AN INVESTIGATION INTO THE CLINICAL AND COGNITIVE CORRELATES OF SAVANT SKILLS IN INTELLECTUALLY ABLE CHILDREN WITH AUTISM SPECTRUM DISORDER

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ABSTRACT

Whilst traditional definitions of savant syndrome assumed an association between intellectual impairment and talent in atypical populations, reports of outstanding talents in intellectually high functioning individuals with Autism Spectrum Disorders (ASD) highlighted limitations in these early definitions and led to a reconsideration of the syndrome. This redefinition raised interesting questions about how talented high functioning individuals with ASD might differ from those with the same diagnosis but without outstanding talents. Motivated by early and more recent theoretical models of savant syndrome, the studies described in this thesis investigated the clinical and cognitive correlates of savant syndrome in a comparison of age and intelligence matched children with ASD who did or did not possess outstanding skills. In the clinical assessment phase of testing, participants with outstanding skills, validated across a number of domains, together with groups of ASD and typically developing (TD) control participants completed tests of symptom severity, sensory abnormality and obsessionality. The results from these assessments failed to reveal a significant difference on measures of symptom severity between the ASD groups, although the savants appeared to be less impaired in the domain of creativity. There was also a trend for savants to be less impaired in sensory domains, and this was particularly marked in visual and auditory filtering which may be important for savant skills. The two ASD groups did not differ on the numbers of obsessions reported, although savant obsessions tended to be more focussed on functional domains (e.g. crafts and numbers) than the obsessions reported for non-savants. Both ASD groups showed marked obsessional tendencies in comparison to TD controls. The cognitive test battery probed concentration, intelligence, cognitive style and pattern perception in the two groups. This revealed superior concentration, pattern perception and performance on several measures of intelligence and local processing in the savant group. However, a logistic regression analysis carried out on the tests that distinguished savants and non-savants in the group comparison studies, showed that measures of concentration and working memory were most powerful in predicting savant status. It was therefore concluded that whilst new theoretical accounts of savant syndrome, highlighting superior pattern processing abilities, provide an advance on earlier theories, they underestimate the importance of working memory and therefore merit further revision.

CONTENTS

CHAPTER 2: METHODOLOGY 33

LIST OF FIGURES

CHAPTER 2: METHODOLOGY

CHAPTER 3: CASE STUDIES OF THREE CHILDREN WITH ASD AND SKILLS IN THE CLASSIC SAVANT DOMAINS OF ART, MUSIC AND NUMBER

CHAPTER 4: IDENTIFYING THE BEHAVIOURAL AND CLINICAL CORRELATES OF SAVANT SKILLS IN CHILDREN WITH ASD

CHAPTER 5: EXPLORING THE COGNITIVE CORRELATES OF SAVANT SKILLS IN CHILDREN WITH ASD

CHAPTER 7: TESTING PATTERN PERCEPTION OF SAVANT SKILLS IN CHILDREN WITH ASD

LIST OF TABLES

CHAPTER 2: METHODOLOGY

CHAPTER 3: CASE STUDIES OF THREE CHILDREN WITH ASD AND SKILLS IN THE CLASSIC SAVANT DOMAINS OF ART, MUSIC AND NUMBER

CHAPTER 4: IDENTIFYING THE BEHAVIOURAL AND CLINICAL CORRELATES OF SAVANT SKILLS IN CHILDREN WITH ASD

CHAPTER 5: EXPLORING THE COGNITIVE CORRELATES OF SAVANT SKILLS IN CHILDREN WITH ASD

CHAPTER 6: EXAMINING THE COGNITIVE PROCESSING STYLE OF SAVANT SKILLS IN CHILDREN WITH ASD

CHAPTER 7: TESTING PATTERN PERCEPTION OF SAVANT SKILLS IN CHILDREN WITH ASD

CHAPTER 8: WHAT COGNITIVE CHARACTERISTICS DEFINE SAVANTS WITH ASD?

DEDICATION

The thesis is dedicated to the savant children on whom the work is focussed, for their love of drawing, music and numbers.

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CHAPTER 1: INTRODUCTION

ABSTRACT

This chapter provides a brief review of the literature into savant syndrome and highlights the outstanding questions that motivated the work described in this thesis. The studies detailed in the empirical chapters address outstanding questions about the behavioural and cognitive characteristics that potentially distinguish savants and non-savants, and the literature that is of direct relevance to these questions is detailed and discussed within those chapters. For an overview of research into the savant syndrome the reader is directed to comprehensive review articles (e.g. Heaton & Wallace, 2004; Miller, 1999; Nettelbeck & Young, 1999; Treffert, 2009) and books on the subject (e.g. Hermelin, 2001; Treffert, 1989, 2010).

HISTORICAL PERSPECTIVES OF SAVANT SYNDROME

Whilst savant syndrome has been well documented in the medical and psychological literature for the last few centuries, early reports were primarily anecdotal case studies and descriptions of specific skills (Hill, 1978). Treffert (2009) estimated that descriptions of savants first appeared in the scientific literature as early as 1783, citing, for example, the case of Jedediah Buxton (1707–1772), a farm labourer with limited education, who could estimate whole areas of land simply by walking around them. Buxton was reported to be so proficient with numbers that he even invented names for the excessive quantities that he worked with (e.g. a "tribe" was the cube of a million). When tested by The Royal Society in 1754, he demonstrated an ability to calculate numbers of up to 39 digits (Mortiz, 1783). Six years later Rush (1789) described the case of Thomas Fuller (1710–1790), an African slave who performed lightening fast complex calculations, despite an inability to understand much else. When asked how many seconds a man had lived by the time he was 70 years, 17 days, and 12 hours old, Fuller gave the correct answer (2,210,500,800) within 90 sec. On being informed that his calculation was wrong, Fuller corrected his examiner by pointing out that the man had not included 17 leap years (Scripture, 1891). Thomas "Blind Tom" Bethune (1849–1908), an American slave, was the subject of the earliest documented case of musical savantism. It was reported that Blind Tom developed an early interest in playing the piano and quickly learnt to play more than 5,000 pieces. His repertoire included compositions by Mozart, Beethoven, Bach and Verdi and it was reported that he learned these pieces after a single exposure. His repertoire also included pieces that he had composed himself. Blind Tom became something of a celebrity and after performing for President James Buchanan at the White House when he was only eleven years old he earned the title "the eighth wonder of the world" (reported in Treffert & Wallace, 2002). His musical talent existed in stark contrast to blindness, limited cognitive ability and a vocabulary of fewer than 100 words.

It was not until 1887 however, almost 100 years after the reported case of Thomas Fuller, that the implications of co-existing ability and disability within the same person was discussed in the medical literature. In a series of lectures to the Medical Society of London, Down (1887) described 10 cognitively impaired patients with accompanying extraordinary talents who he had cared for during his time as a superintendent for the Earlswood Asylum, London. He reported that one patient could multiply numerous digits as fast as they could be written down and another had perfect recollection of all the arias he had heard during a visit to the opera. Twenty seven years after Down's report, Tredgold (1914) presented a series of 20 savant case studies in his text Mental Deficiency. According to Treffert (1988) these colourful and detailed descriptions provide the richest account of savant syndrome in the clinical literature. In his classic work, Tredgold (1914) reported on Gottfried Mind an artist with mental retardation who painted such life-like depictions of cats that he earned himself the title "the Cat's Raphael" and James Pullen, "the Genius of Earlswood Asylum", a deaf and cognitively impaired man who built exquisite model ships with minute details from hand-fashioned parts. Other individuals were reported to possess skills in domains such as music, mathematics, memory and calendar calculation, as well as additional skills in languages, spatial and direction skills and "special senses" (e.g. tactile abilities). These skills map onto the classic domains of savant talent that are still reported almost 100 years later. Seguin (1866), Binet (1894), Ireland (1900) and Goodard (1914) have also devoted space in their works to describing the unusual feats of cognitively impaired individuals. Collectively, these accounts showcase persons with excellence in one field and impairments in almost all other areas, hence arriving at early definitions of savant syndrome.

DEFINITIONS OF SAVANT SYNDROME

In light of his own clinical observations, Down (1887) proposed the term "idiot-savant" to characterise persons of low general intelligence who possessed brilliance in one or more specific domains. At this time "idiot" was a scientific descriptor referring to the clinical classification of impaired intellectual quotient (IQ < 25). Down (1887) therefore combined this term with "savant", from the French word "saviour" meaning "to know", in what became the first accepted definition of savant syndrome. However, evidence suggests that almost all reported cases of savant syndrome have IQ scores ≥ 40 (see Miller, 1998), and researchers have now largely rejected the term "idiot-savant" on the grounds of scientific fallacy. In addition, the negative connotations of the term "idiot" have contributed to a decline in its use. Currently "savant syndrome" or more simply "savant" are considered to be acceptable descriptors (Treffert, 1989).

In an attempt to further define savantism, Treffert (1989) detailed a three-tier spectrum of proficiency. Amongst the rarest individuals are prodigious savants: those whose skills are so exceptional that they would retain their status even when matched with gifted typically developing people. Indeed, these individuals are so few that less than 100 cases of prodigious savants have been reported in the literature during the past century. Stephen Wiltshire is a highly celebrated prodigious savant artist who is diagnosed with autism and is widely recognised for his outstanding contribution to art. Described as the human camera, Wiltshire draws panoramic landscapes and complex architecture perfectly to scale and in exceptional detail relying only upon his memory. Talented savants are individuals with finely tuned skills that clearly contrast with their overall cognitive disability. However, whilst their skills are superior to those of individuals with similar levels of cognitive disability, they do not exceed those observed in talented typically developing persons. At the lowest level, splinter skills are usually confined to feats of memory (e.g. memorisation of phone numbers, car number plates) and would not be considered remarkable in typically developing individuals. However these skills are special when considered in the context of the person's overall ability level. For example, a child with autism who has little expressive language, an inability to form appropriate peer relationships and a high degree of repetitive behaviour, but who remembers train timetables with great ease and accuracy would be considered to possess a splinter skill. As Heaton & Wallace (2004) explain, splinter skills are not unusual in autism and other developmental disabilities and may simply reflect the uneven cognitive profile that is often observed in such populations. Although there is no current reliable data on the frequency of savant skills at the different levels described by Treffert (1989), Miller (1998) proposes that musical, artistic and numerical skills, regardless of skill level, are the most commonly described skill types.

Miller (1998) suggested a conceptual shift in the way that savantism is viewed and defined. In advocating for a discrepancy-based formulation of savant syndrome, Miller (1998) proposed that intra-individual performance should be of importance in deciding upon the savant status of an individual. For example, under Miller's (1998) model a person with an average global IQ but with a developmental disability would be eligible for savant status if s/he possessed an outstanding skill. However, under Down's (1887) criteria his/her normal IQ would preclude this. In support of Miller's model, Heaton & Wallace (2004) suggested that savant research should utilise measures of adaptive functioning in addition to standardised tests of IQ. The question of how best to define savant syndrome is reconsidered in chapters 2 and 5 and in the final discussion of this thesis, but it is important to emphasise here that there has been a move away from traditional definitions of savant syndrome in which an intellectual deficit is mandatory (Heaton, 2010, 2012). Hence, this new conceptualisation of the syndrome enables high functioning individuals with developmental disabilities and special talents to be categorised as savants. The study of savant syndrome poses a number of methodological challenges, not least of which is the defining and measuring of special skills. Whilst the inclusion of cognitively unimpaired individuals in savant studies might seemingly simplify the task of measuring IQ, questions about the limitations of available suitable intelligence tests should also be addressed. Chapter 2 addresses questions about the categorisation of savant skills, and chapter 5 addresses the question of whether savants and non-savants, matched on global IQ, will show qualitatively different profiles of cognitive abilities.

CLINICAL CORRELATES OF SAVANT SYNDROME

One developmental disorder that has a very strong association with savant syndrome is autism. Autism was first described by Kanner in 1943 and today it is diagnosed according to impaired socio-communication and restricted, repetitive behaviours and interests (DSM–IV, APA, 1994). Recent estimates have suggested that autism may affect up to 1 in 88 children in the US, the highest estimate to date, with a ratio of approx. 5:1 males to females (Centers for Disease Control and Prevention, 2012). Unlike other neurodevelopmental disabilities (e.g. Down's syndrome, William's syndrome), autism exists along a spectrum with higher functioning individuals being characterised by relatively unimpaired language and intact global intelligence (i.e. Asperger's syndrome as classified in DSM–IV) and those more impaired persons characterised by social disinterest, severe language impairment and a high degree of stereotyped behaviour (i.e. classic autism). Whilst the key features of this disorder are present in all individuals diagnosed with autism, the extent of symptom severity varies greatly. This group of disorders are now referred to as Autism Spectrum Disorders (ASD) reflecting the heterogeneity in the symptoms that are observed. Interestingly, the prevalence of talent in ASD was noted when the disorder was first described. In his first description of autism, Kanner (1943) described "islets of ability" in areas such as memory, drawing and puzzles that stood in marked contrast to the autistic aloneness of his patients. Further, a recent analysis of Down's (1887) text suggested that the talented patients he described may have had autism, although the disorder was not formally recognised at that time (Treffert, 2004). For example, individuals exhibited a degree of echolalia and were described as self-absorbed, in a world of their own.

In 2009 Treffert estimated that 50% of savants are diagnosed with ASD and this was consistent with results by Rimland (1978) showing that prevalence rates of savant syndrome were far higher in populations of individuals with autism (9.8%) than amongst persons with general mental retardation (.06%: Hill, 1978). Yet, more recent estimates suggest that up to a third of individuals with ASD may possess an enhanced cognitive ability or savant skill (Howlin, Goode, Hutton & Rutter, 2009) and this was supported by Bennett & Heaton (2012) who found a prevalence rate of 42% of their total ASD sample (52 out of 125). While the aim of the study by Bennett & Heaton (2012) was to provide a new screening instrument and prevalence figures were solely reliant upon parental report, the findings confirmed a clear link between talent and ASD. Importantly, these more recent findings suggest that the prevalence of talent in ASD might be even higher than the old estimates permit and this is in line with reported increases in the numbers of cases of ASD. Researchers have long sought to understand the overlap between savant syndrome and ASD, and in their quest have pinpointed clinical correlates as a possible explanation.

It is possible that the core symptoms of ASD may set the foundation for skill acquisition. For example, some researchers have suggested that less time engaged in social interaction (as a result of socio-communicative impairment and/or a disinterest in people) allows more time for the pursuit of special interests and skills (Hoffman, 1971; Nurcombe & Parker, 1964; Tredgold, 1914; Viscott, 1970). However, many individuals with ASD do not possess a specific talent (discussed in Happé & Frith, 2009) and the question of whether those individuals will show reduced symptom severity in comparison with savants has yet to be addressed empirically. There has been much speculation on the potential role of repetitive behaviours and obsessional tendencies in the emergence of savant talent. Here the premise is that mastery in isolated areas results from a tendency to become obsessed with an area of special interest and a consequent repetitive practising of a skill. Despite the longevity of this contention, the evidence to date is extremely weak. For example, in their study of savant obsessions, O'Connor & Hermelin (1991) found that group differences emerged on only 2 out of 15 questionnaire items probing obsessional behaviours. This analysis showed that compared to non-savants, savants with autism were more likely to order their possessions and demonstrate an increased interest in one particular topic. Bennett & Heaton (2012) reported a similar result: compared to non-skilled individuals with ASD, skilled individuals showed a tendency to become absorbed in topics of interest, but were not more obsessional per se. An interesting question concerns the boundary between the kind of highly focussed attention that is seen in some typically developing children (De Loache, Simcock & Macari, 2007) and those with ASD, and this subject will be readdressed in chapters 4 and 5. Questions about symptom severity and obsessionality in savants with ASD have been widely discussed, but no studies to date have directly compared savants and non-savants with ASD on measures of these. The studies detailed in chapter 4 examined the clinical correlates of talent in savant children with ASD and specifically addressed the question of whether these children would show increased symptom severity and obsessionality compared with children with ASD who do not have savant talents.

COGNITIVE CORRELATES OF SAVANT SYNDROME

Empirical investigations of savant syndrome have devoted considerable effort to pinpointing the cognitive correlates of such talents. These have mostly included investigations into intelligence and memory, with limited work on other cognitive factors such as executive functioning, learning or perception. The focus of this discussion is restricted to intelligence and memory only as these factors were integral to the studies carried out in the current thesis. As mentioned, the term "idiot-savant" traditionally assumed the role of impaired intellect as a necessary correlate to superior skills in disabled individuals (Down, 1887). However, this contention has not been well supported by research findings that have described savant skills in individuals with normal intelligence (Heavey, Pring & Hermelin, 1999; Treffert & Wallace, 2002; Young & Nettelbeck, 1995) and findings showing that the range of IQ scores in savants vary considerably. For example, Miller (1998) reported global IQ scores ranging from 33–114 in his review of 58 savant studies, a number of which included participants with autism or autistic behaviours. There has been considerable controversy about the extent of intellectual impairment in ASD and this is important considering that at least half of all savants are diagnosed with ASD (Treffert, 2009). Recent studies have found that intellectual impairment in ASD is not as prevalent as was once thought (Chakrabarti & Fombonne, 2005; Charman, Pickles, Siminoff, Chandler, Loucas & Baird, 2011). Further, some researchers (Dawson, Soulières, Gernsbacher & Mottron, 2007) have speculated that the nature of autistic intelligence is fundamentally different to that seen in typical development and have argued that spiky test profiles, characteristic in ASD, raise important questions about the extent that global IQ provides a valid measure of intelligence in this group. It has long been noted that the intelligence test profiles of people with autism are splintered with some subtests proving especially difficult whilst others are unimpaired, or even enhanced (Frith, 2003; Happé, 1994). Weak Central Coherence theory (discussed in the next section) offers some explanation for spiky profiles in ASD, for example frequently observed superiority on the Block Design test, and several studies have investigated superior Block Design in those with ASD and savant skills (discussed in chapter 5). However, as outlined earlier in this chapter, there has been a redefinition of the savant syndrome and this merits a reinvestigation of cognitive profiles in intellectually able individuals with ASD and savant skills. The studies carried out in chapter 5 present a detailed analysis of intellectual differences between IQ matched groups of savant and non-savant children with ASD. The topic of intelligence in savant syndrome is reconsidered in that chapter and discussed in some detail.

Superior memory has been highlighted as a cognitive factor characterising those with savant skills. Treffert (2009) who has written extensively about savantism has implicated what he described as "characteristically very deep" memory that is "exceedingly narrow within the confines of the accompanying special skill" (p. 1353). Several empirical studies have investigated memory skills in groups of savants with ASD. For example, O'Connor & Hermelin (1987) presented 8 savant artists (4 with autism) and IQ matched non-savants with a variety of simple tasks involving memory recognition and graphic reproduction of shapes from memory. While the performance of both groups was equal in terms of memory recognition (a matching task), the savants demonstrated superior graphic reproduction from memory and this was independent of IQ. In another study, Hermelin & O'Connor (1990) studied 8 savant artists (4 with autism) and compared their drawings to those of typically developing gifted artists across 4 conditions, one of which required participants to draw a 3D scene from memory. Although the drawings produced from memory were equal in terms of artistic merit, the comparison group actually scored higher than the savants in terms of accuracy. Whilst the findings from these two group studies are contradictory and do not clearly support the view that visual memory is enhanced in savants with autism, case reports invariably implicate enhanced visual memory in these individuals (e.g. Sacks, 1995; Selfe, 1977) and it might be that methodological limitations rather than truly unexceptional memory accounts for this lack of empirical support (Heaton & Wallace, 2004).

Other work on memory has been conducted with musical and calendar calculating savants. Exceptional musical memory in autism was first described by Kanner (1943) and has subsequently been linked to absolute pitch (Heaton, 2003; Heaton, Hermelin & Pring, 1998) and knowledge about musical structure (e.g. Miller, 1989; Mottron, Belleville & Ménard, 2000; Pring, Woolf & Tadic, 2008; Sloboda, Hermelin & O'Connor, 1985; Young & Nettelbeck, 1995) in savants. Heavey et al. (1999) studied memory functioning in 8 calendar calculators (7 with autism) and observed superior recall of date (domain-specific) information. However, these participants did not possess unusually increased short- and long-term memory capacities as measured by the Digit Span test or recall of words from a list. This finding was surprising given that several studies, some of which included large participant samples (e.g. Bölte & Poustka, 2004; Young & Nettelbeck, 1995), have described increased working memory capacity, measured using the Digit Span test, in individuals with ASD and specific talents (Rimland & Hill, 1984; Rumsey, Mannheim, Aquino, Gordon & Hibbs, 1992; Spitz & LaFontaine, 1973; Young & Nettelbeck, 1995). Superior Digit Span does not appear to be a general cognitive strength in ASD. For example, in a recent study implementing the Digit Span task with adults with autism and typically developing controls, Poirier, Martin, Gaigg & Bowler (2011) reported an autism-specific short-term memory deficit that was directly related to difficulties in encoding the order of presented items. Taken together this evidence suggests that spared, or indeed superior, Digit Span is specifically associated with talent in ASD, and this will be investigated in chapters 3 and 5.

The idea that savants show exceptional rote memory has been put forward by a number of researchers (Hill, 1978; Horwitz, Kestenbaum, Person, & Jarvik, 1965). In the literal sense, rote memory suggests the encoding of information according to an inflexible, stable knowledge base that is maintained exclusively by rigid rehearsal of that material. However, Pring (2008) reviewed the literature into memory characteristics in savants, with especial regard to the core domains of artistic, musical and numerical talents, and broadly concluded that rote memory is inappropriate as an explanation for savant skills considering that flexibility in the manipulation of domain-specific information is essential, and evident, in these core savant domains. Indeed, other authors are of the same opinion (Heaton & Wallace, 2004, Hermelin & O'Connor, 1986; Nettelbeck & Young, 1999). In contrast to a reliance on rote memory, Pring (2008) proposed that savants with ASD are characterised by restricted interests, a detailed way of thinking and enhanced processing of perceptual material and this enables them to build up complex knowledge structures in long-term memory. Although Pring (2008) acknowledged that the skills of savant artists are harder to explain within this conceptual framework, she proposed that superior long-term memory organisation of visuo-spatial knowledge and perceptual skills are likely to be characteristic of this group.

Contrary to a literal rote memory explanation, other researchers have suggested that savant skills are a function of rule-based memory, the application of rules and the organisation of highly specific knowledge (Nettelbeck & Young, 1999). As an example, Nettelbeck & Young (1999) highlight savant pianists who, when playing previously unknown music, made errors that largely conformed to musical structures that defined style, key centre and rhythmic context. In the area of mathematics, Kelly, Macaniso & Sokol (1997) demonstrated that the mental calculations of one savant were solved by applying a left to right computational procedure, consistent with methods applied by expert calculators. Likewise, Selfe (1983) has reported that knowledge about perspective amongst savant artists is rule-based, depending on depth cues from size-distance scaling. Ideas of rule-based learning and perception have been discussed in recent models of savant cognition put forward by Baron-Cohen and colleagues (2009) and Mottron and colleagues (2009) and these are detailed in the next section. Despite an absence of any clear conclusions about specific memory processes in savantism, it is clear that some kind of unusual memory characteristics are associated with this syndrome (Heaton

& Wallace, 2004). Cases of memory savants, such as Kim Peek (Treffert & Wallace, 2002), highlight the importance of better understanding memory in savants. The role of general and specific memory mechanisms was investigated using a standardised memory battery to assess three children with ASD and savant skills in art, music and mathematics in chapter 3. Comparisons of these children's memory profiles together with the results from the special skills screening study previously described (Bennett & Heaton, 2012) identified factors of interest and motivated the further investigation of memory in savants and non-savants with ASD presented in chapter 5. Other studies into the cognitive correlates of savant syndrome have investigated profiles of cognitive abilities in a more theoretically motivated way and have resulted in the formulation of important theoretical accounts. These are discussed next.

THEORETICAL ACCOUNTS OF SAVANT SYNDROME

A number of theories have been proposed to explain the paradox of co-occuring ability and disability characterising savant syndrome. These theories have largely focussed on a wide array of inter-personal, biological and situational factors, for example concrete thinking, sensory deprivation, compensation, genetics, right brain/left brain localisation, concentration and motivation (for reviews see Hill, 1978; Nettelbeck & Young, 1999, Treffert, 1988). Whilst no current theory can explain all savants, recent theoretical accounts of talent in ASD have built upon old models implicating attention (Rimland, 1978) and perceptual processing (Waterhouse, 1988) and have pinpointed cognitive structures such as a local processing bias (Happé, 1999), hyper-systematizing (Baron-Cohen, Ashwin, Ashwin, Tavassoli & Chakrabarti, 2009) and Enhanced Perceptual Functioning (EPF) (Mottron, Dawson & Soulières, 2009). These theories are discussed at length in chapters 6 and 7 and will only briefly be considered here.

