study which explored the association between personality and cognitive flexibility (presented in chapter 6). Briefly, the results demonstrated an association between ImpASS and poorer performance on the task that required attention towards 2 of the 3 stimulus dimensions in order to achieve a criterion level of performance (in the presence of uni-dimensional rules that yielded relatively high, yet sub-optimal performance). Furthermore, analysis of participants' response strategies, with the use of formal modelling methods, suggested that the association between this trait and poorer performance (and consequently cognitive *in*-flexibility) was related to the use of the more simple (and inappropriate) uni-dimensional rules. In contrast, extraversion was independently associated with better performance on the (crucial) final section of the task and additionally related to the use of more appropriate strategies.

The previous chapter explored the use of eye-gaze measures to assess selective attention towards stimulus dimensions during CL. The rationale for the consideration of eye-gaze as a valid measure of selective attention was discussed in the previous chapter. It was suggested that a variety of variables derived from the ET data may provide a legitimate and objective measure of the stimulus dimensions which participants were attending and consequently utilising in their categorisation decisions. Accordingly, it may be possible to apply this technique to provide a partial validation of the response modelling method applied in study 3. If it is possible to demonstrate a degree of concordance between the dimensions implicated from ET data and response strategy models, this may provide an increased level of confidence in the response modelling technique (additionally supporting the suggestion that the response strategy models partially reflect attentional processes).

An important consideration in the creation of a task suitable for the current ET approach is the design of an appropriate set of stimuli (i.e., to enable the measurement of selective attention during CL). As demonstrated in the previous experiment, the feasibility of the method requires the spatial segregation of stimulus features in order facilitate the assessment of attention to individual dimensions. Naturally, the application of the stimuli used in the previous behavioural version of the task (i.e., study 3; which comprised single lines which varied in length, orientation and horizontal location) is not tenable for the present experiment. The attempt to create an appropriate set of stimuli is detailed in the following Method section.

The primary aim of the current experiment was twofold: firstly, to attempt a replication of the previous cognitive flexibility study and secondly, to supplement the behavioural data through the assessment of selective attention. Consequently, it is expected that the present study will confirm the previous relationships between personality and performance (both in terms of accuracy and strategies employed) on a task requiring cognitive flexibility. Furthermore, it is expected that the additional assessment of eye-gaze during the task will help validate the modelling of response strategy and substantiate the relationship between personality and strategy use in both the present study and previous behavioural version of the task.

METHOD

Participants

The participants in the present study were described in the previous chapter. To briefly recap the sample comprised 16 male and 16 female participants, with a mix of students (in the main, non-psychology) and non-students. Mean age was 25.5 (range 20 – 38 , SD = 5.1) years.

Design

Conjunctive RB CL Task

As described above, the present study aimed to establish a task that was directly analogous with the three-dimensional conjunctive RB task used in the study of cognitive flexibility (described in chapter 6, study 3) while also providing a suitable platform for the assessment of eye-gaze (as described in the preceding chapter). To that end the current task can be viewed simply as a modified version of the original behavioural task. The following section provides a description of the stimuli used, while a summary of the procedural details (number of trials, number of blocks etc) is described in the Procedure section.

As described in the previous chapter, a key aspect in the design of stimuli suitable for the application of the ET method is the requirement for each of the stimulus dimensions to be spatially separable. Therefore, the stimuli used in the previous behavioural version of the task (study 3) were not appropriate for the present study. Another crucial feature in the creation of the present stimuli was the use of continuous-valued dimensions (cf. binary valued dimensions used in the previous ET experiment, study 4). Consequently, the use of such dimensions posed a potential confound in that the eye-gaze measures may partially reflect the specific value on a given dimension on any particular trial (e.g., a long line may require more fixations, or indeed may induce more saccades, than a shorter line). For this reason it was considered crucial that each of the 3 dimensions occupied an equal amount of visual space on each trial, independent of the actual stimulus value. This lead to the creation of stimuli comprised of three circles, as shown in figure 8.1 below.

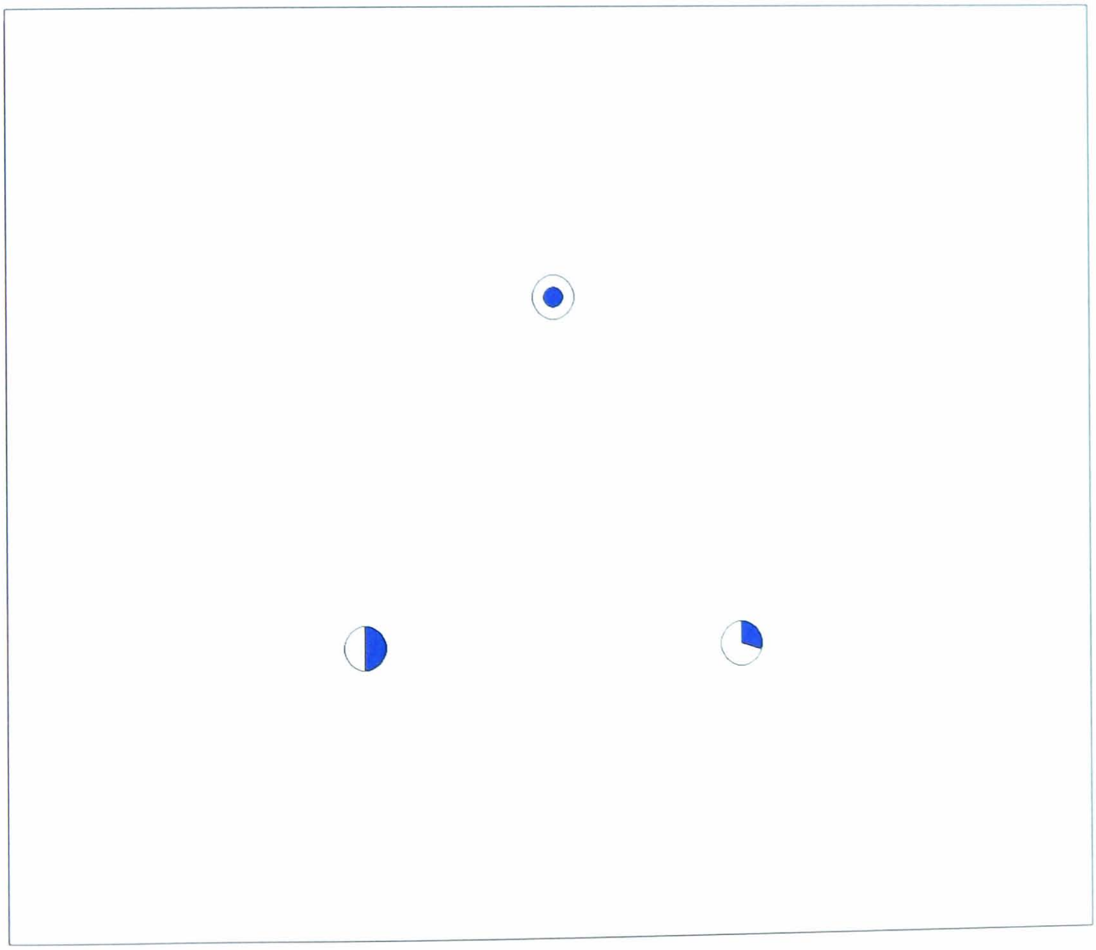

Figure 8.1: *An example stimulus from the present study (actual screenshot)*

Each dimension was presented on a background consisting of a white circle (of equal size for all dimensions). Hence, each dimension was considered to occupy an equivalent area of the visual display regardless of the actual dimension value (see below). Together the three circles comprised a single three-dimensional stimulus, analogous with study 3. The actual stimulus dimensions were 1) the size of the inner circle radius, 2) the horizontal position of the chord and 3) size of the arc (in the top, bottom-left and bottom-right circles respectively). The variation on these 3 dimensions determined the amount of blue presented within each of the background circles. Therefore, the value on the first dimension (top circle) determined the radius of the blue inner circle. The value on the second dimension, the horizontal location of the chord, determined the size of the blue segment. Finally, the value of the third dimension, the angle of the arc, determined the size of the blue sector. The values on the 3 dimensions in figure 8.1 above are all at the mid-point of the variation on the respective dimensions (i.e., the mid-point of the possible range of values applied in the present task).

The generation of the stimulus values followed the identical approach to that described by Maddox, Baldwin et al. (2006), as described in the appendix (E.1, p. 319). As with the previous purely behavioural version of the task, the present category structure was deterministic and followed a conjunctive rule involving 2 of the 3 stimulus dimensions. Consequently, 100% accuracy was obtainable with the appropriate combination of information from dimensions 2 and 3 (i.e., the bottom 2 circles). Therefore the category rule followed the form: "If the horizontal position of the chord in the bottom-left circle is beyond 'x' and the size of the arc in the bottom-right circle is greater than 'y', respond category 'B', otherwise respond category 'A'". (The possibility of interpreting the dimensions in terms of the area of each circle that is 'blue' is discussed below).

In the previous version of the task the position of the single line was irrelevant. This stimulus dimension was specifically chosen by the experimenters as it appeared to be the most salient of the 3 dimensions. It was hoped, therefore, that most participants would use this dimension in the initial stages of the task (and hopefully encourage an initial uni-dimensional response strategy). In the current task the first dimension (top circle) was irrelevant. Owing to the location and manner of variation on this dimension, it was hoped that this stimulus feature would perform a similar function (this dimension was chosen after a brief series of pilot tasks).

As in study 3, the stimuli were generated so that the use of any uni-dimensional rule (with appropriate decision boundary) would yield a relatively high, yet sub-optimal, level of response accuracy. Across the task as a whole the optimal uni-dimensional rules for the 3 dimensions respectively would give 84.7%, 82.8% and 83.8% correct responses. Crucially, these accuracy rates are all below the criterion level of performance of 90%. Furthermore, the use of any of these uni-dimensional rules would not lead to the criterion level of performance on any individual block of trials within the task.

The preceding discussion of the current stimuli focused upon the actual features that were used to construct the dimensions (i.e., the radius of the inner circle, location of a chord and size of an arc). However, as may be somewhat apparent from figure 8.1 above, it is quite possible that participants interpreted the variation in the dimensions in terms of the proportion of the white background circles that were filled with blue (as opposed to the underlying structure described above). Naturally, the proportion of the background circle 'filled' on each dimension was directly (although not always linearly) related to the underlying stimulus value (i.e., the size of the blue inner circle in the top circle was determined by the value of the radius). Although the relationships between the original dimensions and the 'proportion of fill' were not always one-to-one (i.e., the area of a circle is related to the square of its radius), in general the two measures could be considered to be linearly related. Crucially, however, interpretation (or recoding) of the stimulus dimensions in terms of the proportion of fill did not alter the properties of the underlying category structure (i.e., the uni-dimensional rules were still suboptimal and application of the correct conjunctive rule could lead to 100% accuracy).

To some degree, the values on the present dimensions were somewhat directly comparable (i.e., the proportion of 'blue fill' in the 3 circles could be compared). In contrast, such a direct comparison between the values on the 3 dimensions was not possible (or at least not as simple) in the study 3 task. For example, two of the dimensions in the previous task were the length and angle of orientation of a single line. Clearly, the comparison of variation on these distinct dimensions is qualitatively different (i.e., the dimensions vary on different scales – the comparison of orientation and length would require some form of transformation as opposed to a direct perceptual comparison). Therefore, despite the apparent validity of the current category structure, the ability to perceive (or assess) the present stimulus dimensions in terms of the 'proportion of fill' did introduce an additional factor not present in the previous behavioural version of the task.

In an attempt to decrease the similarity of variation across the 3 dimensions, the range of the third dimension was restricted such that the highest possible value on the dimension led to a partial fill of the circle (approximately 60%; figure 8.1 above shows the 3rd dimension, bottom-right circle, at

30% of maximum fill – i.e., the mid-point of the range applied in the experiment). In contrast, the variation on the remaining two dimensions encompassed the whole range. Additionally, the direction of the variation on the second dimension (bottom-left circle) was reversed relative to the remaining 2 dimensions. The stimuli were created such that higher values on each dimension were associated with category 'B' (and the conjunctive rule followed the identical format to the previous study; if the value on dimension 2 is greater than 150 'units' and the value on dimension 3 is greater than 150 'units' then respond category 'B', otherwise respond category 'A'). Therefore, higher underlying stimulus values for dimensions 1 and 3 (top and bottom-right circle respectively) were associated with a greater proportion of fill, whereas the higher values on dimension 2 (bottom-left circle) were associated with a lesser proportion of fill (i.e., higher values moved the horizontal position of the segment to the right).

Although some potential concerns associated with the use of the present stimuli were somewhat anticipated (i.e., in terms of the perceptual similarity in the variation upon the 3 dimensions - thereby allowing the possibility of more direct comparison of the dimensions), an additional issue became clear only after the testing of participants had begun. Although, discussion of this issue clearly pre-empts the following results section, it is convenient to consider the matter in light of the present examination of the stimuli used in the experiment.

Figure 8.2 below shows a scatter plot of the current stimuli across the two critical dimensions (i.e., dimensions 2 and 3; the bottom-left and bottom-right circles). The values on the dimensions are shown coded in terms of the proportion of the background circle that was 'filled' (using the original values, coding the position of the segment and size of the arc, gives an almost identical pattern). Although not shown on figure 8.2, the category structure can be clearly seen and is reflected by the following conjunctive rule: "If the bottom-left circle is less than half blue and the proportion of blue in bottom-right circle is greater than .3 respond category 'B', otherwise respond category 'A'".

However, anecdotal evidence obtained from verbal debriefing of the participants suggested that many were simply comparing the two bottom circles and responding 'A' if the bottom-left circle 'contained' more blue than the bottom-right circle and responding 'B' if the reverse was true. The decision boundary for this simple II rule is indicated on figure 8.2 (shown with a solid line).[1]

[1] This has been labelled as an II rule, reflecting the nature in which the dimensions are combined to arrive at a category decision. However, it is pertinent to note that this rule is clearly easy to verbalise. While it is considered more usual for RB rules to be verbalisable and II rules not to be so, this distinction is not exclusive (i.e., II rules can be verbalisable etc). The specific issue of the distinction between RB and II rules, or indeed whether any definite boundary exists, is not directly relevant to the present study. However, the availability and relative simplicity of this response strategy is critical and considered in more detail below.

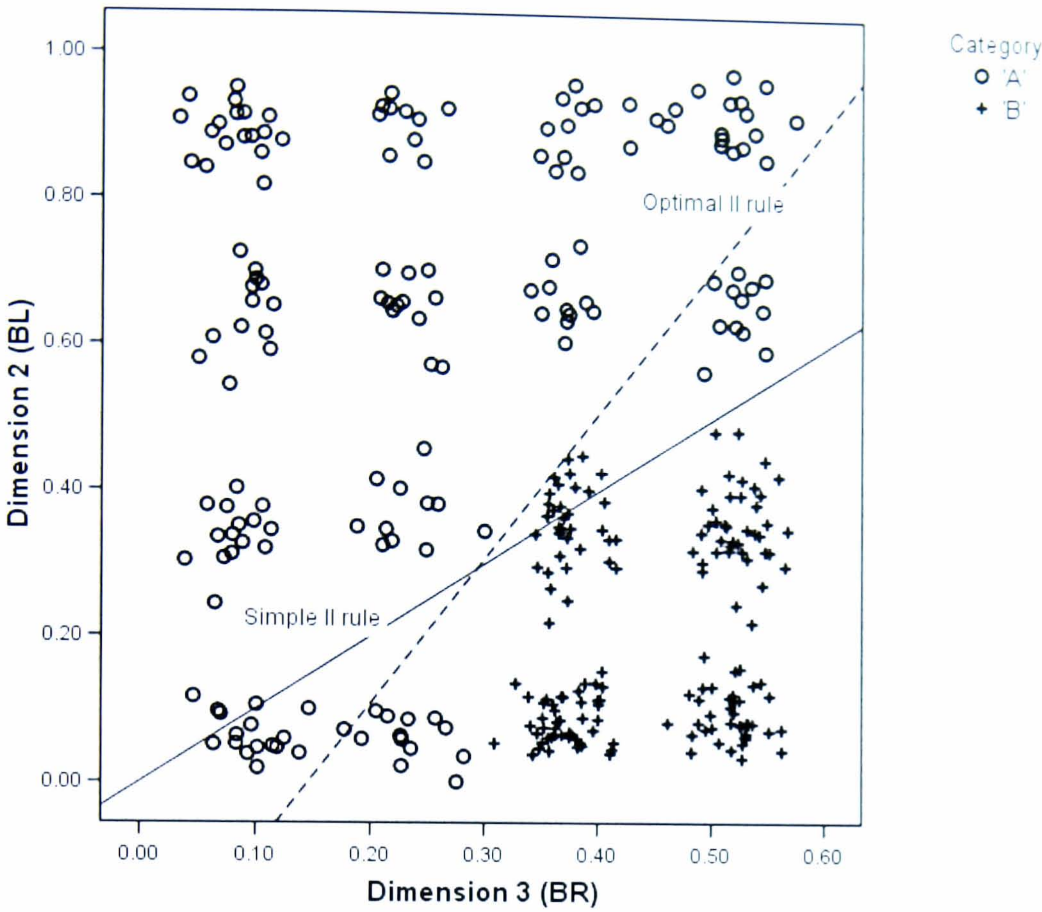

Figure 8.2: *Scatter plot of the stimuli across the two critical dimensions (scaled according to the proportion of fill); BL = bottom left stimulus element; BR = bottom right stimulus element*

A visual inspection of figure 8.2 shows that this simple rule provides a reasonably accurate response strategy that would give the appropriate category on the majority of trials. In fact, across the whole task this rule would lead to a response accuracy of 88.1%. This is marginally below the criterion performance level of 90%. However, if this strategy was applied throughout the task, the criterion level of performance would be obtained in 5 of the 8 blocks of trials. Furthermore, if the optimal II rule was applied, accuracy on the task would exceed the criterion level of performance in all but 1 of the 8 blocks of trials, with an overall accuracy of 92.5% (an approximation of the optimal II decision bound is marked with a dashed line in figure 8.2).

Clearly the availability and effectiveness of response strategies that apply these rules induces a serious caveat in the contemplation of the present study. This issue will be discussed in more detail in due course. However, it is worth a brief moment of reflection to consider the possible implications of this feature of the experiment. For example, these response strategies enable (partial) success on the task without the use of the optimal strategy. This may influence the use of strategies employed in the task and subsequently impact upon the assessment of 'cognitive flexibility'. A related issue concerns the relative complexity of these II (-like) rules. It could be argued that, although involving two-dimensions, these strategies are somewhat less cognitively demanding than the conjunctive rules (this issue is discussed in more detail later in the chapter). This again may affect the interpretation of success on the task as a reflection of cognitive flexibility. Accordingly, this caveat regarding the availability of sub-optimal yet somewhat successful response strategies warrants further consideration throughout the following sections. Crucially, however, the available II rules still require the consideration of more than a single dimension. Hence, it is still possible to assess the association between personality and performance on a task in which uni-dimensional response strategies are sub-optimal (cf. study 3 in which ImpASS was associated with poorer performance and a greater use of uni-dimensional strategies).

Eye-Gaze Assessment

The measurement of eye-gaze followed the identical procedure to that described in the preceding chapter. Participants were re-fitted with the headset at the beginning of the task and subsequently the calibration procedure was repeated. The stimuli were presented on the computer screen on a light-grey background (RGB 236 233 216) as illustrated in figure 8.1 above. The outline box represents the monitor screen (a central fixation point, not shown in the figure, was again presented for 500ms prior to the stimulus presentation at which point it was then cleared from the screen). The co-ordinates of the 3 stimulus dimensions formed an equilateral triangle, accordingly the (on-screen) distance between each dimension was 10 cm. Eye-gaze recordings were taken from the moment the stimulus was presented until 2000 ms after the auditory feedback was given.

Procedure

The present experiment was conducted alongside the task presented in the preceding chapter. The current task took approximately 40 minutes and was performed at the end of the experimental session (which lasted approximately 90 minutes in total). Consequently, all participants had previously completed the RB ET task (i.e., study 4) and were therefore somewhat accustomed to the ET procedure. After completing the initial ET task (study 4), participants completed two of the personality questionnaires (the EPQ and SSS) in order to allow a sufficient interval between the two ET tasks.

The general procedure followed that described for the previous ET task. The instructions were read to the participants prior to the fitting the eye-tracker headgear. Participants were subsequently informed that the present task was similar to the previous task in that they were asked to classify presented 'pictures' (stimuli) into two categories. However, it was emphasized that the categories were completely unrelated to the previous task (only the procedural nature of the task was similar). A description of the stimuli was then given to the participants and a reminder that their task was to learn to correctly classify each stimulus to either category 'A' or 'B' (by pressing the appropriately labeled response key).

Information was then provided that reminded participants of the general task procedure (i.e., to focus on the central fixation point prior to the presentation of each stimulus, that the stimulus would remain onscreen until an appropriate response was given and that auditory feedback would be provided to indicate whether the category response was correct or incorrect etc). Additionally, participants were informed that the task was divided into a number of blocks. Each block would have the same number of trials. Following the method of the previous behavioural version of the task (study 3) participants received points for correct classifications and no points for incorrect classifications. The participants were instructed that their aim was to attempt to reach the bonus level of 72 points in each block of trials. Subsequently, if they were able to attain 72 points or above on the final block of trials they would receive a ticket for entry into a prize-draw for £25 cash. Therefore, the general procedure of the task matched that of study 3.

Owing to the participants having previously performed the ET task that involved an unannounced switch of category rule (as described in the previous chapter), explicit assurances were given that the current task did not contain any 'tricks' and that the categories remained constant throughout the experiment. Participants were again asked to attempt to remain as stationary as possible throughout the task (and that they would be able to pause and relax somewhat at the end of each block of trials) and offered a final chance to ask the experimenter for any further clarification of the procedure.

The apparatus used in the present study was described in the preceding chapter. Each complete stimulus subtended a visual angle of 14.6°, with each individual dimension subtending a visual angle of approximately 1.76°. Each trial began with a central fixation point[2] presented for .5 seconds, followed by the presentation of the stimulus. The stimulus remained on the screen until either the category 'A' or category 'B' key had been pressed. At this point auditory feedback was given to indicate whether the stimulus had been correctly or incorrectly categorised (a pleasant tone or buzzer sound respectively). The stimulus then remained on the screen for a further 2 seconds. At this point the stimulus was cleared from the screen and a point meter, similar to that described in study 3 (p. 168), was presented. If the preceding response was correct, an increment in the point meter (equivalent to 2 points) occurred and this region flashed for a period of 1 second before remaining on the screen (in the 'filled' state) for a further second. This was accompanied by the cash-register ('kerching') sound (also applied in the previous behavioural version of the task). If, however, the preceding response was incorrect, the point meter was simply displayed in its current state for the 2 second period. The display was then cleared and followed by an inter-trial-interval of .75 seconds. Consequently, the use of point meter enabled participants to monitor their current progress and assess the utility of their response strategy in reaching the target level of performance (eye-gaze was not assessed during the presentation of the point-meter).