In her 1999 update of the Weak Central Coherence (WCC) theory of autism (Frith, 1989), Happé highlighted the importance of considering assets as well as deficits in ASD. This updated theory proposed that ASD is characterised by a detail-focussed cognitive style that contrasts with gist processing typically observed in those without ASD. Support for this theory comes from a number of studies of ASD, particularly involving Block Design and the Embedded Figures tests (see Happé, 1999, but also White & Saldaña, 2011). The theory was important in attempting to explain the splinter and savant skills of people with autism. A focus on elements or parts, for example, may serve to equip an individual with the building blocks essential for elaborated hierarchical knowledge, in which case a local processing bias may then facilitate savant talent. Studies have implicated a local processing bias in talented individuals with ASD, but only a limited number of these have investigated local processing in groups of savant and non-savant individuals. A recent study carried out by Pring, Ryder, Crane & Hermelin (2010) aimed to explore local processing in adult savant artists with ASD compared to a number of control groups, including artists without ASD and ASD individuals without art skills. As a diminished awareness of global information and a focus on local elements might help to account for the precision of detail seen in ASD art, it was predicted that the savant artists with ASD would show increased local processing. However, whilst the results from the study revealed that savant artists with ASD achieved higher scores on the Block Design test in comparison to control groups, no group differences emerged on the Embedded Figures test. As this test, together with Block Design has long been considered to be a marker for WCC, this result was surprising. In chapter 3 of the thesis the cognitive processing style of three savant children with ASD was tested using a battery of local processing tasks. This study was used to inform the group studies testing WCC that are presented in chapter 6.

Two recent theoretical accounts proposed by Baron-Cohen et al. (2009) and Mottron et al. (2009) have implicated higher order processes and enhanced pattern processing in individuals with ASD who possess savant skills. Baron-Cohen et al. (2009) elaborated on Baron-Cohen's (2006, 2008) earlier ideas and suggested that the ability to detect repeat patterns in information, especially those with clearly defined hierarchical systems, may predispose savant syndrome in persons with ASD. In their article, Baron-Cohen et al. (2009) provide detailed examples of several of the domains in which savants commonly excel, and explained how proficiency in processing this information could be predisposed by hyper-systematizing. According to this model, the key to savant talent lies in the ability to understand and manipulate domain-specific systems and in noting regularities and rules in the stimuli of interest, in order to make predictions about outcomes. However, Baron-Cohen et al. (2009) do not consider hyper-systematizing sufficient for the emergence of talent in ASD. These authors suggest that the association between ASD and talent begins at the sensory level where attention to detail arises in response to sensory hyper-sensitivity. Hyper-systematizing, characterised as a cognitive style, exists in conjunction with increased attention to detail in savants.

Mottron & Burack (2001) have proposed that individuals with ASD are characterised by an over-development of low level (domain-specific) perceptual abilities and this is discussed in more detail in chapter 7. A newer component to their EPF model implicates pattern recognition in structured material as a uniquely preserved or even enhanced ability in ASD (Mottron et al., 2009). These authors suggest that the perceptual mechanisms which underpin pattern recognition skills play a key role in the talents of persons with ASD. Hence pattern detection mechanisms are thought to be highly superior in this group and enhanced recognition of perceptual similarities amongst stimuli may form the foundation of savant talents. The concepts of veridical mapping and redintegration are further discussed in explaining the savant skills of people with ASD, both of which make explicit reference to an enhanced ability to detect, complete and retrieve patterns. The hyper-systematizing and EPF models suggest the importance of sensitivity to pattern information for talent in ASD, yet pattern recognition has not been operationalised and tested amongst groups of autistic savants in any published studies to date. An important aim of the current thesis was to explore the relationship between a local processing bias and pattern perception. Therefore two newly developed tasks were introduced in chapter 7 and these assessed the pattern perception skills of savant compared to non-savant children with ASD. These tasks assessed pattern perception according to extraction (recognising patterns) and production (generating pattern information). In devising pattern perception tests that mapped closely onto Block Design, a direct comparison between WCC theory (scores on Block Design) and newer models implementing superior pattern skills (scores on the pattern tests) would be made.

AIMS OF THE THESIS

Questions about clinical, cognitive and behavioural substrates of savant skills in high functioning children with ASD provided the major focus of this thesis. During recent years definitions of savant syndrome have been reconsidered and recent increases in the numbers of high functioning individuals diagnosed with ASD allow the opportunity of characterising savant skills in this group. The outstanding questions highlighted in this introduction were investigated in this thesis. Chapter 3 presents the case studies of three savant children with skills in the classic domains of art, music and numbers. These children completed an extensive clinical and cognitive test battery in order to investigate observed similarities and differences between these cases. The group studies of savant and non-savant children carried out in chapters 4–7 were informed by the outcomes of this study, as well by the findings from previous savant research and theory. Chapter 4 addressed questions concerning the clinical correlates of savant syndrome in high functioning ASD, and specifically tested symptom severity, obsessionality and sensory processing. Chapter 5 examined focussed attention and intellectual profiles at composite and subtest levels across savant and non-savant groups. Chapter 6 probed cognitive style utilising a battery of tasks to assess WCC across visuospatial-constructional and verbal-semantic levels. Chapter 7 explored pattern perception abilities utilising two new paradigms. Chapter 8 drew together the results from chapters 5–7 and using the results from cognitive tests distinguishing savant and non-savant groups investigated the predictive value of various cognitive constructs in predicting savant status. Finally, in chapter 9 the results from these studies were discussed within the context of current models of savant syndrome in ASD. Chapter 9 concludes with a discussion of the limitations of the current work and future directions for research in this field.

CHAPTER 2: METHODOLOGY

ABSTRACT

The aim of this chapter is to provide a detailed summary of methods, measures and procedures to be employed in the thesis. The chapter is divided into the following main sections: test battery and materials, recruitment, participants, assessment of reported skills, savant profiles, procedure, ethics and design and statistical analysis.

TEST BATTERY AND MATERIALS

BEHAVIOURAL AND CLINICAL MEASURES

Autism Diagnostic Observation Schedule

The Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore & Risi, 1999) is a comprehensive, standardised assessment designed to assess behaviour that is known to occur in ASD. Clinically, ADOS is used with persons who are suspected of ASD for diagnostic assessment. For research purposes however ADOS is used as a measure of symptom severity or to confirm a prior clinical diagnosis. ADOS consists of four modules labelled 1–4, each of which is designed to be used with a different client population. Module 1 is suitable for young children with little or no expressive speech, while Module 2 is intended for young children with phrase speech. Module 3 is appropriate for verbally fluent children/adolescents and Module 4 for verbally fluent adults. Each module has its own set of numbered activities requiring the use of an official ADOS kit.

Administration of the standard activities provides ample opportunities for the observation of behaviours associated with ASD. The manual states that the tasks within any given module are intriguing enough to prompt the examinee's social exchanges. Importantly, the activities serve to structure the interactions between examiner and examinee. Performance on the tasks themselves is not then the end product as it is with standardised, cognitive measures. Instead the focus of the assessment is on the socio-communicative behaviour expressed by the examinee and his/her play or the imaginative use of speech and/or materials. In this way the activities simply provide a context in which behaviour is observed and recorded. Through the use of standardised presses it is possible for the examiner to observe the extent to which an individual is affected by ASD. If typical social behaviour is not observed on a particular activity, the examiner is instructed to deliberately vary his/her own behaviour using a hierarchy of structured and unstructured social behaviours. The degree of social impairment within a given individual is reflected in the number of presses needed to elicit a response to the examiner. Throughout the assessment the examiner makes detailed notes on the examinees socio-communicative skills and, upon completion, codes these observed behaviours according to specific criteria. Qualitative scores are then produced in an algorithm for DSM–IV diagnosis. Depending on level of severity an individual may meet criteria for autism or ASD, or s/he may miss the cut-off. It is worth noting that ADOS provides information on current behaviour only and so a more complete evaluation of autistic symptoms requires measurement of developmental history in addition. ADOS administration is typically complete in 30–45 mins.

The author of this thesis completed ADOS training, under the guidance of Dr. Slomin at the Newcomen Child Development Centre, Guy's Hospital, London. All course requirements were fully satisfied and certification permitting the use of the ADOS for research purposes was awarded.

Social Communication Questionnaire

Previously known as the Autism Screening Questionnaire (ASQ) (Kazak Berument, Rutter, Lord, Pickles & Bailey, 1999), the Social Communication Questionnaire (SCQ) (Rutter, Bailey & Lord, 2000) is a 40 item measure for screening ASD symptomatology. Designed to be completed by parents/caregivers of individuals with ASD, it is suitable for use in evaluating individuals over the age of 4 years old (minimum mental age = 2 years). The content of the SCQ parallels that of the Autism Diagnostic Interview (ADI–R) (Lord, Rutter & Le Couteur, 1994) and as such the agreement between the two measures is high and unaffected by age, gender, language level or non-verbal IQ (Kazak Berument et al., 1999). The SCQ is available in two forms. While the current form inquires about the level of autism spectrum behaviour observed over the last 3 months, the lifetime form concerns observation of such behaviour across a person's entire development. Independently completed in approx. 10 minutes, a total score is then derived and compared with specific cut-off scores. For the lifetime form a score of $\geq$ 22 indicates a developmental history of autism, while $\geq$ 15 indicates a history of Pervasive Developmental Disorder (PDD). The lifetime form was used to measure developmental history of ASD symptoms in participants. The ADOS was utilised in place of the current form of the SCQ as ADOS is a more comprehensive, in-depth assessment of current behaviour.

Short Sensory Profile

The Short Sensory Profile (Dunn, 1999) is a 38 item parent/caregiver questionnaire that provides a standard measure of a child's sensory processing abilities. According to the test manual, the questionnaire is most suitable for use with children aged 5–10 years old. Each item describes children's responses to various sensory stimuli and parents/caregivers are asked to rate the frequency with which these behaviours occur. These ratings are assigned using a 5-point Likert scale that ranges from (1) always to (5) never. The effect of sensory processing on functional performance in a child's everyday life is examined under seven core areas: tactile sensitivity, taste/smell sensitivity, movement sensitivity, underresponsiveness/seeks sensation, auditory filtering, low energy/weak and visual/auditory sensitivity. When a child has difficulty with sensory processing, many section scores on the Short Sensory Profile will be low indicating more frequent occurrence of sensory difficulties. Factor scores for each of the main sensory domains are computed along with a total sensory score which considers performance in all seven areas. One of three classes of performance emerge for each factor and for the total score: typical performance, probable difference (from normal) and definite difference (from normal).

It is worth noting that multiple versions of the questionnaire exist. For example, the Sensory Profile (Dunn, 1999) is a comprehensive, detailed alternative to the Short Sensory Profile, while the Adolescent/Adult Sensory Profile (Brown & Dunn, 2002) requires respondents who are aged 11 years plus to rate their own sensory behaviours. In order to ensure consistency across a sample of children with assorted ages, the Short Sensory Profile was employed as a quick, reliable measure of sensory processing to be completed by the parents of children with ASD who participated in the studies.

Autism Spectrum Quotient – Children's Version

A group of typically developing (TD) children participated in some of the studies for comparison purposes. To quantify autism spectrum traits in this sample and to rule out any undiagnosed cases of ASD, the Autism Spectrum Quotient – Children's Version (AQ–Child) (Auyeung, Baron-Cohen, Wheelwright & Allison, 2008) was completed by the parent(s) of these children. The AQ–Child was developed to measure autism spectrum traits in individuals aged 4–11 years old. Parents are asked to indicate the extent to which they agree or disagree with each of 50 statements. A cut-off of $\geq$ 76 (out of 150) is employed with scores over this threshold indicating possible ASD.

Autism Spectrum Quotient – Adolescent Version

Parents of TD children over the age of 12 years old were asked to complete the Autism Spectrum Quotient – Adolescent AQ (AQ–Adolescent) (Baron-Cohen, Hoekstra, Knickmeyer & Wheelwright, 2006). Similar in nature to the AQ–Child, the AQ–Adolescent features 50 statements and employs a cut-off of $\geq$ 32 (out of 50). These questionnaires can be completed in approx. 10 mins.

Cambridge University Obsessions Questionnaire

The Cambridge University Obsessions Questionnaire (Baron-Cohen & Wheelwright, 1999) was used to screen for obsessional behaviours in the participant groups. The questionnaire was adapted to probe the extent to which individuals were, or were not, obsessed within each of the domains listed. As this measure was not a part of the original test battery, and was only added upon completion of the initial case studies presented in chapter 3, the questionnaire will be discussed in further detail in chapter 4.

COGNITIVE MEASURES

Raven's Standard Progressive Matrices

A general test of fluid intelligence, the Raven's Standard Progressive Matrices (hereafter abbreviated to Raven's Matrices) is suitable for both children and adults (Raven, 1938). In each test item, the individual is asked to identify the missing element that completes a pattern. Many patterns are presented in the form of a 2×2, 3×3, or 4×4 matrix hence giving the test its name. Problems are presented in a booklet that comprises of five sets (A to E) of 12 items (e.g. A1 through A12). The problems within each set become increasingly difficult and require ever greater cognitive capacity to encode and analyse pattern information. Regardless of age, all examinees begin the test at the same start point and are instructed to work through all 60 problems at their own speed. For this reason administration times can vary greatly. Raven's Matrices was standardised in Great Britain amongst 3,250 children aged 6–16 years old, in 1979 (Raven, 1981). This test was used for the purpose of matching the total ASD sample to a TD comparison group in a number of studies presented in this thesis. It was also used to probe the nature of intelligence in savants compared to non-savants in the studies carried out in chapter 5.

Wechsler Intelligence Scales for Children – Forth Edition

Amongst clinicians and researchers alike, the Wechsler Intelligence Scale for Children – Fourth Edition (WISC–IV) (Wechsler, 2004) is considered the gold standard for measuring general intelligence in children. WISC–IV is an individually administered instrument for assessing intellectual functioning in children aged 6 – 16 years and 11 months. It was developed to incorporate significant revisions, departing from the previous Wechsler Intelligence Scales for Children – Third Edition (WISC–III) (Wechsler, 1991) by including increased attention to working memory, updated norms and new subtests. WISC–IV was standardised on an additional 800 children in 110 UK schools in order to provide UK norms parallel to those derived from the large US sample on which the US version of WISC–IV was normed. Data gathered from the 2001 Census provided the foundation for representative sampling of children from the UK. The test does not contain norms for children with developmental disabilities although the manual includes guidelines for administration with children who have special educational needs. Administration of the core tests requires approx. 65–80 minutes.

Five composite scores are derived from WISC–IV. In addition to full scale intelligence (FSIQ), four composites representing cognitive abilities in more specific domains are obtained: Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI) and Processing Speed Quotient (PSQ). Ten core subtests are divided amongst the four indices: Similarities, Vocabulary, Comprehension (VCI), Block Design, Picture Concepts, Matrix Reasoning (PRI), Digit Span, Letter-Number Sequencing (WMI), Coding and Symbol Search (PSI). Combined these four indices equate FSIQ. WISC–IV also provides 7 process scores for the subtests Block Design, Digit Span and Cancellation. These scores are designed to provide more detailed information on the cognitive abilities that contribute to a child's subtest performance. Block Design No Time Bonus (NTB) examines performance on this subtest without consideration to bonus scores from speeded performance. Digit Span Forwards and Digit Span Backwards refer to the child's performance on the two different portions of the test, while Longest Digit Span Forwards and Longest Digit Span Backwards refer to the number of correctly recalled digits on the last trial of each portion of Digit Span. Cancellation Random and Cancellation Structured process scores refer to the child's individual performance on both trials of Cancellation. Five supplemental subtests also exist for use in special circumstances or to grasp a fuller cognitive profile. The subtests will now be described.

Verbal Comprehension Index

(1) Similarities: A core verbal subtest, Similarities examines the child's ability to describe how two common objects or concepts are alike, characteristically speaking. For example, the child is asked how a butterfly and a bee are alike, how a painting and a statue are alike and, at the most difficult level, how space and time are alike. With 23 items, this subtest contributes to VCI by assessing verbal conceptual reasoning. Examiners discontinue administration should the child provide 5 incorrect responses.

(2) Vocabulary: The child is first asked to name four picture items (e.g. a train). The child is then asked to give definitions for up to 32 words that the examiner reads aloud (e.g. island). Two points are awarded for the most accurate and detailed accounts, 1 point for responses that are correct but lack content and 0 points for incorrect responses. Testing is terminated upon 5 incorrect answers.

(3) Comprehension: The child answers up to 21 questions based on his/her understanding of general principles and social affairs (e.g. why is it important to apologise when you know you have hurt someone?). Questions increase in difficulty and tap knowledge of a variety of principles including health, public services, science and democracy. Four incorrect responses result in discontinuation of this subtest.

(4) Information (Supplemental): Information is a supplemental subtest that can be used to substitute for any of the core VCI subtests. It assesses the child's ability to answer questions that rely on general knowledge of a broad range of topics, including currency, history, geography and the calendar (e.g. how many days are there in a year?). Examiners discontinue testing upon 5 incorrect responses.

(5) Word Reasoning (Supplemental): The examiner provides clues and the child is asked to identify the concept that the examiner describes (e.g. this is a place of learning and it can have many things from the past in it). Presented as a structured guessing game, Word Reasoning increases in difficulty as more clues are given per test item. There are 24 items and a discontinuation rule of 5 scores of 0 applies.

Perceptual Reasoning Index

(1) Block Design: Block Design requires abstract visual-perceptual and spatial problem solving skills. It is considered a sound measure of fluid intelligence. The child's task is to manipulate one- or two-colour blocks according to either a displayed model or picture stimulus in order to reconstruct a patterned design within a specified time limit. At the most difficult level, the child uses nine two-colour red and white blocks whereby the outer framework for the design on the stimulus picture is omitted. Block Design features a total of 14 items, the latter 6 award bonus points for speed. Discontinuation of the subtest occurs upon 3 consecutive scores of 0. An incorrect construction is defined as one that contains obvious error, significant rotation or that is incomplete once the time limit has elapsed.

As mentioned, the test manual allows for an optional process score to be computed. Block Design does not provide information on the extent to which speed vs. difficulty with visuo-spatial construction impacts upon the score. For example, a child might have slow cognitive processing or physical difficulties that prevent him/her from manipulating the blocks quickly enough to achieve time bonus points, where it is these bonus points that lead to higher scores on the test. Block Design NTB omits time bonus points and so reflects a child's ability without consideration to speed. In order to obtain points on Block Design NTB the child must complete each trial within the specified time limit (e.g. 120 sec at the most difficult level). S/he is awarded either 4 points for correct construction with the time limit or 0 points for an incorrect construction, but s/he is not, however, awarded any additional points for having correctly completed the design before the elapsed time limit (as is the case with Block Design). One advantage of considering Block Design NTB is that information can be provided about the extent to which an individual's visuo-spatial construction abilities are reliant upon his/her pace. Both Block Design and Block Design NTB scores were investigated in group studies, although it should be noted that only Block Design contributed toward PRI and overall FSIQ: Block Design NTB is described by the test manual as an optional score.

(2) Picture Concepts: The child is presented with rows of pictures and s/he is asked to select one image per row that has in common a particular characteristic. The child is not required to verbalise this characteristic, rather s/he is required to have this reckoning in mind in order to correctly identify what unites each choice. Picture Concepts assesses categorical reasoning and presents a maximum of three rows of pictures. With 28 items, examiners terminate testing upon 5 scores of 0.

(3) Matrix Reasoning: The child visually assesses an incomplete matrix and is asked to select the missing piece from 5 given options. Successful completion requires the ability to detect a visual rule in order to predict what is absent. Hence Matrix Reasoning is a test of pattern detection, similar in nature to Raven's Matrices. There are 35 items and examiners discontinue this subtest upon 4 consecutive scores of 0 or 4 scores of 0 in total.

(4) Picture Completion (Supplemental): A supplemental subtest, the child's task is to identify the missing element in a set of increasingly difficult pictures (e.g. the gills of a fish). The task requires good attention to detail. A time limit of 20 sec is imposed on each item, with 38 items in total. Examiners discontinue testing upon 6 scores of 0.

Working Memory Index

(1) Digit Span: Digit Span assesses the child's immediate memory for digits of increasing length. The subtest consists of 16 items divided equally across two parts. For Digit Span Forwards (DSF), the child listens to the examiner read out a sequence of digits and then repeats them back in the same order. For Digit Span Backwards (DSB), the child repeats the numbers in reverse order. Each item features two different trials of digits that are the same length. Digits increase by one more with each subsequent test item. At the easiest level, the child's short-term memory for two digits is assessed while at the most difficult level the child is tested for nine digits. Examiners are instructed to discontinue DSF upon scores of 0 on both trials of an item, but to always administer DSB regardless of scores on the Forwards test. Similarly, testing of DSB is terminated upon scores of 0 on both items of a trial. Together, the two tasks tap distinct but highly interdependent neurocognitive functions, namely short-term auditory memory (DSF) and the ability to manipulate verbal information that is held briefly in memory (DSB).

(2) Letter-Number Sequencing: The child's short-term memory for manipulating and organising both letters and numbers sequentially is assessed. A sequence of numbers and letters is read aloud by the examiner. The child's task is to mentally group the numbers in ascending order followed by the letters in alphabetical order and to say the new sequence aloud. For example, the correct response to 5-A-2-B would be 2-5-A-B: digits are grouped in numerical order followed by letters in alphabetical order and then verbalised as a complete sequence. Two qualifying items check the child's ability to understand the instructions. If a child responds incorrectly to either qualifying item, then administration of this subtest is terminated. Following correct responses to the qualifying items, 10 items are verbally presented to the child. Each item has 3 different trials. Subsequent items increase in length, from 2 letter-number sequences to a maximum of 8. The child must hold and manipulate information in short-term memory and is not permitted to use pen and paper to work out their response. The examiner discontinues upon 3 scores of 0 on all 3 trials of an item.

(3) Arithmetic (Supplemental): Arithmetic examines the child's problem solving abilities across the core mathematical domains of addition, subtraction, multiplication and division. The subtest relies upon the ability to understand and manipulate verbally presented, semantically rich information. Young children are first presented with 5 picture items. They are asked to count aloud the number of items that they see and to solve simple subtraction problems via pictorial aid. Twenty nine arithmetic questions are then read aloud to the child and s/he has 30 sec to provide an answer for each question. Items require the child to mentally manipulate increasingly complex information (e.g. Jamal has twice as much money as Seth. Jamal has 17 pounds. How much money does Seth have?). Children are not allowed to use pencil and paper to work out their answers but are not discouraged should they write on the table using their finger. Arithmetic has a total of 34 items and employs a discontinue criterion of 4 consecutive scores of 0.

Processing Speed Quotient

(1) Coding: Coding assesses the child's ability to copy symbols that are paired with either shapes or numbers, at speed. For Coding A (suitable for children aged 6–7 years old), the child is presented with a key of simple geometric shapes each of which contain a particular marking inside it (e.g. a triangle with a horizontal line, a star with a vertical line etc). The child's task is to code blank shapes with their corresponding marks as quickly as possible (65 items). For Coding B (8–16 years old), the child is presented with a key that pairs various symbols with the numbers 1–9. The child's task is then to copy the correct matching symbol underneath a string of randomly organised numbers that are presented in a response booklet (119 items in total). Children are timed for 120 sec whilst performing Coding and are instructed to work as quickly as possible without making errors. Bonus points are awarded for perfect scores within the time limit. Children are provided with the opportunity to practise sample items before beginning the test.

(2) Symbol Search: Symbol Search assesses processing speed via a timed visual scanning and response task. For Symbol Search A (suitable for children aged 6–7 years old), the child identifies whether a target symbol is present in an array of three symbols by striking through either yes or no with a pencil (45 items). Children completing Symbol Search B (8–16 years old) are presented with the same task but must identify whether one of two items is present in an array of 5 symbols (60 items). In both cases, the child is instructed to work as quickly as possible and is timed for 120 sec. Children practise with sample items before beginning the test.

(3) Cancellation (Supplemental): Cancellation assesses the child's ability to scan both random and structured picture arrangements for target pictures (animals) and to strike through these within an imposed time limit. The child is first shown a sample of animals and objects depicted in picture format in a response booklet. The examiner explains that only animals are of interest in this activity in which the aim is to quickly find (and mark) as many animals as possible. The examiner demonstrates and allows the child to practise. Following, the child is timed as s/he marks off as many animals as possible that are featured on the random and structured presentations (45 sec for each). Points are deducted for errors (i.e. marking an object). Bonus points are awarded for children with perfect scores before the elapsed 45 sec.

Children's Memory Scale

The Children's Memory Scale (Cohen, 1997) is a standardised test designed to evaluate learning and memory in children aged 5–16 years old. The scale is divided into two age groups: 5–8 and 9–16 years old. The Children's Memory Scale was nationally standardised on 1,000 TD children in the USA. Analysis of 1995 US census data provided the basis for representative sampling. Special group studies included small samples of children with neurodevelopmental disorders including those with learning disabilities, Attention Deficit Hyperactivity Disorder (ADHD) and Speech and Language Impairment. Norms for TD UK children and children with ASD are not currently available.

Nine subtests assess functioning in each of three domains: 1) Auditory/Verbal learning and memory, 2) Visual/Non-verbal learning and memory and 3) Attention/Concentration. Each domain is assessed through two core subtests and one supplemental subtest. Administration of the core subtest battery requires approx. 30–35 mins, the supplemental battery requires an additional 10–15 mins. All subtests in the Auditory/Verbal and Visual/Non-verbal domains present the tasks in two portions with a 25–30 minute delay in between portions so as to assess both immediate and delayed memory relative to that domain. The Children's Memory Scale yields eight index scores: Verbal Immediate memory, Verbal Delayed memory, Delayed Recognition, Visual Immediate memory, Visual Delayed memory, Attention/Concentration, Learning and General Memory. The General Memory Index (the summation of Verbal Immediate, Verbal Delayed, Visual Immediate and Visual Delayed memory) is the most representative means of thinking about a child's overall memory functioning. A summary of each subtest is described below.

Auditory/Verbal learning and memory

(1) Stories: Stories assesses the child's ability to recall expressive and semantic information based on the auditory presentation of two short stories. In the immediate portion of the subtest, the child is asked to listen to a brief story that is read aloud by the examiner and is then asked to retell the tale from memory as precisely as possible. Following, the child is read a second story and is asked to retell that tale from memory (stories A & B are used for children who are aged 5–8 years old, C & D for 9–12, and E & F for 13–16). Points are awarded for both correct story units and thematic comprehension and the child is instructed to remember both stories for later testing. In the delayed recall portion of the subtest approx. 25–30 mins later, the child is asked to retell the two stories from long-term memory as precisely as possible. The child then answers brief questions about the two stories in the delayed recognition portion of the subtest. Answers require only yes/no responses. For all age bands there are 30 delayed recognition questions, 15 for each of the two stories.

(2) Word Pairs: Word Pairs assesses the ability to learn a list of unrelated word pairs (e.g. nurse–fire) over three learning trials. In the immediate portion, the child listens while the examiner reads aloud a list of word pairs (10 word pairs for children aged 5–8 years old, 14 for 9–15). The examiner then reads aloud the first word of each pair (e.g. nurse) and the child is asked to give the corresponding word to complete that pair (i.e. fire). This learning procedure is repeated twice more with all of the word pairs. Finally, the child is asked to produce from memory as many of the complete word pairs as possible and is instructed to retain them all for later recall. Following delay of approx. 25–30 mins, the child is asked to recall all of the word pairs. To test delayed recognition, the examiner reads aloud a list of word pairs (30 for children aged 5–8 years old, 42 for 9–16) and the child is asked to indicate which ones were the original word pairs and which were not.

(3) Word Lists (Supplemental): Word Lists assesses the ability to learn a list of unrelated words over four consecutive learning trials. In the immediate portion of the test, the examiner reads aloud a list of words and the child is instructed to verbally recall as many from the list as possible in any order. On consecutive trials the child is reminded only of words that s/he did not recall on the previous trial and again is asked to recall as many words as possible. This is repeated for four learning trials and then a new list, a set of distracter words, is read by the examiner on the fifth trial. Following, the child is asked to recall as many words as possible from the original word list in any order. In the delayed recall component of the test presented approx. 25–30 mins later, the child is asked to recall as many words from the original word list as they can remember (without cue). To examine delayed recognition, the examiner reads aloud a list of words and the child is asked to indicate which were in the original word list and which were not.

Visual/Non-verbal learning and memory

(1) Dot Locations: Dot Locations assesses the ability to learn and recall the spatial locations of a series of dots over three learning trials. In the immediate trial, the child is first shown a stimulus picture featuring a number of blue dots within a white box (6 dots for children aged 5–8 years old, 8 dots for 9–15 years). Following a 5 sec exposure, the stimulus is removed from the child's view and s/he is asked to mark on a response grid using counters the locations of the dots that were just presented. The child completes two more learning trials which follow the same procedure. Next, a new stimulus plate, the distracter, is presented featuring red dots in new locations. Following a 5 sec exposure, the child indicates the locations of these newly presented dots again by placing the counters on the grid (this is not scored). Finally the child is asked to recall from memory the locations of the original blue dots and to mark these on the grid. Following delay of approx. 25–30 mins, the child is again asked to recall the locations of the original blue dots using the grid and counters.

(2) Faces: This subtest measures the child's ability to recall and recognise faces. In the immediate trial the child is shown a series of photographed faces, each for an exposure time of 2 sec, and is asked to remember them (12 faces for children aged 5–8 years old, 16 for 9–

16 years). A second series of photographed faces are then shown. Half of these contain target faces (those already presented) while the other half present new, distracter faces. These are presented in a random order (36 faces for children aged 5–8 years old, 48 for 9–16 years). The child is asked to identify which faces s/he has seen before and which are new. Finally, the child is instructed to remember the first set of faces for later testing. For the delayed portion of the subtest, the child is shown yet another series of photographed faces approx. 25 mins later. S/he is asked to identify which faces are from the original set and which are not.

(3) Family Pictures (Supplemental): Family Pictures is a supplemental subtest that assesses visuo-spatial memory. In the immediate trial, the child is first shown a stimulus card depicting a family portrait and the examiner verbally identifies the family members (mother, father, daughter, son, grandmother, grandfather and pet dog). In subsequent cards the child is shown four scenes (picnic, department store, yard and meal) each of which contains an assortment of the family members performing various activities (e.g. serving salad, buying a shirt etc). Each scene is presented to the child for 10 sec with the instruction to remember as much as possible about what is happening. The scene is then removed from view and following a 5 sec delay, the child is presented with the family portrait and the exact same scene minus the family members. The child is asked to point to the family members that they saw in the original scene, to indicate their locations and to state what each family member was doing. Upon completion of all four scenes, the child is asked to remember these details. Approx. 25 mins later the child is again shown the blank scenes with the family members missing and is asked to identify who was where, their positions and what they were doing. Points are awarded for correct identification of each family member, their location and action.

Attention/Concentration

(1) Numbers: Numbers is a core Attention/Concentration subtest that assesses the ability to repeat verbatim sequences of numbers that increase in length. The child is asked to repeat digits both forwards and backwards in sequences that vary from 2 to 8 digits long. Fifteen items are divided across two portions. For Numbers Forward, the child repeats numbers aloud in the same order as said aloud by the examiner. Numbers Backward sees the child repeating numbers in the reverse order to that said by the examiner. For Numbers Forward, there are two trials for each of 8 items. For Numbers Backward, there are two trials for each of 7 items. Examiners are instructed to discontinue Numbers Forward upon scores of 0 on both trials of an item, but to always administer Numbers Backward regardless of the score on Numbers Forward. Testing of Numbers Backward is terminated upon scores of 0 on both items of a trial.

(2) Sequences: Sequences assesses the child's ability to mentally sequence verbal information as quickly as possible. The child is asked to perform 12 sequencing tasks. These include reciting the alphabet, counting backward from 20–1, reciting the 6 times table and ordering the months of the year in reverse. At the most difficult level, children are asked to recite the alphabet whilst counting simultaneously (i.e. A1, B2, C3, D4 etc). Points are awarded for accuracy and speed. All items are administered.

(3) Picture Locations (Supplemental): Picture Locations is a supplemental Attention/Concentration subtest in which the child's immediate visual memory for the spatial locations of pictured objects is assessed. In a format that is similar to Dot Locations, the child is shown a grid with pictured objects (animals and vehicles) placed in various locations inside. The stimulus is removed from view following a 2 sec exposure and the child is asked to use counters to mark the locations of the presented pictures on a response grid. The number of objects increases with each test item. For children aged 5–8 years old there are a total of 10 items with a maximum of 5 pictured objects per trial. Children aged 9–16 complete 16 test items with a maximum of 8 pictured objects per trial. All items are administered.

Cognitive processing style

Block Design

Block Design has commonly been regarded as a primary marker for WCC, discussed briefly in chapter 1 (Happé, 1999; Pring, Hermelin & Heavey, 1995; Shah & Frith, 1993). Whilst intact global processing is certainly required to successfully construct the finished presentation, good local processing would presumably convey an initial advantage by enabling the examinee to perceptually isolate the individual elements of the design at the early stages of the test. As well as being discussed in the study of autistic intelligence in chapter 5, Block Design was used as a stand-alone test in exploring cognitive style in those with ASD and savant skills in chapters 3 and 6. Block Design is discussed in further detail above, in the section on WISC–IV.

Object Assembly

Object Assembly requires the ability to create an integrated global representation from parts, specifically by solving jigsaw-type puzzles depicting familiar objects (e.g. a football). Puzzle pieces are presented in a standardised fashion and must be completed within a specified time limit ranging from 120–180 sec. At the most difficult level, there are 8 pieces to manipulate (13 junctures). Bonus points are awarded for speed, with shorter completion times resulting in higher scores. Object Assembly was included as a non-verbal subtest in WISC–III and was normed on 814 UK children as a part of the 1991 standardisation project. It was dropped from the proceeding WISC–IV namely to decrease dependency on time bonus points and promote user friendliness. The task measures visuospatial-constructional skills which might be of especial importance in examining the underpinning of savant skills for those gifted in art.

Picture Completion

Taken from WISC–IV, Picture Completion is another test on which individuals with a local processing bias may be advantaged. Here children are asked to locate a missing detail from a set of increasingly difficult pictures (e.g. nostrils from a pig). It is likely that good performance requires the ability to resist context, in order to explore smaller elements of the pictures and isolate the missing details. Picture Completion is discussed in the section describing WISC–IV, above.

Children's Embedded Figures Test

The Children's Embedded Figures Test (CEFT) (Witkin, Oltman, Raskin & Karp, 1971) is a perceptual non-verbal test suitable for children aged 5–12 years old. The child is shown a simple target shape and is asked to find this shape as quickly and as accurately as possible within a larger complex design in which that shape is embedded. The task is presented in a game format where the child is asked to find a shape that is described as hiding in a number of pictures. Testing begins with the child learning how to discriminate between a tent shape and other similar triangular shapes. Once adequate discrimination has been achieved, the examiner demonstrates the disembedding process and the child practices. S/he is then tested on 11 trials of the tent series. The same process of training, demonstrating and practicing applies for a second series in which the child's aim is to now locate a house like shape that is embedded in 14 new pictures. All responses are recorded as either 1 point (correct) or 0 (incorrect) and are scored out of a maximum of 25. Examiners are permitted to assist the child if s/he requests help but any detection of the target shape that results from support is scored 0.

The test was originally normed on 160 children randomly selected from two elementary public schools in New York, USA. Children were equally divided amongst four age groups (5–6, 7–8, 9–10 and 11–12 years old) with exactly 20 males and 20 females per group. The original test did not impose any time restriction on the completion of each trial, rather an overall score out of 25 was recorded where all test items were administered. The authors of the test described it as a measure of perceptual style and discussed the construct of field-dependence/field-independence. Field-dependence refers to a perceptual style that is strongly characterised by the overall organisation of the surrounding field, and field-independence refers to a perceptual style where parts of the field are experienced as discrete elements (Witkin et al., 1971). It is perhaps no surprise that the CEFT has been considered by many researchers as a measure of WCC: high scores on the CEFT are thought to indicate greater field-independence (lower field-dependence) or a tendency to process visual information at the local level.

A new administration and scoring approach, advocated by Pellicano, Maybery, Durkin, & Maley (2006), and followed by Low, Goddard & Melser (2009), allows the child a maximum of 30 sec to complete each trial. Should the child fail to identify the target shape for a particular trial within the time limit, a score of 30 sec is then recorded for that trial; otherwise the time taken to successfully locate the target shape (< 30 sec) is recorded. By averaging latency times across all 25 trials, a mean score can be calculated. Pellicano et al. (2006) suggest that low scores are indicative of greater WCC, although thresholds for low/high scores are not discussed. In order to measure response latencies and keep administration time succinct, the method of administration and scoring advocated by Pellicano et al. (2006) was employed in the group study using the CEFT presented in chapter 6. While it is acknowledged that using a new administration/scoring approach would render the original test norms unusable, this did not pose difficulties within the context of the current work. The CEFT was intended for experimental use to compare groups of participants and in this way consultation of test norms was not required.

Sentence Completion Task

The Sentence Completion Task (SCT) (Booth & Happé, 2010) is a brief test of verbal coherence. In this test participants are instructed to complete 14 sentence stems that are read aloud by the examiner. Whilst four sentences are included as filler items to mask the true focus of the activity, the other ten sentence stems have been constructed to provoke conflict between an appropriate global response and a local associate response. For example, a local completion to the stem 'you can go hunting with a knife and …' might be "fork" whereas a globally meaningful completion might be "gun", "spear" or any such variant (Booth & Happé, 2010). While the response "fork" is locally coherent with the last two words, it is not coherent within the context of the entire sentence. Hence individuals who provide a significant number of local responses to such sentence stems are thought to possess a local processing bias.

Scoring of the SCT is based on the participant's first response. Two dependent variables were computed for each participant in the study: a completion score and the number of local completions. With regard to completion scores, the 3-point scoring system developed by Booth & Happé (2010) was employed: 0 points were assigned for globally meaningful sentence completions, 1 point when no response was given, the response was delayed (i.e. (≥ 10 sec) or the response was deemed "odd" (e.g. a repetition) and 2 points for a response that was a local completion to the end of the sentence but not coherent within the context of the entire sentence. Completion scores range from 0 to 20 per participant. While cut-offs for an absolute local vs. global processing style have not been specified by the authors, Booth & Happé (2010) suggest that individuals with a relatively high number of local endings might be characterised as locally biased information processors. For this reason, the number of local completions for each participant (i.e. the total number of 2 point responses) were analysed separately. This was used as a measure of extreme local performance and a maximum score out of 10 was recorded for each participant. In their study, Booth & Happé (2010) found that this test revealed individual differences in cognitive style that were unrelated to IQ in typical development. Further, the results indicated that most (but not all) people with ASD show WCC on this task and that performance is not related to inhibitory control. As savant syndrome has been associated with a local processing style, the SCT was used to investigate local/global processing of language in savant and non-savant children with ASD.

Wechsler Individual Achievement Test – Second Edition

The Wechsler Individual Achievement Test – Second Edition (WIAT–II) (Wechsler, 2005) was employed in order to grasp a fuller examination of cognition, specifically scholastic aptitude, in the case studies presented in chapter 3. The WIAT–II is an individually administered assessment battery for examining the academic achievement of individuals aged 4 – 16 years 11 months (US norms are available for individuals aged up to 85 years old). The WIAT–II is a revision of the earlier edition which was standardised in the UK and published as the Wechsler Objective Reading Dimension (WORD), Wechsler Objective Numerical Dimension (WOND) and Wechsler Objective Language Dimension (WOLD). Developed to include significant revisions such as lowered age norms and new items, the WIAT–II was standardised on 892 children aged 4–16 years old in the UK during the 2004 standardisation of WISC–IV. Studies with special groups included those with learning disabilities, ADHD and hearing impairments, but not those with ASD. The test requires 45 mins to administer for children aged 4–5 years, 90 mins for 6–11 years and up to 120 mins for 7–16 years.

In addition to a total score, four composite scores are derived: Reading, Mathematics, Written Language and Oral Language. While norms are available for children as young as 4 years old, some subtests (and so adjoining composites) have not been normed on children as young as this. Consequently, UK norms are available for individuals aged 6 years plus for all subtests, although not all of the subtests were normed on very young children. The subtests are detailed below.

Reading

(1) Word Reading: Word Reading assesses early reading skills by examining word recognition and phonological decoding abilities across a number of tasks. Children aged 4–5 years old begin by naming letters of the alphabet that are presented in a stimulus book. They are then asked to discriminate between rhyming and non-rhyming words and to generate rhyming words themselves (e.g. words that rhyme with fly). Children aged 7 years old begin by identifying the beginning and ending sounds of words. They then blend sounds to form words (e.g. /c/ /at/ to form cat) and match sounds with letters and letter blends. Individuals aged 8 years or older are asked to read aloud from a word card (81 words in total). Word Reading features an overall total of 131 items; examiners begin at age appropriate start points and are instructed to continue unless 7 consecutive scores of 0 are achieved. Reading automaticity (defined as $\geq$ 3 sec) and self corrections are optionally scored to form the basis of qualitative analysis (word card task only).

(2) Reading Comprehension: This subtest examines the individual's understanding of reading material that is presented in a number of different formats. The subtest is suitable for individuals from the age of 6 years and aims to assess reading comprehension both as taught in the classroom and as used in everyday life. Children aged 6 begin by matching a printed word to its representative picture in a stimulus book. For later items, the child reads sentences and passages of text and answers short questions based on their understanding of what they have read. These include questions that involve identifying the main ideas, specific details and drawing inferences. The ability to read target words is also scored as is reading speed which can be calculated based on the time it takes a child to read passages of text. Examiners have the option of noting the frequency of reading behaviours for qualitative analysis. The subtest does not have a discontinuation rule; rather the examiner administers and scores all items within the examinees age appropriate item set.

(3) Pseudoword Decoding: Pseudoword Decoding assesses the ability to apply phonetic decoding to a list of pronounceable non-words. Such words are designed to imitate the phonetic structure of words found in the English language (e.g. infrections). Suitable for individuals from the age of 6 years old, the examiner begins by demonstrating how pseudowords should be read using examples. The examinee is given a list of 55 pseudowords printed on a word card and is asked to read each word as precisely as possible. Each pseudoword is scored for either correct or incorrect pronunciation where examiners discontinue testing upon 7 incorrect responses. Prior to testing, examiners are instructed to listen to the Pseudoword CD that accompanies the test battery in order to grasp the correct pronunciations.

Mathematics

(1) Numerical Operations: This subtest examines various numerical skills. Children aged 5–6 years old begin by performing tasks such as discriminating numbers from letters, recognising missing numbers from sequences, writing numbers and counting by rote to 8. Those aged 7 years old or older begin by working through calculation problems presented in a response booklet. The problems assess knowledge of whole numbers, decimals and fractions and at the hardest levels square roots, algebra and geometry. The test has a total of 54 items and a discontinue rule of 6 consecutive scores of 0. For the purpose of qualitative examination, examiners may also note how frequently the individual engages in behaviours such as writing reversed numbers, using fingers for calculating or demonstrating automatised mathematical facts when computing.

(2) Mathematical Reasoning: This subtest presents individuals from the age of 4 years old with a series of problems using both visual and verbal prompts that are designed to assess mathematical reasoning skills. With age appropriate start points, young children count objects, identify shapes and describe quantities using whole numbers. At later stages problems involving time, money and measurement are presented. At the most advanced stages the individual solves problems based on information which is presented in graphs, sequencing number patterns, rotating shapes and multi-step word problems. Pencil and scrap paper are permitted to work out answers but all final answers are given verbally. Mathematical Reasoning has a total of 67 items and a discontinuation rule of 6 consecutive scores of 0. For further evaluation, examiners have the option of recording behavioural observations related to performance.

Written Language

(1) Spelling: Spelling employs age appropriate start points to assess the ability of individuals aged 5 years or older to spell dictated letters, letter blends and words. The examiner reads aloud items that are to be written down in a response booklet by the examinee. So as to avoid any confusion concerning homonyms, all words are provided with contextual clues (e.g. knew - the teacher knew how many were going). With a total of 53 items, the test employs a discontinue rule of 6 consecutive scores of 0.

(2) Written Expression: Written Expression assesses the process of writing across five sections: Alphabet Writing, Word Fluency, Sentences, Paragraph and Essay.

Alphabet Writing: Children aged 4–7 years old are administered this section only. The task is to print the alphabet in order and from memory, quickly and carefully. The task is timed and the examiner records the letter that is written at exactly 15 sec in order to measure automaticity in writing. Points are awarded for the number of correctly written letters within the time limit according to specific scoring criteria as set out in the manual.

Word Fluency: Individuals from the age of 8 years old begin Written Expression at this section. Word Fluency assesses the ability to generate and write a list of words that adhere to a pre-determined category (things that are round) within a 60 sec time limit. An example is given to demonstrate and prompt thinking. Acceptable responses score 1 point each. The total score is converted to a quartile score.

Sentences: This section evaluates the ability to use visual and verbal cues to combine two or three short sentences into one coherent written statement. Following, the examinee is asked to construct and write down one sentence each in response to various pictures. Children aged 6–7 years old are administered Sentences following completion of Alphabet Writing (they are not administered Word Fluency). Children aged 8–11 years old however are administered Sentences upon completion of Word Fluency. For those aged 12–16 old, Sentences begins at a more advanced level by combining three sentences into one well written sentence. This is before proceeding to write sentences that match more complex illustrations presented in a stimulus book.

Paragraph: This section is administered to 8–11 year old children. It assesses the ability to form a well-written paragraph according to one of two stems: 'my favourite game is…' or 'on a rainy day I like…' Children are instructed to use correct spelling and punctuation and to attempt 5–10 good sentences in writing their paragraph. The activity has a time limit of 10 mins. The task is scored according to mechanics (e.g. spelling, punctuation), organisation and vocabulary in accordance with set guidelines.

Essay: This section is only administered to examinees aged 12 years or older. Essay assesses the ability to structure and write an argument in the form of a semi-professional letter. Examinees aged 12–17 years old write a letter based on their opinion of whether physical education or school uniform should be a fundamental school requirement. For individuals aged 18–21 years old, the letter is written in regards to whether university students should, or should not, be provided with free tuition by the government. Letters are addressed to editors of either a school or local newspaper. Examinees are instructed to include a minimum of three supporting arguments and are allowed 15 mins to write. Scrap paper is provided for rough work. Letters are scored with consideration to mechanics, organisation, theme development and vocabulary.

Oral Language

(1) Listening Comprehension: This subtest assesses the ability of examinees aged 4 years or older to comprehend verbal information, across three sections: Receptive Vocabulary, Sentence Comprehension and Expressive Vocabulary. A discontinue rule of 6 consecutive scores of 0 applies to all three sections. However examinees are administered all three sections regardless of their performance on any preceding section. A raw score is computed for each of the three sections and for the combined total of Listening Comprehension.

Receptive Vocabulary: The examiner reads aloud a word which the examinee matches to one of four presented pictures (16 items).

Sentence Comprehension: The examinee matches the examiners spoken sentence to one of four picture options with subtle differences (10 items).

Expressive Vocabulary: The examinee verbally names the object or concept that matches both a representative picture and the examiners verbal definition (14 items).

(2) Oral Expression: Oral Expression examines the general ability to use spoken language effectively for the purpose of communication. There are four sections: Sentence Repetition, Word Fluency, Visual Passage Retell and Giving Directions. Raw scores are computed for each of the four sections to derive an overall Oral Expression total raw score.

Sentence Repetition: This section examines the ability to repeat sentences verbatim with correct structure and pronunciation. Only children aged 4–8 years old are tested. There is a total of 6 items and examiners discontinue should 6 consecutive scores of 0 occur.

Word Fluency: This section assesses the ability to demonstrate verbal fluency using words in accordance with predetermined categories. Examinees of all ages are administered both Word Fluency A and B with Visual Passage Retell administered in between the two portions. For Word Fluency A, individuals are asked to name as many different animals as possible (60 sec). For Word Fluency B, individuals name ways of moving (60 sec). Responses are scored according to specific criterion.

Visual Passage Retell: This section assesses the ability, of all ages, to generate tales verbally from visual cues. The examiner models the process of storytelling by reading aloud a short tale about a girl who adopts a puppy. While the examiner reads the story, the examinee observes three illustrations that highlight the main events of the story in order. The examinee then views two comic strips depicting four pictures each and is asked to tell two make-believe stories in line with the presented illustrations. The examiner records each story for later scoring. Points are awarded according to good storytelling principles (e.g. naming characters, setting the scene, having a plot, relaying the sequence of events and providing a conclusion).

Giving Directions: This section assesses the ability (of all ages) to generate oral directions from visual and verbal prompts. Individuals view a set of five pictures that depict the sequence of events for obtaining a snack from a vending machine. Examinees are asked to describe the necessary actions at each stage so that the examiner could obtain a snack in the same way but without ever needing to view the pictures. In a second task, the examinee is asked to give oral directions for making a peanut butter and jam sandwich (no pictorial aid). Responses to both tasks are scored independently according to set criteria.

Experimental tasks of pattern perception

Two new paradigms were developed to test possible pattern perception differences amongst groups of savant and non-savant children with ASD. These tasks were added to the test battery upon completion of the case studies presented in chapter 3 and are described in full in chapter 7.

RECRUITMENT

A new questionnaire was designed for the purpose of screening savant skills in children with ASD. The questionnaire was developed with the aim of identifying two groups of potential participants for the studies presented in this thesis. Whilst the initial classification to savant/non-savant groups was based on parental report, skill validation was later carried out. In forming the questionnaire, two measures were consulted: the special isolated skills section of the ADI–R (Lord et al., 1994) and the questionnaire devised by Bennett & Heaton (2012).

The questionnaire was constructed in two sections. The first section (section A) concerned gathering background information about the child and his/her diagnosis (e.g. date of birth, age, diagnosis, gender etc). These questions also probed when the diagnosis was made, who by and using what clinical assessments. Section B asked parents/carers to consider if their child has any particular talents. A definition of talent was provided: by talent we mean the presence of any outstanding skill (or skills) that you consider to be markedly better than your child's general skills and that may, or may not, be better than those of same aged children. Examples of skill were also given. Seven categories of skill were then queried and these mapped onto the classic savant domains. For more unusual skills that were not covered by the former categories, parents/carers were asked to detail these in a final skill category loosely labelled other skills. Again examples were given (i.e. unusual language skills, exquisite sensory discrimination, perfect appreciation of passing time without access to a clock). Parents/carers were instructed to circle either yes/no to each skill and to provide specific details about the nature of their child's skill should they circle yes to any category. The brief questionnaire is completed in approx. 10 mins and is shown in Appendix A.

Details of the study were featured on the National Autistic Society (NAS) website. While the advertisement was live for 6 months, it yielded few responses and individual branches of the NAS were asked to assist with recruitment. Emails were sent to 12 London branches of the NAS and a further email was sent to NAS Surrey. The emails asked for support in recruitment, outlined the study and included a letter which branches could use to forward onto their members if they were willing to help. Seven out of 13 branches responded positively and confirmed that they would forward the request onto their branch members via email. Members were instructed to contact the author of the thesis directly should they require further information or wish to express an interest in taking part. In addition to contacting branch members via email, one branch also advertised the study via their online forum. Two parents of participating children with ASD kindly offered to circulate research letters at their local parent groups. Lastly, participants were recruited via word of mouth having been in receipt of good feedback about the study from other parents. Of the 36 participants with ASD, 24 were recruited via NAS branches, 8 via word of mouth and 3 from parent groups. One child (the savant D.B.) was recruited after the author of the thesis attended an autism and creativity publicity event and met with the child's mother. All 17 of the TD comparison children were recruited locally via word of mouth.