The task consisted of 8 separate blocks of 40 trials. Participants were attempting to learn how to successfully obtain 72 points within a single block of trials (i.e., the point meter was re-set to zero at the beginning of each block of trials) in order that they could win the prize-draw ticket in the final block of trials. At the end of each block of trials a summary of the participants' performance over the preceding block was given. For all except the final block trials, if the performance criterion had been reached (or exceeded), the participant was congratulated and informed that had that been the last block of trials then they would have earned the prize-draw ticket. If they had not attained the performance criterion within the block, the participant was encouraged to keep trying and informed that they would not have earned the tickets for the prize draw had that been the last block of trials. Naturally, on the final block of trials all participants were thanked and informed as to whether or not they had obtained the prize-draw ticket.

[2] The fixation point was located at the mid-point of the height of triangle as opposed to the centroid of the triangle; it was felt that the centroid, which is lower on the vertical plane than the midway point, may have biased participants' attention away from the top dimension

*(These analyses are based on the results from 31 of the participants. Owing to equipment failure the data from 1 participant was not recorded)

General Performance

Analogous to the previous behavioural version of this task (study 3, chapter 6), the performance criterion was 90% accuracy or above. Eleven (36%) of the participants met or exceeded this criterion on the last block of trials. Approximately half of the participants (15/31) failed to reach the performance criterion in any of the 8 blocks. The mean number of blocks in which the criterion performance was attained was merely 1.7 (SD = 2.3) demonstrating the difficulty of the task.

A plot of accuracy rates demonstrates a clear pattern of generally improving performance over the entire task which reaches an asymptote by the fifth block of trials. However, unlike the previous behavioural version of the task, presented in study 3, there appears to be no drop in performance between the first and second block of trials (cf. figure 6.3, p. 171). This suggests a rather different pattern of performance during the early stages of the task.

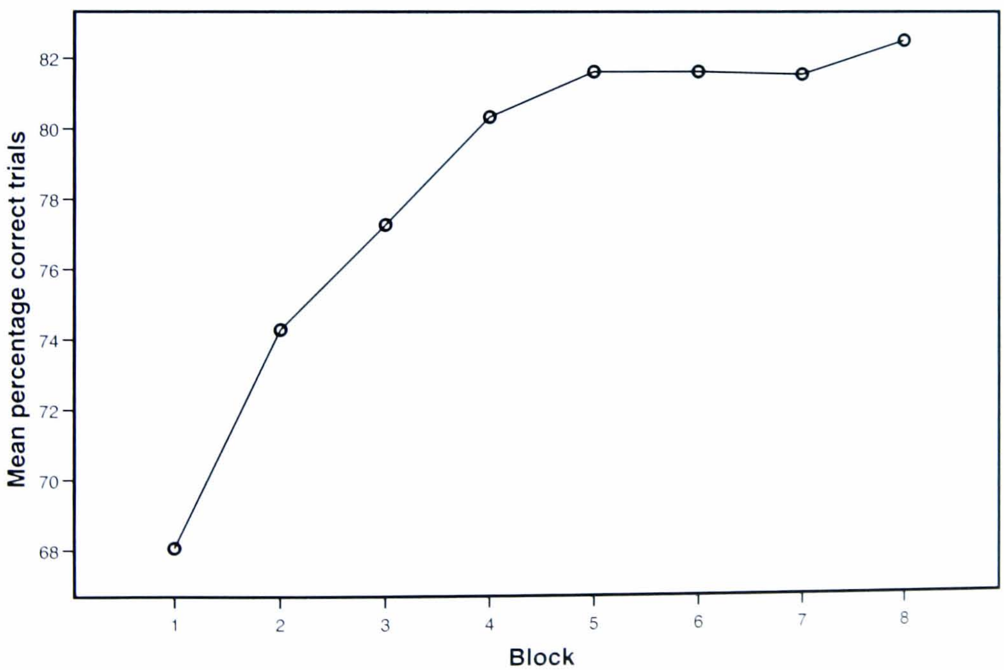

Figure 8.3: *Mean percentage of correct trials across the 8 blocks of trials*

Performance and Individual Differences

Overall accuracy (mean percentage correct trials) was not significantly related to age or gender (r's < .041) or any of the personality factors (shown in table 8.1 below).

Table 8.1: *Correlation between mean percentage of correct trials and personality*

		Extraversion	**ImpASS**	**Neuroticism**	**Positive Schizotypy**
Percentage correct trials (mean)	Pearson Correlation	.098	.090	.056	-.183
	Sig. (2-tailed)	.600	.632	.765	.323

A variety of methods were used to explore performance as indexed by other criteria. A median split procedure was applied to group participants into high and low scorers on the four personality factors. The initial analysis assessed the first block in which the performance criterion was exceeded. Hence scores ranged from 1 to 8, with 9 being used to code for those participants who did not reach the criterion performance in any block (i.e., the minimum number of blocks that would have been required). There were no significant differences between any of these groupings on the mean achievement of criterion performance. However, the largest between-groups difference was seen with ImpASS. The high ImpASS group first achieved the criterion level of performance after an average of 5.9 blocks, compared to 7.5 blocks for the low ImpASS group. This difference, although not significant ($t_{(29)} = 1.54$, $p = .135$), is in the opposite direction to that which may have been predicted from the previous 'equivalent' purely behavioural task.

Additionally, the number of blocks in which the criterion level was reached (i.e., range 0 – 8) was compared across the high/low personality groupings. Again there were no significant differences. However, there was a trend for better performance (by this measure) for the high extraversion group, who on average achieved at least 90% accuracy on 2.4 blocks (SD = 2.9) compared to only 1 block (SD = 1.4) for the low extraversion group ($t_{(21)} = -1.72$, $p = .100$, equal variances not assumed). For the following analyses only the results for ImpASS will be reported. (Analyses were performed on the remaining 3 personality factors, yet there were no significant findings).

To explore accuracy performance over the task a mixed design, block (8) by ImpASS group (2), ANOVA was performed on the percentage of correct trials in each block. There was a significant main effect of block ($F_{(3.7,\ 107.9)}$ 11.578, $p < .001$; Greenhouse-Geisser applied), with a significant linear trend of increasing accuracy over blocks ($F_{(1,\ 29)} = 21.731$, $p < .001$). In addition there was a significant quadratic trend ($F_{(1,\ 29)} = 16.258$, $p < .001$). Inspection of figure 8.3 above would indicate a negative quadratic pattern, whereby accuracy improved over the initial stages before levelling off somewhat over the latter half of the task.

There was not a significant main effect of ImpASS group ($F_{(1,\ 29)} = .076$, $p = .785$) however there was a significant interaction ($F_{(3.72,\ 107.9)} = 5.146$, $p = .001$; Greenhouse-Geisser applied). Following the significant linear and quadratic trends, consideration of the trend by ImpASS group interaction terms showed a significant interaction between the groups for the linear trend score ($F_{(1,\ 29)} = 6.532$, $p = .016$) and a similar, although non-significant, interaction for the quadratic trend ($F_{(1,\ 29)} = 3.259$, $p = .081$).

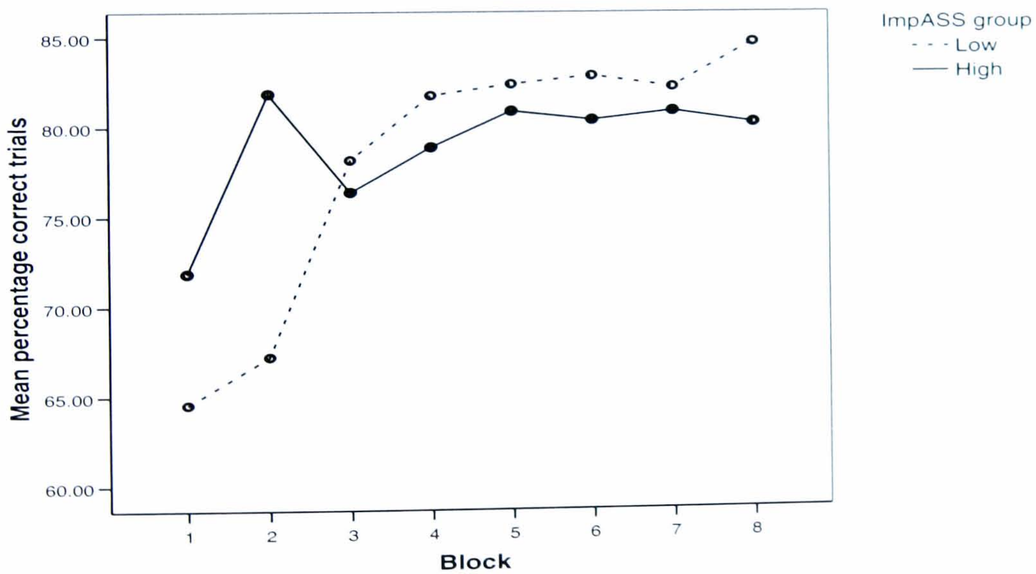

***Figure 8.4:** Mean percentage of correct trials across the task for the ImpASS groups*

The figure above suggests that the high ImpASS group initially achieved a relatively higher level of performance earlier in the task, yet their performance did not appear to improve as much as the low ImpASS group over the entire task. To compare the improvement in performance across the two groups, linear trend scores were calculated for each participant (cf. study 3). The significant interaction between the linear trend score and ImpASS groups reported above shows that the low ImpASS group showed greater improvement in performance across the task with a significantly higher linear trend scores (mean = 17.8, SD = 12.5) relative to the high ImpASS group (mean = 5.2, SD = 14.9). In addition, a one-sample t-test suggested that that mean linear trend score for the high ImpASS group was not significantly above zero ($t_{(14)} = 1.350$, $p = .199$). In contrast, the mean linear trend score was significantly above zero for the low-ImpASS group ($t_{(15)} = 5.681$, $p < .001$).

Quadratic trend scores were also calculated for each participant. The non-significant interaction between the quadratic trend and ImpASS groups, demonstrated there was only a trend for a greater (negative) quadratic trend in the low-ImpASS group. However, a one-sample t-test showed that the mean quadratic trend score was significantly different from zero for the low-ImpASS group ($t_{(15)} = -5.225$, $p < .001$). In contrast, the mean quadratic trend score was not significantly different from zero for the high-ImpASS group ($t_{(14)} = -1.320$, $p = .208$).

In this task participants were aiming to reach the criterion performance level in the last block of trials in order to win the chance to enter a prize-draw. Although the present sample size was somewhat limited, chi-squared tests were performed to test the association between achieving the performance criterion in the last block of trials (or not) and the median split groupings (i.e., high/low) of the four personality factors individually. No significant associations were found.

In summary, the accuracy analyses suggested that performance on the task generally increased over the blocks, although the significant quadratic trend suggested that performance levelled off over the final blocks. There was a trend for participants in the high extraversion group to reach the criterion level of performance more often. However, while there appeared to be no clear cut relationships between personality and overall performance, there was a clear demonstration of differences in learning across the task. Participants in the high ImpASS group appeared to attain the performance criterion earlier in the task. This result is in the opposite direction to that predicted from the behavioural experiment (study 3). However, the subsequent finding that the low ImpASS group showed relatively greater improvements in performance over the task, whereas the high ImpASS group's performance appeared relatively stable, was highly consistent with the previous study.

Response Strategy Modelling

Concordant with the previous behavioural version of the task (study 3), there appeared to be distinct qualitative differences in the pattern of performance across the task for the high- and low-ImpASS groups. To explore these differences in more detail formal modelling of participants' response strategies was performed. This was directly analogous to the modelling procedure applied in chapter 6, with similar models fitted to the data in the exactly the same manner as described for study 3 (e.g., the response data was modelled individually for each participant, for each block separately). In light of the feedback from participants, it was decided to model the data using the recoded stimulus values (i.e., the proportion of blue 'fill' on each dimension) as opposed to the raw dimension values.

Models Applied

The models applied were identical to those used in study 3. To recap, two categories of rule based models were fitted; uni-dimensional rules and two-dimensional conjunctive rules. In addition, two-dimensional II models were also fitted.[3] A 'guessing' model was also applied to the current data. These models involved the use of a single parameter that reflected the probability of responding with category 1 as opposed to category 2. Owing to the additional assessment of eye-gaze, the ability to filter participants who appeared to be 'guessing' on any individual block of trials may help in the ensuing comparison of response modelling and eye-gaze measures. All of the models were fitted to each participant's data individually. The models were fitted on a block by block basis to allow the examination of changes in strategy used over the task.

Modelling Results

Good fitting models (assessed by goodness of fit tests – see p. 177) were found for 203, of a possible 248 cases (i.e., 31 participants by 8 blocks). As described above, the stimuli in the present study may have enabled the greater use of II response strategies. As discussed earlier in the thesis it is likely that the modelling procedure has more power to distinguish the use of particular dimensions relative to the ability to discern the actual method of combining the information from these dimensions (i.e., II or RB strategy).

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[3] Three-dimensional models were also applied but are not discussed here

Accordingly, the best fitting models were classified into the following 4 categories:

Type 1) guessing

Type 2) uni-dimensional rules

Type 3) incorrect two-dimensional rules (either RB or II)

Type 4) correct two-dimensional rules (either RB or II)***

***Type 4 models use the appropriate two dimensions, whereas one of the two dimensions used in the type 3 models is not the correct one.

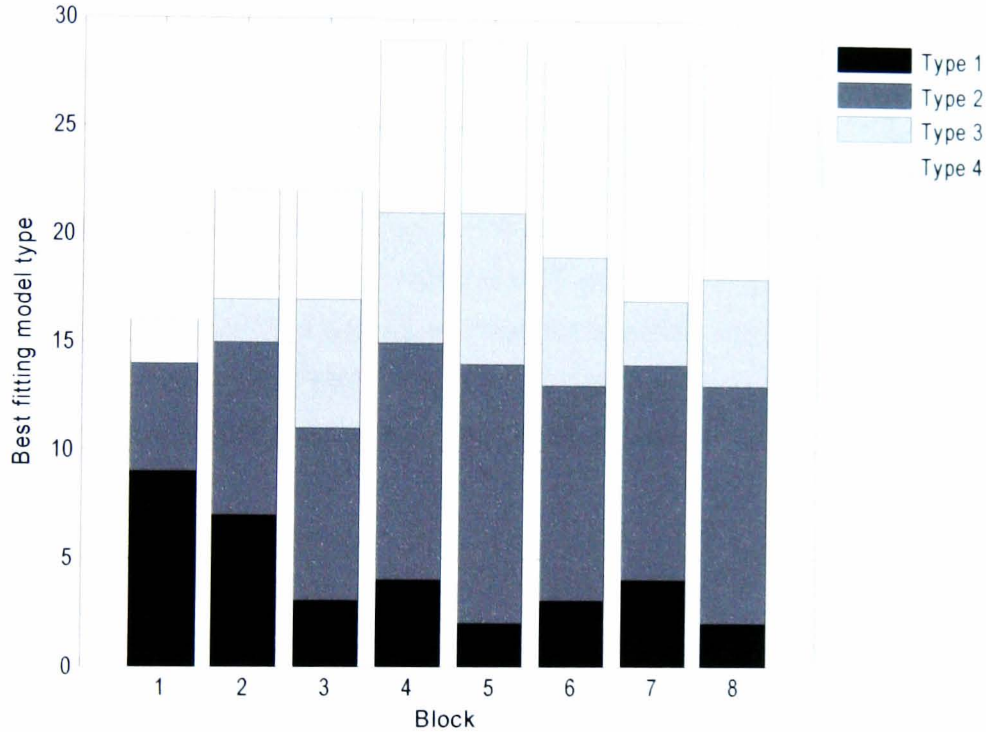

Figure 8.5: *Proportion of best-fitting model-types in each block*

Figure 8.5 above shows the frequency of the best fitting model types across the 8 blocks of the task. Firstly, it can be seen that the number of participants that appeared to be guessing decreased gradually over the task, from 9 in the first block to only 2 in the final block of trials. The use of uni-dimensional rules increased from just 5 (of 31) in block 1, up to 11 in block 4. From this point onwards the use of uni-dimensional rules remained relatively consistent, with an average of 11 (35%) of the participants' data best fitted by this model type between blocks 4 and 8. Model types 3 and 4 are the two-dimensional rules, whether (conjunctive) RB or II, for the incorrect and correct combinations of two dimensions respectively. The use of the incorrect combinations of two dimensions increased from 0 in block 1 up to an average of 5 over the last four blocks of trials. The use of the correct two combinations increased from only 2 in the first block to an average of 10 over the last 4 blocks of trials.

The performance of participants using the correct dimensions (type 4) was compared to the performance of those using either type 2 or 3 strategies. This was performed for the last 2 blocks of trials, where the application of a particular response strategy is thought likely to be most reliable. In both blocks 7 and 8, those using the correct dimensions performed significantly better, on average making 13% more correct responses ($t_{(23)} = -7.911$, $p < .001$; $t_{(24)} = -5.846$, $p < .001$ respectively). Critically the mean levels of performance for these comparison groups lay either side of the performance criterion level of 90% correct responses. Those using the correct two-dimensional strategy attained on average 93% and 94% correct trials on blocks 7 and 8 respectively, whereas those using inappropriate strategies achieved 80% and 82% respectively.

Additionally, there was a significant association between the strategy used in the last block of trials and whether the performance criterion (in this final block) was attained ($\chi^2_{(2)} = 17.396$, $p < .001$). None of the 11 participants who appeared to be using a uni-dimensional rule reached the criterion, whereas 9 out of 10 participants who used the appropriate two dimensions were able to obtain the prize draw ticket. Of the 5 participants who appeared to use an incorrect combination of two dimensions, 2 were able to reach the criterion in the final block of trials.

The general pattern of the modelling data across the task appeared to follow the expected progression and was related to performance in the predicted manner.

Strategy and Personality

As with the previous behavioural version of the task (study 3), various measures were created in order to explore possible relationships between personality and strategy use. The proportion of blocks in which a uni-dimensional strategy was used was calculated for each participant. This measure appeared unrelated to overall accuracy on the task ($r = -.115$, $p = .538$, $n = 31$). The proportion of uni-dimensional strategy was not significantly associated with personality (as shown in table 8.2 below).

__Table 8.2:__ Correlation between mean proportion of uni-dimensional rule use and personality (n = 31)

		Extraversion	ImpASS	Neuroticism	Positive Schizotypy
Proportion of uni-dimensional rules	Pearson Correlation	-.227	-.222	-.230	-.126
	Sig. (2-tailed)	.219	.230	.213	.501

In study 3, lower levels of ImpASS were related to the earlier use of the correct two-dimensional rule. Additionally, those participants who did not use the correct rule at any point during the task were significantly higher on ImpASS relative to those participants who did use the rule (at least on 1 block). It was therefore predicted that the corresponding relationships may be observed in this version of the task. While earlier use of the two correct dimensions was strongly related to better overall performance (percentage of correct trials; $r = -.694$, $p < .001$), it was unrelated to any of the personality measures. However, it was most strongly related to ImpASS, but in the opposite direction to that predicted and non-significant ($r = -.222$, $p > .05$). Hence, higher levels of ImpASS were actually related to earlier use of the correct two dimensions. In parallel with this, a trend for lower levels of ImpASS for those participants who did not appear to use the appropriate two dimensions at any point during the task relative to those that did was also observed ($t_{(29)} = -1.651$, $p = .109$).

Another prediction obtained from the previous behavioural version of the task (study 3) was that higher levels of extraversion may be associated with the earlier use of a two-dimensional strategy. Indeed, it was observed that the higher levels of extraversion were related to earlier use of a two- dimensional strategy ($r = -.359$, $p = .024$; 1-tailed). No other significant relationships were observed.

Finally, the relationship between personality and strategy use in the last 2 blocks of the task (when it is predicted that strategy use is the most stable and the modelling analyses most reliable) was considered. From the previous behavioural version of the task, it was predicted that lower levels of ImpASS would likely be associated with the use of the correct two-dimensional strategy relative to both incorrect multi-dimensional strategies and, possibly to a greater extent, uni-dimensional strategies. The number of participants in each response strategy classification on the final two blocks of the task is shown in table 8.3 below.

Table 8.3: Distribution of best-fitting model across final two blocks of trials

	Type 1 (Guessing)	Type 2 (Uni-dim.)	Type 3 (Incorrect two-dim.)	Type 4 (Correct two-dim.)
Block 7 (n = 29)	4	10	3	12
Block 8 (n = 28)	2	11	5	10

One-way ANOVAs were performed (individually for the last 2 blocks) with response strategy as the IV (4 levels; guessing; uni-dimensional rules, incorrect two-dimensional rules and correct two-dimensional rules) and scores on each personality factor as the DV. In the penultimate block of trials (i.e., block 7), there was a significant main effect of strategy type when looking at levels of ImpASS across these 4 groups ($F_{(3, 25)}$ = 4.207, p = .015). Those using the correct two-dimensional strategy had significantly higher levels of ImpASS relative to those participants using uni-dimensional strategies ($t_{(25)}$ = -3.412, p = .002 - uncorrected). Further contrasts were not considered due to the large disparity in group sizes. No other differences in personality were observed across these groups.

While on average ImpASS was highest for those participants using the correct two-dimensional rule in the final block of the task (block 8), the difference did not reach significance. There was no significant difference in ImpASS across the four strategy types. This result may be somewhat surprising and appears to reflect a change in the participants classified as using uni-dimensional rules across the two blocks (Only 7 of the 11 participants classified as using a uni-dimensional strategy in block 8 were also classified as using a uni-dimensional strategy in the previous block. In contrast, all 10 participants classified as using the correct two-dimensional in the final block had used this strategy in the previous block). Additionally, two participants that had used the correct two-dimensional rule in block 7 were classified as using a uni-dimensional and incorrect two-dimensional rule in the final block of the task; hence the reduction from 12 to 10 participants in this group. This may possibly reflect the combination of II and RB strategies. As discussed previously, the II strategy using the correct two dimensions would be only partially successful in achieving the criterion level of performance. This may suggest why these participants switched away from using the 'correct' two-dimensional strategy in the final block of trials.

There was also a significant difference in the levels of N across the four strategy groups on the last block of trials ($F_{(3,24)}$ = 3.874, p = .022). Those using two-dimensional rules showed higher mean levels of N relative to the remaining two groups. Those using the correct two-dimensional strategy were significantly higher on N relative to those using uni-dimensional strategies ($t_{(24)}$ = -2.625, p = .015 - uncorrected).

New variables were created to reflect the variety of strategy use throughout the task. Firstly the number of different strategy types used by each participant was calculated (i.e., range 1 – 4: guess/uni-dimensional rules/two-dimensional conjunctive rules/ two-dimensional II rules). While there was a significant positive relationship between the number of different strategies used and performance on the last block of trials (r = .542, p = .002), this measure was unrelated to any of the personality factors.

Similarly, the number of different combinations of dimensions used was also calculated. There were 6 different possible combinations of the 2 dimensions considered; the 3 dimensions used individually as well as the 3 possible combinations of 2 (from 3) dimensions. In addition, the use of two-dimensional strategies was further classified into conjunctive and II forms. Hence, there were 9 different possible strategy combinations considered overall (although the maximum number of different strategies used was limited by the fact that there were only 8 blocks of trials). Again, a positive relationship was seen with this measure and performance on the last block of trials (r = .532, p = .003, n = 29). Personality, however, was not significantly related to this measure.

To explore the relationship between use of two-dimensional conjunctive rules and two-dimensional II rules a ratio of conjunctive rule use relative to overall two-dimensional rule use was calculated. Hence, higher values indicated a greater proportion of conjunctive rule use. Surprisingly, given the design of the task, this measure was significantly negatively related to performance on the last block of trials (r = -.601, p = .003, n = 22) and also generally poorer performance on the whole task (r = -.393, p = .070, n = 22). While this measure was generally unrelated to personality, there was a weak negative relationship with ImpASS (r = -.310, p = .173, n = 22). This suggests very weakly that higher levels of ImpASS were related to proportionally greater use of II relative to conjunctive rules.

In conclusion, simple measures of strategy use on the present task appeared to be generally unrelated to the personality factors. However, in tandem with the previous behavioural version of the task (study 3), higher levels of extraversion were found to be related to use of multi-dimensional strategies earlier in the task. In contrast to the previous study, higher levels of ImpASS appeared to be related to earlier use of the correct dimensions and there was trend for lower levels of ImpASS for those participants who did not appear to use the correct dimensions at any point during the task. Additionally, in the penultimate block of the task, those using the correct two-dimensional strategy were significantly higher on ImpASS relative to those using uni-dimensional strategies. This pattern was the same for the last block of trials yet the difference was not significant. A final finding appeared to be a positive relationship between ImpASS and preference for two-dimensional II strategies relative to two-dimensional conjunctive rule strategies.

Before moving on to consider the data from the analysis of eye-gaze, it is worth briefly re-examining the modelling process. It was noted in chapter 6 (i.e., study 3, p. 179) that the modelling method was likely to be more powerful in distinguishing between the particular dimensions employed in a response strategy relative to the manner in which the dimensions were combined (i.e., in an RB- or II-like fashion). Hence, in both the previous and current study, response strategies were classified according to whether a single dimension or two dimensions were used and subsequently whether the correct two dimensions had be used (or not). In light of the stimuli set employed in the present experiment, it may appear somewhat unfortunate that a clear distinction between II and RB rules was not possible (and therefore detailed assessment of the relationship between personality and the use of RB or II rules involving the correct dimensions was not possible). However, the relatively small size of the present sample may have substantially limited the comparison of these types of strategies (involving the two relevant dimensions) even if a confident distinction was possible (furthermore, the ET data would not have been able distinguish between these types of rules).

Accordingly, the key distinction between the dimensions used in two-dimensional rules (as well as uni-dimensional rules) was maintained. However, in view of the ensuing assessment of selective attention, it is of interest to consider how much confidence can be afforded to the distinction between uni-dimensional and two-dimensional strategy use? There were 92 instances (of a possible 248) in which both a uni-dimensional and two-dimensional (either II or conjunctive RB) model provided a satisfactory fit to a participant's responses during a block of trials. A comparison between the best fitting uni-dimensional and the best fitting two-dimensional model was performed by considering the evidence ratio, obtained from the AIC values of the respective models. This considers the likelihood of the first model being correct relative to the likelihood of the second model being correct, as defined by the following equation:

$$\text{Evidence ratio} = 1 / \exp(-0.5 * AICd)$$

(where $AICd$ is the difference in AIC values between the models)

The evidence ratio is equal to 2 in the case where the AIC values on the two models differ by 1.3863. This means that the model with the lower AIC value is 2 times more likely to be correct compared to the model with the higher AIC value. If this difference increases to 5 then this likelihood increases to just over 12. The model with the lower AIC value is 148 times more likely to be correct if it is 10 units less than the comparative model's AIC value.

In the majority of cases (59%) the better fitting models were more than 12 times more likely to be correct (compared to the alternative best fitting model). In only 13 of the 92 cases (<15%) was the better fitting model less than 2 times more likely than the comparison model. Hence, in the majority of cases in which both model types (i.e., uni- and two-dimensional rules) provided an adequate fit to the data, the distinction between the two model types (in terms of likelihood of being correct) was unambiguous. This analysis therefore provides a degree of confidence in the classification of participants in terms of the distinction regarding the application of uni-dimensional or two-dimensional rules.

Eye-Tracking Data

The initial analysis of the ET data (i.e., determination of fixations and allocation of fixations to stimulus dimensions) was performed following the procedure described in the previous chapter. Importantly, the results presented in the preceding chapter appeared to provide a degree of support for the method (involving the extraction of fixations and subsequent assessment of eye-gaze measures). Before presenting the results of the analyses it is worth briefly considering a couple of issues related to the present experiment. Firstly, the task was of fixed length and involved significantly more trials than the previous ET study (320 trials cf. an average of 150 trials in the previous task). The initial calibration of the ET equipment occurred at the beginning of the experiment and the subsequent accuracy of eye-gaze measurement across the task was dependent upon the participant maintaining a stable position (i.e., upon the headrest). Naturally, the length of the task may have increased the possibility of substantial changes in the position of the participant over the course of the experiment, leading to degraded recording of eye-gaze. However, although there was a number of un-assessable ET data sets (particularly in the later blocks), in general the majority of the ET data appeared to be appropriate for further analysis (this issue is discussed in more detail below).

As discussed previously, the stimuli used in the present task introduced some ambiguity as to whether participants may have interpreted the variation upon the dimensions in terms of the underlying stimulus values (e.g., size of the radius of the blue inner circle, dimension 1) or the resultant proportion of the dimension feature filled with blue (i.e., the relative size of the inner blue circle in comparison with the background circle). Furthermore, the ability to directly compare the stimulus dimensions on this latter scale (i.e., proportion of 'fill') enabled the use of simple response strategies (e.g., the II rule described previously p. 228) not available in the previous behavioural version of this task (additionally, it is possible that the comparison of two dimensions in this manner may have lead to fixations occurring in between the locations of the two dimensions).

Naturally, analysis of the ET data is not able to assess these two issues directly (i.e., interpretation of the stimulus values and the use of RB or II strategies). However, it is hoped that the ET data may provide an additional method of assessing performance on the task as well as offering a means with which to verify the validity of the response strategy modelling.

<u>Fixation Analysis</u>

The first analysis involved a simple comparison between the dimensions that appeared to be fixated upon during each block and the dimensions that were implicated from the response strategy modelling. Firstly, the eye-tracking fixation data was examined for each participant individually on a block by block basis. The initial assessment (and filter) concerned whether the fixation data was clearly unusable or whether determination of the dimension locations (and hence assignment of fixations to dimensions) was ambiguous (see appendix G.1, p. 323, for examples of excluded data). Subsequently, for each block of the task, the dimensions upon which fixations appeared to be occurring were recorded for each individual participant. This process is best illustrated with the use of actual examples.

Figure 8.6 below shows the fixations extracted for an individual participant over the first block of trials.[4] The (mean) co-ordinates for each individual fixation extracted by the analysis program is represented by a single cross on the figure. The clusters of fixations appear to follow the location of the 3 dimensions of the stimuli. Accordingly, the boundaries of the 3 dimensions, determined through visual inspection of the data by the experimenter, are marked on the figure. Each fixation is subsequently attributed to one of the 3 dimensions (i.e., any cross located within the blue box is categorised as a fixation upon dimension 1 etc) or as an outlier (i.e., the 8 fixations not located with any of the dimension boundaries).

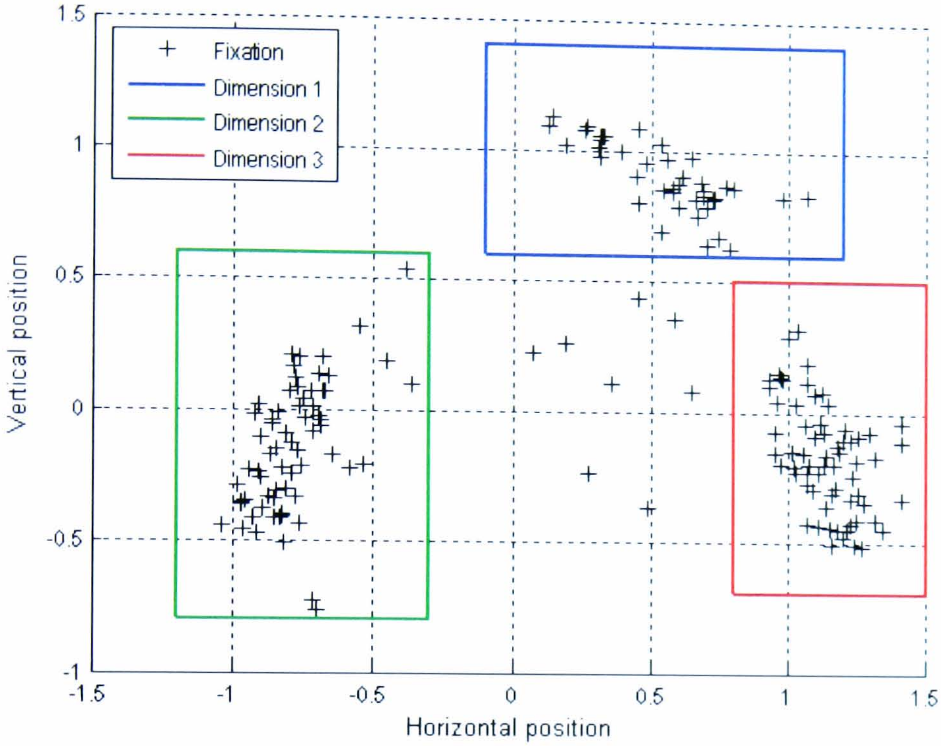

Figure 8.6: *Fixations and dimension boundaries for the first of block of trials (Participant 15)*

Figure 8.6 suggests that all 3 of the stimulus dimensions appeared to be fixated during the first block of trials, consequently, the pattern of fixations on block 1 for this participant was coded '123'. This enabled the comparison of the dimensions fixated over a block of trials with the dimensions implicated from the best-fitting response strategy model (i.e., provided such a model existed). In this example, the best-fitting model was the 'guessing' model. It is important to note that the experimenter was not aware of the respective response models during the coding of the fixation data. This process was repeated for each block of trials. Figure 8.7 below shows the pattern of fixations on the fourth block of trials (for the same participant).

[4] For clarity of presentation the first fixation of each trial has been excluded. These fixations often occur 'outside' of the dimension locations, likely reflecting the initial central fixation point

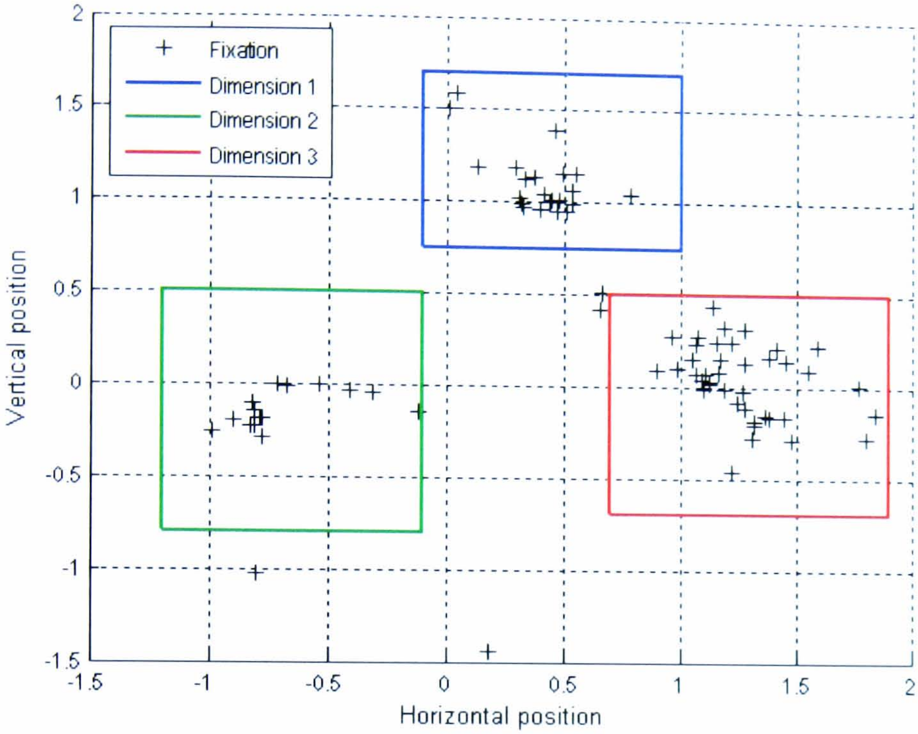

Figure 8.7: *Fixations and dimension boundaries for the fourth block of trials (Participant 15)*

In this example it can be seen that the number of fixations upon dimension 2 (bottom-left circle) was much reduced relative to the first block of trials (and less than the number of fixations made upon the other 2 dimensions). In fact there were only 14 fixations recorded for this dimension across the whole block of trials (again this figure does not include the first fixation from each trial. This reduced the number of fixations appearing on dimension 1, top-dimension, yet did not affect the number located with the dimension 2 boundary). Therefore, it was considered that this dimension would only have played a minor role (if any) on the response strategy for the respective block of trials. In contrast, it appeared more likely that the participant was 'focusing' upon dimensions 1 and 3. Consequently, the pattern of fixations on this block of trials was coded '13.2' (the decimal value '.2' indicating that dimension 2 may have had a minor role, while dimensions 1 and 3 were most prominent). In this example the best-fitting was indeed an II rule involving dimensions 1 and 3.

The final example presents the subsequent block of trials for the same participant (block 5). Figure 8.8 appears to suggest that only dimensions 1 and 3 were fixated during the block; subsequently this pattern of fixations was coded '13'. Again, for this participant, the pattern of fixations was concordant with the best-fitting response strategy model, which was a conjunctive RB model involving dimensions 1 and 3.

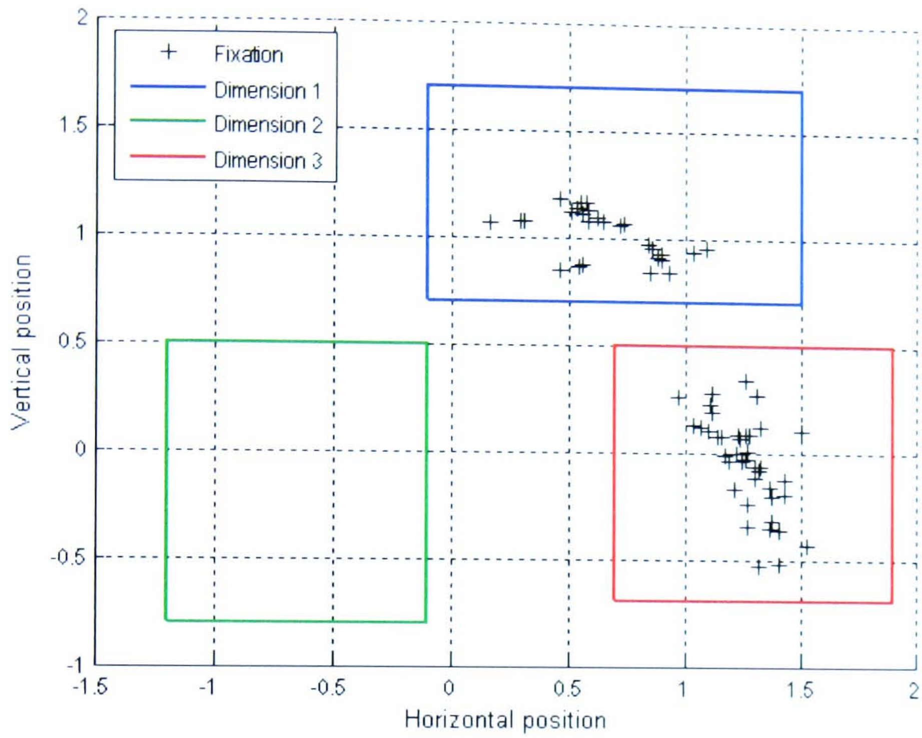

Figure 8.8: *Fixations and dimension boundaries for the fifth block of trials (Participant 15)*

Using this simple method, approximately 81% (200 of the 248 blocks; 31 participants by 8 blocks) of fixation patterns appeared to provide reasonably clear indications of the dimensions which were fixated in each block. In the majority of these cases (143 of the 200 assessable blocks, 72%) all three dimensions appeared to be fixated (i.e., those coded '123'). This is not unsurprising. As reported by Rehder and Hoffman (2005), participants tend to fixate all stimulus dimensions during the initial stages of learning (the fact that 100% accuracy was achieved in less than 3% of the blocks, 7 of the 248 blocks, suggests that in most cases 'learning' may have continued for the duration of the task). This pattern was supported in the current data; 93% of participants (with assessable ET data, 27 of 29) appeared to fixate all 3 dimensions in the first block of trials whereas only 65% (13 of 20) appeared to fixate all 3 dimensions in the final block of trials. Of course the fact that all 3 dimensions appeared to be fixated does not mean that they were all used in the concurrent categorisation strategy. Therefore, any of the possible response models could be regarded as congruous with this pattern of eye fixations.[5]

[5] As mentioned previously, three-dimensional II models were also fitted to the response data. However, this model was found to be the best-fitting model in only 15 cases/blocks. Hence it is unlikely that the fixation of all 3 dimensions indicated that a three-dimensional was being applied

Possibly more informative are those blocks in which fewer than all 3 of the dimensions appear to have been fixated. In 7.5% of the valid ET blocks (15 of the 200 assessable blocks) eye fixations seemed to focus upon a single dimension, while in the remaining 21% of blocks (42 of the 200 assessable blocks), 2 dimensions appeared to be fixated. The level of congruency between the dimension fixations and dimensions implicated from the response modelling in these blocks may therefore provide a useful assessment of the response strategy modelling. In total there were 57 blocks in which the eye-tracking data suggested that fewer than all 3 dimensions were fixated upon (compared to 143 in which all 3 dimensions appeared to be fixated). 51 of these blocks also had a good fitting response model. However, one of these models was a guessing model and consequently this data was excluded as this does not provide any prediction regarding use of the dimensions.

The following analysis is therefore based upon the 50 instances, or blocks (just over 20% of all possible), in which the ET data suggested that fewer than 3 of the dimensions were used and additionally a good fitting response strategy model was available. The comparison of the fixation data and response strategy yielded three distinct classifications:

1) congruent
2) partially congruent
3) incongruent

The two sets of data were classed as congruent if the predicted dimension/s fixated or used (in the response strategy) matched exactly (any dimension/s listed as having a 'minor role' from the fixation analysis were ignored). If the dimensions predicted from the response strategy model did not exactly match, but were a subset of those predicted from the fixation data (including any dimension/s listed as having a 'minor role'), then this was classed as partially congruent. Incongruent data was therefore any instance in which any dimension or dimensions predicted to be involved in the response strategy did not appear in the eye fixation data. Figure 8.8 above gives an example of a congruent classification (examples of a partially incongruent classification and the single incongruent classification can be found in the appendix, G.2, p. 324)

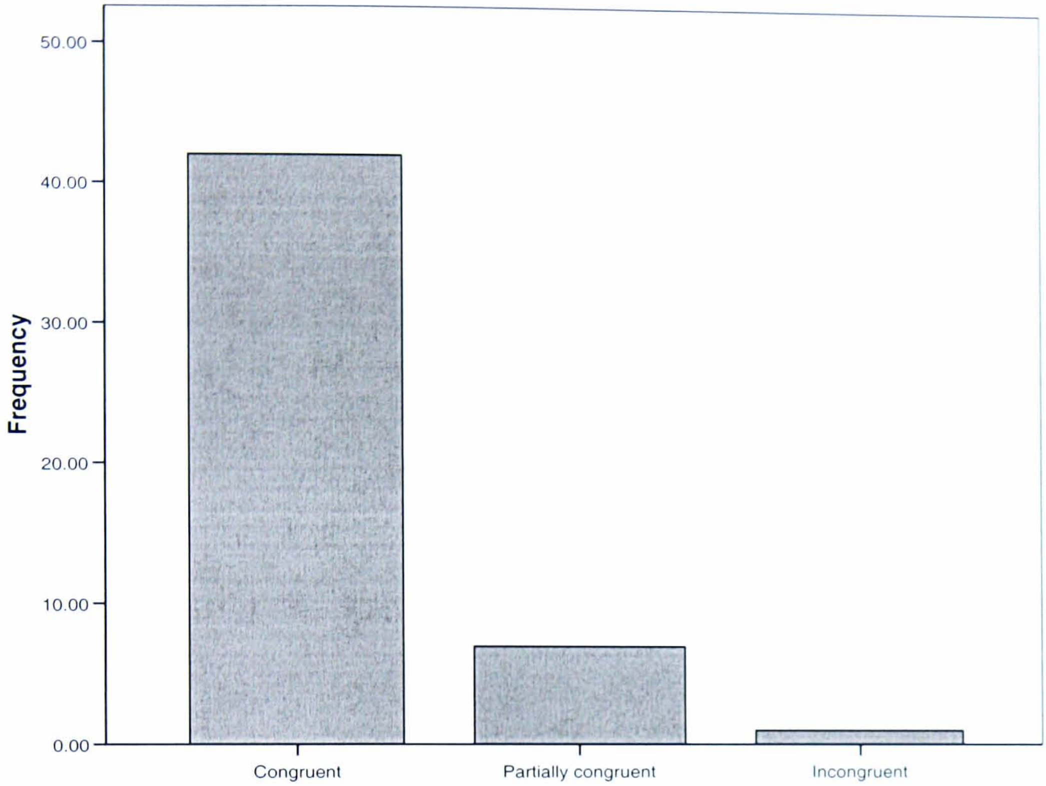

Figure 8.9: *Congruency between ET data (implicating two- or uni-dimensional response strategies) and formal modeling of response strategy*

Figure 8.9 clearly shows that for the vast majority of this data (84%) the predicted use of dimensions from the response strategy modelling was completely congruent with dimensions that appeared to be most often fixated (from the eye-tracking data). In 7 cases the response modelling prediction was at least partially congruent with the fixation data. For 6 of these 7 cases, the response modelling predicted the use of a single dimension which appeared to be one of the two main dimensions fixated upon (i.e., in only case did the single dimension predicted from the response modelling appear to be playing a 'minor role' in the fixation data). Only one instance was observed in which a dimension, predicted to have been used from the response strategy model, did not appear to have been fixated upon. These results would therefore appear to demonstrate fairly robust initial validation of the response strategy modelling.