PARTICIPANTS

Savants with ASD

The savant group included 17 males aged 8 years 3 months to 12 years 5 months ($M = 123.79$ months, $SD = 16.28$). All children had received a clinical diagnosis of autism spectrum prior to taking part in the study. Children had been assessed by a variety of professionals (e.g. paediatricians, clinical psychologists and psychiatrists) and in some cases multi-disciplinary teams had been involved. Diagnoses were mostly carried out using standardised assessments, for example ADI–R (Lord et al., 1994), Diagnostic Interview for Social and Communication Disorders (DISCO) (Wing, Leekam, Libby, Gould, & Larcombe, 2002) or Developmental, Dimensional and Diagnostic Interview (3di) (Skuse, Warrington, Bishop, Chowdhury, Lau, Mandy & Place, 2004). Behaviour checklists and school observations had also been used in some cases. Inspection of the available assessment data showed considerable heterogeneity in diagnoses within this group. While 9 out of 17 children had been diagnosed with Asperger's syndrome, others were diagnosed with ASD (3 children), High Functioning ASD (3 children), autism (1 child) and High Functioning Autism (1 child). Three of these children were in receipt of co-morbid diagnoses: ASD and dyslexia, Asperger's syndrome and ADHD (medicated), and Asperger's syndrome with dyspraxia and severe anxiety disorder. The majority of children (14 out of 17) attended mainstream schools at the time of participation in the study. Two children were reported to attend schools for children with special educational needs. A third child was currently home schooled due to severe anxiety problems specifically associated with the school environment.

The majority of parents with children in this group (15 out of 17) reported that their child had one or more specific talents and that these were outstanding relative to their child's overall skill level and to the skills of same aged, TD peers. Two children were originally recruited to the non-savant group because their parents failed to report the possession of any outstanding skills. However, during the course of testing these children's talents were observed and the extent of their skills was sufficient enough to warrant exclusion from the non-savant group and inclusion in the savant group. These cases of unreported skill are discussed in detail below (see savant profiles for L.H. and P.G.). Considering Treffert's (1989) three-tier classification of savant skills, the children in this participant group were best described as talented savants: skills were prominent and highly honed, more advanced than low level splinter skills but not as spectacular as those exhibited by prodigious savants. Consistent with new criterion stating that savant skills should be considered within the context of the individuals overall intra-personal functioning rather than from their intellectual functioning (Heaton, 2010, 2012; Heaton & Wallace, 2004; Miller, 1999) skills in this group contrasted with social and communication deficits (i.e. ASD).

Non-savants with ASD

The non-savant group included 19 boys aged 8 years 0 months to 12 years 9 months (*M* = 123.79 months, *SD* = 16.70). As with the savant group, diagnoses were heterogeneous: 9 children had been diagnosed with ASD, 7 with Asperger's syndrome and 3 with High Functioning Autism. Nine of these children had co-morbid difficulties and this included overlap with ADHD, dyspraxia, dyslexia, developmental delay, moderate learning difficulties (MLD) and stress and anxiety issues. All children had received clinical diagnoses prior to taking part in the study. Children had been seen by a variety of professionals (e.g. paediatricians, clinical psychologists and psychiatrists) and diagnoses had been made using assessments such as the ADI–R (Lord et al., 1994), DISCO (Wing et al., 2002) and 3di (Skuse et al., 2004). One child attended a specialist school whilst all others attended mainstream establishments, some with classroom support. Parents of the children in this participant group stated that their child did not possess any specific talents or skills compared to their general skills or that of same aged, TD peers.

Typically developing comparisons

A final participant group included 17 TD boys aged 8 years 1 month to 12 years 11 months (*M* = 123.59 months, *SD* = 19.28). Parents of this participant group were asked if their child had any developmental or psychological disorders, or if any of their child's immediate family members had a diagnosis of ASD. None of these children presented with developmental or psychological disorders and no child was detailed to have any immediate family members with an ASD diagnosis. The AQ–Child version was administered to the parent(s) of each participant aged 8–11 years old; the AQ–Adolescent was used for those aged 12 years. All children scored below the cut-off of 76 for the AQ–Child (*M* = 42.79, *SD* = 8.39) or below the cut-off of 32 for the AQ–Adolescent (*M* = 7.33, *SD* = 2.31). This indicated that the likelihood of these children having ASD was extremely low.

Group matching

Some of the studies presented in the thesis directly compared the savant and non-savant groups. These groups were matched on diagnosis (all children were in receipt of clinical diagnoses of autism spectrum), age ($t(34) = .284, p > .05$) and FSIQ ($t(34) = 1.70, p > .05$). Table 2–1 presents this information.

Table 2–1. Chronological age (CA) and intelligence data for savant and non-savant groups

	Savants (M, SD)	**Non-savants M (SD)**
CA (in months)	125.35 (16.28)	123.79 (16.70)
FSIQ	112.35 (19.13)	102.95 (13.90)
Verbal Comprehension Index (VCI)	101.29 (17.78)	97.26 (9.20)
Perceptual Reasoning Index (PRI)	115.12 (20.82)	104.95 (12.70)

The research questions addressed in some of the studies presented in the thesis required a TD comparison group. This group was matched to the total ASD sample for CA ($t(51) = .185, p > .05$) and raw scores on the Raven's Matrices ($t(51) = -1.54, p > .05$). Table 2–2 presents this information.

Table 2–2. Chronological age (CA) and Raven's Matrices data for the total ASD sample and TD comparisons

	Total ASD sample (M, SD)	**TD comparisons M (SD)**
CA (in months)	124.53 (16.28)	123.59 (19.28)
Raven's Matrices (raw score)	41.36 (9.55)	45.24 (5.9)

ASSESSMENT OF REPORTED SKILLS

Fifteen parents of children with ASD reported that their child had one or more talents that were outstanding relative to that child's general skills and those of same aged TD children. In order to determine whether children met criteria for inclusion in the savant group, a skill validation methodology was developed. While standardised batteries were used to assess reported skills wherever possible, procedures to validate savant skills were for the most part not drawn from standardised tests. This is because reliable tests suitable for use with individuals with developmental disorders and creative talents (e.g. art, music) or skills rarely seen in typical populations (e.g. calendar calculating, perfect pitch or proficient knowledge of public transport routes) are not currently available.

None of the 17 savant children had undergone formal skill assessment prior to entering the study. The most commonly reported and validated skill was in the domain of mathematics (10 children), followed by musical talent (3 children), artistic talent (2 children) and calendar calculating (2 children). Other, more obscure skills were also reported. This included prime number calculation, literacy, sensory discrimination and appreciation for passing time without access to a clock face. Most children (10) were reported to have multiple skills. In the majority of these cases only the most prominent skill was validated. The background test battery was large and this approach to validating one skill only was taken in the interest of keeping testing to a minimum. Therefore, inclusion to the savant group required validation of only one outstanding skill.

Mathematics

Children who were reported by their parents to have advanced mathematics skills were formally assessed using a standardised maths battery. These children were individually administered the mathematics subtests from the WIAT–II. Following this, an overall maths composite was computed for each child and each child's performance score was compared to norms for TD children of the same age. Whilst an average score is around 100, superior maths scores range from 120–129 and very superior scores total ≥ 130. Superior/very superior scores were expected on both the Mathematics composite of the WIAT–II and the Arithmetic subtest of WISC–IV in order for these children to be included into the savant group. Skill validation results are reported within individual savant profiles and these are presented below.

Art

Standardised tests for assessing artistic output are not currently available due to the highly subjective nature of what constitutes skilful artwork. Parents reporting that their child possessed advanced art skills were asked to select one example of their child's art work which they considered to be a fair portrayal of their child's overall artistic ability. Following Hermelin & O'Connor's (1990) approach, a professional artist was then consulted and asked to assess the artistic merit of each artwork submitted for review. Information regarding gender and disability was not disclosed, although details of participants' age were provided. In line with Hermelin & O'Connor (1990) five main criteria were utilised: 1) liveliness of and sensitivity to the object/subject drawn, 2) vitality and the character of line and texture, 3) presence of a distinct personal style, 4) organisation and composition of the piece and 5) the degree to which a compelling and interesting image had been produced. While Hermelin & O'Connor (1990) employed a rating scale covering grades from A+ to E- (i.e. 15 points), the criteria were simplified for the purposes of the current thesis: the rating scale here covered grades A to E (5 points). The results of skill validation for artistic output are discussed within the context of savant profiles below.

Absolute pitch

All children presenting with reported musical ability were assessed for absolute pitch. Absolute pitch is rare in TD populations (1 in 10,000; Profita & Bidder, 1988) and is not strongly associated with musical talent in this group. However, research suggests that absolute pitch is universal in musical savants (Miller, 1989) and it has been suggested that the association between absolute pitch and musical talent may be strong in groups with developmental and other disabilities. A pitch series naming task, used by Heaton, Davis & Happé (2008), was presented to individuals with reported absolute pitch ability. Twenty five tones were presented via CD. The tones spanned C3–C5 in quasi-random order, with each note presented in a different octave to the preceding tone. Participants were asked to listen to the CD and verbally name all presented tones. Results for the validation of absolute pitch are discussed within savant profiles below.

Calendar calculation

Traditionally calendar calculating skills have been assessed by testing the accuracy with which an individual is able to calculate the day of the week for any given date, over a specific time span. Parents who reported calendar calculating skills in their child were asked about the extent of their child's calendar calculating span. In response to these estimates a battery of date questions were then constructed on an individual basis. Results for the validation of reported calendar calculating skills are discussed within the relevant savant profiles below.

SAVANT PROFILES

Brief profiles for each of the 17 savants are presented below along with skill validation results.

A.L.

An 11 year old boy with ASD and dyslexia, A.L.'s mother reported that he was an exceptional artist. Figure 2–1 shows the artwork that A.L.'s mother selected for independent assessment, a drawing of a boy produced in ball-point pen from imagination. This drawing was awarded the following ratings: liveliness of and sensitivity to the object/subject drawn (grade A), vitality and the character of line and texture (grade A), presence of a distinct personal style (grade B), organisation and composition of the piece (grade B) and degree to which a compelling and interesting image was produced (grade B). These assessment ratings were sufficiently high enough for A.L. to be included in the savant group. A.L. was one of the children who participated in the case studies in chapter 3 and further examples of his drawings are presented there.

Figure 2–1. Boy by A.L.

J.R.

A 10 year old boy with a diagnosis of Asperger's syndrome, J.R. featured as one of the case study children described in chapter 3. Reported to have advanced maths skills compared to his classmates, J.R.'s mathematics was formally assessed and found to be very superior (Mathematics composite = 149, > 99.9 percentile; Arithmetic = 130). These results confirmed parental report by validating the presence of exceptional maths relative to same aged, TD children. J.R. is described in detail in the case studies presented in chapter 3.

D.B.

D.B. is an 11 year old boy with High Functioning Autism. His parents reported outstanding musical talent, specifically for drumming and playing the guitar. His parents speculated that he may also possess absolute pitch. When assessed for absolute pitch, D.B. rapidly named all of the tones and achieved 100% accuracy on this task. His performance confirmed the presence of this skill. The case of D.B. is discussed at length in chapter 3, where a clinical and cognitive comparison of A.L., J.R. and D.B. is presented.

H.W.

H.W. is an 8 year old boy with a diagnosis of autism. He was reported to have many skills, the most salient being in the domain of music. H.W.'s mother reported that he had been playing the violin and the piano from an early age. She speculated on whether he possessed absolute pitch: H.W. would often sit at the dinner table and chime cutlery against his glass of water, proclaiming with much excitement the tones that he was able to make. Assessment of absolute pitch revealed perfect accuracy (100%) and this included naming all sharps and flats. Several other skills were also reported although these were not explicitly assessed: instant recall for times tables, knowledge of the London Underground tube lines and the ability to memorise and repeat verbatim children's story books. H.W.'s mother recalled that he once had the ability to calendar calculate (forward and backward in time by approx. two years) but that H.W. no longer did this.

T.J.

T.J. is a 9 year old boy with Asperger's syndrome. His mother reported strong skills in maths, science and mechanics. T.J. performed in the very superior range on assessments of maths (Mathematics composite = 130, 98^{th} percentile; Arithmetic = 190). These results validated his maths skills and suggested a definite superiority compared to same-age, TD peers. On consideration of T.J.'s mechanical skills, his mother stated: "[T.J.] has a seemingly instant knowledge for how to connect electrical machinery without the use of instructions. When he was 5 years old, he set up the surround sound equipment in the sitting room of our family home. He did this quickly, with ease and without needing to look at the accompanying manual". During the course of testing T.J. was exceptionally formal, articulate and very well spoken. Testing sessions were almost treated like business meetings. T.J. is highly intelligent (FSIQ = 137) and attends a private school with one of his best friends, P.F.

P.F.

An 8 year old boy with Asperger's syndrome, P.F. was described to have a love of mathematics especially mental arithmetic. Formally assessed, he achieved very superior scores (Mathematics composite = 133, 99th percentile; Arithmetic = 170). These results confirmed the presence of a skill, normatively speaking. Other reported skills included good memory for details, places and tunes and very good attention to detail when solving mazes and spot-the-difference games. In his recreational time, P.F. enjoys reading joke books, playing board games and learning to play the cello which he had just started. He has a strong interest in memorising scientific facts about animals and insects, and is described as being obsessed with his twin cats Ronnie and Reggie.

C.W.

A 10 year old bilingual boy with High Functioning Autism, C.W. was reported to have a number of skills in diverse areas. Mathematics was described as his foremost skill. Other talents included: playing the violin for which he had recently passed grade 2, memory for historical facts (e.g. the order of reign for English Monarchs), memory for London Transport routes and spatial skills (e.g. navigation, jigsaw puzzles). Whilst C.W. was reported to calendar calculate aged 6–8 years old, his mother confirmed that he no longer had an interest in this. C.W. was assessed for mathematics and absolute pitch. Whilst very superior maths were confirmed (Mathematics composite = 141, 99.7th percentile; Arithmetic = 140), C.W. was not found to possess absolute pitch (2 out of 25 tones were identified correctly). One of C.W.'s favourite past times is to create his own language from words spelt backwards (e.g. good afternoon = noonretfa doog). He greatly enjoys teaching this to his friends at school and has even formed a club consisting only of children who practise this pseudo-language. C.W. aspires to be an architect and cites Formula 1 racing as a main interest.

H.C.

H.C. has a diagnosis of Asperger's syndrome and ADHD, for which he currently takes medication. His mother reported that his main skill was maths. H.C.'s maths skills were formally assessed: he achieved very superior (Mathematics = 135, 99th percentile) and superior scores (Arithmetic = 120) on the assessment batteries. Of other skills, his mother wrote: "[H.C.] is very musical and can tap a rhythm on his body at great speed and accuracy; he also sings quite well and makes up songs. He would like to learn various instruments but so far has not had the chance. He also seems to be getting interested in beat boxing. I think he is quite mechanical and spatially aware in an engineering kind of way. His personal spatial awareness is not good as he always bumps into people and things. However, he loves playing games where you have to move things around to create a structure to get something from A to B. He has a good memory for numbers, details, events and facts. He has a very strong sensory discrimination for textures and smells. An understanding of passing time without a clock is also a skill". H.C. was described by his mother as a highly sensory child who is fascinated by spinning objects, fast cars and fire. He often burns paper and small objects in his garden as he feels that this helps him to release angry thoughts. On calmer days he enjoys caring for his pet chickens and baking cakes. During testing H.C. was incredibly energetic, often exiting and re-entering the room several times per session. He was highly engaging and very talkative. H.C. is 11 years old.

N.A.

Diagnosed with Asperger's syndrome, N.A. is a 10 year old boy. His mother reported that he is proficient in maths and literacy. These skills were assessed using the two relevant composites from the WIAT–II. Mathematical performance was recorded in the very superior range (Mathematics composite = 154, >99.9th percentile; Arithmetic = 190). Literacy skills were also very superior (Reading composite = 135, 99th percentile). These results confirmed the presence of advanced mathematics and literacy relative to same aged, TD peers. Further skills were reported in computing, recalling factual information and map/route reading. N.A. is described as a high achieving and self-motivated child, who is very intelligent (FSIQ = 142). During testing he asked many questions about the research and showed a genuine interest in learning about the normal curve (WISC–IV), how it had been formulated and where he scored on various subtests in relation to age-appropriate norms. A profound reader with excellent general knowledge, N.A. often cited facts that were over and above what was required to answer a particular question. For example, when asked which country has the largest population (Information subtest from WISC-IV), N.A. answered correctly and then proceeded to give additional facts about China.

G.H.

G.H. is a 12 year old boy with Asperger's syndrome, dyspraxia and severe anxiety disorder. His mother reported him to be skilled in maths and science. G.H.'s mathematical ability was found to be superior (Mathematics composite = 124, 95th percentile) while mental arithmetic was recorded in the very superior range (Arithmetic = 170). These findings confirmed reported talent. G.H.'s interests include war history, war games and the Nazi's. During testing he commented that one of the Block Design constructions looked like the Swastika. G.H.'s favourite game is Minecraft which involves constructing blocks in order to build objects. He plays this everyday for hours at a time with other young people and adults online. G.H. is currently home schooled due to a severe phobia in regard to the school environment. During ADOS, socio-emotional questions concerning friendships at school were responded to with elective mutism.

D.U.

Aged 12 years old with a diagnosis of ASD, D.U. was reported to have an assortment of skills: calendar calculating, calculating prime numbers and memory for London Transport routes. Three individual tests were devised to assess these obscure skills. D.U. reported that he had the ability to calculate the day of the week for dates of up to 4 years forwards and backwards in time. Calendar calculating skill was validated with 18 questions probing dates from the years 2007–2015 (2 questions per year). Of prime numbers, D.U. successfully named the first 500 prime numbers from memory. After the 500th prime number D.U. asked to switch to a new task, although he said he could happily calculate thousands more. D.U.'s knowledge of London Transport was assessed in two portions: 1) route knowledge using any means of public transport and 2) route knowledge of bus systems serving north and south London only (a particular interest). Ten questions were constructed to assess knowledge of travelling from A to B across north, east, south and west London, as well as north-west, north-east, south-west and south-east (e.g. how do I get from Finchley Central to West Ham?). All 10 questions were answered correctly using extensive knowledge of tube lines, London Overground and local bus services. Another 10 questions probed knowledge of bus services in north and south London exclusively. These questions reflected a broader range of concepts (e.g. routes, night buses, type of bus [single, Double Decker etc], the first or last stop of a particular route etc). Again, D.U. answered all questions correctly, with enthusiasm and elevated volume. In order to investigate the possibility of other numerical based skills, the decision was made to assess D.U.'s mathematics more broadly. Average mathematics were revealed (Mathematics composite = 96, 39th percentile; Arithmetic = 110). D.U. is proficient in prime number and calendar calculation, with the additional skill of transport route memorising, but he does not possess advanced mathematical skills overall. Appendix B presents the full results for D.U.'s skill validation while Figure 2–2 shows one of the many logs in which D.U. records transport information.

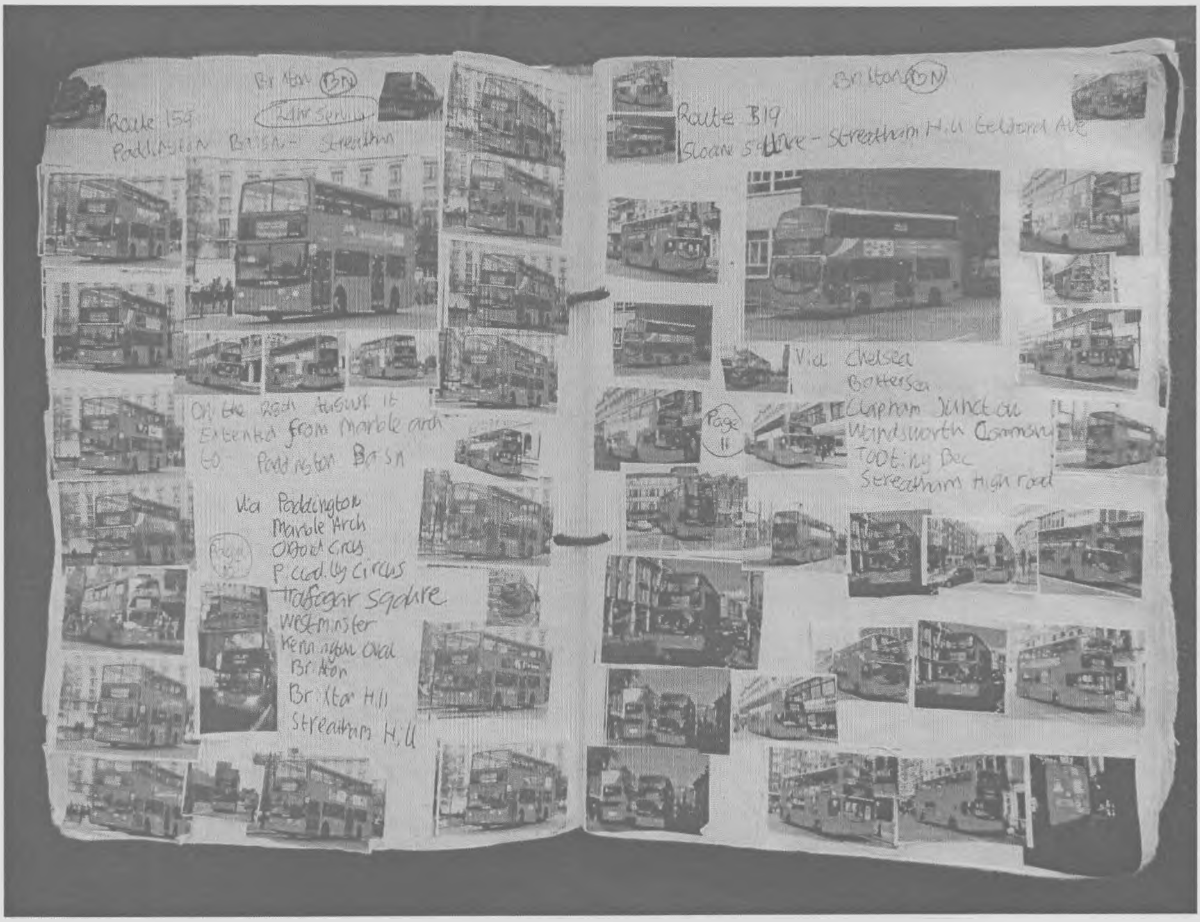


Figure 2–2. Transport log by D.U.

C.S.

C.S. has High Functioning Autism and is 9 years old. His main strength was reported in the area of maths. Performance was recorded in the superior range (Mathematics composite = 125, 95th percentile), while mental arithmetic skills were very superior (Arithmetic = 170). Other talents were reported in science and mechanical skills (e.g. aged 4 years old C.S.

completed Lego kits intended for children aged 9 years old, and aged 6 he worked on constructions suitable for children aged 12–16 years old). At the time of participation C.S. attended a mainstream school with classroom support of up to 28 hours per week. He presented as a bright, talkative child with good ability to focus. His mother reported that he loves cross-country running, sleepovers and origami.

R.C.

R.C., diagnosed with Asperger's syndrome, was aged 10 when he was recruited to the study. His mother reported him as a natural mathematician. R.C. achieved very superior scores when assessed using standardised maths assessments (Mathematics composite = 135, 99th percentile; Arithmetic = 140). Other reported skills included memory for autobiographical events (e.g. personal conversations, places that he has visited) and details about TV programmes which he enjoys emulating in comic strips.

K.M.

An 11 year old boy with ASD, K.M. was reported to have advanced calendar calculating skills although the extent of his date span was unknown. Upon meeting the family for the first time, K.M.'s mother told me the following story: a family friend recalled her wedding day and K.M. had asked what date she married. In response to her reply, he proclaimed "Saturday!" and was promptly told by the friend that he was in fact wrong. K.M. refused to believe that he had miscalculated a date and upon further investigation it was revealed that K.M. was in fact correct and that the family friend had misremembered the day she married.

The following is an extract from talking with K.M. about his calendar knowledge:

E.B.: How many years can you calculate for?
K.M.: Hundreds of thousands.
E.B.: How do you make the calculations?
K.M.: I just got a way that no-one will never know how to understand.
E.B.: When you were younger did you like looking at calendars? Did you ever try to memorise any?

K.M.: No, it just hit me.

E.B.: So how do you make the calculations?

K.M.: People think I memorised a calendar but I didn't. I don't know how I do it. I just do. People have their gifts. I guess this is just mine.

Appendix C shows the results for K.M'.s skill validation. It was found that K.M. could calendar calculate from the present day to as far back as the year 1905 and as far forward until the year 2099. On subsequent dates given after this time K.M. could not correctly calculate the day of the week, instead providing answers that were one day ahead. K.M.'s calendar skills were successfully validated with 40 out of 44 date questions being answered correctly (a span of approx. 200 years). While K.M. was not reported to possess outstanding mathematical skills, the decision was made to assess his number skills more broadly. Average maths skills were revealed (Mathematics composite = 97, 42nd percentile) although mental arithmetic was very superior (Arithmetic = 130). K.M. was incredibly polite during the testing sessions. He showed consideration and excellent humour. At the time of testing, K.M. attended a specialist school for children with ASD.

L.H.

L.H.'s mother did not initially report him to have any exceptional talents. As such L.H. was originally intended as a participant for the non-savant group. During the course of testing however several pieces of detailed artwork were noticed and these were sufficiently intriguing enough to warrant professional assessment. Figure 2–3 shows a highly detailed sketch of robots that L.H. produced from imagination. This drawing was awarded the following ratings: liveliness of and sensitivity to the object/subject drawn (grade A), vitality and the character of line and texture (grade B), presence of a distinct personal style (grade B), organisation and composition of the piece (grade B) and degree to which a compelling and interesting image was produced (grade B). These assessment ratings were sufficiently high enough for L.H. to be included in the savant group. While L.H.'s mother had always found his artwork interesting, she explained that she had not considered him specifically talented as she did not have a marker by which to compare the artwork of other, same aged TD children. She cited L.H.'s art therapy classes as the onset for his interest in this area. Aside from producing detailed sketches of imagined robots and building robots and other subjects from recycled waste, L.H. has deep interests in Dr. Who and assembling complex Meccano models without need for instruction. At the time of testing L.H. was in attendance of a mainstream school with little one-to-one support. His mother reported that he was having great difficulty staying in the classroom as he would spontaneously leave the room several times a day. During testing sessions L.H. would often rock in his chair, exit the room, crawl under the table or stand on the table. He is 8 years old and has a diagnosis of Asperger's syndrome with suspected ADHD.

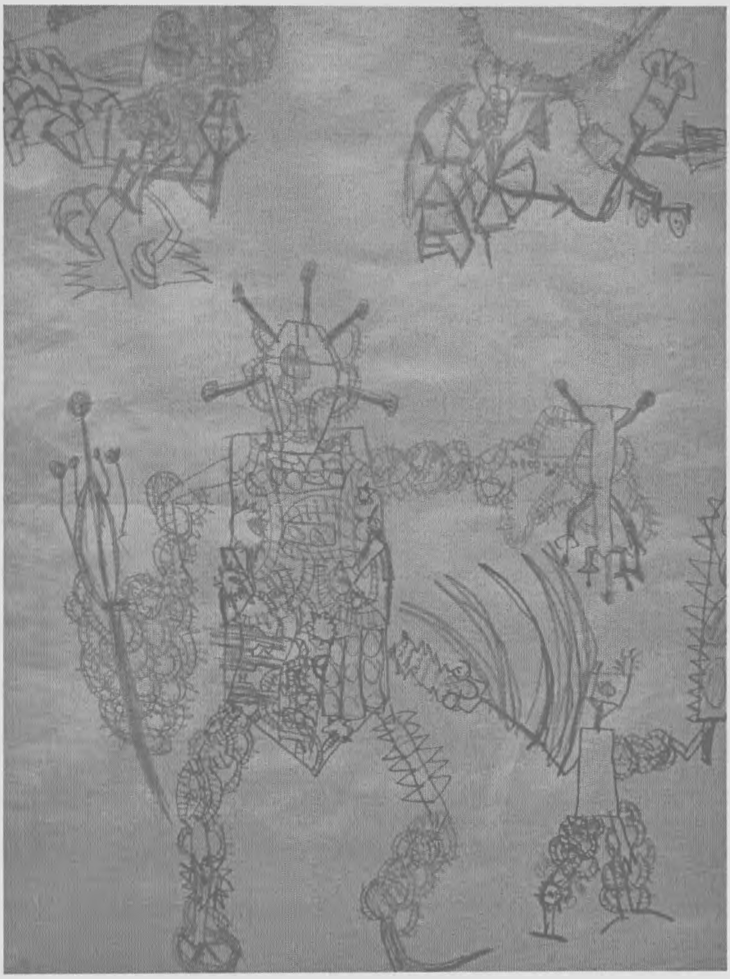


Figure 2–3. Robots by L.H.

P.G.

P.G. is a 10 year old boy with a diagnosis of Asperger's syndrome. As P.G.'s parents did not initially report him to have any particular talents, P.G. was intended for inclusion in the non-savant group. However, during the course of testing it was noted that P.G. achieved a very superior Arithmetic score (160). Considering this, the decision was made to assess P.G.'s overall mathematics. Such testing revealed superior mathematics (Mathematics composite = 122, 93rd percentile). Normatively speaking, P.G.'s maths skills exceeded those of same aged TD peers, and in light of these findings he was excluded from the non-savant group and included in the savant group. P.G. was often anxious about his test performance. Socio-emotional questioning (ADOS) resulted in angry outbursts. P.G. was in attendance of a private school for children with behavioural and emotional needs at the time of taking part.

B.M.

B.M. is a delightful 8 year old boy with a diagnosis of High Functioning ASD. He was reported to possess a number of creative talents. Music is B.M.'s foremost passion, especially the piano which he has been playing by ear since the age of 5 years old. Prior to this (3–4 years old) he played the glockenspiel and electric keyboard. B.M.'s mother reported that he has an exceptional musical memory, especially for complex and lengthy pieces of classical music which is his favourite. Aged 7 he began attending classical concerts (aimed at adults) and would sit still throughout, listening intently. B.M. now writes and memorises his own compositions. While B.M.'s mother suspected absolute pitch, this had not been formally assessed before. Absolute pitch was confirmed with a performance score of 21 out of 25 on the assessment CD. Other skills were reported in the areas of arts and crafts (e.g. knitting, sewing, weaving, mosaic making and photography), mechanical skills (e.g. 3D model making and complex Lego construction) and autobiographical memory (especially for emotive events from up to 5 years prior and the day of the week on which such events took place). B.M. was once reported to have shown a mild interest in calendar calculating. Figure 2–4 shows an example of music that B.M. has memorised.

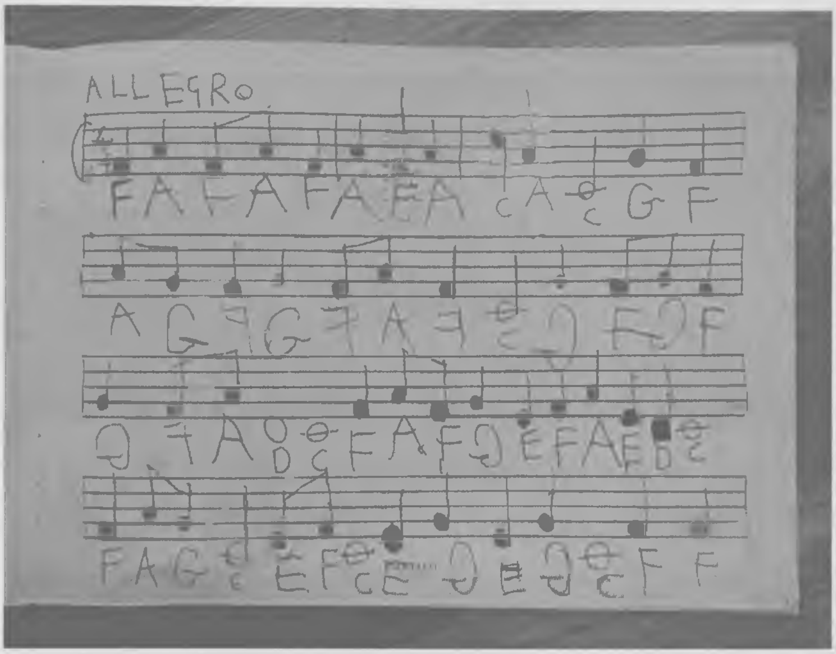


Figure 2–4. Musical composition by B.M.

PROCEDURE

Participants in the two ASD groups were tested individually in a quiet room at their family home. Of the 36 children with ASD, each child completed testing over four sessions. These testing sessions typically lasted 1–2 hours each depending on the pace at which children felt comfortable working. While some children required a number of breaks per session, others were happy to work continuously without wanting to stop. Tasks were presented as short games and structured activities, as opposed to formal tests. With the exception of ADOS, the order in which the tasks were presented was randomised. With consideration to the highly personal nature of the socio-emotional questions, ADOS administration was deliberately placed toward the end of the battery to afford the opportunity of building rapport first. This was with the aim of reducing any possible anxieties surrounding the content of the ADOS in order for a clearer presentation of social-communicative symptoms, anxiety aside, to be observed. TD comparison children received a less intensive test battery (e.g. they did not receive ADOS or a full WISC–IV). These 17 children were tested over a maximum of 2 sessions, in a quiet room at their home. Here testing sessions lasted approx. 1 hour each, but again these were dependent upon the speed at which children felt comfortable working. As before, all tasks were randomised. Standardised instructions were adhered to for all published tests and children were informed that they could stop at any time should they wish. All participants completed testing over a maximum period of 8 weeks. All testing sessions (approx. 178 in total) were conducted by the author of this thesis.

ETHICS

Ethical approval was granted by the Ethics Committee of the Psychology Department at Goldsmiths, University of London, and by the NAS at the time of applying for a research advertisement to be placed on their website. When writing to individual NAS branches to request their assistance with recruitment, details of this two-fold ethical approval were provided. Parents of child participants were informed that the project had been approved by Goldsmiths, University of London, and the NAS. While it is recognised that children are often classed as vulnerable participant groups in psychological research, no major ethical concerns were raised before the onset of the study or during testing.

DESIGN AND STATISTICAL ANALYSIS

The thesis employed mixed methods. Standardised assessments were used in conjunction with questionnaire data and new experimental paradigms. Case studies were conducted in chapter 3 and these formed the basis for later group studies comparing savant, non-savant and TD participants in chapters 4–7. Group was the dependent variable that was tested in all analyses whereby independent variables included clinical correlates (e.g. symptom severity, obsessionality, sensory processing) and cognitive correlates (attention, intelligence, cognitive processing style, pattern perception) of savant syndrome. The data were analysed using the Statistical Package for the Social Sciences (SPSS) (version 17) mostly using independent samples t-tests for data from studies comparing savants and non-savants, and one-way ANOVAs for data comparing savant, non-savant and TD groups. Post hoc analyses employed Tukey HSD or Games-Howell tests dependent on whether equal variances were, or were not assumed, and these tests were used to investigate the specific nature of observed group differences. The final empirical chapter also implemented logistic regression analyses in exploring the value of various cognitive tests in predicting group membership (savant vs. non-savant). Finally, the power of the statistical procedures used was an important issue, as low power facilitates greater chance of committing a Type II error. A primary factor that affects statistical power is sample size. An indication of the numbers of participants required for the studies carried out in this thesis was estimated from previous studies of a similar nature. Reliable results have been reported using between 8 and 20 participants (Heavey et al., 1999; Hermelin & O'Connor, 1990; Pring, Ryder, Crane & Hermelin, 2010; Shah & Frith, 1993). The studies presented in this thesis were conducted with 17 savants, 19 non-savants and 17 TD comparison participants. These sample sizes were deemed adequate enough to ensure statistical power.

CHAPTER SUMMARY

This chapter has detailed the methods and procedures used in the studies described in the thesis, and has provided information on participant groups. The following chapter examines the clinical and cognitive profiles of three children with ASD who are gifted in the classical savant domains of art, mathematics and music.

CHAPTER 3: CASE STUDIES OF THREE CHILDREN WITH ASD AND SKILLS IN THE CLASSIC SAVANT DOMAINS OF ART, NUMBER AND MUSIC

ABSTRACT

This chapter presents the case studies of three children with ASD and skills in art, mathematics and music. While Bennett & Heaton (2012) reported on a number of factors that differentiated skilled from non-skilled individuals with ASD in their questionnaire study, these findings were based on parental report and individuals were not assessed using standardised measures. The findings of the questionnaire study revealed that skilled individuals were not characterised by increased socio-communicative impairments, repetitive behaviours, obsessionality, sensory abnormalities or a local processing bias. However, skilled individuals were reported to have enhanced memory and a capacity to become highly absorbed in topics of interest. These findings were investigated in the case studies presented in this chapter. Clinical factors included measures of symptom severity, obsessionality and sensory processing. Investigation of cognitive correlates focussed on intelligence, memory, cognitive processing style and individual achievement. The results of the questionnaire and case studies were important in revising the test battery for later group studies, and in formulating hypotheses about the clinical and cognitive factors differentiating groups of savant and non-savant children with ASD.

Recently, Bennett & Heaton (2012) conducted a questionnaire study with 125 parents of children, adolescents and adults with ASD with the aim of identifying specific correlates of talent in this group. The questionnaire was designed in two parts and aimed to identify individuals with and without reported skills and to provide preliminary data on the basic cognitive and diagnostic profiles distinguishing these two groups. Specifically the questionnaire items tapped a number of factors that have been implicated in the development and maintenance of talent in ASD: 1) socio-communicative deficits, 2) memory, 3) isolated interests, 4) restricted and repetitive behaviours and 5) sensory sensitivities. Parents/caregivers were also asked to provide detailed information as to whether they considered their child to possess any outstanding skill(s) relative to that persons overall disability. Of the total sample screened, 42% (52 out of 125) agreed or strongly agreed that their child possessed one or more outstanding skills in areas such as mathematics, art, music or memory. This figure was far higher than Rimland's (1978) estimate of 10% for persons with autism and more in line with recent estimates of up to 30% presented by Howlin et al. (2009). Further, special skills were not restricted to one subgroup and were instead prevalent across the entire spectrum.

Analysis of the questionnaire results revealed that the two groups did not differ on factors tapping socio-communication, repetitive behaviour or sensory abnormalities. Similarly, preoccupation with parts of objects (suggestive of a local processing bias) also failed to differentiate the groups. However, analysis of the obsessions and special interests factor revealed an intricate pattern of findings. While individuals with ASD and reported skills were not characterised by increased levels of rigidity, obsessionality or ritualistic behaviour, they were reported to show a greater tendency to become absorbed in topics that capture their interest than those without reported skills. Analysis of the memory factor showed that skilled individuals were reported to be better at remembering dates, facts and things of interest compared to those without skills, and they were also reported to have greater general memory skills overall. There were no group differences concerning memory for places visited, personally experienced events (autobiographical memory) or memory for any kind of (non-specific) information. These results were important in highlighting correlates of reported talent in relatively large samples of screened individuals with ASD and provided the first phase in a two-part study concerning ascertainment and validation.

However, the study was not without limitations for example in relying upon parental/carer report of talent in the absence of validating these skills. While questionnaire studies relying on parental reports run the risk of under or overestimating the prevalence and extent of special skills in ASD, the questionnaire presented by Bennett & Heaton (2012) asked respondents to record whether or not anyone outside of the family unit had commented on the individual's skill(s). For 9 out of 10 of the skilled cases this question elicited a positive response, providing a preliminary measure of skill validation in the absence of formal assessments. Further, possible local processing differences were measured using a single questionnaire item and groups were not formally tested on cognitive constructs such as IQ profiling which may play a role in distinguishing groups. Nonetheless, results from the analysis of the questionnaire data were intriguing and provided the rationale for carrying out detailed case studies investigating those factors in children with ASD and reported skills in classical savant domains. This chapter describes three case studies and presents data from an extensive clinical and cognitive test battery. It should be noted that whilst the questionnaire study formed the basis for the first author's MSc Thesis, this case study investigation was conducted as the initial phase of PhD research. The questionnaire and case studies were published in the Journal of Autism and Developmental Disorders (Bennett & Heaton, 2012) and they informed the hypotheses that were tested in the group studies presented in chapters 4–7 of this thesis.

This chapter is presented in two main sections. First, qualitative data will be presented and this will include descriptions of the children, their birth and early development, details on reported skills, developmental trajectory of skills and ultimately, validation. The second half of the chapter is focussed on comparing the clinical and cognitive profiles of these three individuals. Clinical profiles were compared with regard to symptom severity, obsessionality and sensory processing, while the results from cognitive testing focussed on intelligence profiles, a standardised assessment of memory, tests of cognitive processing style and an individual achievement battery. Should the questionnaire study isolate factors that distinguish skilled from non-skilled participants, it would be expected that these same characteristics might also be observed in the subjects of the case studies.

A. L.

Description of A.L.

A.L., an 11 year old boy with ASD and dyslexia, was noted for his excellent drawing ability. The oldest child of a family of two, he is bilingual having learnt both Brazilian Portuguese (mother) and English (father) from an early age. A.L. is described as an energetic child with a real need for body movement. He practises martial arts (Aikido, Judo) and had recently joined the cubs. A.L. has many interests amongst which are a passion for gadgets, Greek mythology and constructing science fantasy figures from Lego. Asked why drawing is so central to him, he replied "I don't know; it's just something I like doing sometimes". At the time of testing A.L. was currently in his last year of primary school and was reported to have made much academic progress within the last year. During testing sessions, A.L. was highly cooperative and demonstrated good concentration. Other family members were reported without developmental or psychological disability and without artistic talent.

Birth and early development

A.L. was born premature at 33 weeks weighing little over 2lb 13oz. At 26 weeks his mother became concerned that she had not felt A.L. moving and sought ultrasound examination. Such revealed that A.L. had normal brain size but a small stomach, and a smaller than average placenta. Following delivery by caesarean section at the onset of pre-eclampsia, A.L. was monitored in an incubator for 4 weeks but developed an intestinal hernia upon discharge. No further complications emerged following successful treatment. As an infant A.L. interacted equally well with objects and people. He developed a preference for people, however, which his mother attributed to him spending half of his infancy in Brazil with close family and friends who were highly orientated to care for him. A.L. babbled as an infant and said his first word "nenen" (Portuguese for baby) at the age of 12 months. This was followed by "ventilador" (fan) aged 13 months reflecting his fascination with a ceiling fan which he often gazed at. Periods of ceased or echolalic speech whilst learning to speak were not reported. Concerning motor development, A.L. began to crawl aged 10 months and began walking aged 18 months. A.L. is right handed and is not reported to have been ambidextrous at any point. It remains unclear as to when he first achieved hand dominance.

Description of skill

A.L is gifted in drawing. Amongst the various styles that he experiments with, his best work is perhaps the high quality tonal sketches that he produces. These are well composed, realistic and detailed. A.L. always begins his drawings from local points, neglecting the typical process of drawing global outlines first, and works from one detail to the next until his picture is complete. He works effortlessly with speed and shows confidence: his pencil barely leaves the paper. Similarly to other savant artists, (e.g. Nadia, Selfe, 1977; E.C., Mottron &

Belleville, 1995), A.L. he does not labour over or erase lines. His ability to maintain intense concentration whilst drawing is admirable. He works from a variety of sources (e.g. observation, film and his own imagination). Figure 3–1 displays an example of A.L.'s drawing, a direct observation of life-sized equestrian armour drawn from a display at The Wallace Collection. A.L. began this piece by detailing the horse's left ear. It is semi-reminiscent of the drawings produced by the savant child Nadia (Selfe, 1977), both in theme and style.

Figure 3–1. Knight on horseback by A.L.

Developmental trajectory of drawing skills

A.L. first embraced artistic expression at the age of 3 years old. He was given a Megasketcher from a friend for his third birthday and first drew a shark with the pen attached to the toy. This was inspired by a fascination with sharks that he had developed following a family outing to the London Aquarium. Having never entered the pre-schematic phrase of scribbling, he then moved onto drawing another recognisable concept, a crab, using his Megasketcher. This was also inspired by direct experience, seeing a crab on the beach while he was on holiday. A.L. went on to produce more and more pictures, namely of similar aquatic animals.

A.L. began drawing via more traditional means aged 4 years 1 month. His early drawings were highly schematic, reflecting both his interests and imagination (e.g. scenes from the Walt Disney film The Lion King or scenes from his own make-believe stories). Typically he used felt tip or biro pens and his mother attributed this to liking the flow of pens for quick, effortless work. A.L. would often draw from different angles including upside down and would voice what was happening in his pictures as he drew. While A.L. spoke of imaginative stories and created drawings to match them, his mother would write the stories down. With limited speech otherwise his parents were overjoyed with this new found way to communicate. Filling whole sketchbooks at a time with set themes such as sea creatures, pirates and dinosaurs, A.L. had the ability to draw for "hours and hours" according to his mother who described him as having an intense need to produce "sheer volumes of drawings". In one series, A.L. depicted, and verbally described, a talking boat, an octopus who had tried to eat him and dinosaurs eating each other. A.L. is described to have always worked in sequence, rarely lifting his pen and never evaluating a drawing before moving onto the next. He would not actively show his work to others for praise and instead is described as drawing for the sake of the process and not for the end product. His use of colour was minimal and only for the purpose of highlighting a particular element in his work (e.g. red fire or blue water). Further, A.L. would present himself with drawing challenges: facial expressions, figures in profile and working on large scales, for example a sea monster drawn to fill the entire length of a strip of easel paper measuring approx. 2 ½ metres.

Monsters are a theme that has remained prominent in A.L.'s art along with mythological creatures and battles. Aged 8 years old, he would repeatedly draw detailed fighting scenes depicting warriors, sword-fighting and fire breathing dragons. He developed the ability to imagine the spatial orientation of whole objects yet depict on page only a portion of what he saw in imagination, so as to show greater movement in his work. For example, in one piece, a dragon's face approaching on the left hand side of the paper was balanced with another dragon's tail exiting the scene on the far right. A.L. would continue to make full use of the page whilst drawing, again using minimal colour and maximum energy. He would produce countless sequences in this way, depicting bloody battles mainly from imagination but also sourced from films (e.g. Star Wars). He continued to show a good understanding of scale evidenced in large studies of the faces of dragons contrasted with tiny armoured warriors.

It was around this time that A.L. entered into Art Therapy. He is reported to have obsessively drawn monsters and fighting scenes for weeks on end which his art therapist attributed to him expressing jealousy for his younger sister. A.L. was not explicitly encouraged to experiment with varied artistic techniques during the course Art Therapy, rather the aim of the one-to-one sessions were for him to draw freely whilst talking to the therapist simultaneously. His sessions of one hour per week came to an end at the age of 10 years 11 months, and A.L. was reported to have made excellent progress both psychologically and artistically during the three year period. Figure 3–2 displays an example of a drawing produced by A.L. whilst engaged in Art Therapy. The drawing is large and was produced on A2 sized paper using ball-point pen.

Figure 3–2. Monster by A.L.

A.L.'s technical skill and willingness to explore more varied techniques and subjects in art has developed tremendously over the years. He now experiments with pencil to create detailed tonal studies and had recently attempted watercolour painting inspired by seeing another child painting. With this development he includes work featuring animals, landscape and Japanese Manga characters, although he will still only create art that depicts his interests. Further, A.L. has moved away from repeat sequences of producing one drawing after another. He continues to present himself with artistic challenges such as working in varied styles and with different materials: recently he created a short animation film using an application for a popular games console. His animation, depicting a man running and jumping over a riverbank, was completed with 2 sessions of unbroken concentration, each session lasting approx. 3 hours. Perhaps most indicative of his skill development, A.L. has become very aware of his strengths and limitations. This is evidenced in him periodically stopping to assess his work, learning to use an eraser (aged 9 years 6 months) and taking great pride in the compliments that he receives from those who admire his art. Additional examples of A.L's drawings are shown below. Figure 3–3 shows A.L.'s study of a goblin and Figure 3–4 shows a dinosaur drawn from memory

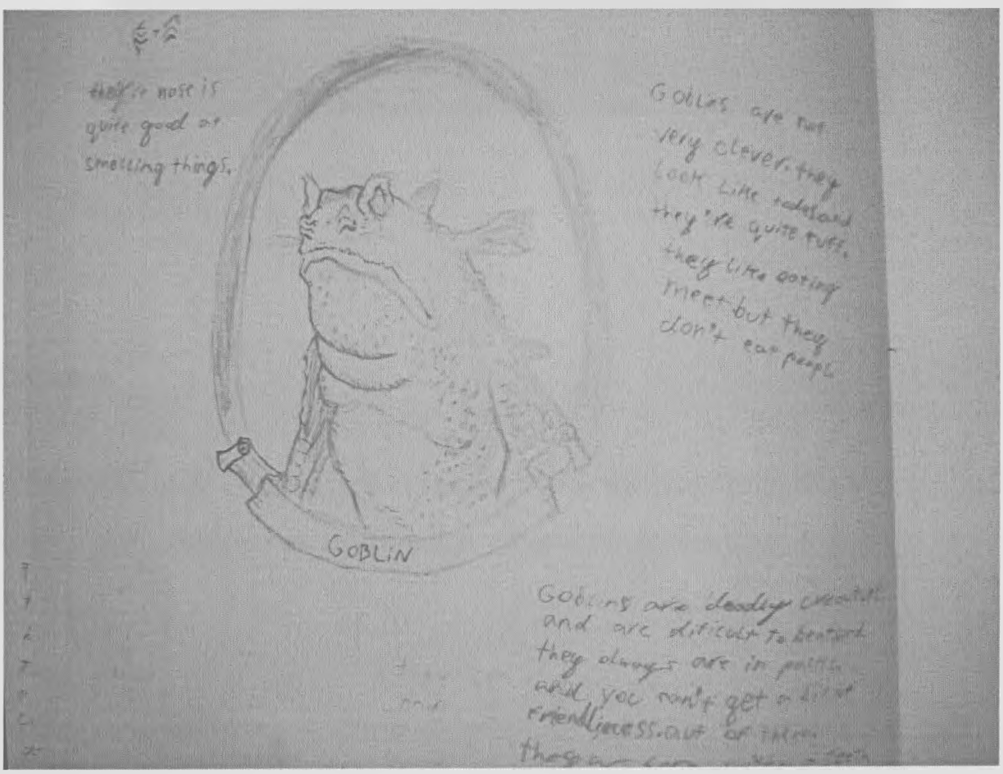


Figure 3–3. Goblin by A.L.

Figure 3–4. Dinosaur by A.L.

Skill validation

Skill validation for A.L. is discussed in chapter 2. For the purpose of this chapter, readers are reminded that A.L. fulfilled skill validation criteria for inclusion to the study as an artistic savant.