Eye-Tracking Analyses

In addition to the consideration of the mean number of fixations made, three key measures were derived from the ET data, identical to those described in the preceding chapter. In contrast to study 4, these measures were assessed on a block-by-block basis (although in some respects this is equivalent to a 'per-trial' measure as the blocks were all of fixed length). In addition, the emphasis was placed upon the comparison of the response strategy modelling and ET measures (cf. the ET measures and critical rule dimension in the uni-dimensional RB task). To recap, the measures were 1) the mean number of dimensions fixated, 2) the proportion of fixation time (upon the dimensions implicated by the response strategy models) and 3) fixation priority (again reflecting the dimensions implicated from the modelling). The results presented below are a brief selection of the analyses performed.[6]

Number of Fixations

The overall number of fixations made did not appear to be strongly related to performance on the task or personality measures. The mean number of fixations (per block of trials) was weakly positively related to neuroticism ($r = .243$, $p = .205$, $n = 29$), positive schizotypy ($r = .247$, $p = .197$, $n = 29$) and extraversion ($r = .200$, $p = .299$, $n = 29$). Performance appeared also unrelated to the number of fixations (whether this was comparing mean number of fixations across the task with the performance on each block or performance overall, or individually comparing the number of fixations and performance on each block separately).

Mean Number of Dimensions Fixated

For each participant, the mean number of dimensions fixated was calculated for each block. Subsequently the overall mean number of dimensions fixated (and standard deviation) was calculated for the entire task. As may be expected, this measure was positively, albeit weakly, related to overall percentage of correct trials ($r = .303$, $p = .110$, $n = 29$). A similar relationship was observed with higher levels of extraversion also weakly positively related to mean number of dimensions fixated ($r = .311$, $p = .100$, $n = 29$). Extraversion was also negatively related to the standard deviation of this measure (for participants with good fixation data on all 8 blocks: $r = -.585$, $p = .007$, $n = 20$; all participants with at least one valid block of good fixations: $r = -.344$, $p = .067$, $n = 29$).

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[6] This brief summary is offered in light of the ambiguity inherent in the present task, i.e., the ability to apply II-like rules, and general lack of any clear cut findings in the results

Proportion of Fixation Time

For each participant (with acceptable ET data), the proportion of fixation time for each of the 3 stimulus dimensions was calculated for each block. This data was then compared to the participant's response strategy (again provided there was a good fitting model). There were 61 instances (or blocks) in which both the best fitting model was uni-dimensional and credible eye-fixation data was available. In addition, there were 74 cases in which the best fitting model was two-dimensional and eye-fixation data appeared reliable.

1. Uni-dimensional rules (61 blocks)

If a single dimension was being used to guide responses then it may be expected, although not essential (see later discussion), that this dimension was likely to receive the greatest proportion of trial by trial fixation time, at least when averaged across the entire block. This indeed appeared to be the case. For 58 (95%) of the 61 cases, the single dimension predicted to have been used received the greatest proportion of overall fixation time.

The degree to which the single dimension (predicted to have been used from the response strategy modelling) monopolised fixation time was assessed. The mean proportion of fixation time given to the single dimension was 68% (SD = 18), ranging from 40% to 100%. There were 17 participants that contributed to these 58 instances, or blocks, in which a uni-dimensional response strategy was used and in which the ET data was congruent (that this dimension received the greatest proportion of fixation time). For each of these participants, the mean (i.e., averaged across the number of blocks in which a uni-dimensional strategy was used) proportion of fixation time on the relevant dimension was calculated. Hence, a higher value indicated that when using a uni-dimensional rule the participant fixated to greater degree on this single dimension (to the exclusion of fixation time upon the other dimensions). This measure was unrelated to overall performance, yet was highly negatively correlated with extraversion ($r = -.526$, $p = .030$, $n = 17$) and positively related to the neuroticism factor ($r = .477$, $p = .053$, $n = 17$). This would tentatively suggest that, when using uni-dimensional rules, extraversion was related to a lower degree of focus, and neuroticism a higher degree of focus, upon the (single) dimension being used.

As reported above there were 3 cases in which the single dimension predicted to have been used from the response strategy model did not receive the greatest proportion of fixation time. However, the dimension implicated (dimension 1, top circle) did receive a sizeable proportion of fixation time (ranging between 20 – 35%, as averaged over the block). There are a number of reasons why this may occur. For example, the participant may have used another dimension at the beginning of the block, or continued to view the other dimensions while making responses based on the top dimension. An important point, however, is that in no instance did the single dimension predicted to have been used receive a negligible degree of fixation time (say <5%). (This contrasts with 21% of the cases in which at least 1 of the 2 'unused' dimensions received less than 5% of the overall fixation time).

2. Two-dimensional rules (74 blocks)

A similar approach was taken for the 74 cases in which the modelling indicated that a two-dimensional response strategy was used. Again, it may be expected that the two-dimensions implicated by the response strategy would receive a greater proportion of fixation time. Indeed, in 54 of these cases the dimension not connected to the response strategy received the lowest proportion of fixation time. The mean proportion of fixation time given to the dimension not implicated by the response strategy was 9% (SD = 9), ranging from 0% to 30%. There were 18 participants that contributed to these 54 cases. Again a measure was created which calculated the mean proportion of fixation time given to the 'unused' dimension for these 18 participants. This value was then subtracted from 1, and hence reflected the (mean) proportion of fixation time devoted to the dimensions implicated by the two-dimensional response strategy. (This allows easier comparison with the analogous uni-dimensional measure). Therefore, a higher value on this measure indicated a greater proportion of fixation time given to the 2 relevant dimensions (and hence a lower proportion of fixation time on the 'unused' dimension).

In line with the corresponding analysis for the uni-dimensional strategies, this measure was again unrelated to overall performance. However, it was positively correlated with extraversion ($r = .473$, $p = .048$, $n = 18$) and negatively related to the neuroticism factor ($r = -.426$, $p = .078$, $n = 17$). This would appear to suggest that, when using two-dimensional rules, extraversion was related to a greater prioritisation, and neuroticism a lesser prioritisation, upon the two dimensions being used. This is pattern is exactly opposite to that observed with uni-dimensional rules.

Therefore, there were 20 cases in which one of the dimensions implicated in the two-dimensional response strategy received the lowest proportion of fixation time. Again, there are a number of possible reasons to explain why this may occur. For example, comparison of the proportion of fill of two of the dimensions being used may occur quite rapidly. A greater of proportion of time may then be spent on the additional assessment of the third dimension (e.g., comparison of the proportion of fill of the 3rd dimension relative to each of the other 2 dimensions individually could plausibly lead to a greater time spent fixating the 3rd dimension as it is involved in both of the comparisons). Alternatively some dimensions may take longer to assess. However, in 15 of the 20 cases, the combined proportion of fixation time for the two response strategy dimensions was greater than that of the remaining dimension. Naturally, it is also possible that this situation may arise due to errors in the assignment of fixations to specific dimensions.

Dimension Priority

The results from the assessment of the dimension priority measure mirrored those of the proportion of fixation time and are not reported.

Eye-Tracking Analysis Summary

Initial analyses appeared to demonstrate a good level of congruency between the eye tracking data and the response strategy modelling. A degree of support for the validity of the response strategy models was demonstrated by the finding that in only 1 case (out of 50) in which fewer than all 3 dimensions appeared to be fixated, did the response strategy model suggest the use of a stimulus dimension that did not appear to have been fixated upon. This view was also supported by the fact that in 95% of blocks in which a uni-dimensional strategy was used, the dimension implicated received the highest proportion of fixation time. Likewise, in 73% of the cases in which a two-dimensional strategy was used, the dimension thought not to be involved in guiding responses received the least proportion of fixation time (in 20% of the remaining 27% of cases the combined proportion of fixation time upon the relevant two dimensions was still greater than that of the remaining dimension).

The proportion of fixation time devoted to the dimension/s implicated by the response strategy modelling within any given block of trials was considered to reflect the degree of attentional focus (i.e., upon the dimensions involved in the response strategy). When using a uni-dimensional strategy extraversion was related to a lesser, and neuroticism a greater, degree of focus upon the single dimension being used. The degree of focus was however, unrelated to overall performance. Likewise, when using a two-dimensional strategy, the degree of focus upon the two dimensions implicated was unrelated to overall performance. However, in direct contrast to the findings with uni-dimensional rule use, extraversion was related to a greater, and neuroticism a lesser, degree of focus upon the two dimensions being used.

Additionally, the number of fixations made appeared to be generally unrelated to either personality or performance. However, extraversion was related to a higher mean number of dimensions fixated (per trial) (which was in turn weakly related to better overall performance), as well as lower variation on this measure.

DISCUSSION

The principal objective of the present study was the re-examination of the association between personality and performance on a task requiring cognitive flexibility (as reported in chapter 6). The current experiment aimed to further the understanding of personality mediated differences in performance through the additional assessment of selective attention (eye-gaze) during the learning of novel stimulus-category associations. As discussed in detail in the preceding Method section, a methodological oversight in the design of the stimuli in the present study gives rise to a significant caveat in the resulting interpretation of the data. This issue will be briefly re-visited before further discussion of the results.

A key feature of the cognitive flexibility paradigm employed in the previous behavioural version of the present task (study 3) was the availability of a variety of sub-optimal response strategies. More specifically, any of the individual stimulus dimensions could be used to construct a uni-dimensional response strategy that subsequently afforded a reasonably high, although sub-optimal, level of performance. Crucially, use of the uni-dimensional rules did not allow the criterion level of performance to be achieved. Consequently, the ability to abandon the relatively successful uni-dimensional rules for more complex strategies (and ultimately the appropriate two-dimensional conjunctive rule) was considered to reflect the capacity for cognitive flexibility. To recap, study 3 found that ImpASS was associated with decreased cognitive flexibility (and a preference for uni-dimensional rules) whereas extraversion was associated with increased cognitive flexibility and greater success on the task.

Accordingly, the present task aimed to replicate the previous study alongside the additional examination of selective attention in order to provide a further assessment of response strategies employed during the task. The inclusion of eye-gaze measures necessitated the creation of an appropriate set of stimuli, as discussed previously. Unfortunately, the stimuli used in the present study allowed the use of response strategies not available in the previous study (i.e., the direct comparison of stimulus dimensions through the consideration of the proportion of fill on each dimension). Naturally, the availability of these rules may have affected the variety of ways in which participants attempted to classify the stimuli.

While the possibility of these additional response strategies was somewhat anticipated, the relative success of the II-like strategy involving the 2 relevant dimensions was not envisaged. Consequently, although not 100% effective, it was possible for the participants to obtain the criterion level of performance with the application of a response strategy other than the correct two-dimensional conjunctive rule. This provided an additional complication in the consideration of performance on the task. For example, if a participant achieved success with the II-like rule then they may not have continued to pursue an alternative response strategy (e.g., any failures to achieve the criterion level of performance in subsequent blocks may have be interpreted as an inaccurate application of the decision criterion rather than an invalidation of the current strategy).

Furthermore, classifying the exact nature of rules that involved the direct comparison of dimensions was somewhat ambiguous. For example, comparison of two dimensions in respect of the 'proportion of fill' may be viewed as an II rule (i.e., the information from the two dimensions is combined at a pre-decisional stage). However, such rules may also be easily verbalisable (e.g., if the bottom-left circle has more 'blue' than the bottom-right circle, respond 'A' etc) and in that way be more similar to typical (e.g., RB) rules. Thus, it may be somewhat speculative to attempt to order the different rules in terms of their cognitive complexity (i.e., were the two-dimensional conjunctive RB rules more or less complex than the respective two-dimensional II-like rules).

Therefore, from the perspective of cognitive flexibility, the assessment of performance on the present task is somewhat tempered by the availability of these additional (II-like) rules. More specifically, the possible attainment of the criterion level of the performance, through the comparison of the relevant dimensions using an II-like rule, may interfere with the expected progression from uni-dimensional rules to the correct two-dimensional conjunctive rule. Furthermore, although involving 2 dimensions, the simplicity of the verbalisable II-like rule may not require as great a degree of cognitive flexibility as the two-dimensional conjunctive rule (although, as mentioned above, a definitive position on this issue is somewhat speculative). However, despite this caveat, the present data did offer a variety of results worthy of further discussion.

In common with study 3, accuracy levels generally increased across the task. However, one distinct difference with performance on the present task was the absence of a drop in accuracy levels in the second block of trials (accordingly, the negative cubic trend observed in the previous study was not seen in the present data). It is possible that this reflects the structural differences between the two sets of stimuli (i.e., the availability of simple II-like rules). For example, a proportion of participants may have discovered the (partially) successful II-like rule in the first block of trials and subsequently continued with this strategy in the second block of trials (and possibly beyond). In contrast, it was suggested that participants in the previous study may have applied uni-dimensional rules in the first block of trials, which provided reasonable yet sub-optimal accuracy levels, and subsequently the drop in performance upon the second block of trials may have reflected the pursuit of more successful strategies.

Results from the previous behavioural version of the task (briefly reprised above) lead to some specific predictions concerning the association between ImpASS, extraversion and performance on the task. In contrast with the previous version of the task, ImpASS was not associated with poorer overall accuracy. In addition, the relationship between this trait and the criterion level of performance was in the opposite direction to that which would be expected from the previous task; ImpASS was weakly related to the earlier attainment of the criterion level of performance. Naturally, an obvious postulation for these results could be the availability of the II-like rule that subsequently lead to greater accuracy (i.e., relative to the previous association with poorer performance) and earlier achievement of the criterion level of performance. However, as discussed previously, a simple II-like rule involving the comparison of the bottom two dimensions (i.e., responding 'A' or 'B' depending on whether the bottom-left or bottom-right circle contained a higher proportion of blue) was only partially successful in obtaining the 90% accuracy level required. This may be one explanation for the lack of an association between this trait (or indeed any trait) and overall performance.

However, one pattern of results which appeared highly consistent with the previous behavioural study (chapter 6) concerned the relationship between ImpASS and variation in performance across the task. In the present experiment, the high-ImpASS group did not appear to demonstrate significant improvements in accuracy levels across the 8 blocks of trials (i.e., linear and cubic trend scores, reflecting increasing accuracy across the task, were not significantly different from zero for this group). In contrast, the low-ImpASS group showed a significantly greater linear pattern of increasing accuracy across the blocks of trials relative to the high-ImpASS group (and a trend for a greater negative quadratic pattern). This pattern was essentially identical to that observed in study 3, wherein the greater improvement in performance across the task was thought to reflect greater cognitive flexibility.

However, in the present study it could be argued that the lack of association between the high-ImpASS group and increasing accuracy across the task simply reflected the fact that this group attained a higher level of accuracy earlier in the task as opposed to a demonstration of decreased cognitive flexibility. This interpretation is suggested by the observation that, on average, this group obtained a higher number correct responses on the first two blocks of trials relative to the low-ImpASS group. There was no significant difference between the high- and low-ImpASS groups on overall levels of performance. Hence in this instance, the stronger linear trend for the low-ImpASS group may simply reflect the relatively poorer earlier performance of this group. Again this result may possibly have been influenced by the availability of the II rule (involving the 2 relevant dimensions) which may have enabled the high-ImpASS group to obtain (and possibly maintain) the relatively high level of performance from the outset. However, this is purely speculative and would still leave unanswered the question of why this group were able to apply this strategy.

A contrasting perspective may view the performance of the high-ImpASS group as a demonstration of cognitive *in*-flexibility; these participants appeared unable to improve upon their initial (albeit comparatively high) level of performance over the later stages of the task. Although their performance on the first 2 blocks of trials appeared poorer than the high-ImpASS group, the low-ImpASS group showed greater improvement in performance; in fact on average this group attained higher levels of accuracy on each of the final 6 blocks of trials. Consequently, to some degree, this pattern may be construed as demonstrating greater cognitive flexibility. Owing to the constraints of the ET method, the present task was substantially shorter than the previous behavioural version (i.e., 8 cf. 12 blocks of trials, 40 cf. 48 trials). It is therefore interesting to speculate as to whether the greater improvement in performance shown by the low-ImpASS group would possibly have lead to significantly better performance had the task been of sufficient length.

Despite the caveat detailed above, the present study may offer tentative support for the previous behavioural results reported in study 3. Although, there were some distinct qualitative differences in the patterns of performance over the two tasks, a consistent finding concerned the generally static level of performance of the high-ImpASS group relative to the generally improving performance of the low-ImpASS group. Additionally, while the previous association between extraversion and better performance was not significant in the present study, there was some evidence for a similar pattern, as extraversion was (weakly) associated with the more frequent attainment of the criterion level of performance.

Formal modelling of participants' response strategies again appeared to provide a useful insight into performance on the task. The models were somewhat validated by predictable relationships with performance on the task (e.g., over the last 2 blocks of trials, those participants that employed a strategy involving the 2 correct dimensions performed significantly better than those that did not. Consequently, the use of strategies involving these 2 dimensions was associated with the successful achievement of the performance criterion in the final block of trials). The results of the modelling additionally suggested that (a form of) cognitive flexibility was indeed associated with better performance on the task as the use of both a greater variety of response strategies and a wider range dimension combinations were associated with better performance on the last block of trials.

In general, the simple measures of response strategy appeared to be unrelated to personality. However, in support of the result reported in study 3, extraversion was again positively associated with the earlier use of two-dimensional strategies. Together with the positive association between extraversion and the more frequent attainment of the performance criterion, the present data would appear to demonstrate a degree of congruency with the previous behavioural version of the task. Accordingly, the present finding supports the possible link between extraversion and superior performance on such tasks, possibly mediated by cognitive flexibility or situational factors (e.g., reward-dependent learning).

However, the relationship between ImpASS and strategy use during the task was somewhat at odds with the previous study. For example, higher levels of ImpASS were associated with the earlier use of the correct two stimulus dimensions as well as the use of the correct two-dimensional rule (relative to uni-dimensional rules) over the last 2 blocks of trials (although the difference was only significant in the penultimate block). This contrasts with the previous study in which higher levels of ImpASS were associated with reduced cognitive flexibility and a preference for uni-dimensional rules. However, the relationship between response strategy modelling and

ImpASS may be considered largely compatible with the preceding discussion of the association between performance (i.e., response accuracy) and ImpASS. For example, the high ImpASS group attained a relatively high level of performance over the first 2 blocks of trials and appeared to maintain this level of performance across the task. This would seem highly consistent with the earlier use and preference for response strategies involving the correct two dimensions.

Again an obvious candidate for a partial explanation of these results could be the availability of the simple II-like rules. The early discovery and use of this type of rule (especially involving the comparison of the 2 relevant dimensions) could lead to the pattern of performance and association with strategy measures observed for the high-ImpASS group. Naturally, this speculative suggestion invokes the untested assumption that the high-ImpASS group may have an enhanced ability or preference for this type of rule. Interestingly, however, there was a weak association between ImpASS and the greater use of two-dimensional II rules relative to two-dimensional rules which may support this proposal (although a degree of caution is required owing to the relatively small size of the sample and constrained power of the modelling method to distinguish between II/RB strategies).

If the validity of the assertion above could be verified, then the present results may not be as incompatible with the previous study as they may at first appear. It could be argued that the II-like rules available in the present task are more akin (e.g., in terms of salience) to the simple uni-dimensional rules than the more complex conjunctive rules. In addition, in comparison with the decision processes involved in the application of uni-dimensional rules, the II-like rules could be construed as involving only one (key) judgement (i.e., does the bottom-left circle contain more blue than the bottom-right circle cf. does the bottom-left circle contain more than 50% blue). Therefore, although involving 2 dimensions these response strategies may be somewhat less complex than the conjunctive rules (which require separate decisions to be made upon each dimension value before a final judgement involving the combination of these two decisions). It could therefore be suggested that the association between ImpASS and the use of these rules is somewhat congruent with the preference for uni-dimensional rules found in study 3. Furthermore, this may suggest an interpretation that reflects a preference for more simple or more salient rules, rather than a more specific preference for uni-dimensional rules.

Naturally the ability to attain the criterion level of performance with these sub-optimal rules (at least for a significant proportion of blocks) somewhat interfered with the ability to assess cognitive flexibility on the present task. Additionally, the length of task was significantly reduced relative to the previous behavioural version. This is somewhat unfortunate as a greater number of blocks (and trials) may have allowed an increased possibility for variation in performance and response strategy to develop across the task. These factors may have impacted upon the unexpected association between the low-ImpASS group and a greater use of uni-dimensional strategies. However, this result remains difficult to interpret with respect to the previous study. Clearly, further research is required to disambiguate the association between personality and CL in the presence of multiple response strategies. One future line of study could attempt to consider separate features of category complexity including the number of dimensions involved and the manner in which dimensions need to be combined or compared.

A novel aspect of the current study was the application of measures of eye-gaze as an index of selective attention during the performance of the task. The logic of this method was discussed in the preceding chapter and will not be reprised here. Alongside the general exploratory utility derived from the application of this technique, one key benefit of the assessment of selective attention during the task was the objective corroboration of participants' response strategies. A number of results involving the ET measures provided a high degree of support for the general efficacy of the modelling data. Firstly, there were 50 individual blocks of trials (of 200 assessable blocks) in which the ET data suggested that 2 or fewer of the dimensions were being fixated. There appeared to be only one case in which the dimensions that appeared to be fixated during the block of trials appeared completely incongruent with the dimensions implicated by the best-fitting response strategy model. Furthermore, in the majority of these cases the dimensions implicated from the ET data and response models were entirely congruent.

Further support for the response strategy modelling was provided by the assessment of the proportion of fixation time afforded to the 3 dimensions during the course of each block of trials. There were 61 individual blocks of trials in which the best-fitting model was a uni-dimensional rule. In 95% of these cases the apparent rule dimension received the highest proportion of fixation time during the block. Similar support was offered by the consideration of blocks in which a two-dimensional strategy appeared to be applied. In the majority of cases, the dimension that appeared to be irrelevant to the response strategy received the lowest proportion of fixation time (twice the number of blocks that would have been expected by chance alone).

The apparent level of concordance between the ET measures and the modelling data would seem to substantiate the current method of assessing participants' response strategies. Furthermore, this appears to be the first attempt to employ an objective (psychophysical) measure in the cross-validation of formal models of CL performance. Consequently, interpretation of the modelling results (e.g., as described above) can be viewed with a degree of confidence. Additionally, these results may also tender support for the previous application of the models; particularly in respect to study 3. Hence, despite the limitations of the present study, one valuable result would appear to be the potential verification of the response strategy modelling method and the resultant reinforcement of the previous findings associated with strategy use and cognitive flexibility reported in chapter 6.

There were few clear cut relationships between personality and the ET measures. Naturally, one likely contributory factor was the limited size of the sample (further reduced by the availability of usable ET data). However, the strongest findings were observed for the proportion of fixation time given to the rule dimension/s. When using uni-dimensional rules, extraversion was related to a lower proportion of fixation time upon the dimension being used as the rule (suggesting a lower degree of 'focus' upon the rule dimension). This result may appear somewhat congruent with the previous association between this trait and the distractor cueing effect (DCE) reported in study 2. If more extraverted individuals have a lower degree of focus upon the relevant rule dimension then this may contribute to the correlation between extraversion and an increased DCE (observed for left-hand responses) found in the Steel et al. (2002) study and somewhat replicated in the RT study reported in chapter 5. Therefore, the present association between extraversion and a lower degree of attentional focus (specifically related to the use of a uni-dimensional rule) may suggest a plausible causal explanation for the association with increased DCE, and provides a clear avenue for future research. Interestingly, neuroticism was related to a greater degree of focus upon the relevant dimension. This too appears somewhat congruent with previous RT study, in which this trait observed to be associated with a decreased DCE (possibly lateralised for right-hand responses).

Curiously, when examining attentional focus during two-dimensional strategy use (i.e., the proportion of fixation time upon the relevant two dimensions) the direction of the relationships between extraversion, neuroticism and the degree of focus were reversed. Naturally, it is likely that the participants were performing at a superior level (i.e., greater accuracy) when using a two-dimensional strategy (relative to the uni-dimensional strategies). Therefore, it may be considered that the more extraverted participants exhibited a greater degree of focus when using the more successful strategy. In contrast, when using the uni-dimensional rules, this trait was associated with a decreased attentional focus. Consequently, one interpretation for the apparent reversal in the association between extraversion and the degree of focus upon the (strategy) relevant dimensions may support the idea of an association between this trait and a more adaptive attentional style (cf. cognitive flexibility); adopting a more open attentional style when employing uni-dimensional strategies, yet more focused when using (potentially) more successful strategies. The notion that extraversion may be related to a more adaptive attentional style may further be supported by the (albeit weak) association with higher (mean) number of dimensions fixated in the present task, in which a two-dimensional strategy was optimal, yet a lower number of dimensions fixated in the previous ET task in which attention to only one dimension was required. However, it would appear more difficult to interpret the association between neuroticism and a lower degree of focus when two-dimensional strategies were in operation.

In summary, despite the methodological limitations of the current task, a number of results of interest were reported. For example, ImpASS was again related to variation in performance across the task. Although not associated with poorer accuracy levels, the performance of the high-ImpASS group was static across the task a result that was largely congruent with the previous behavioural version of the task. Again the utility of formal modelling of participants' response strategies was demonstrated and was associated with performance in a predictable fashion. Furthermore, the technique appeared to be corroborated by the concurrent assessment of eye-gaze during the experiment. Accordingly, the potential for the ET method was again highlighted. The present data suggest a variety of avenues of future research. An obvious initial path would be a replication of the present study involving stimuli that remove the possibility of confounding response strategies in the assessment of cognitive flexibility.

Chapter 9

General Discussion

This chapter will present a brief synopsis of the thesis and assess the implications and limitations of the main empirical findings. The current work will be considered in light of previous research and the underlying rationale and general aims of the thesis. Finally, the potential for future research in the area will be addressed.

Background to the Research

The opening chapter introduced the concept that inter-individual variation in particular personality traits may partially reflect differences in the functioning of basic biological systems. Specifically, three personality dimensions (i.e., extraversion, ImpASS and positive schizotypy) were discussed and evidence that variation upon these traits may be associated with the functioning of the dopaminergic system was also briefly considered. Dopamine has been suggested to play an important role in a variety of cognitive processes including attention and reward-dependent learning. Hence, the possibility arises that predictable relationships may be expected to occur between notionally biologically-based personality traits and particular aspects of cognitive performance. Accordingly, previous research which examined the association between these personality traits and performance on cognitive tasks thought to be dependent on processes such as attention was presented.

In Chapter 2, a brief review of the category-learning (CL) literature was presented and the suitability of this paradigm for application in the research area of the thesis was put forward. In addition to a substantial neuropsychological background, which provides a useful insight into the likely neurobiological systems involved in CL, the paradigm also provided a useful methodology with which to examine the association between personality and cognitive processes engaged during learning. For example, some tasks may benefit from an enhanced ability to focus upon the relevant features of a stimulus, while other tasks (e.g., II) may be more dependent on procedural learning and consequently benefit from enhanced reward-driven learning. Hence, distinct CL tasks may be differentially reliant upon attentional and reward processing and thus it may be expected that the relationship between personality and performance on CL tasks may be dependent upon the specific nature of the task. Consequently, patterns of association between personality and performance on distinct CL tasks may be suggestive of the underlying (neurobiological) mechanisms with which the personality traits may or may not be related.

The limited literature pertaining to personality and CL performance was also discussed in the second chapter. Previous research appeared to suggest an association between ImpASS-like traits and superior performance on simple (RB) CL tasks in which a single dimension determined category membership. It was suggested that this association may reflect enhanced selective attention abilities of individuals scoring more highly on ImpASS-like traits. In contrast, ImpASS-like traits were associated with poorer performance on a task that involved the integration of information from 2 dimensions. Furthermore, the personality measure was also related to a greater tendency towards the use of a uni-dimensional strategy, providing additional support for the possible involvement of attentional processes in the association between this personality cluster and CL performance.

The association between the ImpASS-like traits and CL performance just described was independent of any association with extraversion. Likewise, independent of ImpASS-like traits, extraversion was associated with superior performance on a CL task thought to be dependent upon reward-based learning. Furthermore, extraversion was unrelated to performance on a matched version of the task in which CL occurred through paired-associate training. In contrast, an ImpASS-related trait was associated with superior performance on this task. This suggested that extraversion may indeed be associated with enhanced reward-based learning and demonstrated a clear dissociation from performance related to ImpASS traits (which may in turn be associated with superior paired-associate CL).

Naturally, through its connection with schizophrenia, positive schizotypy has long been associated with executive function, especially attentional processes. Associations between this trait and CL performance were also reported in chapter 2. This trait was associated with poorer performance on a RB task especially after an unannounced switch of the relevant category dimension. Additionally, this trait was also related to poorer performance on the task requiring the integration of information from both features of a two-dimensional stimulus (cf. ImpASS association described above).

General Aims of the Thesis

Together the opening two chapters provided a broad framework upon which the ensuing studies were constructed. It was suggested that biologically-based personality traits may relate to performance on specific tasks through association with particular aspects of cognitive function. The current research programme attempted to further the investigation of the association between personality and cognitive processes. The general aim, therefore, was to expand upon previous research and to help advance the knowledge of the possible biological foundations of specific personality traits. In turn, the current research may provide further insight regarding similarities and dissimilarities of core domains of personality such as extraversion and the ImpASS cluster. In addition, the research aimed to consider the association between positive schizotypy and cognitive processes.

The CL paradigm was proposed as a suitable means with which to explore the broad research aims and appeared particularly applicable for the contemplation of processes related to attention and learning. Although limited, previous research suggested that associations between CL performance and personality could indeed be observed. Consequently, a more specific set of research objectives were established.

One key aim of the research programme was to pursue and further evaluate the CL paradigm as an effective method with which to approach the general research area (i.e., the association between notionally biologically-based personality traits and cognitive function). Consequently, the thesis intended to build upon initial studies that demonstrated a link between personality and performance on CL tasks (e.g., as discussed by Pickering, 2004). More specifically, the research endeavoured to further explore the traits of extraversion and ImpASS and their association with learning and attentional processes during the attainment of novel category-response associations. An additional goal was the application of the paradigm in the consideration of cognitive function, specifically attention, associated with positive schizotypy and CL performance.

Personality Measures

Chapter 3 considered the assessment of personality in the current research. A variety of widely-used self-report personality questionnaires were applied across the studies, many of which contained scales putatively measuring the same underlying constructs (e.g., extraversion as measured by the EPQ or 'big-five' questionnaire). The approach taken in the thesis was to consider broadly defined personality dimensions and to this end factor scores were created for the key personality traits of interest (through the combined use of the different questionnaires administered). In addition to the 3 personality traits considered above, neuroticism was also considered a fundamental personality trait which ought to be included. Consequently personality, as assessed in the present thesis, broadly followed the 'big three' framework with factors representing extraversion, neuroticism and ImpASS. In addition, positive schizotypy was also assessed; included as a factor when sufficient data was available or individually assessed with the use of separate scale (i.e., a component from the OLIFE).

Empirical Studies: Findings, Limitations and Relationship with Previous Research

<u>Study 1</u>

The first study (chapter 4) compared the association between personality and performance on (matched) RB and II CL tasks. The results were somewhat in contrast to earlier findings. ImpASS had previously been associated with enhanced performance on RB-like tasks, although in the present study this trait was associated with poorer performance on the second phase of the RB task. In addition, positive schizotypy, previously associated with poorer performance, was associated with enhanced learning of the second category rule (although this result is possibly congruent with the association between positive schizotypy and decreased latent inhibition; e.g., see Pickering & Gray, 2001).

It was suggested that one possible explanatory factor for the discrepant results could be the specific nature of the stimuli involved in the different studies. A broad variety of tasks may be considered to represent RB CL, however, it is likely that subtle differences in design may influence the processes involved in the learning of novel categories. For example, studies in which there are a limited number of stimulus exemplars may facilitate the use of episodic memory for specific stimulus-category pairings. This strategy may not be possible in the situations where stimuli are more numerous.

In the first study, the values on each dimension were discrete (and binary-valued). Consequently, the placement of a suitable 'decision boundary' (i.e., that distinguishes between the possible dimension values) would be considered to be 'error-free'. In contrast the learning of other (RB) categories, for example involving continuous valued or multi-valued dimensions, may be more dependent upon an accurate placement and application of an appropriate decision boundary.

Other variables, such as whether category membership is deterministic or probabilistic, may also affect the successful acquisition of category rules. This limited set of examples clearly indicates that a variety of processes may be differentially engaged in the learning of even very simple RB category structures. Thus, the potential for variation in the association between personality and performance across, albeit subtly different, RB CL tasks may not be surprising. Furthermore, such specific design issues may warrant further consideration in the creation of future studies and comparison of performance upon putatively comparable RB CL tasks.

Performance on the II task also suggested the careful interpretation of performance upon CL tasks. The number of participants who applied the optimal rule appeared to be very few, crucially this may suggest that the association between personality and performance upon this task is unlikely to have reflected the functioning of the 'implicit' (II) CL system (Ashby et al., 1998; Waldron & Ashby, 2001). Furthermore, this may provide a possible explanation for the lack of the predicted association between extraversion and superior performance on the II task.

Formal modelling of participants' response strategies provided support for the notion that participants often appear to employ sub-optimal rules or response strategies during the learning of novel categories (e.g., Ashby et al., 1998; Maddox et al., 2003; Maddox, Filoteo et al., 2004). Additionally, the finding that WM appeared to have facilitated accuracy levels on the II task is also concordant with the preceding assertion and further supported the idea that the many participants may not have been reliant upon the 'implicit' system during the II task. The modelling data also revealed that positive schizotypy was related to poorer performance on the II task over and above the influence of strategy employed (and WM). It was tentatively suggested that this result may be in agreement with previous research, for example Steel et al. (2002), and present work (i.e., study 2) which showed an association between this trait and reduced distractor-cueing-effects (DCE). It is possible that the processes which may be involved in this phenomenon (as discussed in chapter 5; e.g., tendency to encode fewer features of a multi-dimensional stimuli, poorer associative learning etc) could also be detrimental to performance on the current II task.

The results of the II task suggested that the examination of this mode of CL may be somewhat more difficult to assess and require the use carefully considered and appropriate tasks, possibly allowing a greater period of time for the learning episode to occur in order that the implicit CL system may be fully engaged. Consequently, the remainder of the research presented in the thesis was concerned with learning of a range RB categories. The utility of considering the response strategies of participants during CL was also demonstrated and pursued in the remaining studies where appropriate.

Study 2

The second study employed the CL paradigm to explore the influence of nominally irrelevant stimulus information on response times during a speeded categorisation task. The task was specifically created to re-examine the results reported by Steel et al. (2002) that found a relationship between positive schizotypy and decreased distractor cueing effects (DCE). The results of the experiment appeared to provide support for the target study findings with the demonstration that positive schizotypy was associated with decreased interference from irrelevant dimensions (and additionally demonstrated that the Steel et al. finding was unlikely to have been due to a 'novelty' effect). Furthermore, in tandem with the Steel et al. data, the effects appeared to be somewhat lateralised to right-hand responses. Despite the qualitatively dissimilar nature of the two paradigms, the association between this personality dimension and decreased effects of nominally irrelevant task-related information appears to be somewhat robust.

The current study also provided a degree of support for an additional result not reported in the original Steel et al. (2002) paper. In contrast with the association observed for positive schizotypy, extraversion was associated with increased effects of irrelevant distractor cues in the Steel et al. study. Furthermore, this effect appeared lateralised to left-hand responses. Although this result was not strongly replicated in the present study, there was some evidence that extraversion was positively associated with increased interference from irrelevant stimulus information in left-hand responses. The apparent lateralisation of this effect was also supported by the finding that extraversion was, to some extent, associated with reduced interference for right-hand responses (cf. positive schizotypy).

Study 2, therefore, appeared to provide support for the Steel et al. (2002) findings. However, the methodology applied in the current study was somewhat distinct from the remaining research presented in this thesis (e.g., the 'learning' component of the task, in terms of the category rule, was considered to be minimal; the key dependent measure was response time etc.). Hence, the direct comparison of the findings with other results within this thesis is not possible. However, the discussion section of chapter 5 began to explore plausible mechanisms which may underlie the (interference) effects of the irrelevant dimensions observed in the present study. It is possible that the processes discussed (e.g., inhibition of the 'processing' of irrelevant dimensions; inhibition of responses; breadth of attention across the stimulus features etc.) may be associated and involved with other forms of CL. Consequently there exists the potential for future work in this area (discussed in the 'Future Research' section below). Thus, the examination of these processes in more detail may be informative not only for the present study but also for the wider domain of CL. In turn, this may provide further insight into the potential mechanisms through which personality may be associated with CL.

As intimated above, one limitation of the present study was the inability to determine the specific causal mechanisms involved in the DCE. However, the feedback (FB) manipulation provided a potentially valuable finding. The DCE was observed, and of a comparable magnitude, irrespective of the provision of trial-by-trial FB during the training phase of the task. Although it is not possible to infer that in both the FB and non-FB conditions the DCE arose through the same causal mechanism, the demonstration that the DCE was obtainable without trial-by-trial FB encouraged the consideration of mechanisms which may generate the effect in the absence of a reward signal (additionally suggesting that the involvement of a dopaminergic reinforcement processes was not an essential component for the DCE to occur). Knowledge of the processes involved in the DCE is of interest and may be informative with regards to the cause of the association between personality and performance on cognitive tasks. The potential for further exploration of the mechanisms involved in the DCE is discussed below.

Study 3

The (RB) CL task presented in chapter 6 was thought to assess cognitive flexibility; optimal performance required the use of a conjunctive rule which was more complex than the partially successful, yet sub-optimal, uni-dimensional rules. Consequently, study 3 examined the association between personality and cognitive flexibility during CL. ImpASS was related to poorer performance upon the task and it was suggested that this reflected decreased cognitive flexibility. Assessment of participants' response strategies supported this result and demonstrated that the poorer performance of the high ImpASS participants was related to the use of sub-optimal, uni-dimensional strategies.

In contrast to ImpASS, extraversion was associated with greater cognitive flexibility and superior overall success on the task. It was suggested that extraversion may be related to a greater 'promotion' focus. The 'gains' reward structure applied in the task may have led to increased 'regulatory fit' which may have subsequently facilitated greater cognitive flexibility for more extraverted participants. This result was considered to support the possibility that trait extraversion may reflect variation in BAS function. Consequently, the possibility that the performance of more extraverted individuals reflected aspects of BAS function (i.e., motivational, learning or cognitive components) was discussed. Although the result may have provided additional support for the suggestion that extraversion may index BAS function, as will be reviewed below, the present study did not allow the specific mechanism for the association between extraversion and performance to be determined.

As intimated above one limitation of the present study was the use of a single condition in which a 'gains' reward structure (i.e., participants aimed to maximise their accuracy and received points for every correctly categorised stimulus but did not gain any points, or receive any deductions, for incorrectly categorised stimuli) and 'promotion' focus (i.e., participants attempted to obtain a criterion level of accuracy in order to a *receive* a prize-draw ticket) was used. Naturally, this limits the interpretation of the likely causal mechanisms behind the observed correlations between personality and performance on the task (i.e., the personality traits may have been directly related to cognitive flexibility or the association with performance may have arisen indirectly by way of an interaction with the situational factors cf. 'losses' reward structure and 'prevention' focus). Furthermore, the assessment of cognitive flexibility may benefit from the additional consideration of tasks in which cognitive *in*flexibility may facilitate performance. These issues will be considered further in the 'Future Research' section below.

Owing to the differences between the experimental methods employed, comparison between the results of study 3 and the previous two studies was considered somewhat tentatively. For example, the finding that ImpASS was associated with poorer performance on the second phase of the RB task in study 1 could be considered to be somewhat congruent with the idea that this trait is associated with reduced cognitive flexibility (i.e., reduced ability to modulate response strategy). However, other personality factors associated with performance on the second phase of the RB task in study 1 (i.e., neuroticism and positive schizotypy) did not appear to be associated with the present task.

However, the relationship between personality and performance on the cognitive flexibility task, particularly pertaining to the apparent association between ImpASS and cognitive *in*flexibility, was congruent with previous research. As predicted, higher levels of ImpASS were related to poorer performance on the task and additionally associated with the greater use of, inappropriate, uni-dimensional rules. This result supports the findings of a previous study by Tharp (2003, discussed in chapter 2) which found that ImpASS was related to poorer performance on a task requiring the attention to both features of a two-dimensional stimulus and preference for (inappropriate) uni-dimensional rules. Likewise, as reported by Pickering (2004), ImpASS traits have been associated with superior learning of (nominally) RB categories. One interpretation of these results may suggest that high ImpASS individuals demonstrate a predilection, or perhaps a 'cognitive' style, for learning which involves simple or salient rules. This may manifest in the present situation as a preference for uni-dimensional strategies and thus partially account for the poorer performance on the cognitive flexibility task. Future work to expand upon these findings is considered below.

Study 4

The final two studies of the thesis employed a novel method in the exploration of the association between personality and attentional processes during CL. Following original work by Rehder and Hoffman (2005), eye-tracking (ET) technology was used in an attempt to assess selective attention towards individual stimulus features during the learning of novel categories. Stimuli were specifically created such that the dimensions which comprised a single stimulus were spatially separable, thus allowing the variation in attention towards each stimulus feature (both relevant and irrelevant) throughout the task to be considered.

The first study presented a simple RB CL task in which 1 of the 4 (binary-valued) dimensions determined category membership. In addition, the task contained an unannounced change in the category structure (involving a previously irrelevant dimension) after the first category rule had been successfully learned. The personality measures were not significantly related to performance on the task. There were, however, some results of interest concerning the association between personality and the derived ET measures.

One notable finding appeared to be a divergent association between extraversion, ImpASS and the derived measures of selective attention. For example, ImpASS was generally positively associated with a greater number of fixations and significantly positively associated with the fixation of more dimensions (per trial) over the second phase of the task. In contrast, extraversion tended to be associated with these measures in the opposite manner to that observed for ImpASS. Extraversion was also associated with the prioritisation (in terms of fixations) of the respective rule dimensions. In the first phase, extraversion was associated with the earlier prioritisation of the relevant rule-dimension. In contrast, this trait was related to the slower prioritisation of the second category-rule dimension.

The first ET study did appear to generate some stimulating results (the comparison of the results of the present study with previous studies was considered in more detail in the earlier chapter and will only be briefly reprised here). For example, in study 1, extraversion was associated with superior performance on the first phase of the RB task (the design of which was analogous with the present task). Consequently, it was suggested that the association between this trait and an earlier prioritisation of the rule dimension (as measured by the ET data) in the current task may provide a plausible mechanism for the association just described.

An additional finding, derived from the ET measures recorded in the present task, suggested that, once the category structure had been established, positive schizotypy was associated with greater selective attention towards the rule dimension. It was proposed that this apparent 'attentional' style would be congruent with the association between this trait and reduced DCE observed in study 2.

However, the interpretation of the data, in particular those concerning measures of selective attention, was not without issue. For example, the apparent relationship between ImpASS and a broader attentional style (suggested by the association between this trait and the fixation of a higher proportion of stimulus dimensions across the task) was somewhat unexpected and contrary to the pattern which may have been predicted from previous research suggesting an association with superior selective attention and preference for uni-dimensional rules (e.g., Ball & Zuckerman, 1990; Pickering, 2004; Pickering & Gray, 1999). In addition, the response modelling data reported in study 3, which demonstrated an association between ImpASS and greater use of uni-dimensional response strategies, would also appear somewhat at odds with the current ET data.

Accordingly, the interpretation of the present ET data warrants careful consideration, not least the basic premise underpinning the study which considered the assessment of eye-gaze as a valid measure of selective attention. For example, it should be noted that the association between ImpASS and the tendency to attend more stimulus dimensions does not imply that more complex response strategies (i.e., involving a greater number of dimensions) were being employed. Rather, the findings simply suggest that a greater number of stimulus dimensions were attended. This interpretation is in line with the view of Rehder and Hoffman (2005) who suggested that participants tended to fixate all stimulus dimensions in the early stages learning despite evidence suggesting that uni-dimensional rules were being assessed at this time.

Study 5

The final study attempted to incorporate the ET method in a replication of study 3 which explored cognitive flexibility during CL. Accordingly, the study 5 task was generally analogous with the previous experiment with the exception of minor methodological changes (i.e., stimuli were created with spatially separable dimensions; the number of trials was slightly reduced etc.). Crucially, however, the necessary creation of stimuli suitable for the ET analysis inadvertently gave rise to response strategies not available in the previous behavioural version of the task (i.e., the direct comparison of stimulus dimension values within a single trial cf. II CL). This introduced an important caveat in the subsequent interpretation of performance on the ET version of the task in relation to the previous version and the general cognitive flexibility component.

The limitation imposed by the design of the present stimuli was considered in detail in the preceding chapter. It was suggested that the availability of the additional II-like rules, which were also somewhat successful in the attainment of the performance criterion, may have had considerable influence upon participants' performance upon the task. For example, the ability to apply these II-like rules, with some degree of success, may have affected the key manipulation of interest; the requirement to abandon simple, yet sub-optimal, uni-dimensional rules in favour of the more complex conjunctive rules. (Additionally, it is somewhat difficult to 'locate' the II-like rules in terms of their relative complexity). If a participant was successful with an II-like rule, then this may have encouraged the continued use of the rule (even if performance upon some of the following blocks of trials was below the target criterion). This may have had an impact upon the qualitatively different pattern of performance observed in the present task (i.e., unlike the previous behavioural version of the task, accuracy levels demonstrated a quadratic, rather than a cubic pattern – there appeared to be no drop in the performance upon the second block of trials).

Accordingly, it was not unsurprising that some of the findings appeared to contradict those which were predicted as a result of the previous behavioural version of the task (study 3). For example, in study 5 ImpASS was not associated with lower overall accuracy. In fact, this trait was associated with the earlier achievement of the criterion level of performance. Furthermore, the results of the response strategy modelling, although in line with performance on the present task, were also somewhat divergent from those which were expected (i.e., high ImpASS scorers showed earlier use of the correct two-dimensional strategy and greater use of the correct two dimensions over the last 2 blocks of trials).