J.R.

Description of J.R.

J.R., a 10 year old boy with a clinical diagnosis of Asperger's syndrome, was reported to have a great interest in numbers and advanced mathematical skills. J.R. is the second oldest child born to a family of three. J.R. has a high degree of insight and fully recognises that he is in some ways different from other children his age. On one occasion, after watching his younger brother make friends with another child in the park, he asked his mother why he felt unable to do this. He is prone to experience anger, described by his mother as "black moods" which can last for weeks. However, he is for the most part softly spoken with an ethereal appearance and an excellent sense of humour. His interests include computer games, canoeing and solving maths problems, and at the time of participation he was currently learning to play the trumpet. A second cousin of J.R.'s mother is reported to have three children with ASD, while one of J.R.'s uncles, on his father's side, is thought to have Asperger's syndrome. Mathematical skills are reported in other family members. J.R.'s father's half brother is registered as gifted in mathematics and J.R.'s older sister is described to be good at maths but not naturally gifted.

Birth and early development

J.R. was born after a normal full term pregnancy and delivered with a birth weight of 8lb. As an infant, J.R. is reported to have screamed non-stop, and child care was largely provided by his maternal grandmother. Whilst this disturbance was interpreted as ill temper, the results from the Sensory Profile raise the possibility that he may have been reacting to sound and light triggers that he found aversive. At the age of 3 months his mother took him to see a cranial osteopath. He had previously undergone physical exam and no abnormalities had been identified. J.R's parents do not recall if he interacted equally well with people and objects or if he showed a preference for one or the other. Rather they described him as a difficult baby who was disinterested in play. J.R.'s language acquisition did not appear to be marked by large abnormalities. He babbled as an infant, used a few words by 12 months and phrase speech by 18 months. He is reported to have begun speaking in sentences by the age of 2 years old. Periods of mutism or echolalic language were not noted. In his milestones, J.R.

began crawling at the age of 6 months and walked unaided at 12 months. It is unclear as to when J.R. achieved hand dominance. He is not reported to have ever been ambidextrous.

Description of skill

J.R.'s parents reported that he possessed mathematical skills that are considerably above average for a child of his age. Whilst J.R. likes mathematics he does not practise extensively. He rates his liking as "about 9 out of 10 because if it were a 10 then I would practise". In addition to performing at a high level on basic mathematical operations, J.R.'s parents reported skills in more diverse areas of mathematics including working with fractions, probability, decimals, percentages and algebra. He is also able to calculate square roots and exponents (e.g. 10^3) and can solve maths problems related to time, money, measurement, graphs and geometry. His spatial reasoning is good and he is able to solve multi-step word problems mentally. Unsurprisingly, J.R. reports that he does not find the maths at school sufficiently challenging. Despite being skilled in mathematical calculation, J.R. does not, nor has ever, calendar calculated. When asked why he thinks he is very good at mathematical calculation, J.R. said rather humbly: "we are all born with skills so I guess this is just my skill".

Developmental trajectory of mathematical skills

J.R.'s parents first noted that he had a particular interest in numbers at the age of 4 years. During a parent/teacher meeting, J.R.'s reception class teacher informed J.R.'s parents that he was showing advanced maths skills relative to the other children in the class. Counting and sequencing numbers were given as examples and the teacher further reported that J.R. seemed to process information very quickly. Prior to this, J.R.'s parents had not observed any early preoccupation with numbers nor mathematical constructs, such as shapes and symbols. However, aged 2½ years he did enjoy early maths computer games that required visuo-spatial problem solving. In these he would complete tasks such as building walls and making drainpipes on screen using shapes. He is reported to have concentrated very intensely during these activities which "engrossed him" and to have finished them quickly. As J.R. did not show obsessional behaviour concerning maths related activities, and other interests were also apparent (e.g. particular children's TV programmes), his parents did not assume that J.R. possessed unusual competence in maths.

Following the initial report from his reception class teacher, J.R. quickly learnt addition and subtraction (aged 4–5 years old) and later multiplication and division (5–6 years old). He is reported to have learnt in line with the National Curriculum but to have always grasped maths more quickly and to have performed at higher levels compared to his peers. Further, J.R. is reported to have never needed explicit maths teaching; rather competency in number work occurred both independently and automatically. In this way he learnt his times tables effortlessly (up to the 15^{th} times table) without the aid of adult support. Around this time his parents began to give him verbal number puzzles. J.R. would enjoy this and almost always answered correctly. Although J.R. never asked questions about how to carry out mathematical calculations, he would ask his parents to pose maths questions to him so that he could demonstrate and hone his skills. J.R. is reported to have always been at the top of his class for maths and in year 4 (aged 8–9 years) he was able to complete 30 minute maths homework in just 2–3 minutes. His mother would ask the school for maths extension work which again he would finish rapidly. It is reported that J.R. would find conventional pencil and paper methods for solving maths problems frustrating as he did not need to labour over working out his answers.

J.R.'s parents reported that he had developed a particular skill for working out maths problems mentally. Family members often quiz him with difficult maths problems, or he sets himself a problem, for which he needs total silence to work out the correct answer. He typically talks aloud when calculating and if interrupted will say: "Shhhh! I'm working it out!" Any further interruption results in J.R. becoming angry and upset. He particularly enjoys the 30 second Number Crunch problems that are printed in newspapers. Here, the reader is given a number and must apply several given mathematical operations to their running total, from left to right, in order to reach the correct answer. With three difficulty levels, J.R. often calculates correctly at the advanced level within the 30 second time limit (e.g. 121 ÷ 11 + 125 75% of this -25 4/7 of this -31 ×9 +38 40% of this = answer). Recently, he was the only student in his class of 30 who could correctly solve a mystifying online maths problem that the teacher was unable to correctly solve herself: a lamp and a bulb together cost £32. The lamp costs £30 more than the bulb. How much does the bulb cost? While the class and their teacher presumed that the bulb must cost £2, J.R. explained that the bulb actually had a price of £1 in order for the lamp to be £30 more than that and the total not to exceed £32. The lamp therefore cost £31, exactly £30 more than the bulb (£1), bringing the total to £32.

Currently, J.R. continues to excel within the domain of mathematics. He is reported to have surpassed the highest Scholastic Aptitude Test (SAT) mathematics level for primary school children his age (10–11 years old). He even reports that he likes to "play" with high numbers mentally and that brain-teasers, such as those described above, are his favourite. He feels that his school gives him maths work that is age but not level appropriate and consequently he has begun experimenting with square and prime numbers which he now knows into their early hundreds. When asked how dealing with numbers is different to dealing with people, he replied: "people have emotions so you need to be careful not to hurt their feelings. You can't hurt the feelings of numbers. Numbers are less hard to handle than people, they are simpler". Having recently been teased by a boy at school for not being athletic, J.R. discussed the incident with his mother that night at home. His mother reminded him that people have different strengths, his own being maths, and suggested that if he had set the boy a hard maths problem then that boy would likely have failed to solve it. Trying to work out the answer to the hypothetical maths question his mother had used, J.R. missed the point of how he might have applied this argument in order to resolve a playground quarrel and instead focussed on the numbers.

Skill validation

Skill validation for J.R. is discussed in chapter 2. Readers are reminded that J.R. achieved a mathematics score in the top > 99.9 percentile for his age on a standardised assessment.

D.B.

Description of D.B

D.B., an 11 year old boy with a diagnosis of High Functioning Autism, was reported to be an exceptionally gifted drummer and musician. D.B. was recruited for case study evaluation with the kind assistance of British Broadcasting Centre (BBC) TV producers following the screening of a two-part documentary in which D.B. was featured playing a large drum kit to a live studio audience. This programme was aimed at raising awareness of autism and in particular musical talent in autism. The oldest of two sons, D.B. is a very literal young man. When asked to describe himself he said: "black hair, white skin, freckles". He also has a good degree of insight into his own limitations and can often be heard saying: "it's because of my autism". Although described by his parents as petulant and stubborn at times, D.B.'s parents stated that he is very loving, has a good sense of humour and enjoys the company of others as much as he does his own. Besides music, other interests include social networking, watching horror films, updating his film trivia and writing songs. Autism is reported in at least two other distant family members (the two children of D.B.'s mother's first cousin) but exceptional musical talent is not. While D.B.'s father, a professional actor, also enjoys playing musical instruments (e.g. drums, guitar, bass) he does not perform with the high level of musical talent that D.B. possesses. As D.B.'s mother says, her husband is "not a patch" on D.B.

Birth and early development

Due to a failure to progress, D.B. was born by emergency caesarean section. His birth weight was recorded as 7lb 1oz and there were no neonatal concerns. The pregnancy had been complicated by hyperemesis which did not require hospitalisation. Aged 9 months, D.B. experienced a convulsion during a rising fever but was discharged following casualty. He was in hospital for two weeks at the age of 12 months with possible septic arthritis. This settled with antibiotics and no cause was found.

D.B. was reported to have been a passive, easy-going infant who was a pleasure to have at home. Largely happy, he could often be found smiling and laughing. His interaction with people and objects was normal although he developed a particular preference for adult interaction and musical toys. D.B. was aged between 12–24 months when he said his first words, a full sentence to the effect of "its cold outside" or "its dark outside". However, the vast majority of his language development showed delayed echolalia and in comparison little speech was generated spontaneously. D.B.'s speech was idiosyncratic at times and he used pronoun reversal. In his milestones, D.B. began crawling aged 8 months old and walked at 12 months. It is unclear as to when D.B. achieved hand dominance. He is not reported to have ever been ambidextrous.

Description of skill

D.B. is incredibly musical. He adores drumming and spends a lot of his time engaged in this activity. Described by his parents as a "hard drummer", he is typically tense whilst he drums and his mother wonders if this is linked to a need for sensory stimulation. D.B. is wholly self-taught and drums with confidence, perfect timing and seemingly innate rhythm. He is reported to be able to drum back any piece of music heard once and enjoys improvising as well as composing. With a real passion for rock music, he cites Led Zeppelin, Queen and Bruce Springsteen amongst his favourites. D.B. was given his first drum kit aged 3 years old and has since worn out this drum kit plus the interiors of two others. D.B. is reported to excel in a number of musical domains including playing the guitar, steel pans and the piano. Further he enjoys singing, writing lyrics and creating harmonies with his father. His mother explained that D.B. hears drumming in his head all the time. She recently asked him if this were the case to which he laughed and replied: "yeah, can't you?" When she informed him that she could not, he leant forward and touched his head to hers and said: "can you hear it now?" D.B. has a preference for large drum kits and attributes his talent to the ability to "move my hands around really fast". He never goes a day without listening to music and describes it as very important to his life.

Developmental trajectory of musical skills

D.B.'s parents first noted that he had an affinity with drumming at the age of 6 months old.

His mother reported that he would run his hands down the wall of his cot in a rhythmic way and would sound out rhythms and patterns on countless surfaces. D.B. would frequently bang and tap his hands on objects too, including his mother's arms as she held him, and toys, in order to make beats. Intermittently drumming with his hands on surfaces occurred in a variety of contexts for many months. At the age of 12 months he was observed to sway to music that his parents would play on CDs at home. D.B. would lie passively in his parent's arms for hours at a time attentively listening to a variety of musical genres while sucking his thumb. His father described him as being "enchanted by music". D.B. showed clear preferences for songs from a very early age: at one point as an infant D.B. greatly liked the song Teardrop by Massive Attack which would be played for him on repeat, but this same song would later cause great distress when played on different occasions resulting in temper tantrums and much crying.

As an infant, D.B. is described to have been preoccupied with musical toys, listening to music and sounding out patterns using his hands. By the age of 2 years old he had independently learnt how to turn on the stereo system, choose CDs and play them. On one occasion the CD had begun far too loudly and this frightened D.B. Subsequently when playing CDs, D.B. would run out of the room into the hallway with his hands covering his ears. Once at a safe volume level, D.B. would return to the room and listen to endless CDs each one tossed aside when finished and a new one selected. D.B. is reported to have gone through dozens of CDs at a time in this way. Soon after, D.B.'s parents brought him his own stereo for his bedroom. D.B. would continue to listen to music and drum with his hands everywhere he went often attracting attention from other people. On one occasion, while in a restaurant, a professional drummer approached the family having watched D.B. drum on the table. This man had shown the exact same behaviour when he was D.B.'s age and recognised the signs of precocious drumming. As a strategy for preventing D.B. from continuing to drum at the table during family meal times, D.B.'s parents would ask for "quiet hands".

D.B. received his first drum kit on his third birthday. Clear differences between D.B.'s drumming ability and that of the other, same aged children were observed at his birthday party. While other children held the drumsticks incorrectly and banged carelessly in a very primitive way, D.B. worked his way around the drum kit with his hands palm-side down and instinctively held the drumsticks in the correct manner. His drumming technique was natural and he demonstrated how to use the drums for all his guests to see. The drum-kit provided

D.B. with many hours of interest and proved his favourite pastime, so much so that his parents felt they had to limit his time on the drums or he might do little else. At this point, D.B. started to show signs of drumming from memory. For example, he had heard the beginning of the theme tune from the TV programme Eastenders at his grandparents home and drummed this spontaneously a few days later at home.

From the age of 3–6 years old, D.B. took part in Music Therapy aimed at developing his verbal communication. D.B.'s therapist would often play the piano while D.B. would play along with another instrument of his choice from a selection. D.B. is reported to have greatly enjoyed exploring music with adult company. The therapist reported to D.B.'s mother at that time that D.B. was hugely talented: he could correctly pick out the tunes that his therapist was playing and match them with his own instrument. There was suggestion that D.B. may possess absolute pitch, although this was not tested out. D.B. would further take part in children's workshops involving music, singing and dancing. At 3 years of age, he showed the ability to play multiple instruments simultaneously and in harmony.

Despite his obvious love of music, and drumming especially, D.B. parents were reluctant for him to partake in formal drumming lessons too early as they wondered whether such would interfere with the natural emergence of his musical talent. Rather, from the age of 6 years old, D.B.'s parents employed a music teacher from his primary school to play music casually with D.B. after school. This was on the basis of once every few weeks and involved D.B. exploring music with an adult in much the same way that he had done prior. Once this teacher had moved away, a new teacher was employed with a similar work ethic. D.B. mostly explored varied percussion instruments at this time and enjoyed the combined adult interaction. Aged 9 years old, D.B. began drumming grades at a drumming and percussion school in London. This was with the aim of him obtaining professional qualifications for his talent. Here he learnt how to read drum music for the first time. His tuition mainly focussed on practising set rock pieces for later performing. With an average attendance of once a week for 1½ years, D.B. passed grades 1–4 with the highest distinction.

More recently D.B. took part in a TV documentary aimed at showcasing exceptional musical talent in ASD. This programme, produced and filmed by the BBC, was screened in two parts and combined documentary with studio performance to a live audience. D.B. was the youngest person to feature on the programme and the only drummer amongst pianists, singers and a guitarist who were also featured. D.B.'s participation occurred via a family friend who had heard about recruitment for the show and forwarded the details to D.B.'s mother.

At the time of filming, D.B. was simultaneously partaking in a four day interactive musical experience entitled Rock School. Suitable for 9–16 year old children and designed to give participants the chance to play, write and perform rock music, participants of this program were grouped together in small bands led by qualified musicians. On the last day of school, participants performed a 15 min set for family and friends. D.B.'s Rock School finale, with him taking centre stage on the drums, took place on the same day as filming the live studio performance for the BBC documentary. D.B. performed for the BBC on the drums alongside a 15 year old electric guitarist diagnosed with Asperger's syndrome and again in the grand finale which collectively featured all seven of the musical individuals appearing together.

D.B. continues to excel musically. At the time of partaking in the study, he had begun guitar lessons at home. He quickly learned to hear the chords in songs, pick them up and play them back. He was also teaching himself how to play the piano and had begun experimenting with sections of music from his favourite horror films. D.B. attends a performing arts secondary school with a specialist music department.

Skill validation

D.B.'s skill validation is discussed in chapter 2. Readers are reminded that he has exceptional drumming skills and absolute pitch.

SUMMARY OF CASE STUDY DESCRIPTIONS

So far this chapter has focussed on describing three case study children, their development and the progression of their skills. While the children express talents in an assortment of creative and academic domains, developmental commonalities can be detected amongst them. First, it was noted that all three boys developed skill proficiency at a relatively early age. Second, none of the boys were described by their parents to be obsessed by their area of skill or to exclude other topics at the expense of a single interest. Third, a high degree of focussed attention whilst engaged in skill related activity was reported for all three boys. The next section of this chapter will detail the clinical and cognitive profiles of these children in order to 1) test findings from the questionnaire study presented by Bennett & Heaton (2012) and 2) inform hypotheses for later studies concerning groups of savant and non-savant children with ASD.

CLINICAL PROFILING

Methods

Participants

The subjects of the case studies for clinical and cognitive profiling were the three boys described above. Two children had participated in previous studies in our lab and a third was identified after he took part in a public event showcasing creativity and autism. None had taken part in the original screening study carried out by Bennett & Heaton (2012). Each child had a previous clinical diagnosis of ASD. Participant data are presented in Table 3–1.

Table 3–1. Participant details for the three cases

	A.L.	**J.R.**	**D.B.**
Age (year, months)	11:0	10:3	11:10
Clinical diagnosis	ASD	Asperger's syndrome	High Functioning Autism
Skill type	Art	Mathematics	Music
Onset of skill (months)	36	30	6

Measures

Mapping onto the clinical factors utilised in Bennett & Heaton's (2012) questionnaire study, clinical profiling included measures of symptom severity (ADOS, SCQ), obsessionality (drawn from ADOS and SCQ data) and sensory processing (Short Sensory Profile). These tests are described in the previous chapter detailing methodology.

Procedure

The children were tested individually in a quiet room at their home. Tests were administered over a number of sessions and with adherence to instructions as set out by the test manuals. Breaks were offered and children took them accordingly. One child (A.L.) had been administered ADOS for clinical assessment prior to taking part in the study. As A.L.'s parents made his ADOS data available it was not deemed necessary to administer a second ADOS.

Results

SYMPTOM SEVERITY

ADOS and SCQ results for the three cases are presented in Tables 3–2 and 3–3, respectively.

Table 3–2. ADOS data for the three cases

	A.L.	**J.R.**	**D.B.**
Communication (autism cut-off = 4, ASD = 2)	1	3	4
Reciprocal Social Interaction (autism cut-off = 6, ASD = 4)	6	6	8
ADOS Total (autism cut-off = 10, ASD = 7)	7	9	12
Classification	ASD	ASD	Autism
Imagination/Creativity	1	1	0
Stereotyped Behaviours and Restricted Interests	0	0	0

Table 3–3. SCQ data for the three cases

	A.L.	J.R.	D.B.
SCQ total	26	24	17
(autism cut-off $\geq$ 22, PDD $\geq$ 15)			

As can be seen from Tables 3–2 and 3–3, symptom severity for the three children was not uniformly high. Indeed, only one child scored in the autism range for the total ADOS score where the other two children scored in the ASD range. Scores of 0 were recorded for each child on the Stereotyped Behaviours and Restricted Interests component of the ADOS, indicating no observed abnormalities. Deficits in Imagination/Creativity were no more than mild for two out of three children (A.L., J.R.), while the other child (D.B.) did not show any abnormalities in this area.

OBSESSIONALITY

In order to measure obsessionality, six items were drawn from SCQ and ADOS. These items were examined in isolation as they probe obsessional content, for example ritualised behaviour, preoccupations, intense interests occurring to an unusual degree and compulsions. Parents of the case study children responded to the four SCQ items with either yes/no answers, whereas the scores on the two ADOS items reflected the degree of abnormality that was observed during the assessment. The results are shown in Table 3–4.

Table 3–4. Obsessionlity data for the three cases

	Item	A.L.	J.R.	D.B.
SCQ	8. Has s/he ever had things she/he seemed to have to do in a very particular way or order, or rituals that s/he insisted you go through?	Y	Y	N
SCQ	11. Has s/he ever had any interests that preoccupy her/him and might seem odd to other people (e.g. traffic lights, drainpipes, timetables)?	N	Y	Y
SCQ	13. Has s/he ever had any special interests that were unusual in their intensity but otherwise appropriate for her/his age and peer group (e.g. trains, dinosaurs)?	Y	Y	Y
SCQ	18. Has s/he ever had any objects (other than a soft toy or comfort blanket) that s/he had to carry around?	N	N	N
ADOS	D4. Excessive interest in or references to unusual or highly specific topics or objects or repetitive behaviours	0	0	0
ADOS	D5. Compulsions or rituals	0	0	0
	TOTAL	2/6	3/6	2/6

Analysis of the obsessionality items revealed that the children did not appear to show high levels of obsessional behaviour. D.B. and A.L. showed signs of obsessional behaviour on two out of six items (33%), J.R. on three items (50%). The question of whether high levels of focus provide a better explanation for savant skills in ASD will be considered later.

SENSORY PROCESSING

Analysis of parental responses to the Short Sensory Profile revealed that all three cases experienced sensory processing in a way that is generally abnormal compared to TD children. Scores concerning visual and auditory processing were of especial interest, as two out of three cases possessed validated skills in the domains of visual arts and musical performance. Parental responses to these items revealed that visual/auditory processing is experienced in a way that is probably different from normal for the artist A.L., but normal for the musician D.B. However, both of these boys were reported to experience auditory filtering in manner that is definitely different from normal. Scores concerning tactile sensitivity, taste/smell, movement, underresponsiveness and low energy are also reported in Table 3–5, but results for these senses are not elaborated on as they do not hold especial theoretical interest within this group.

Table 3–5. Short Sensory Profile data for the three cases

	A.L.	**J.R.**	**D.B.**
Sensory Profile total	Definite	Definite	Probable
Tactile	Definite	Probable	Typical
Taste/smell	Definite	Definite	Typical
Movement	Typical	Typical	Typical
Underresponsiveness/ seeks sensation	Definite	Typical	Probable
Auditory filtering	Definite	Definite	Definite
Low energy/weak	Typical	Definite	Definite
Visual/auditory sensitivity	Probable	Definite	Typical

Note: Definite = sensation is experienced in a way that is definitely different from normal. Probable = probable difference from normal. Typical = sensory processing as normal.

SUMMARY OF CLINICAL PROFILING

The results from the questionnaire study carried out by Bennett & Heaton (2012) failed to observe higher levels of symptom severity, obsessionality or sensory abnormalities in individuals with ASD and reported skills. These results were largely supported by the investigation of clinical factors in three children with ASD and validated savant skills in the areas of art, mathematics and music. The questionnaire study had indicated that special skills were not limited to one PDD subtype and the case studies confirmed this. The three children were in receipt of clinical diagnoses that covered the entire spectrum (ASD, Asperger's syndrome and High Functioning Autism) and total ADOS scores were not restricted to one diagnostic classification. In line with results from the questionnaire (Bennett & Heaton, 2012) which indicated that skilled individuals do not show increased levels of rigid behaviour relative to those without skills, the case study children did not show high levels of obsessionality. Six items were drawn from SCQ and ADOS tests based on their probing of obsessional content, but while one savant scored 50% of the time (3 out of 6 items) the other two savants scored only 33% of the time (2 out of 6 items). Additionally, scores on the repetitive behaviours factor of ADOS were in the normal range for all three children. Bennett & Heaton's (2012) questionnaire was important in showing that skilled individuals with ASD have the tendency to become absorbed in topics that capture their interest. This was also observed in the case study children: all parents responded positively to the SCQ item which queried the existence of any unusually intense special interests. Lastly, the questionnaire study failed to reveal a significant difference between skilled and non-skilled individuals on the factor probing sensory processing. While the three case study children were found to experience sensations in a manner that is fundamentally different from normal, questions concerning the extent of this difference relative to those with ASD but without skills can only be addressed in group studies. This question will be considered in chapter 4 where groups of savant and non-savant children will be tested on the clinical factors examined here. The next section will consider cognitive profiling of the case study children and how the results of this profiling compare to the findings of the questionnaire screen carried out by Bennett & Heaton (2012).

COGNITVE PROFILING

Methods

Measures

Cognitive profiling employed an extensive test battery investigating intelligence (WISC–IV), memory (Children's Memory Scale), cognitive processing style (Block Design, Picture Completion, Object Assembly, CEFT and SCT) and individual achievement (WIAT–II).

These tests are described fully in the previous chapter.

Procedure

Children were tested individually at their home. Tests were administered over a number of sessions and with adherence to the test manuals. Breaks were offered as needed. Children had not completed any of these tests before.

Results

INTELLIGENCE

Table 3–6 presents WISC–IV composite scores for the three cases. Scores are out of a possible maximum of 160.

Table 3–6. WISC–IV composite scores for the three cases

	A.L.	**J.R.**	**D.B.**
FSIQ	92 Average	120 Superior	104 Average
VCI	93 Average	106 Average	87 Low average
PRI	90 Average	106 Average	112 High average
WMI	116 High average	138 Very superior	138 Very superior
PSQ	83 Low average	121 Superior	88 Low average

Intact global intellectual functioning (FSIQ) was recorded for all three savants. Normal abilities were also recorded for VCI, PRI and PSQ. Enhanced working memory (WMI) was observed with each child score on this aspect of intelligence test achieving their highest composite. Two out of three children (J.R. and D.B.) scored in the very superior range (both 138). Figure 3–5 presents these composite scores via line graph. A strikingly similar pattern of performance can be seen across the savants. It is clear that peak performance for all children rests in the domain of working memory.