Naturally, one possible explanation for these unexpected results was the availability of II rules; the design of the stimuli in study 5 enabled the direct comparison of the 'values' on the 3 stimulus dimensions (i.e., the proportion of area filled) in a manner which was not possible in the previous, purely behavioural version of the task (i.e., study 3, in which the stimulus dimensions were the angle of orientation, horizontal position and length of single lines). Furthermore, the application of these relatively simple II rules (e.g., in contrast to many II rules these rules were easily verbalisable) was, potentially, somewhat accurate (i.e., the criterion level of performance could be achieved in 5 of the 8 blocks) and, therefore, the use of the optimal conjunctive rule was not the only method by which a participant was able to perform the task successfully. Unfortunately, as the two dimensions relevant for the optimal conjunctive rule were also able to be used in an II fashion, the ET data was not able to help delineate the type of response strategy employed (additionally, as discussed in the earlier chapters, the response strategy modelling was also unable to confidently distinguish between two-dimensional II and RB response strategies).

Despite this caveat, however, there was some degree of congruency in the association between personality and performance across the two tasks. While some qualitative differences in the pattern of performance may have existed, in both instances higher levels of ImpASS were associated with a static level of performance accuracy across the respective tasks. In contrast, the low-ImpASS groups were associated with greater improvements in accuracy. Additionally, extraversion was associated modestly with superior levels of performance in both tasks in addition to the earlier use of two-dimensional strategies.

Again, a novel aspect of the present task was the concurrent assessment of eye-gaze. While, as described above, a degree of caution is required in the interpretation of the ET data, it was suggested that the derived measures of eye-gaze could most confidently be used to inform which dimensions were 'unlikely' to have been applied in the participants' response strategy (i.e., if there were virtually no fixations upon a particular dimension, on any given block of trials, it would seem most unlikely that this dimension was integral to the respective response strategy). Accordingly, in the majority of cases (in which fewer than 3 dimensions appeared to be fixated) the dimensions implicated by the response were congruent with ET data. This then provided a degree of support for the response strategy modelling. Further support for the strategy modelling was also provided in the assessment of fixation time. Although generally unrelated with personality, the assessment of eye-gaze in the present task appeared to afford a further level of confidence and objective verification in the response strategy modelling. Furthermore, this result may also help to increase the confidence in the assessment of the findings associated with strategy use and cognitive flexibility reported in study 3.

The findings of the present study were also of potential relevance to other previous studies. For example, when applying uni-dimensional rules in study 5, extraversion was associated with a broader attentional style (i.e., a smaller proportion of total fixation time was devoted to the current 'rule' dimension). This would appear to provide a possible mechanism through which this trait was associated with increased DCE. It was additionally suggested that the association between this trait and increased attentional focus, when applying two-dimensional rules, may reflect a more adaptive attentional style. Consequently, this may provide tentative support for the proposed association between extraversion and cognitive flexibility discussed in study 3.

Future Research

The results reported in study 3, which explored performance upon a CL task requiring cognitive flexibility, provide a firm foundation for further investigation into the association between personality and CL (and associated processes). As discussed in the earlier chapter, a key follow-up study might consider performance upon a task in which cognitive flexibility would be considered to be detrimental to task performance. Consequently, if ImpASS is truly associated with reduced cognitive flexibility then it may be expected that ImpASS would be associated with enhanced performance on such a task. In addition, the association between extraversion and performance on the task would also be of interest.

One method which may be utilised to explore this issue was reported by Maddox, Baldwin et al., (2006, experiment 2). In their study a CL task involving two-dimensional stimuli (single lines which varied in length and orientation) which belonged to 1 of 4 categories (A – D) was administered. The optimal rule, as described by Maddox, Baldwin et al., was as follows: "Respond 'A' if the length is short and the orientation is shallow; Respond 'B' if the length is short and the orientation is steep; Respond 'C' if the length is long and the orientation is shallow; Respond 'D' if the length is long and the orientation is steep".

Maddox, Baldwin et al. proposed that the two-dimensional nature of the category rule would be apparent to the participant at an early stage of the experimental session. Consequently, it was suggested that the form of cognitive flexibility which was beneficial in the task performed in study 3 (chapter 6; which may have profited from wholesale changes in strategy) would be detrimental to performance on the new task. In contrast, it was argued that performance would benefit most from more gradual, incremental changes in response strategy – cf. decreased cognitive flexibility.

Two further manipulations were also applied in the Maddox, Baldwin et al. task just described. Firstly, the category structure was not deterministic. Hence, there was some overlap in the category distributions. The decision criteria, therefore, were somewhat 'noisy' (i.e., a perfect decision bound between a 'long' or 'short' line was not possible). Secondly, there were an unequal number of stimuli from the 4 categories (A – D). This introduction of bias in the base rate (i.e., the proportion of each category type) is likely to bias the decision criterion away from the equal likelihood criterion point. Although not presented fully here, these two additional manipulations were also suggested to promote conditions in which lower levels of cognitive flexibility would facilitate performance on the task.

Subsequently, the relationship between ImpASS and performance on the task described in the preceding paragraphs may provide further insight into the results of the current study (i.e., study 3). If ImpASS was found to be related to *superior* performance on the new task, then this may suggest that this trait is indeed related to lower levels of cognitive flexibility and provide substantial support for the present result. In contrast, should an association between this trait and poorer performance (and/or inappropriate strategy use) be observed this may suggest that ImpASS is not related to cognitive flexibility per se, but rather the use of more simplistic category rules (or simply impaired learning of tasks that require the use of more complex rules).

The task proposed above would also provide a useful tool with which to further examine the association between extraversion and cognitive flexibility. The results of study 3 appeared to suggest that this trait was related to a higher degree of cognitive flexibility, hence it may be expected that extraversion would be associated with poorer performance on the task proposed above. However, in study 3, it was uncertain whether the association between extraversion and cognitive flexibility occurred by way of a direct relationship or whether higher levels cognitive flexibility were induced by other situational factors (i.e., promotion focus, 'gains' reward structure). This suggests that an additional line of research is required to fully explore the results of study 3 in terms of the mechanisms underlying performance on the task.

For example, if cognitive flexibility on the task presented in study 3 was facilitated in more extraverted individuals by the regulatory fit between the task conditions and disposition to a (chronic) promotion focus, then if these situational factors were reversed (i.e., 'prevention' focus, 'losses' reward structure) cognitive flexibility would be inhibited for these individuals. Therefore, in combination with tasks in which cognitive flexibility is either beneficial or disadvantageous, the manipulation of situational factors would allow greater confidence in the attribution of the causal mechanisms underlying the associations between personality and performance. As already intimated, they may be through direct association with cognitive factors, such as cognitive flexibility; or via indirect association with cognitive factors, through manipulation of regulatory fit; or through association between regulatory fit and additional processes, such as motivational effects.[1]

The CL paradigm was utilised in study 2 to explore the effects of nominally irrelevant stimulus information during speeded categorisation (i.e., the DCE). The results appeared to be in accord with previous work reported by Steel et al. (2002). The finding that the FB manipulation did not appear to influence the magnitude of the DCE encouraged the consideration of plausible models of the DCE (and the association with personality) and it was suggested that future work could attempt to focus upon the mechanisms involved. For example, Miller's (1987) account suggested that the formation of stimulus-response (S-R) associations for the (nominally) irrelevant stimulus features led to the DCE.

One method to pursue this hypothesis could be to consider the use of the paired-associate technique during the training phase of the current task, thus removing the response component during the training phase (i.e., each stimulus and category label is simultaneously presented). The subsequent consideration of the DCE may be informative with regards to the role of S-R associations (during the training phase) in this process.

An alternative means with which to assess the involvement and nature of S-R associations could the manipulation of the category-response assignment. Following Ashby, Ell and Waldron (2003), for example, a hand-switch/button-switch manipulation could be performed. The hand-switch condition requires the participant to cross their response hands between the training and test phase of the task (i.e., the location of the response buttons remain the same – category A, left button; category B, right button – but the hand of response changes). In contrast, the button-switch condition reverses the location of the category response buttons (e.g., category A is the left button during training and the right button during the test phase etc – response hand does not change i.e., the left hand is used for the left response button regardless of the category assignment).

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[1] It is noted that manipulation of situational factors, such as prevention focus or 'loses' reward structure, may also affect the involvement of other systems which may be associated with other sources of variation in personality – e.g., the BIS or Fight, Fight, Freeze system, associated with anxiety/neuroticism, may be activated in such a condition

If the hand-switch manipulation interfered with the DCE this may suggest that the stimulus-motor response (i.e., left- or right-hand) association is an important component of the phenomenon. If, however, the button-switch manipulation affected the DCE this may suggest that stimulus-response position is a contributory factor in the effect. Finally, if neither manipulation appeared to influence the DCE this may suggest that the phenomenon is more reliant upon mechanisms other than S-R associations.

An additional explanation, considered briefly in chapter 5, suggested that the DCE may arise from the unitization or configuration of (some or all of) the irrelevant stimulus features. A simple model of stimulus 'similarity' was constructed that supported this possibility. One avenue for future research could be to explore the effect of reducing the ease with which the irrelevant dimensions are 'configurable' with the target dimension. This would possibly lead to a reduction in the DCE and thereby implicate this process in the phenomenon. The resulting effect on the relationship between personality and, albeit potentially diminished, DCE would also be informative with regards to the likely cause of the association. A subsequent manipulation could consider dimensions which vary in the degree with which they are (perceptually) integral with the target dimension and additionally vary the degree to which the dimensions are associated with the target value (i.e., will an increase in the association between an irrelevant dimension and the target have a greater impact upon the DCE if the dimension is more integral with the target dimension).

Furthermore, the model suggested that the association between positive schizotypy and a decreased DCE could arise if high schizotypes tended to encode fewer of the (irrelevant) stimulus features. Consequently, the number of irrelevant dimensions, together with the strength of their association with the target dimension, may be worthy of further consideration. For example, in the Steel et al. (2002) study, there was only one irrelevant dimension suggesting that the association between this trait and reduced DCE may arise through an alternative mechanism.

An additional model, which appeared to be able to account for dissociable influences upon the magnitude of the DCE, was also briefly presented. This simple neural network representation included inhibitory mechanisms in addition to associative connections between individual stimulus features (both relevant and irrelevant) and response units (which broadly reflected the level of co-occurrence between the stimulus feature and response). Thus it was proposed that the independent effects of positive schizotypy and extraversion upon the DCE could relate to these separable mechanisms within the neural network model. For example, it was suggested that positive schizotypy may be associated with reduced inhibitory effects. In correspondence with the observed behavioural effect, the simulation of reduced inhibitory mechanisms at the response output stage of the model resulted in a reduction of the DCE.

Further simulation revealed that increasing the 'attention' towards the non-target dimensions (relative to the target dimension) increased the magnitude of the DCE. Thus, this mechanism may provide a suitable means through which the, independent, association between extraversion and the DCE may arise. Furthermore, this associative mechanism suggested that the DCE may contain both facilitatory and inhibitory components; a relatively greater weighting of the non-target dimensions facilitates faster responding on the congruent probes and, conversely, leads to increased response times on the incongruent probes. Thus, future work may be attempt investigate this possibility in more detail.

Additionally, the expected role of the 'intention' units in the preceding neural network model may be assessed. The effect of informing participants to reverse their response strategy (i.e., switching the intention-response unit associations) during the test-phase of a task akin to study 2 may be considered. A-priori predictions regarding the influence of the inhibitory mechanisms and associative strength (weighting) of the irrelevant dimension-response connections upon the DCE can be made; which in turn may derive expectations regarding the effect of this manipulation upon the association between personality and the DCE.

Clearly, the application of such models would appear constructive and may guide the direction of future studies and aid in the prediction of likely outcomes. Furthermore, recent work by Colzato, van Wouwe and Hommel (2007a; 2007b) would appear to support the involvement of dopaminergic function in mechanisms akin to those in the preceding models. These studies suggested that dopamine (as indexed by the manipulation of affective stimuli and spontaneous eye-blink rate respectively) modulated the strength of task-relevant visuo-motor bonding. Consequently, the proposed link between extraversion and dopaminergic function may suggest a plausible mechanism for the association between this trait and the DCE; greater bonding between the motor responses and nominally irrelevant, although (at least) partially task-relevant, dimensions of the stimuli may concurrently facilitate/inhibit responses on the respective congruent and incongruent probe trials thus leading to increased DCE effects.

However, as discussed in the earlier chapter, an additional line of research is likely required to investigate the apparent lateralisation effects present in the association between personality and the DCE. Naturally, a first step would be to assess whether the processes which underlie the DCE are themselves lateralised in the brain. One simple approach would be to employ a task in which the stimuli are presented unilaterally (i.e., to either the left or right visual field) on each trial. This then would allow the comparison of the DCE for stimuli which are individually presented to (and presumably predominantly processed by) either hemisphere (as assessed by reaction times for the contra-lateral hand of response). If the DCE arises through processing which is being executed primarily in either the left or right hemisphere, it may be predicted that the magnitude of the associated DCE would be increased for stimuli presented to the one hemisphere relative to the other hemisphere. Furthermore, the subsequent consideration of the relationship between personality (especially schizotypy and extraversion) and the magnitude of the separable hemispheric DCE components, whether lateralised or not, seems likely to be informative.

The final two studies of the thesis introduced a novel technique in this research area and employed measures of eye-gaze as an additional method of assessing the association between personality and attentional processes during learning. Although far from definitive, the assessment of eye-gaze during the learning of a uni-dimensional category rule did reveal some interesting findings. There appeared to be some divergent associations between personality and the eye-gaze measures (e.g., ImpASS and extraversion) and the possibility that some mechanisms may relate to performance on other tasks presented in the study (e.g., the association between positive schizotypy and greater focus on the rule dimension cf. decreased DCE). It may, therefore, be worthwhile to pursue similar studies, especially those involving unannounced changes in the category structure which allow the modulation of eye-gaze to be considered. The use of continuous valued dimensions in future studies may help introduce a greater degree of variance in performance of the task and allow for a greater possibility for associations between personality, learning and eye-gaze to occur.

The application of the ET method appeared to provide a valuable insight into performance on the 'cognitive flexibility' task involving stimuli comprising 3 dimensions (i.e., study 5). As discussed in some depth previously, the design of stimuli used in the study introduced an unforseen confound in the availability of response strategies and subsequent assessment of cognitive flexibility. Naturally, it would seem pertinent to consider a replication of the present study with a suitable modification of the stimuli in order to remove the possibility of II-like response strategies and hence allow a greater comparison with the previous, purely behavioural version (study 3).

A further study may wish to embrace the issues which unwittingly arose in study 5. For example, a wider range of rules may deliberately be made available. It may be possible to create stimuli with which uni-dimensional, two-dimensional conjunctive rules and two-dimensional II-like rules could be applied. The stimuli could be constructed from 4 spatially separable dimensions. The optimal uni-dimensional rule on each (or a subset) of the 4 dimensions may provide reasonable levels of performance. Two of the dimensions (e.g., A & B) may vary in such a way that they are able to be used in an II-like fashion (e.g., comparing the proportion of area of each dimension cf. study 5) and, in addition, this rule may made be particularly salient. The accuracy of this response strategy could be superior to the uni-dimensional rules, yet still sub-optimal. The 2 remaining dimensions (C & D) could be constructed such that an II-like rule is unlikely. Instead, these dimensions may form the optimal conjunctive rule. Thus, the design of such an experiment would enable the assessment of performance upon a task in which distinct response strategies are available and differentially successful. Furthermore, the assessment of eye-gaze may help substantiate the findings from the application of response strategy models (i.e., attending dimensions A & B may suggest an II-like strategy was employed, whereas attending dimensions C & D would suggest a conjunctive rule was being applied).

The study just proposed may require sufficient time in order that cognitive flexibility can be observed and hence introduces additional factors which can complicate the design. As described previously, for example, the ET technique introduced a limitation on the length of the experiment; participants were required to maintain a stable poise throughout the experiment and any significant head movement during the task would have impaired the accuracy of the ET data (i.e., calibration of the ET headset was only performed at the start of the task). Consequently, the attempt to reduce the length of the time the participants were required to be in the ET setup (i.e., by reducing the number of blocks from 12 to 8 and reducing the number of trials per block) may have impacted upon the ability to assess the influence of cognitive flexibility across the task (notwithstanding the effect of the category structure of the stimuli). One possibility, in future studies, could be to employ the eye-tracker only on selective blocks of a longer task (e.g., the first and last 2 blocks of a 12 block experiment) which may allow sufficient time for variation in response strategy, and possibly selective attention, to occur.

Another area for future research is the further investigation of the association between personality and CL that putatively engages the implicit II system. As described in chapter 2, previous work (e.g., as discussed by Pickering, 2004) suggested that extraversion may be associated with this form of learning. It is clear from the consideration of the results from study 1 (concerning the II version of the task), however, that the assessment of such learning can be complicated by the availability (or perceived availability) of explicit rules. Thus, the association between performance on such tasks and personality may be somewhat occluded by confounding factors.

One method which may help to address this issue could be the use of appropriately created stimuli. For example, the stimuli used in study 1 involved a small number of exemplars (i.e., 16) and each of the 4 dimensions had only two possible values. Hence, these stimuli may have suggested that explicit rules could be applied and possibly encouraged the use of memorisation strategies. Consequently, an II task may benefit from stimuli which participants are unlikely to perceive as being open to these forms of response strategy and thus, may be more likely to rely upon the implicit, procedural system. This may be achievable with stimuli that comprise continuous valued dimensions, the variation of which are somewhat less explicitly verbalisable than discrete categories such as shape or colour.

An example of such stimuli were employed by Maddox and colleagues (e.g., Maddox et al., 2003; Maddox, Ashby et al., 2004). The stimuli comprised circular sine-wave gratings (an example can be found in appendix A). These stimuli have the appearance of disks which contain black and white lines which vary across stimuli in their thickness and angle of orientation. Consequently, II category structures that require the combination of information from these two dimensions are difficult to verbalise and may provide a suitable means with which to assess the learning of II structures and the operation of the implicit system.

As described earlier in the thesis, Reinforcement Sensitivity Theory (RST, e.g., Gray, 1970; Gray, 1981, 1991) suggests that learning, driven by positive reinforcement, may be facilitated (e.g., quickened) for an individual with a more reactive Behavioural Activation System (BAS) relative to an individual with a less reactive BAS. Consequently, if successful performance upon such II tasks is thought to be primarily driven by reinforcement-based (procedural) learning then it may be expected that individuals with a more reactive BAS are able to learn new stimulus-response associations more quickly than individuals with a less reactive BAS. As discussed in previous literature (e.g., Depue & Collins, 1999; Pickering & Gray, 2001; Smillie, Pickering et al., 2006), and possibly supported in the present thesis (e.g., study 3), trait extraversion may be a valid index of BAS-reactivity, thus it may be predicted that superior performance on such II tasks would be associated with higher levels of extraversion. This would support the previous finding of an association between extraversion and superior performance on a CL task (weather prediction task) thought to be reliant upon procedural learning (Pickering, 2004).

An underlying theme of the thesis was the possible influence of dopaminergic functioning upon both variation in the key personality traits (i.e., extraversion, ImpASS and positive schizotypy) and cognitive processes considered in the present research. Consequently, a further area for future research could be the consideration of psychopharmacological manipulations. A number of recent papers have demonstrated that the effect of dopaminergic drugs on cognitive functioning (e.g., working memory) may be modulated by individual differences in baseline levels of both extraversion (Chavanon et al., 2007; Wacker et al., 2006) and impulsivity (Cools, Sheridan, Jacobs, & D'Esposito, 2007).

Echoing a previous demonstration by Lieberman & Rosenthal (2001), Wacker, Chavanon and Stemmler (2006) found that higher levels of extraversion were associated with superior performance (shorter response times) on an n-back WM task, and it was suggested that, relative to introverts, this may reflect a greater capacity for information to be held in WM. Furthermore, relative to a placebo condition, the application of sulpiride (a D_2 dopamine antagonist) reversed the association between extraversion and response times on the task, suggesting that the association between this trait and differences in WM performance is at least partially mediated by individual differences in dopaminergic (D_2) activity.

Such an approach may be informative in follow-up studies of the research presented in this thesis. For example, extraversion was shown to be related to superior performance and the use of more complex conjunctive category rules (cf. sub-optimal uni-dimensional rules) on the CL task which required cognitive flexibility (study 3). As discussed previously, WM appears to be an integral feature of the explicit system involved in the learning of RB categories (e.g., Ashby et al., 1998; Maddox & Ashby, 2004). Consequently, the proposed superiority of extraverts in maintaining a greater level of information in WM may have facilitated performance on the study 3 task. The effect of a dopamine antagonist on performance on a task akin to study 3 may therefore be expected to be dependent upon baseline levels of extraversion and demonstration of such an effect would imply the involvement of dopaminergic systems (cf. Wacker et al., 2006).

Furthermore, poorer performance on the cognitive flexibility task (study 3) was found to be associated with ImpASS. A study by Cools et al. (2007) found that administration of a dopamine agonist (bromocriptine) decreased the switch costs associated with the updating of information in WM; a process which may be associated with cognitive flexibility (i.e., an enhanced ability to update task relevant information in WM may be required to consider more complex category rules). Crucially, however, this effect was only found for high-impulsive individuals. Consequently, an additional future study may explore whether bromocriptine helps to remediate cognitive *in*flexibility on the study 3 task in individuals scoring more highly on ImpASS; in turn, this would again be informative regarding the involvement of dopaminergic systems on the cognitive flexibility task and the possible association between trait impulsivity (or ImpASS) and variation in dopamine activity.

Finally, the association between dopaminergic functioning and behavioural effects associated with (positive) schizotypy may also be considered through the application of dopaminergic manipulations. For example, impaired latent inhibition (LI) has been associated with both schizophrenia and schizotypy (e.g., see Gray & Snowden, 2005), while administration of dopamine agonists (e.g., d-amphetamine and bromocriptine) in healthy participants has also been found to impair LI (e.g., Gray et al., 1992; Swerdlow et al., 2003). Consequently, the consideration of the effects of dopamine agonists on the DCE in healthy (and low positive schizotypy) individuals may suggest whether the association between positive schizotypy and decreased DCE is related to dopaminergic functioning. Furthermore, the concurrent assessment of the effects of such manipulations on both LI and DCE may help to establish whether the mechanisms which underlie these two processes are indeed independent.[2]

[2] As discussed previously, Steel et al. (2002) consider that the association between positive schizotypy and both impaired LI and reduced DCE is unlikely to be attributable to a single mechanism as reduced distractor inhibition, thought to underlie reduced LI associated with high positive schizotypy, would be expected to give rise to increased DCE. This contrasts with decreased DCE observed here for high positive schizotypy implying a reduced influence of distractors. This therefore suggests that positive schizotypy is associated with the functioning of at least two distinct attentional mechanisms.

Summary

This thesis explored the association between putatively biologically based personality traits, attention and performance during the learning of novel categories. The application of the CL paradigm offered an innovative method with which to explore a variety of processes that may be differentially associated with inter-individual variation in distinct personality traits. One robust finding showed that ImpASS was associated with *poorer* performance on a CL task which required cognitive flexibility; the use of relatively successful uni-dimensional rules had to be repressed in favour of a more complex, yet optimal, two-dimensional conjunctive rule. Formal modelling of participants' response strategies suggested that ImpASS was indeed positively related to the greater use of inappropriate uni-dimensional rules and, furthermore, it was suggested that this 'attentional' style may be able to account for previously reported associations between ImpASS-like traits and *superior* performance on RB CL tasks (which required attention to a single stimulus dimension). Additionally, and independent of the effects of ImpASS, extraversion was associated with superior performance on this task. It was suggested that the relationship between extraversion and superior cognitive flexibility, verified by the earlier and greater use of the optimal strategy, may have been mediated by situational factors (i.e., 'reward' structure and 'promotion' focus).

Attentional processes during CL were also explored in the remaining studies. For example, the utility of the CL paradigm was further demonstrated by the consideration of the Distractor Cueing Effect during a speeded categorisation task. The results supported previous research which showed that positive schizotypy was associated with reduced interference from nominally irrelevant stimulus information. In addition to an apparent association between extraversion and greater DCE, it was shown that the DCE was not critically dependent upon trial-by-trial feedback and the implications for causal underlying mechanisms were discussed. Further to a number of preliminary results of interest, the assessment of eye-gaze during CL provided additional corroboration of the validity of the response strategy modelling technique applied in a number of the studies.

As discussed above, the present results provide a number of avenues for further research. A particular emphasis for future work should be to continue detailed multi-method analyses of the links between personality and attentional mechanisms affecting strategy use during learning. The present thesis has shown the utility of the multi-method approach and established a number of robust effects. The next step should be to specify and investigate detailed process models which may account for the observed associations.

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Appendix A

Introduction: Examples of Gabor pattern stimuli

The two figures below are two examples of Gabor patch stimuli used in by Ashby, Maddox, Filoteo and colleagues (including Filoteo et al, 2007) in a variety of categorisation tasks. The stimuli vary on two dimensions: orientation and spatial frequency of the Gabor pattern.

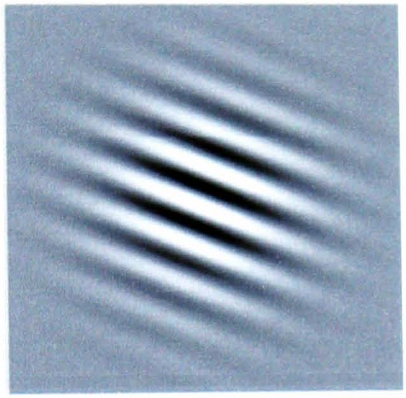


Figure 1: *Example of a Gabor patch stimulus, orientation is relatively shallow and frequency relatively low compared to the example below (figure 2)*

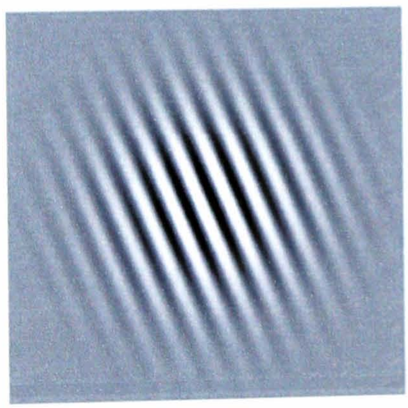


Figure 2: *Example of a Gabor patch stimulus, orientation is relatively steep and frequency relatively high compared to the example in figure 1 above*

Appendix B.1

Initial factor analyses

Intercorrelations between the 13 initial questionnaire sub-scales. There were 249 participants in total, the sample of the table below varies between 243 – 249 depending on missing data.

	BFI-N	BIS	EPQ-P	EPQ-N	EPQ-E	CogDis	IntAnh	ImpNon	SSS	BAS	UnEx	BFI-C
BFI: Extraversion	-.283**	-.185**	.119	-.235**	.802**	-.278**	-.475**	.211**	.210**	.346**	.118	.134*
BFI: Neuroticism		.679**	-.015	.720**	-.344**	.569**	.263**	.111	-.097	.033	.149*	-.164**
BIS			-.156*	.617**	-.227**	.553**	.162*	.020	-.178**	.141*	.123	-.110
EPQ-Psychoticism				.032	.091	.151*	.116	.577**	.457**	.164**	.257**	-.305**
EPQ-Neuroticism					-.248**	.764**	.272**	.245**	-.030	.130*	.306**	-.174**
EPQ-Extraversion						-.276**	-.658**	.271**	.280**	.353**	.185**	.043
OLIFE: Cognitive Disorganisation							.338**	.325**	-.038	.138*	.434**	-.384**
OLIFE: Introvertive Anhedonia								-.058	-.256**	-.142*	.013	-.073
OLIFE: Impulsive Non-conformity									.506**	.356**	.442**	-.334**
Sensation Seeking Scale										.235**	.158*	-.165**
Summed BAS											.277**	-.009
OLIFE: Unusual Experiences												-.136*

** Correlation is significant at the ≤ .001 level (2-tailed)
** Correlation is significant at the <.01 level (2-tailed)
* Correlation is significant at the <.05 level (2-tailed)

Sample size = 243 – 249

Appendix B.2

Initial Factor Analyses: Analysis 1

Initial exploratory Factor analysis with all 13 sub-scales

Table 1: *Initial and extraction communalities for the initial factor analysis solution*

	Initial	Extraction
BFI: Extraversion	.671	.640
BFI: Neuroticism	.636	.624
BIS	.569	.629
EPQ-Psychoticism	.463	.582
EPQ-Neuroticism	.728	.777
EPQ-Extraversion	.781	.967
OLIFE: Cognitive Disorganisation	.731	.752
OLIFE: Introvertive Anhedonia	.525	.429
OLIFE: Impulsive Non-conformity	.577	.753
Sensation Seeking Scale	.403	.381
Summed BAS	.279	.267
OLIFE: Unusual Experiences	.352	.288
BFI: Conscientiousness	.299	.202

Extraction Method: Principal Axis Factoring.

Table 2: *Loadings of the 13 scales on the extracted factors for the Varimax rotated 3-factor solution*

	Factor		
	1	2	3
EPQ-Neuroticism	.861	-.118	.145
OLIFE: Cognitive Disorganisation	.780	-.206	.319
BIS	.780		-.136
BFI: Neuroticism	.765	-.196	
EPQ-Extraversion	-.191	.957	.126
BFI: Extraversion	-.179	.775	
OLIFE: Introvertive Anhedonia	.216	-.616	
Summed BAS	.185	.410	.253
OLIFE: Impulsive Non-conformity	.176	.232	.817
EPQ-Psychoticism			.757
Sensation Seeking Scale	-.134	.231	.556
OLIFE: Unusual Experiences	.310	.186	.396
BFI: Conscientiousness	-.177	.120	-.395

* Loadings below .1 are omitted

Appendix B.3

Initial Factor Analyses: Analysis 2

UnEx and BFI-C scales removed.

Table 1: *Initial and extraction communalities for the second factor analysis solution-BFI-C removed*

	Initial	Extraction
BFI: Extraversion	.663	.624
BFI: Neuroticism	.634	.644
BIS	.566	.647
EPQ-Psychoticism	.450	.579
EPQ-Neuroticism	.718	.792
EPQ-Extraversion	.772	.984
OLIFE: Cognitive Disorganisation	.663	.673
OLIFE: Introvertive Anhedonia	.524	.446
OLIFE: Impulsive Non-conformity	.556	.739
Sensation Seeking Scale	.401	.407
Summed BAS	.267	.260

Extraction Method: Principal Axis Factoring.

Table 2: *Loadings of the 11 scales on the extracted factors for the Varimax rotated 3-factor solution*

	Factor		
	1	2	3
EPQ-Neuroticism	.876	-.119	.103
BIS	.784		-.178
BFI: Neuroticism	.781	-.182	
O-life: Cognitive Disorganisation	.764	-.206	.216
EPQ-Extraversion	-.196	.959	.160
BFI: Extraversion	-.181	.755	.145
O-life: Introvertive Anhedonia	.221	-.630	
Summed BAS	.191	.386	.273
O-life: Impulsive Non-conformity	.220	.198	.807
EPQ-Psychoticism			.758
Sensation Seeking Scale		.211	.594

* Loadings below .1 are omitted

Appendix B.4

Initial Factor Analyses: Analysis 3

UnEx and BAS scales removed.

Table 1: *Initial and extraction communalities for the second factor analysis solution-BAS removed*

	Initial	Extraction
BFI: Extraversion	.638	.595
BFI: Neuroticism	.633	.650
BIS	.553	.630
EPQ-Psychoticism	.461	.600
EPQ-Neuroticism	.728	.782
EPQ-Extraversion	.738	.968
O-life: Cognitive Disorganisation	.697	.707
O-life: Introvertive Anhedonia	.500	.453
O-life: Impulsive Non-conformity	.549	.714
Sensation Seeking Scale	.395	.397
BFI: Conscientiousness	.275	.217

Extraction Method: Principal Axis Factoring.

Table 2: *Loadings of the 11 scales on the extracted factors for the Varimax rotated 3-factor solution*

	Factor		
	1	2	3
EPQ-Neuroticism	.862	-.150	.130
BFI: Neuroticism	.779	-.208	
BIS	.777		-.143
O-life: Cognitive Disorganisation	.753	-.246	.282
EPQ-Extraversion	-.151	.960	.154
BFI: Extraversion	-.162	.747	.103
O-life: Introvertive Anhedonia	.181	-.647	
O-life: Impulsive Non-conformity	.190	.202	.798
EPQ-Psychoticism			.770
Sensation Seeking Scale	-.110	.232	.575
BFI: Conscientiousness	-.199	.108	-.407
EPQ-Neuroticism	.862	-.150	.130

* Loadings below .1 are omitted

Appendix B.5

Correlation between personality factor scores and personality scales

Sample size = 166

Table 1: Correlation between the Big Five Inventory and the 4 extracted factors

		Neuroticism (PAF 2)	Positive Schizotyp y (PAF 2)	Extraversion (PAF 2)	ImpASS (PAF 2)
BFI: Extraversion	Pearson Correlation	-.112	.171(*)	.770(**)	.187(*)
	Sig. (2-tailed)	.150	.027	.000	.016
BFI: Neuroticism	Pearson Correlation	.847(**)	-.041	-.191(*)	-.052
	Sig. (2-tailed)	.000	.597	.014	.503
BFI: Conscientiousness	Pearson Correlation	-.259(**)	-.072	.053	-.460(**)
	Sig. (2-tailed)	.001	.357	.501	.000
BFI: Agreeableness	Pearson Correlation	-.254(**)	-.045	.318(**)	-.360(**)
	Sig. (2-tailed)	.001	.563	.000	.000
BFI: Openess	Pearson Correlation	-.120	.165(*)	.088	.244(**)
	Sig. (2-tailed)	.124	.033	.259	.002

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 2: Correlation between the EPQ and the 4 extracted factors

		Neuroticism (PAF 2)	Positive Schizotypy (PAF 2)	Extraversion (PAF 2)	ImpASS (PAF 2)
EPQ-Extraversion	Pearson Correlation	-.189(*)	.184(*)	.947(**)	.209(**)
	Sig. (2-tailed)	.015	.018	.000	.007
EPQ-Neuroticism	Pearson Correlation	.914(**)	.142	-.154(*)	.082
	Sig. (2-tailed)	.000	.068	.048	.292
EPQ-Psychoticism	Pearson Correlation	-.091	.226(**)	-.069	.824(**)
	Sig. (2-tailed)	.243	.003	.375	.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Appendix B.5 (continued)

Table 3: *Correlation between the Sensation Seeking Scale, BIS/BAS scales and the 4 extracted factors*

		Neuroticism (PAF 2)	Positive Schizotypy (PAF 2)	Extraversion (PAF 2)	ImpASS (PAF 2)
Sensation Seeking Scale	Pearson Correlation	-.075	.153(*)	.246(**)	.687(**)
	Sig. (2-tailed)	.334	.050	.001	.000
BIS	Pearson Correlation	.813(**)	.041	-.027	-.188(*)
	Sig. (2-tailed)	.000	.603	.732	.015
BAS-Drive	Pearson Correlation	.024	.147	.280(**)	.176(*)
	Sig. (2-tailed)	.760	.060	.000	.023
BAS-Fun Seeking	Pearson Correlation	.067	.212(**)	.331(**)	.323(**)
	Sig. (2-tailed)	.388	.006	.000	.000
BAS-Reward Responsiveness	Pearson Correlation	.285(**)	.121	.224(**)	.012
	Sig. (2-tailed)	.000	.122	.004	.874
Summed BAS	Pearson Correlation	.167(*)	.216(**)	.377(**)	.232(**)
	Sig. (2-tailed)	.032	.005	.000	.003

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 4: *Correlation between the OLIFE sub-scales and the 4 extracted factors*

		Neuroticism (PAF 2)	Positive Schizotypy (PAF 2)	Extraversion (PAF 2)	ImpASS (PAF 2)
OLIFE: Unusual Experiences	Pearson Correlation	.237(**)	.928(**)	-.012	.246(**)
	Sig. (2-tailed)	.002	.000	.877	.001
OLIFE: Cognitive Disorganisation	Pearson Correlation	.775(**)	.306(**)	-.278(**)	.264(**)
	Sig. (2-tailed)	.000	.000	.000	.001
OLIFE: Introvertive Anhedonia	Pearson Correlation	.182(*)	.030	-.724(**)	.030
	Sig. (2-tailed)	.019	.698	.000	.700
OLIFE: Impulsive Non-conformity	Pearson Correlation	.219(**)	.330(**)	.172(*)	.852(**)
	Sig. (2-tailed)	.005	.000	.027	.000

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Appendix C.1

Study 1: Conjunctive RB and II rule ambiguity

The method applied in study 4 is considered below using an example to illustrate the issue.

A discriminant function for category response (H) was constructed such that:

$$H = w1*B + w2*S + w3*C + w4*N$$

where 'B', 'S', 'C' & 'N' represent the respective stimulus dimensions (**B**ackground colour, **S**hape, (shape) **C**olour, and **N**umerosity). The relative weightings for each dimension are therefore given by w1 – w4.

The decision bound parameter, 'd', defines the criterion by which a category response is calculated from the discriminant function (H). Assuming an unbiased decision bound (i.e. d=0; no bias/preference for responding either category 'A' or 'B'), a participant's response set can be described as:

Respond category 'A' if H > d;
else respond category 'B' if H < d
(guess if H = d)

<u>Model 1: II Strategy – Stimulus Dimensions Vary on a Continuous Scale</u>

We begin with the situation in which 1) the stimulus dimensions vary on a continuous scale 2) a two-dimensional II strategy involving the **C**olour and **N**umerosity dimensions (C & N) is applied, and 3) these two dimensions are weighted equally (i.e. w3 = w4).

Consequently, ignoring the dimension weightings (which are not relevant to the present demonstration) the discriminant function (H) for this particular rule can be represented as:

$$H_{II} = C + N$$

And the corresponding response bound (identical to that above):

if $H_{II} > d$;   respond category 'A'
if $H_{II} < d$;   respond category 'B'

(guess if H = d)

Appendix C.1 (continued)

Model 2: Conjunctive RB Strategy – Stimulus Dimensions Vary on a Continuous Scale

A corresponding conjunctive RB strategy (not applied in study 1 – see below), involving the same two dimensions, requires a separate decision to be made upon each dimension before these decisions are combined to make an appropriate category decision. If 'x' and 'y' represent the decision criteria for dimensions C and N respectively, then one example of conjunctive RB decision strategy can be described as follows:

If C > x, and D > y;	respond category 'A'
Else;	respond category 'B'

Consequently, when stimulus dimensions are continuous valued the distinction between II and conjunctive RB strategies (models) is clear; in the conjunctive RB strategy, decisions are made independently before being combined to reach an appropriate response decision. In contrast, in the II strategy information from the relevant stimulus dimensions are combined at a pre-decisional stage.

II and Conjunctive RB Strategies – Stimulus Dimensions Vary on a Binary Scale

In the present study the stimulus dimensions varied on a binary scale (i.e. each dimension could take only 1 of 2 possible values; represented by the values "1" and "-1"). This does not alter the description of the models presented above. However, the functional outcomes of the two models are now indistinguishable.

For example, if participants responded category 'A' only when both dimension values were equal to 1 (cf. -1), then a suitable value for the decision bound ('d') for the II model could be 1.5. Consequently, the response arising from model 1 would be category 'A' only if the values on the two dimensions (C and N) were both equal to 1 (and category 'B' in all other cases).

A functionally identical outcome could arise from the conjunctive rule described above (model 2). For example, if the value of the two decision criteria, 'x' and 'y', were both equal to '0', then the response arising from model 2 would be category 'A' only if the values on the two dimensions (C and N) were both equal to 1 (and category 'B' in all other cases).

Consequently, the modelling method applied in study 1 (involving the discriminant function described above cf. model 1), although following a theoretical II framework, could not distinguish between an II or a conjunctive RB strategy (as either case can give rise to an identical set of responses). Crucially, however, the modelling was able to distinguish between the use of multi-dimensional and uni-dimensional response strategies.

Appendix C.2

Study 1: Models applied

The discriminant function (H), described on the previous page, was as follows:

$$H = w1^*B + w2^*S + w3^*C + w4^*N$$

Response is category 'A' if $H > d$ and category 'B' if $H < d$ (guessing if $H = d$), where d is the decision criterion. We assume $d = 0$ (in an unbiased case), but assume there is zero mean Gaussian noise associated with the criterion placement. The variance of this noise is σ^2.

The probability (P) of responding to a particular stimulus, K, which has values B_K, S_K, C_K, and N_K on each dimension was modelled by the following expression:

P(cat = 'A' | stim = K) = CDFNORMAL(H_K, 0, σ)

where $H_K = w1^*B_K + w2^*S_K + w3^*C_K + w4^*N_K$ and CDFNORMAL(z,m,s) describes the probability associated with value 'z' under the cumulative distribution function for a normal distribution with mean 'm' and variance s^2.

For each individual participant, maximum likelihood estimates (MLEs) were found for the parameters w1, w2, w3, w4 and σ under the model above, subject to a variety of constraints that determine the model variant. The first constraint is that we can set one of the weight values (e.g. w1) to 1, as it is the relative size of the weight parameters that is important. For the MLEs under each model, we note the value of the loss function (-2LL).

As discussed within the text there were two broad classifications of models fitted: Multi-dimensional (MD) and Single-dimension (SD).

MD models

<u>Model 1</u> (4 parameters): general linear classifier (the most general information integration model): w1=1, but the other 4 parameters were free to vary ($w >= 0$; $\sigma > 0$).

<u>Model 2</u> (2 or 3 parameters): as model 1 but with 1 or 2 of the w values set to 0 starting with dimensions with the smallest weights in the model 1 fit (note that for the II task used here, it is correct to treat the number dimension as irrelevant to task performance). The better fitting of the two possible models was recorded.

<u>Model 3</u> (1 parameter): as model 2 but with each stimulus dimension contributing equally to the function H (w1=w2=w3=1; w4=0)

SD models

<u>Model 4</u> (1 parameter): w1=1; w2=w3=w4=0 (a rule-based model in which a single dimension, i.e. w1 dimension, is used to assign categories). This was repeated for all 4 dimensions (i.e. varying the dimension which was used for the rule – had a weight = 1).

Appendix C.3

Study 1: Model comparisons

For each individual participant, the loss-function (-2 Log-Likelihood) was calculated for each model; the lower the loss function the better the fit of the model to the data. The models fitted to the II-task response data from study 1 are described on the previous page. Crucially, it was possible to compare the model fits between any pair of models in which the number of free parameters was unequal (i.e. all comparisons except between model types 3 & 4) using a chi-square comparison at *df* equal to the difference in the number of free parameters in the models. If it was possible to determine the best fitting model (relative to the number of model parameters) in this fashion the participant's response strategy was *confidently* classified as either an MD or SD strategy. In situations when such a contrast was not possible (e.g. in some circumstances when the single parameter MD and SD models provided good fits to the data), the model with the lowest loss-function was chosen and this was termed a *probable* classification.

Model comparisons

The MD model types 1 and 2 (MD1 & MD2) had between 2 and 4 free parameters (multi-parameter models) and could therefore be compared with either the MD model with a single free parameter (MD3) or the SD model(s) with a single free parameter (SD – i.e. model type 4). Hence, if the best-fitting SD model provided a significantly poorer fit to the data (relative to the reduced number of model parameters) than either a MD1 or MD2 model (in which the SD model is nested), the participant's response strategy could be confidently classified as MD (assuming the MD model provided an adequate fit to the data).

In the remaining cases the strategy classifications followed the outline described below. The term "best-fitting" refers to the model with the lowest loss-function (-2LL). The best-fitting multi-parameter model (i.e. MD1 or MD2) will be referred to as the "best M-P model".

If the best-fitting SD model was *not* a significantly poorer fit to the data than the best M-P model and:

a) the single parameter MD3 model was a significantly poorer fit to the data than the best M-P model;

>> this resulted in a *confident SD* classification

b) the single parameter MD3 model was *not* a significantly poorer fit to the data than the best M-P model yet had a greater loss-function than the SD model;

>> this resulted in a *probable SD* classification

c) the single parameter MD3 model was *not* a significantly poorer fit to the data than the best M-P model yet had a greater loss-function than the SD model;

>> this resulted in a *probable MD* classification

Appendix D

Study 2: Graded Exemplar Similarity Model of the DCE

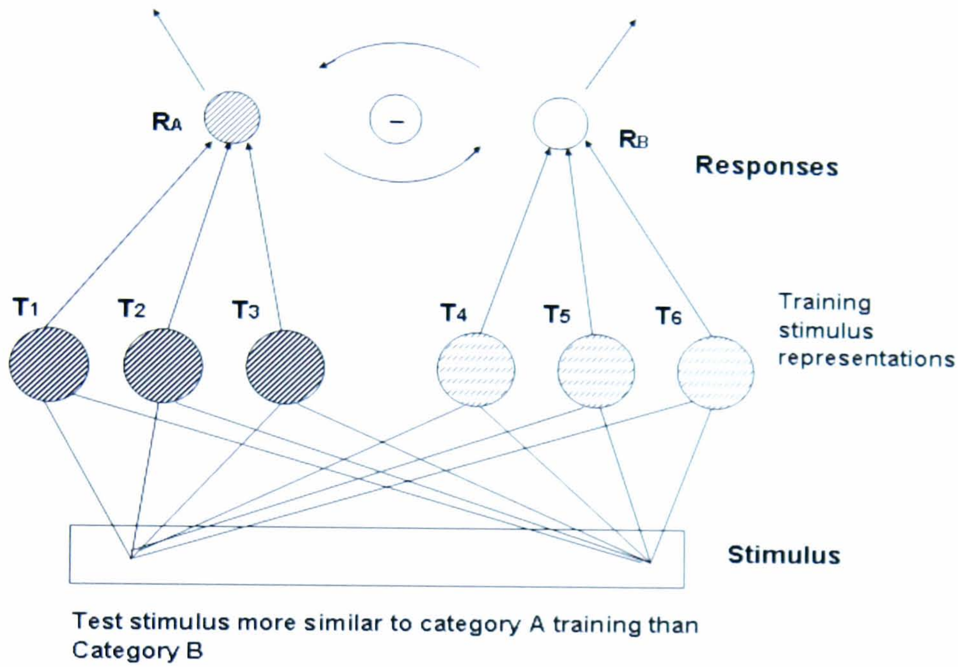


Figure 1: *Representation of an exemplar comparison model which may underlie the DCE*

The figure above illustrates an exemplar based model of processes which may be involved in the RT task. A test stimulus (i.e. novel probe) is compared to the stored representations (*including* the irrelevant dimensions) of previously experienced exemplars of the two categories (i.e. training stimuli). In the current example there are 3 exemplars from category 'A' ($T_1 - T_3$) and 3 exemplars from category 'B' ($T_4 - T_6$), which are associated with the competing response outputs R_A and R_B (for either a category 'A' or category 'B' response respectively). The more similar the probe stimulus is to the individual training representations, the greater the degree of activation of the training stimulus representation units ($T_1 - T_6$) and associated response units (R_A/R_B). A category response is initiated only when the activation of a particular response unit (R_A) is above a threshold and of sufficient strength to inhibit the competing response (i.e. R_B). Therefore, the greater the similarity differential between a test stimulus and the two sets of category exemplars, the greater discrepancy in the activation of the stimulus representation units and resultant activation of the response units and thus, the speed of a category response is facilitated. Consequently, if stimuli are encoded or processed in this way the DCE may arise if the *congruent* probe stimuli are more similar to the training stimuli than the respective *incongruent* probe stimuli. A theoretical consideration of this proposal is considered below.