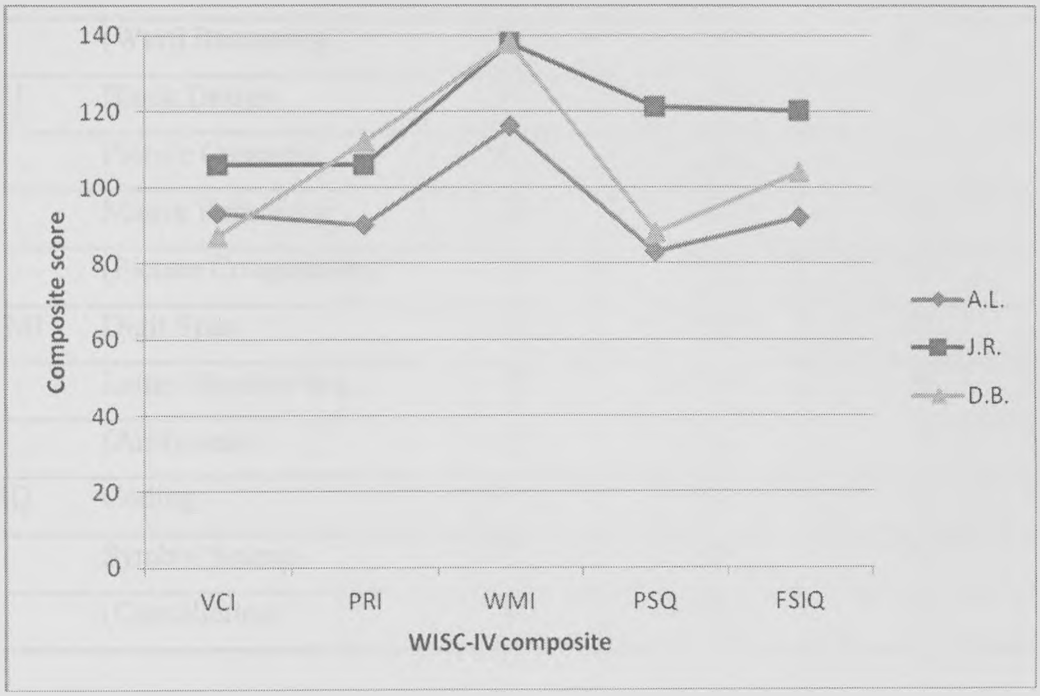


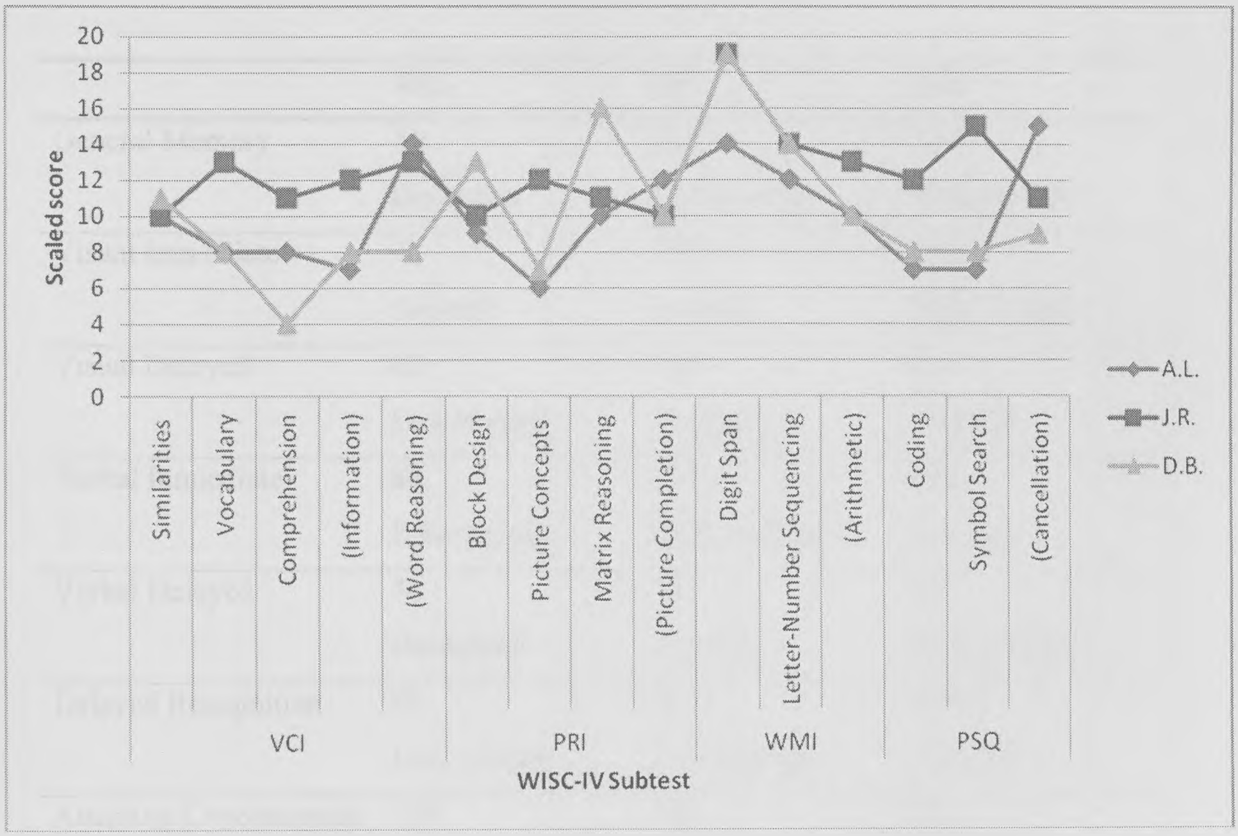
Figure 3–5. WISC–IV composite scores for the three cases

However, a closer examination of subtest performance revealed great heterogeneity and few commonalities. Table 3–7 presents scaled scores for all fifteen subtests of the WISC–IV (supplemental subtests are shown in brackets). Scores are out of a possible maximum of 19.

Table 3–7. WISC–IV subtest scores for the three cases

		A.L.	J.R.	D.B.
VCI	Similarities	10	10	11
	Vocabulary	8	13	8
	Comprehension	8	11	4
	(Information)	7	12	8
	(Word Reasoning)	14	13	8
PRI	Block Design	9	10	13
	Picture Concepts	6	12	7
	Matrix Reasoning	10	11	16
	(Picture Completion)	12	10	11
WMI	Digit Span	14	19	19
	Letter-Number Seq.	12	14	14
	(Arithmetic)	10	13	10
PSQ	Coding	7	12	8
	Symbol Search	7	15	8
	(Cancellation)	15	11	9

Performance on verbal subtests revealed a very superior score on Vocabulary (13) and superior performance on Information (12) for the mathematician J.R. Both J.R. and A.L. performed in the very superior range on the supplementary verbal subtest Word Reasoning, achieving scores of 13 and 14 respectively. Unremarkable scores were otherwise noted on verbal IQ subtests. Regarding non-verbal tests, a similar pattern of sporadic performance across the cases was observed. The musician D.B. performed exceptionally well on Block Design (13) and Matrix Reasoning (16), yet scores for the other two cases were not better than average on these tests. For example, both A.L. and J.R. scored in the average range for Block Design (9 and 10, respectively) and in the average to high average range for Matrix Reasoning (10 and 11, respectively). A.L. achieved his best non-verbal subtest score on the supplementary test Picture Completion, whereas J.R. achieved his highest non-verbal score on Picture Concepts (both 12, superior range). Enhanced performance was recorded on subtests that assess working memory, for all cases. Digit Span sores were recorded in the very superior range for all three savants and for two of these individuals the scores were at ceiling (19). The children also excelled on the Letter-Number Sequencing test achieving scores that were superior (A.L. = 12) and very superior (J.R. and D.B. = 14). Test scores for processing speed subtests were mostly unremarkable with the exception of a very superior score for A.L. which was achieved on the supplemental subtest, Cancellation, and a very superior score for J.R. on Symbol Search (both 15). These results are shown in Figure 3–6 where supplementary subtests are shown in brackets.



Note: VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, WMI = Woking Memory Index, PSQ = Processing Speed Quotient, FSIQ = Full Scale IQ

Figure 3–6. WISC–IV subtest scores for the three cases

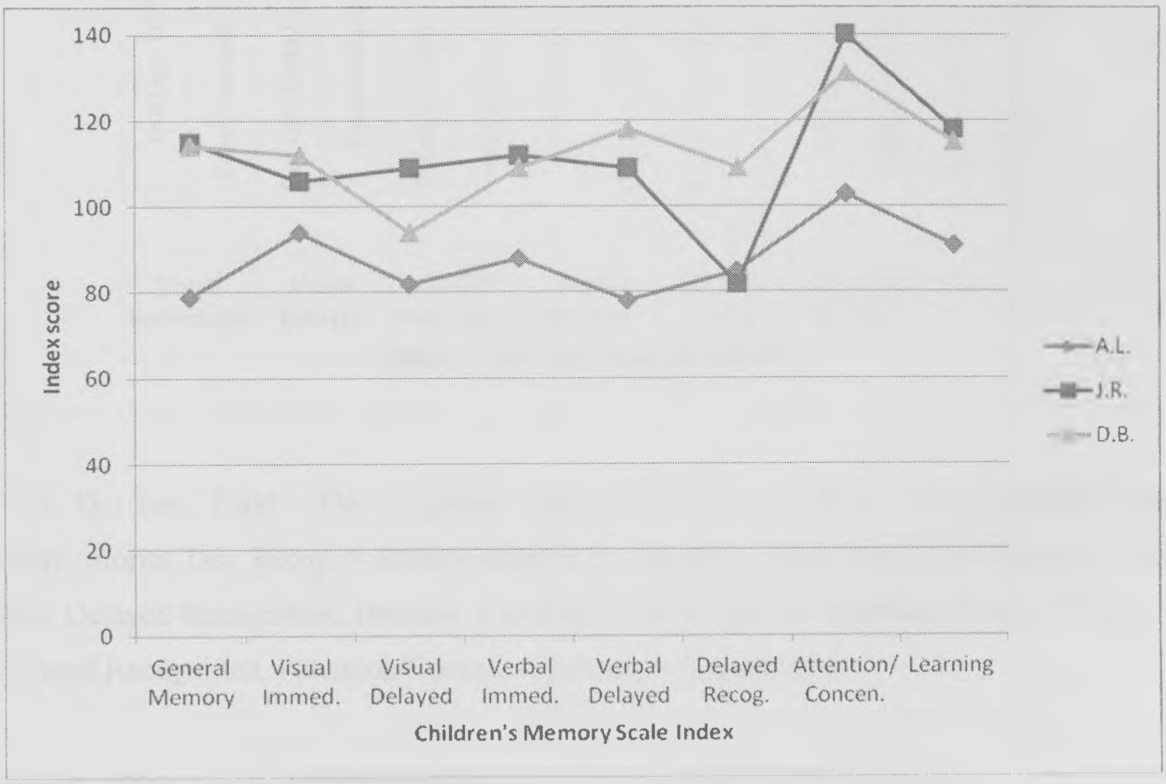
MEMORY

Performance scores for Children's Memory Scale indexes are displayed in Table 3–8. Index scores for this test range from 50–150.

Table 3–8. Children's Memory Scale index scores for the three cases

	A.L.	J.R.	D.B.
General Memory	79 Borderline	115 High average	114 High average
Visual Immediate	94 Average	106 Average	112 High average
Visual Delayed	82 Low average	109 Average	94 Average
Verbal Immediate	88 Low average	112 High average	109 Average
Verbal Delayed	78 Borderline	109 Average	118 High average
Delayed Recognition	85 Low average	82 Low average	109 Average
Attention/Concentration	103 Average	140 Very superior	131 Very superior
Learning	91 Average	118 High average	115 High average

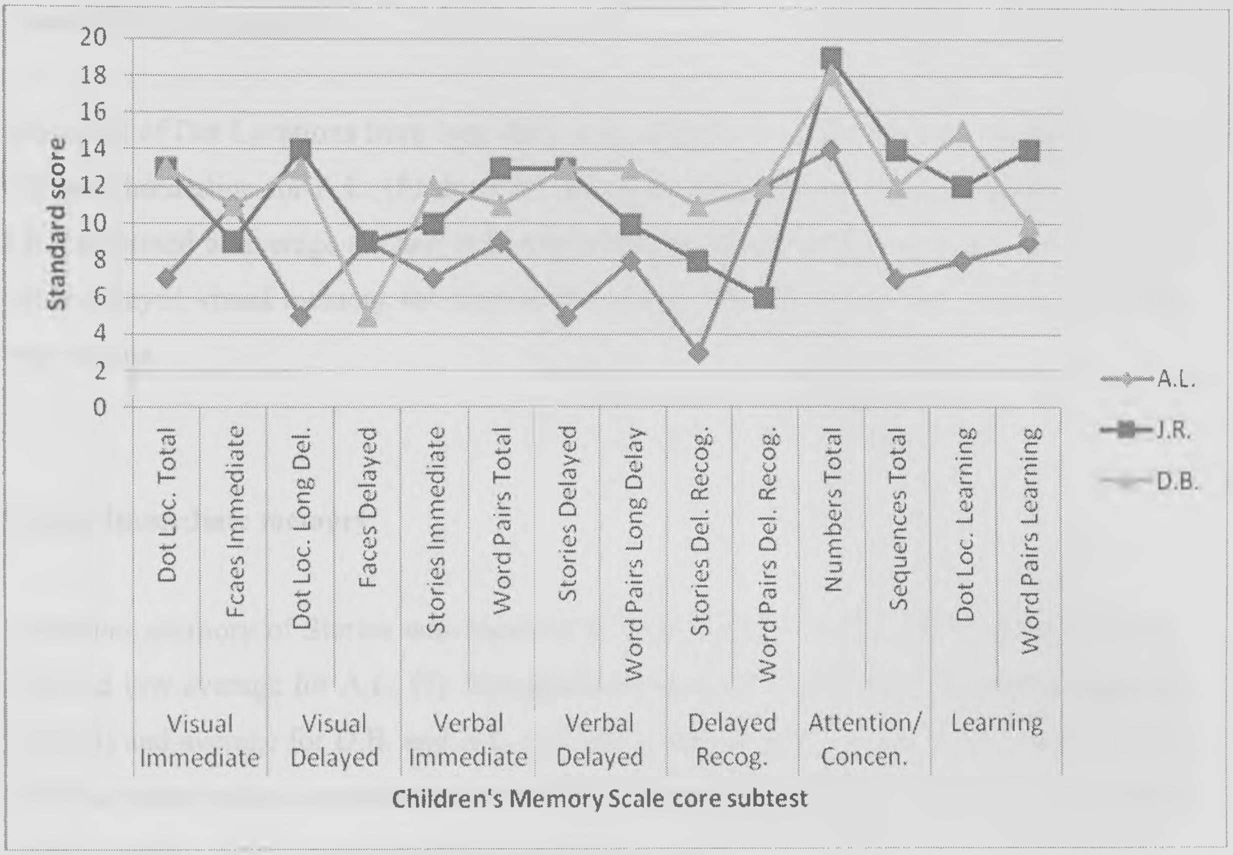
General memory skills were not found to be better than average for any of the savants. While J.R. and D.B. achieved high average general memory scores (115 and 114, respectively), A.L. performed in the borderline range (79). A.L.'s performance on visual memory scores was of especial interest considering his artistic talent, but surprisingly his scores were unremarkable (visual immediate memory = 94, visual delayed memory = 82). The other two savants also scored at average on indexes of visual memory. Verbal memory scores were consistently average for all children. Verbal immediate memory scores ranged from low average (A.L.) to high average (J.R.), verbal delayed memory scores ranged from borderline (A.L.) to high average (D.B.), and delayed recognition scores were low average (A.L., J.R.) to average (D.B.). All three children achieved their highest index score on the Attention/Concentration factor. J.R. and D.B. achieved very superior Attention/Concentration scores of 140 and 131, respectively. For A.L. Attention/Concentration was average (103) but this was his highest factor score from a set of eight. Learning indexes were again no better than average. Figure 3–7 presents the index scores where elevated performances on the Attention/Concentration factor can be seen.



Note: Visual Immed. = Visual Immediate, Verbal Immed. = Verbal Immediate, Delayed Recog. = Delayed Recognition, Attention/Concen. = Attention/Concentration

Figure 3–7. Children's Memory Scale index scores for the three cases

Figure 3–8 presents the core subtest scores for the memory battery, for the three cases. Scaled subtest scores range from 1–19.



Note: Dot Loc. Total = Dot Locations Total, Dot Loc. Long Del. = Dot Locations Long Delay, Stories Del. Recog. = Stories Delayed Recognition, Word Pairs Del. Recog. = Word Pairs Delayed Recognition, Dot Loc. Learning = Dot Locations Learning, Delayed Recog. = Delayed Recognition, Attention/Concen. = Attention/Concentration

Figure 3–8. Children's Memory Scale core subtest scores for the three cases

Visual Immediate memory

For Dot Locations total, J.R. and D.B. were high average in their ability to recall the abstract locations of dots (13) while A.L. was low average (7). In recalling Faces from immediate memory, A.L. achieved an average score (11) while D.B. and J.R. performed at average (11 and 9, respectively). These results indicated that A.L. had better immediate visual memory for faces than for dots, yet the reverse was true for the other two savants.

Visual Delayed memory

The recall of Dot Locations from long delay was superior for J.R. (14), high average for D.B. (13) and borderline for A.L. (5). In recalling Faces from delayed visual memory, A.L. and J.R. performed at average (9) and D.B. borderline (5). These results indicated that A.L. had better delayed visual memory for faces than for dots, but the reverse was true for the other two savants.

Verbal Immediate memory

Immediate memory of Stories was found to be high average for D.B. (12), average for J.R. (10) and low average for A.L. (7). Immediate memory of Word Pairs was high average for J.R. (13) and average for D.B. and A.L. (11 and 9, respectively). These results indicated that D.B. had better verbal immediate memory for semantically rich stories than for meaningless pairs of words, yet the reverse was true for the other two savants.

Verbal Delayed memory

Post delay, J.R. and D.B. recalled Stories at high average (13); A.L. borderline (5). Recall of Word Pairs post delay was high average for D.B. (13) and average for J.R. and A.L. (10 and 8, respectively). These results suggested that while J.R. recalled semantic stories better than abstract word pairs, the reverse was true for A.L. D.B. was equally as good at recalling both kinds of verbal information from long-term memory.

Delayed Recognition

Delayed recognition of Stories was average for D.B. and J.R. (10 and 8, respectively) but impaired for A.L. (3). A.L.'s delayed recognition of Word Pairs was high average (12), D.B.

average (11) and J.R. low average (6). These results revealed a sharp discrepancy in A.L.'s memory for different kinds of verbal information.

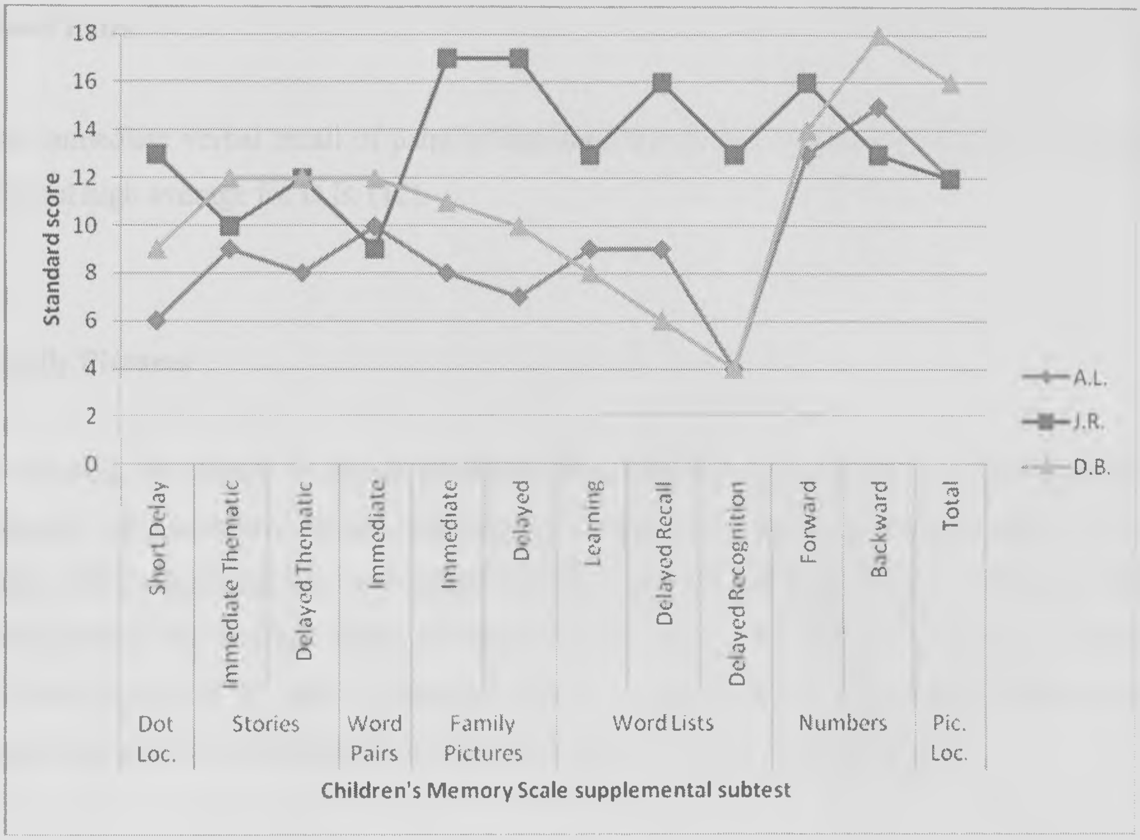
Attention/Concentration

All three children performed in the superior or very superior range for Numbers. J.R. and D.B. achieved exceptional scores that were in the very superior range (19 and 18, respectively) and A.L. achieved a superior score (14). For Sequences, J.R. performed in the superior range (14), D.B. high average (12) and A.L. low average (7).

Learning

For the learning of Dot Locations, D.B. performed in the superior range (15), J.R. high average (12) and A.L. low average (7). For the learning of Word Pairs, J.R. performed in the superior range (14) and D.B. and A.L. average (10 and 9, respectively). While D.B. performed to higher levels in learning visuo-spatial information compared to learning unrelated words, J.R. showed the opposite. A.L.'s learning across the two tasks was equally average.

Figure 3–9 shows the supplemental subtest scores for the memory battery, for the three savants.



Note: Dot Loc. = Dot Locations, Pic. Loc. = Picture Locations

Figure 3–9. Children's Memory Scale supplemental subtest scores for the three cases

Dot Locations

Following a short delay, the ability to recall the locations of dots from visual memory was high average for J.R. (13), average for D.B. (9) and low average for A.L. (6).

Stories

Ability to immediately recall the main themes of two short stories was high average for D.B. (12) and average for both J.R (10) and A.L. (9). However, following delay J.R. recalled the story themes better achieving a high average score of 12. D.B. remained high average (12) and A.L. average (8).

Word Pairs

The immediate verbal recall of pairs of unrelated words was average for A.L. (10) and J.R. (9), and high average for D.B. (12).

Family Pictures

In recalling the details of family members, their locations and their actions from presented pictures, J.R. performed in the very superior range (17) (Family Pictures Immediate). Post delay, J.R. maintained this very superior performance (17) (Family Pictures Delayed). D.B. performed in the average range for both the immediate and delayed portions of Family Pictures (scores of 11 and 10, respectively). A.L. performed in the average range for the immediate portion of this test (8) and low average for the delayed portion (7).

Word Lists

In learning lists of unrelated words, J.R. performed in the high average range (13), and A.L. and D.B. in the average range (9 and 8, respectively). Delayed recall of these words was very superior for J.R. (16), average for A.L. (9) and low average for D.B. (8). In answering delayed recognition questions about the word lists, performance was high average for J.R. (13) but borderline for both A.L. and D.B. (4).

Numbers

For the forward portion of the Numbers subtest, J.R. performed in the very superior range (16), D.B. superior (14) and A.L. high average (13). For the backwards portion, D.B. performed in the very superior range (18), A.L. superior (15) and J.R. high average (13). Enhanced performance on both portions of Numbers was evidenced by all three children and this can be seen by peaks in Figure 3–4.

Picture Locations

For Picture Locations, D.B. achieved a very superior score (16), while A.L. and J.R. achieved high average scores (12).

COGNITIVE PROCESSING STYLE

Five tests were employed to assess whether a local processing bias was characteristic of the three savant children. Table 3–9 presents the results of three out of five tests, subtests taken from the WISC where attention to local detail would convey a performance advantage.

Table 3–9. Block Design, Picture Completion and Object Assembly scores for the three cases (max. score = 19)

	A.L.	J.R.	D.B.
Block Design	9 Average	10 Average	13 Very superior
Picture Completion	12 Superior	10 Average	11 High average
Object Assembly	11 High average	11 High average	7 Borderline

As can be seen from Table 3–8, only one child achieved a very superior Block Design score, the musician D.B. While J.R. and A.L. had the ability to carry out the task requirements of Block Design they did not perform above average. With regard to Picture Completion, A.L. performed in the superior range (12), D.B. high average (11) and J.R. average (10). Performance on Object Assembly was noted as high average for both J.R. and A.L. (11) but borderline for D.B. (7).