Appendix D (continued)

Study 2: Graded Exemplar Similarity Model of the DCE - continued

The table below represents the structure of the stimuli used in the RT task, the two possible values on each of the four dimensions (I – IV) represented by a '1' or '-1'.

Table 1: *Underlying structure of the Reaction-Time task stimuli*

	Category A				Category B			
	I	II	III	IV	I	II	III	IV
Training	**-1**	1	-1	-1	1	-1	1	1
Training	**-1**	-1	1	-1	1	1	-1	1
Training	**-1**	-1	-1	1	1	1	1	-1
[illegible]	**-1**	1	1	1				
Congruent	**-1**	-1	-1	-1	1	1	1	1

The dimension values of the congruent category 'A' probe stimulus have been highlighted in a red font. Additionally, every instance in which this value is present in the 6 training stimuli has also been highlighted in red. The table clearly illustrates that the congruent category 'A' probe is more similar to the category 'A' training stimuli, 'sharing' 3 of 4 dimension values, than the category 'B' stimuli, in which only one dimension value is common. The sharing of dimension values may be represented in numerical terms by, arbitrary, 'similarity' units; thus, the congruent category 'A' probe has a similarity of 3 units with the category 'A' training exemplars compared with a single similarity unit with the category 'B' training stimuli. Furthermore, it may be valid to suggest that the value on the target dimension (i.e. dimension I) is likely to receive a greater weighting in the similarity assessment. The weighting of the target dimension can be represented by 'α', and furthermore that this value is (much) greater than a single similarity unit associated with the non-target dimensions (thus, $\alpha >> 1$).

Thus the similarity between the congruent category 'A' probe and the category 'A' training stimuli can be summarised by the expression "$\alpha + 2$", whereas the similarity between the congruent category 'A' probe and the category 'B' training stimuli is merely equal to "1" unit (on the same scale). Therefore, as "$\alpha + 2 > 1$", the similarity of the probe to category 'A' (cf. category 'B') is clear and participant should make the appropriate response. This process can be repeated for the incongruent probe (category 'A') and it is found that the similarity between the *incongruent* category 'A' probe and the category 'A' training stimuli will equal "$\alpha + 1$" units, whereas the similarity between the incongruent category 'A' probe and the category 'B' training stimuli is equal to "2" units (on the same scale). Again the participant should make the appropriate response as "$\alpha + 1 > 2$".

Appendix D (continued)

Study 2: Graded Exemplar Similarity Model of the DCE – continued

Crucially, as described above, the RT to a test stimulus is a function of the similarity differential between the probe and the category exemplars associated with the two category responses. Hence the similarity differential for the congruent category 'A' probe is given by:

$$\alpha + 2 - 1 = \alpha + 1$$

The corresponding similarity differential for the incongruent probe category 'A' probe:

$$\alpha + 1 - 2 = \alpha - 1$$

Thus the DCE arises from the fact that the similarity differential for the congruent category 'A' probe ($\alpha + 1$) is greater than that of the incongruent category 'A' probe ($\alpha - 1$).

As described in chapter 5, one possible mechanism for the association between schizotypy and decreased DCE could be a tendency to encode fewer than all 3 of the non-target dimensions. For example, if only one of the non-target dimensions were encoded the similarity differential for the congruent category 'A' probe would be:

α + 2/3 (similarity to category 'A' exemplars) – 1/3 (similarity to category 'B' exemplars) = α + 1/3

while the similarity differential for the incongruent category 'A' probe would be:

α + 1/3 (similarity to category 'A' exemplars) – 2/3 (similarity to category 'B' exemplars) = α - 1/3

therefore, although still present, the DCE is much reduced as the difference in RTs is smaller (i.e. "α + 1: α - 1" cf. "α + 1/3: α – 1/3").

Appendix E.1

Study 3: Stimuli

The task used in study 3 was identical to the one used by Maddox, Baldwin et al. (experiment 1, 2006) and the following summarises the description of the generation of the stimuli as described in their paper. On each trial a single stimulus, a white line with a length of 'x' pixels, orientation of 'y' units and horizontal position (location on the screen) of 'z' pixels was presented on the computer screen (black background) in the (vertical) centre of a 650 pixel (square) box (which had a white outline). A set of 576 unique stimuli were generated (i.e. which varied on the 'x', 'y' and 'z' dimensions) with an equal number (i.e. 288) of category 'A' and category 'B' items. The stimuli were divided into 12 separate blocks (i.e. 48 trials per block) with an equal number of each category (i.e. 24) in every block. Crucially, the population parameters (mean and variance) for the two categories on the stimulus dimensions (i.e. length, orientation and horizontal location) were equivalent in each block. Each participant was presented with all 12 blocks of trials, although the order in which the blocks were presented was randomised for each participant.

Category 'A' items comprised stimuli sampled from 12 bivariate-normal distributions on the length and orientation dimensions (24 stimuli were selected from each distribution). The category 'B' stimuli were selected from 4 bivariate-normal distributions on the length and orientation dimensions (72 items were selected from each distribution). The distribution parameters (mean and SD) for these samples are shown in the table below. The category distributions on the position were generated independently with category 'A' items sampled from a normal distribution with a mean of 253 pixels (displacement from the left-hand edge of the display box) and standard deviation of 75 pixels. The category 'B' items had mean horizontal position of 397 pixels (SD = 75). The wide range of values on this *irrelevant* dimension was created especially in order to make this position dimension particularly salient.

Category distribution parameters for the length and orientation dimensions

Category	μ_l	μ_o	σ_l	σ_o	cov_{lo}	Category	μ_l	μ_o	σ_l	σ_o	cov_{lo}
A1	42	42	12	12	0	B1	186	186	12	12	0
A2	42	114	12	12	0	B2	186	258	12	12	0
A3	42	186	12	12	0	B3	258	186	12	12	0
A4	42	258	12	12	0	B4	258	258	12	12	0
A5	114	42	12	12	0						
A6	114	114	12	12	0						
A7	114	186	12	12	0						
A8	114	258	12	12	0						
A9	186	42	12	12	0						
A10	186	114	12	12	0						
A11	258	42	12	12	0						
A12	258	114	12	12	0						

Where μ_l and μ_o are the mean values on the length and orientation dimensions of the respective populations and σ_l and σ_o are the associated SD parameters (cov_{lo} the covariance between the two dimensions). The orientation units were transformed into radians by multiplying each value by π/500.

Appendix E.2

Study 3: Model fitting

As described within the text, the modelling of response strategy used maximum likelihood estimation to assess a number of separate decision bound models. For example, one decision bound model was a conjunctive rule-based model involving the two relevant dimensions (length and orientation of the stimulus) and had 4 parameters which were free to vary; the two decision criteria (i.e. 'x' and 'y': is the length of the line greater than 'x', *and* is the orientation of the line greater than 'y') and the two noise parameters associated with each criteria (i.e. a combination of *perceptual* and *decisional* noise).

Modelling was performed using the Matlab software package. Using an iterative process, the model parameters were modified in an attempt to minimise the discrepancy between the participant's response data and the responses predicted by the model (with the current parameters). This was achieved by minimising the loss-function (-2 Log-Likelihood; i.e. -2* the sum of the logged probabilities of the model predicting the actual responses made by the participant) on each iteration. When the iteration process was complete, the final likelihood estimate ($-2LL_{model}$) of the model was recorded along with the estimated model parameters.

The model fit was then compared to the saturated (perfect) model (i.e. -2 Log-Likelihood = 0; $-2LL_{sat}$) to calculate a log-likelihood ratio (i.e. $-2LL_{model} - -2LL_{sat}$) and assess whether the decision bound model provided a reasonable fit to the data (assessed by chi-square equal to the log-likelihood ratio, at *df* equal to the difference between the number of model parameters and data points).

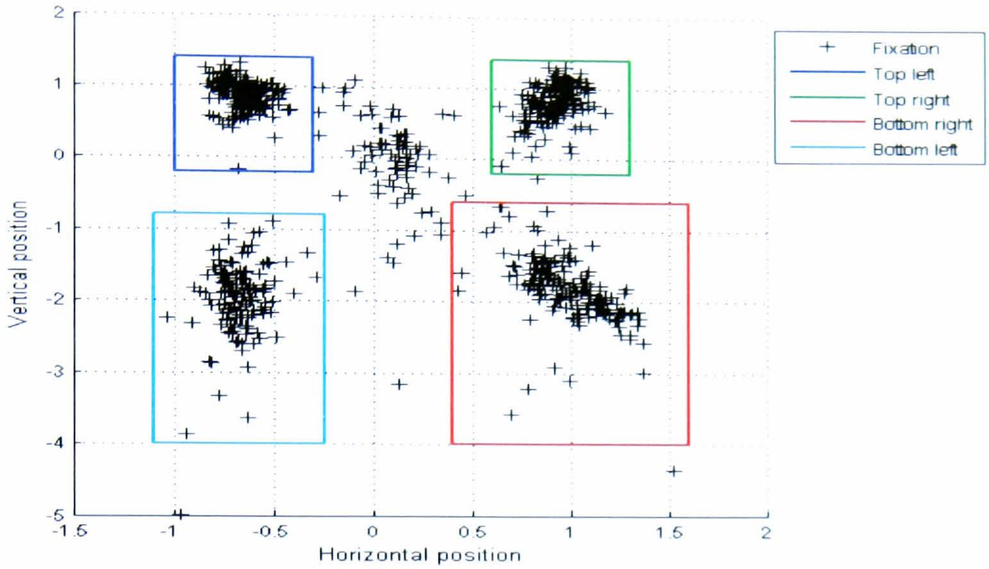
Finally, a goodness-of-fit statistic (AIC) was calculated for each (well-fitting) decision bound model as given by the following equation:

$$AIC = 2r + (-2LL_{model})$$

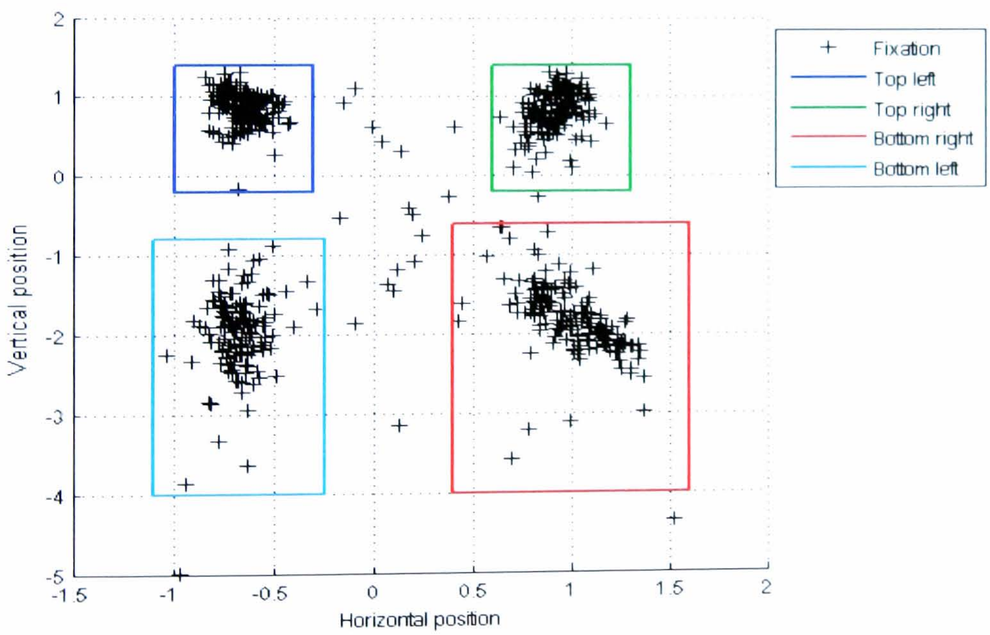
where r is the number of free parameters in the model. The smaller the AIC value the better the fit of the model, irrespective of the number of model (free) parameters. Hence, the best fitting decision bound model was chosen on the basis of the smallest AIC value.

Appendix F.1

Study 4: Fixation plots



Scatter plot 1: *Fixations and dimension location boundaries for one participant on the first rule phase of the task*



Scatter plot 2: *Fixation locations for the same participant on the first rule phase of the task with the first fixation of each trial removed*

The two scatter plots above show all fixations recorded for a single participant on the first rule phase of the task. The second plot has the first fixation of each trial excluded. The increased range of the vertical co-ordinates reflects the lesser accuracy of the vertical recording.

Appendix F.2

Study 4: Relationship between personality and the number of dimensions fixated during the first rule phase

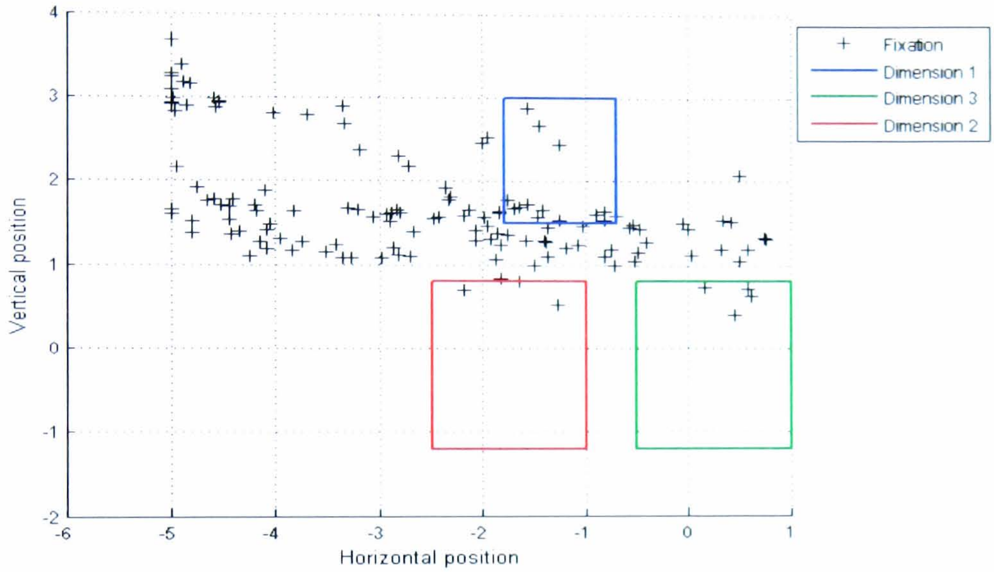
		Neuroticism	Positive Schizotypy	Extraversion	ImpASS
Mean number of dims fixated in 1st 10 trials (rule 1)	Pearson Correlation	-.104	-.185	**-.223**	**.179**
	Sig. (2-tailed)	.592	.337	.244	.352
	N	29	29	29	29
Mean number of dims fixated pre-criterion run (rule 1)	Pearson Correlation	.169	-.103	**-.117**	**.206**
	Sig. (2-tailed)	.398	.608	.561	.303
	N	27	27	27	27
Mean number of dims fixated in last 8 trials (rule 1)	Pearson Correlation	-.055	-.100	**-.205**	**.258**
	Sig. (2-tailed)	.786	.620	.305	.194
	N	27	27	27	27

The table above shows further examples in which extraversion and ImpASS appeared to be differentially associated with the ET measures related to the number of dimensions fixated per trial.

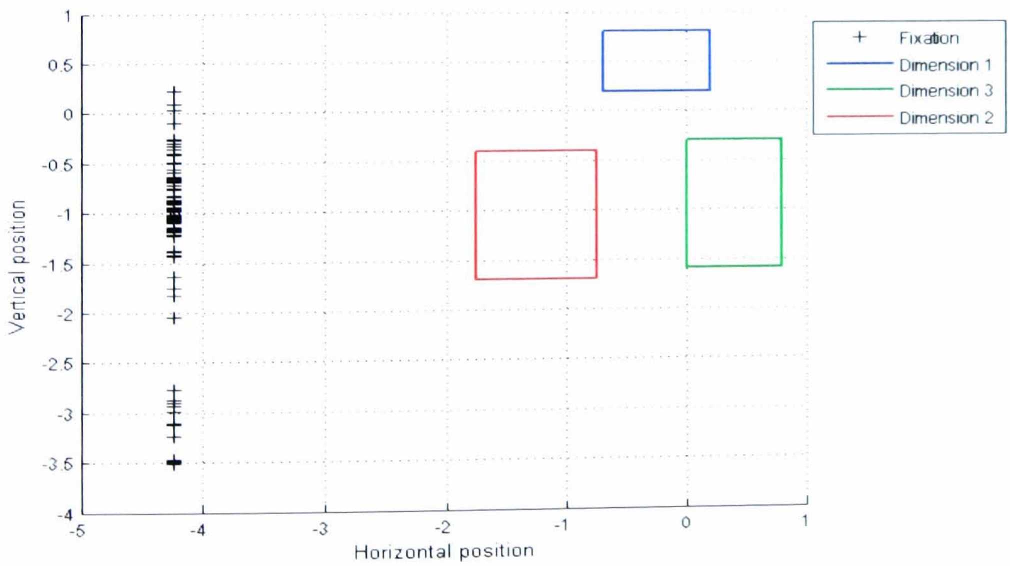
Appendix G.1

Study 5: Examples of excluded ET data

The dimension boundaries, marked on the figures below, were calculated from the preceding block of trials. In each case, the preceding block of trials provided reasonable data (and hence stimulus dimension boundaries were definable). The figures below clearly demonstrate examples in which the ET data for a particular individual on a single block of trials were un-assessable and therefore excluded from further analyses.



Scatter plot 1: *Fixations and previous dimension location boundaries for one participant (28) on the 7th block of trials*

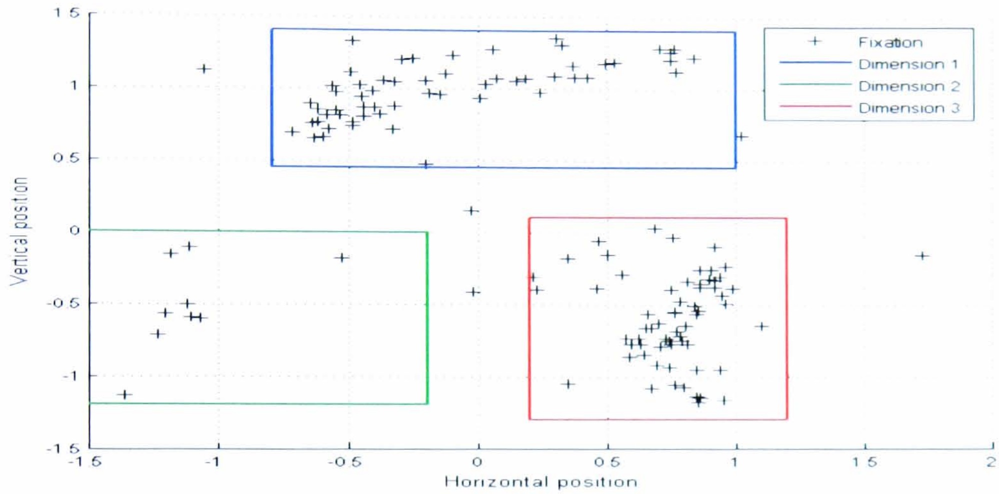


Scatter plot 2: *Fixations and previous dimension location boundaries for one participant (31) on the 4th block of trials*

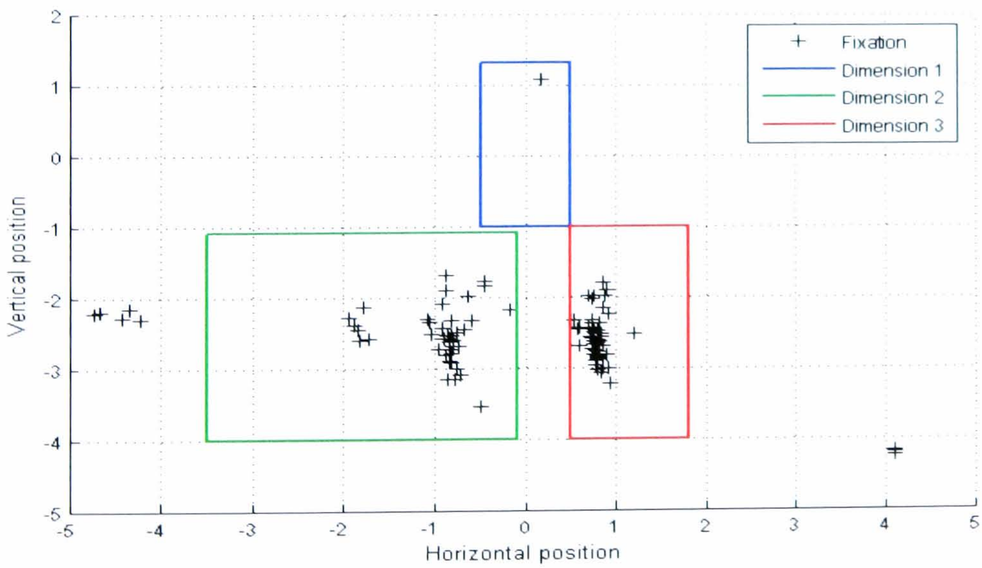
Appendix G.2

Study 5: Examples ET and modelling data congruency

The two figures below demonstrate examples in which the ET data was classified either partially incongruent or incongruent with the response modelling data



Scatter plot 1: *Fixations and dimension location boundaries for one participant (18) on the 7th block of trials in which response modelling suggested a uni-dimensional strategy involving only dimension 1 was used: Partially congruent classification*



Scatter plot 2: *Fixations and dimension location boundaries for one participant (16) on the 3rd block of trials in which response modelling suggested a two-dimensional strategy involving dimensions 1 and 3 was used: Incongruent classification*