The results concerning the CEFT were less mixed and indicated a trend toward advanced performance. All children were able to correctly identify target shapes 88% or more of the time. D.B. performed at ceiling achieving 25/25 on this test, 1.4 SD above the mean for children in his aged band (11–12 years old) as stated in the test manual (Witkin et al., 1971). A.L. achieved 24/25, 1.2 SD above the mean for children aged 9–10 years old. J.R. achieved 22/25, almost 1 SD above the mean for children aged 9–10 years old. In contrast, the children produced very few local endings on the test of sentence completions. A.L. produced one local ending to the sentence stems, J.R. and D.B. produced none. This indicated that the children processed language in a global manner.

INDIVIDUAL ACHIEVEMENT

Table 3–10 presents the results of WIAT–II composite scores for the three cases. Scores for this test are out of a possible maximum of 160.

Table 3–10. WIAT–II composite scores for the three cases

	A.L.	**J.R.**	**D.B.**
Total score	90 Average	134 Very superior	99 Average
Reading	98 Average	125 Superior	100 Average
Mathematics	84 Low average	149 Very superior	96 Average
Written Language	88 Low average	132 Very superior	99 Average
Oral Language	92 Average	120 Superior	106 Average

All three boys were found to have normal skills in reading, mathematics, written language and oral language. Considering the composite profiles presented in Figure 3–10, D.B. and A.L. showed an almost identical pattern of mostly average performance scores. J.R. achieved much higher peaks than the other two children across the composites, with an especial peak in Mathematics which is his savant domain.

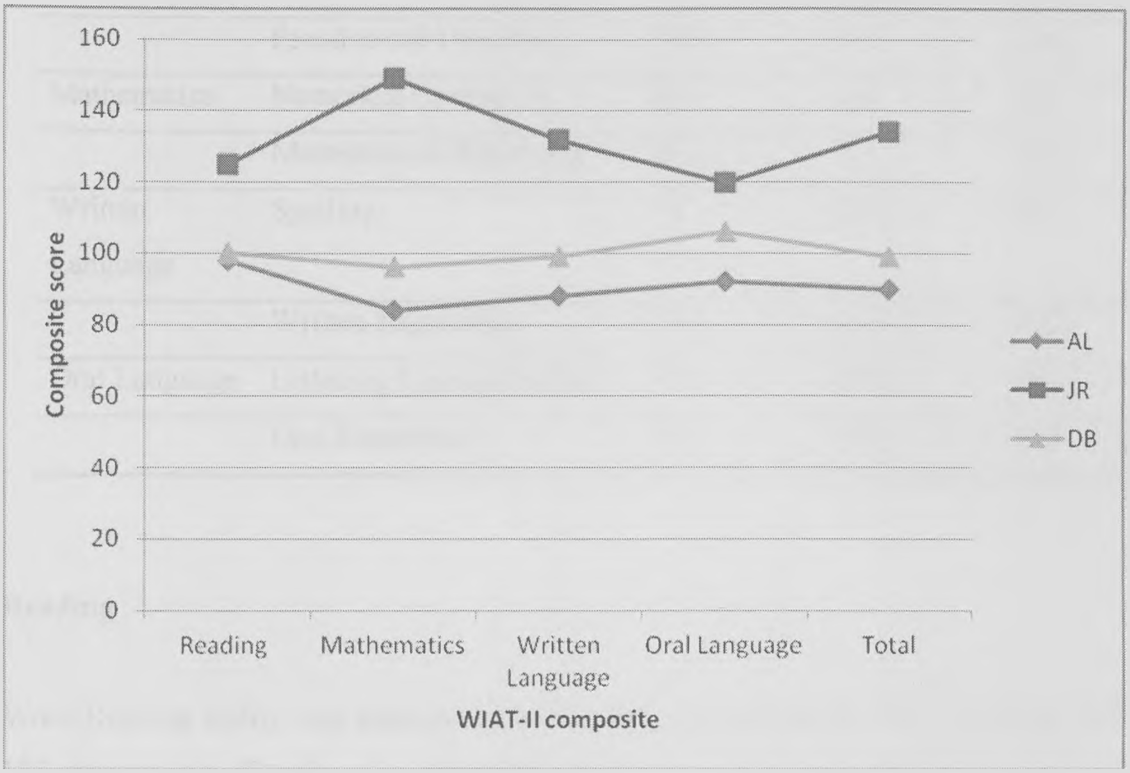


Figure 3–10. WIAT–II composite scores for the three cases

Closer examination of individual achievement subtest scores revealed great variation in subtest performance and this is shown in Table 3–11. Scores are out of a possible maximum of 160.

Table 3–11. WIAT–II subtest scores for the three cases

		A.L.	J.R.	D.B.
Reading	Word Reading	104	123	100
	Reading Comprehension	82	117	96
	Pseudoword Decoding	115	117	113
Mathematics	Numerical Operations	83	148	94
	Mathematical Reasoning	88	132	100
Written Language	Spelling	75	120	98
	Written Expression	105	132	102
Oral Language	Listening Comprehension	98	114	99
	Oral Expression	91	120	113

Reading

Word Reading ability was superior for J.R. (123), but average for A.L. and D.B. (104 and 100, respectively). Reading Comprehension scores were high average for J.R. (117), average for D.B. (96) and low average for A.L. (82). All three children performed in the high average range for Pseudoword Decoding (J.R. = 117, A.L. = 115, D.B. = 113). Figure 3–11 shows where the three cases converge on this particular test.

Mathematics

J.R. performed in the very superior range for Numerical Operations (148), while average and low average scores were recorded for D.B. and A.L. (94 and 83, respectively). For Mathematical Reasoning, J.R. scored in the very superior range (132), A.L. low average (88) and D.B. average (100).

Written Language

Wide variation was observed with regard to spelling. While J.R. scored in the superior range for this subtest (120), D.B. performed at average (98) and A.L. borderline (75). For the Written Expression test, J.R. achieved a very superior score (132) and A.L. and D.B. performed at average (105 and 102, respectively).

Oral Language

Listening Comprehension scores were high average for J.R. (114) and average for D.B. and A.L. (99 and 98, respectively). For Oral Expression, J.R. performed in the very superior range (120), D.B. high average (113) and A.L. low average (91). Subtest results are displayed in Figure 3–11.

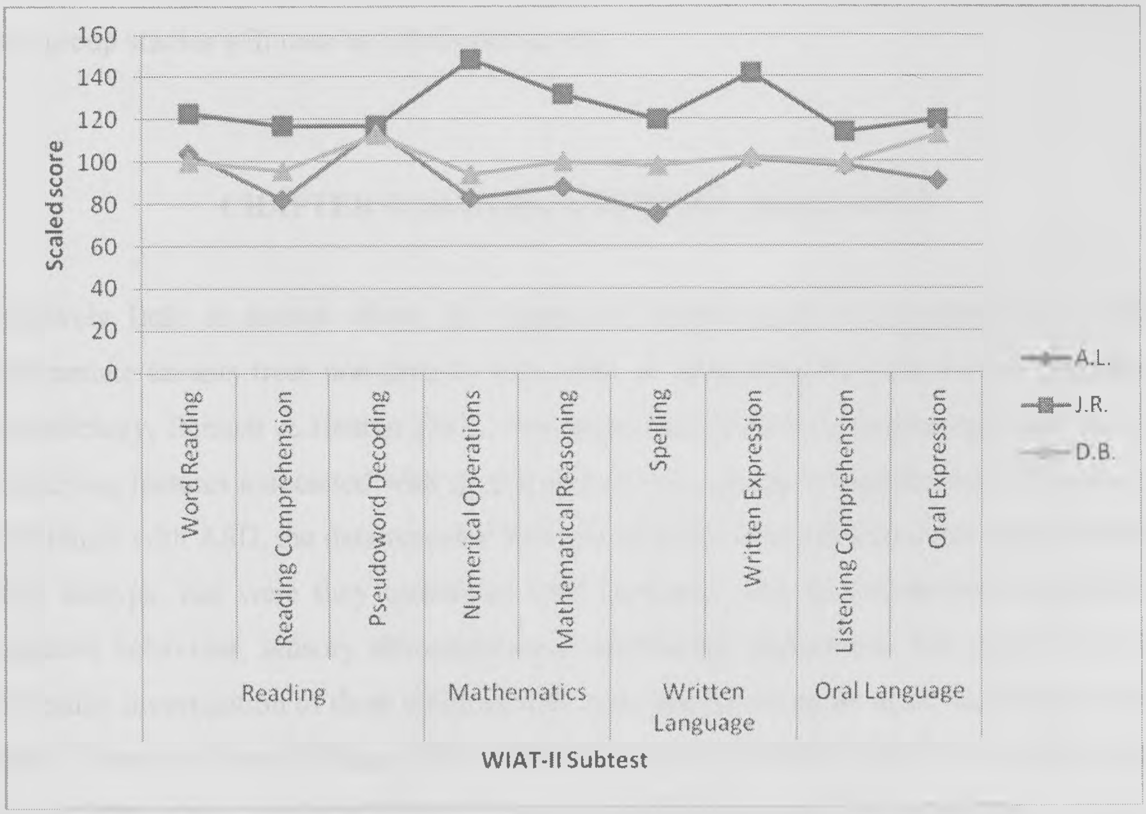


Figure 3–11. WIAT–II subtest scores for the three cases

SUMMARY OF COGNITIVE PROFILING

Results from the WISC–IV have shown that all three children have intact intellectual abilities across all five IQ composites. While composite profiles revealed much congruity, greater variability was observed on the individual subtest profiles. All savants achieved working memory peaks and indeed this was the highest composite score for each child. Concerning the memory battery, general memory was not found to be remarkable. However, the children did show enhanced performance on the Attention/Concentration factor and amongst the set of eight factors examined this was the highest score for each child. Collectively the results from the battery of WCC tests revealed a trend for advanced CEFT performance, a Block Design peak in the musician D.B. and a Picture Completion peak in the artist A.L., but unremarkable scores otherwise. Finally, tests of individual achievement revealed mostly average performances across factors testing attainment (e.g. reading, written language skills) although all children scored very similarly on one test, Pseudoword Decoding. The significance of the clinical and cognitive profiling results for the three case studies and how they will inform later group studies will now be briefly discussed.

CHAPTER SUMMARY AND BRIEF DISCUSSION

Relatively little is known about the diagnostic, behavioural and cognitive factors that differentiate savants from non-savants with ASD. In addressing the need for new validation methodology, Bennett & Heaton (2012) developed and piloted a screening questionnaire for identifying features associated with special skills in this group. Completed by 125 parents of individuals with ASD, the data revealed that special skills were not associated with a specific PDD subtype, nor were they associated with increased socio-communicative impairment, repetitive behaviour, sensory abnormalities or intellectual impairment. The results from the case study investigation of three children with ASD and savant skills in art, maths and music, largely supported these findings. The children were not restricted to one PDD subtype and total ADOS scores reflected this. Further, ADOS scores on the restricted, repetitive behaviours factor were recorded in the normal range. Importantly, the screening study indicated that only 5% of the skilled group were intellectually impaired (compared to 10% of the non-skilled group) and the case studies supported this broadly as all children were found to have intact intellectual skills when tested for IQ. These findings, showing that intellectual impairment is not universally associated with savant skills and that special skills may be more common amongst intellectually able individuals with ASD, raise important questions about how savantism should be defined.

The results from the questionnaire study (Bennett & Heaton, 2012) suggested that skilled individuals with ASD possess exceptional general memory skills and this is consistent with the view that exceptional memory abilities underpin savant skills (Treffert, 1989, 2009). However, when memory abilities were directly assessed using a standardised battery of memory tasks the three case study children showed unremarkable general memory abilities and in one case general memory skills verged between impaired and average (borderline). Interestingly, the artist did not show exceptional visual memory and this was not consistent with theorised associations between artistic talents and enhanced visual memory. However, the finding was consistent with findings from other studies which suggest that visual recognition memory in savant artists is not superior when compared to that of non-gifted, IQ matched participants; rather superior visual memory in savant artists is indexed by (domain-specific) tasks involving a drawn response (O'Connor & Hermelin, 1987; Mottron & Belleville, 1993). Despite insignificant scores on general memory, the children did show exceptional working memory skills but this was largely restricted to performance on the Digit Span test. This finding was consistent with results from a number of studies showing peak performance on this test in savants (Bölte & Poustka, 2004; Rimland & Hill, 1984; Rumsey et al., 1992; Spitz & LaFontaine, 1973; Young, 1995) and will be further considered in chapter 5.

The parents of skilled individuals who completed the questionnaire reported a tendency to become absorbed in topics of particular interest. In contrast to low or moderately low scores on the six items assessing obsessionality, case study scores on the measure assessing focussed attention were striking. All three children obtained their highest memory battery score on the Attention/Concentration factor and for two children these scores were in the very superior range. The measures of attention were unrelated to the children's areas of special interest in two out of three cases, and it may be the case that increased focus/concentration, like superior Digit Span, is a domain-general characteristic of individuals with ASD and specific talents. High scores on the Attention/Concentration factor are consistent with parental descriptions of highly focussed attention characterising skilled individuals in the questionnaire study.

Theoretical accounts have implicated a local bias in the emergence of special skills in autism. While Bennett & Heaton (2012) tested a local bias using a single questionnaire item, which revealed a non-significant difference between skilled and non-skilled groups, the decision was made to include a number of tests of WCC in the case studies. Five measures were used to determine whether the three savant children would demonstrate a strong local processing bias. All three children showed enhanced performance on the CEFT but the results from the other local processing tasks were mixed. One child achieved a Block Design peak while another performed to high standard on the Picture Completion test, but other than this the findings were not consistent or remarkable. Interestingly all three cases performed equally well on one aspect of the individual achievement battery where local processing might be tested. The Pseudoword Decoding subtest requires decoding of fabricated words and in this sense may be advantaged by the ability to process local elements. Other scores on the individual achievement battery did not reveal group differences, but as similar performance was observed between the cases on Pseudoword Decoding this test will be retained for use with later group studies investigating WCC. The results from the case studies detailed here will inform research questions and hypotheses to be addressed with groups of savant and non-savant children in the proceeding chapters.

CHAPTER 4: IDENTIFYING THE BEHAVIOURAL AND CLINICAL CORRELATES OF SAVANT SKILLS IN CHILDREN WITH ASD

ABSTRACT

The case studies of children with ASD and special skills presented in chapter 3 built on the findings from a questionnaire study identifying a number of factors that appeared to differentiate ASD groups with and without special skills (Bennett & Heaton, 2012). Factors that have been associated with savant syndrome in the literature but were not validated in the case studies included increased symptom severity and obsessionality. However, the extent that results from case studies can be generalised to broader populations is acknowledged and the current chapter presents group data on these factors, from savant and non-savant children with ASD and TD controls. Symptom severity may address questions about whether increased social withdrawal will predispose special interests and was tested using ADOS and the lifetime version the SCQ. Obsessionality was probed in a modified version of a questionnaire developed by Baron-Cohen & Wheelwright (1999) and sensory profiles were measured using the Short Sensory Profile.

Individual case studies of children with ASD and savant skills were compared in chapter 3. These were important in providing an initial understanding of the clinical correlates of talent in children with savant skills in the classic domains of art, mathematics and music. While all three children scored in the definitely different range compared to normal on the total scores of the Short Sensory Profile, scores on the ADOS were not universally high (two out of three children scored in the ASD range, the third in the autism range). This suggested that increased socio-communication impairment was not a necessary feature of savant syndrome in individuals with ASD. Obsessionality was also measured, using items drawn from two clinical measures and this failed to reveal increased obsessionality in the children. However, focussed attention scores for all three boys were noted to be strikingly high. Historically, the literature on savant skills has been largely drawn from anecdotal reports and case studies (see Heaton & Wallace, 2004) and while case studies are useful in providing rich, qualitative data regarding specific individuals, they lack the statistical power of group studies and are therefore limited in the extent that they can be generalised to larger populations. Group studies into savant syndrome were first carried out by Hermelin & O'Connor in the 1980's and this marked the beginning of hypothesis driven, scientifically rigorous research into the savant syndrome. More recently, Heavey and colleagues (e.g. Heavey, 1997; Pring et al., 1995) have carried out group studies on savants skilled in various domains and Young (1995) provided information on 51 savants, the largest sample tested to date. One of the many positive outcomes of this shift in methodological approach from single case studies to group studies is that questions about the clinical profile of talented individuals with ASD can be revisited. Group studies addressing this issue are the focus of this chapter.

Savant skills have largely been considered within the context of theoretical models of cognitive style in autism (see chapter 6), however it has also been suggested that the diagnostic characteristics of ASD may predispose, or at least contribute, to the development and maintenance of special skills in this group. Treffert (1988) discussed the idea that savants might be characterised by increased socio-communication deficits. This idea, taken up by a number of other authors (Hoffman, 1971; Nurcombe & Parker, 1964; Tredgold, 1914; Viscott, 1970) was based on the assumption that reduced social engagement (or greater social isolation) enables the individual to spend more time engaging in specific interests and skills. However, according to anecdotal reports, savants whose access to their skill (e.g. playing the piano, drawing) has been restricted have not shown increases in social engagement. Several researchers have noted that savants who do not have clinical diagnoses of ASD often show increased levels of autistic-type behaviours (DeLong & Aldershof, 1988; Heavey, 1997; Young, 1995) and these behaviours have even been noted in TD individuals with enhanced skills (Brown, Cammuso, Sachs, Winklosky, Mullane, Bernier, Svenson, Arin, Rosen-Sheidley & Folstein, 2003; DeLoache et al., 2007; Vital, Ronald, Wallace & Happé, 2009). For example, in the study conducted by Vital et al. (2009) TD children with reported special skills were regarded by their parents as having greater socio-communicative impairment compared to TD children without skills. Furthermore this finding held true across three levels of skill, loosely mapping onto the three-tier classification proposed by Treffert (1989, 2006). The question of whether a similar increase in social deficits would distinguish savant from non-savant individuals within an ASD population is an interesting one.

While socio-communicative impairments are core diagnostic criteria for all individuals with ASD, talented or otherwise, it is plausible to suggest that increased symptom severity will be observed in those who have developed specialised skills. The questionnaire study comparing skilled and non-skilled individuals with ASD attempted to address questions about the association between socio-communication difficulties and talent in this group (Bennett & Heaton, 2012). Of the parents who reported one or more specific talents in their child (52 out of 125), 53% did not believe that their child's skill and the time that their child spent engaging in skill related activity interfered with their child's development. This was compared to only 25% who felt that their child's skill negatively impacted on their development in other core areas, such as social functioning. In the case studies described in chapter 3, all three talented children received positive scores on ADOS and SCQ. However, questions concerning the extent of socio-communicative impairments in talented individuals relative to age, diagnosis and intelligence matched controls without such talents can only be probed in a group study. This will therefore be investigated in the group studies to be described in this chapter. ADOS scores will be investigated for possible group differences concerning current symptom severity, while the lifetime version of the SCQ will provide information about any symptom severity differences from a developmental perspective.

By nature of the disorder individuals with ASD are characterised by repetitive behaviour and restricted interests, of which obsessional behaviour plays a part. Heaton & Wallace (2004) discussed several lines of evidence to support the view that these non-social deficits may be increased in autistic savants. First, a significant proportion of individuals with savant skills are noted to have autism (at least 50% according to Treffert, 2009) where a key feature of the disorder is repetitive behaviours and restricted interests. Second, in cases where savant skills arise without autism they are frequently shown by individuals from other clinical populations where obsessive behaviours and/or restricted behaviours are characteristic (e.g. Tourette's syndrome, frontal lobe dementia). Third, obsessive features have been noted in TD populations where skills have been developed to very high levels (e.g. musicians with perfect pitch, Brown et al., 2003). In line with this, Vital et al. (2009) noted increased levels of repetitive behaviour in TD children with reported special skills.

However, despite evidence linking restricted behaviour to enhanced abilities, empirical studies on special skills in ASD populations have largely failed to confirm the association. For example, in a sample of 137 individuals with ASD, Howlin et al. (2009) failed to observe increased levels of repetitive behaviour in savants compared to non-savants. Similarly, Bennett & Heaton (2012) found that individuals with reported skills and ASD did not show increased levels of rigidity, obsessionality or ritualistic behaviour compared to non-skilled individuals, although they did show a greater tendency to become absorbed in topics of interest. Further, the case study children presented in chapter 3 did not show uniformly high levels of obsessionality. Indeed, scores on the Stereotyped Behaviours and Restricted Interests factor of ADOS were not abnormal for any of the cases. These findings suggest that assumptions about the role of obsessionality in savant talents may be unwarranted. In the original study associating savantism and ritualistic, obsessive behaviours, O'Connor & Hermelin (1991) asked caretakers of savants with and without autism, together with non-savant controls matched on diagnosis and intelligence, to complete a 15 item repetitive behaviours questionnaire. The comparison of the savant groups with and without autism failed to reveal significant differences on any of the 13 questions that probed routines and checking and hoarding behaviours. Group differences only emerged on two of the questionnaire items: savants with autism were more likely to order their possessions and demonstrate an increased interest in one particular topic than non-autistic savants. Whilst a tendency to order possessions is commonly observed in autism, highly focussed attention, in response to a special interest, is not uniquely associated with the disorder. For example, DeLoache et al. (2007) observed an unusually narrow focus of attention in TD children with special interests. Questions about obsessionality in savant and non-savant children with ASD will be examined in this chapter using an adapted version of Baron-Cohen's obsessions questionnaire.

As deficits in imagination form one third of the triad of impairments characterising autism, it is unsurprising that researchers have raised questions about creativity in savants (Nettelbeck & Young, 1996; Treffert, 2006). Yet reports of creativity in savantism are frequently cited. For example, savant artists with ASD are often reported to produce novel and original pieces of art. The autistic savant Gilles Trehin conceived and developed an imaginary city, Urville, and has since produced more than 300 highly detailed drawings of the districts in his fabricated world (Trehin, 2006). The savant artist A.L. was reported to produce drawings reflecting his own make-believe stories at the age of 3 years old (see chapter 3 for more details). In the domain of music, creativity has been well documented (Hermelin, O'Connor & Lee, 1987; Hermelin, O'Connor, Lee & Treffert, 1989; Ockelford & Pring, 2005; Treffert, 2009). Further, savants who initially replicate a piece of music are reported to later improvise and create their own pieces. This was reported in the 8 year old savant B.M. who took part in the group studies presented in this thesis. Not only does B.M. compose but he writes his own songs, a pastime also enjoyed by the savant D.B (see chapters 2 and 3, respectively). Whether calendar calculating savants can be considered truly creative is, however, more questionable: these skills involve manipulation of concrete information such as dates or numbers, but they do not involve generating new or novel output per se. However, Pring & Hermelin (2002) report a savant calendar calculator with absolute pitch who displayed an initial facility with basic number-letter associations. This savant was able to quickly learn new associations and provide novel manipulations of these letter-number correspondences, demonstrating a capacity for creative action.

Few studies have attempted to assess creativity amongst groups of savants. Duckett (1976) tested savants on measures of fluency, flexibility and originality using the Torrance Test of Creative Thinking (Torrance, 1974) and compared their performance to a comparison group matched for age, gender and IQ. The hypothesis stating that savants, regardless of their skill type, would score highly on these measures was not supported. While the savants obtained high scores on one measure (elaboration), these scores were still below mental age equivalent norms and were restricted to those with calendar calculating skills. Recently, Pring, Ryder, Crane & Hermelin (2012) assessed the creativity of a group of nine savant artists with ASD and compared them to three control groups: art students, adults with ASD and adults with mild/moderate learning difficulties. Creativity was assessed using tests that were either domain-related or domain-unrelated in order to pinpoint the nature of enhanced savant creativity should such be observed. Results indicated that while art students produced significantly more creative outputs than did savants on a (domain-related) drawing task, savants scored higher on the measure of elaboration; a finding that is consistent with Duckett's (1976) study. Elaboration referred to each new idea incorporated within the drawing and in this way elaboration indexed generativity. Although savants were not found to have domain-specific deficits in fluency, flexibility or originality, they were not found to score higher than the comparison groups either. The savants did, however, demonstrate a capacity for enhanced originality on the domain-unrelated task. Pring et al. (2012) noted that the two tasks measured originality in very different ways (with the first confounded by verbal ability) and as such the results from these tasks may not be comparable. In the present study, savant creativity will be investigated using the Imagination/Creativity factor of ADOS. ADOS assesses creativity in a standardised fashion by recording the observation of imaginative use of materials or language.

Finally, sensory abnormalities, included in the previous diagnostic criteria for autistic disorder but not the current DSM–IV, have also been implicated in savantism. Anecdotal reports and case studies have highlighted fine sensory discrimination skills including delicacies of smell, unusually discriminating taste and hyper-development of the tactile sense (Tredgold, 1914; Treffert, 1989). For example, one obscure case documented a boy whose sense of touch was described to be so delicate that he could take a page and split it into two perfect sheets (Tredgold, 1914). As reports of unusual sensory abilities are far less common than cases of talent in classical areas (e.g. art, music), and more problematic to validate, some researchers have expressed reservation about including fine sensory discrimination as a category of savant skill in its own right (Hill, 1974). Indeed, Rimland (1978) has suggested that acute sensory abilities may be better understood as co-existing with other special skills and as support Miller (1998) noted that the most common types of skill are exhibited in the visual arts and musical performance, both of which have direct links to visual and auditory senses. Further, calendar calculating savants might not fit as neatly into this sensory formulation as well as artistic or musical savants, yet Horwitz, Deming & Winter (1969) in their study of the calendar calculating twins George and Charles noted coinciding sensory skills: these savants had the ability to pick out their own bedroom slippers via smell alone. However, it is worth noting that a quantitative test for abnormally sensitive smell failed to confirm superior ability in these individuals (Horwitz et al., 1965). More broadly, a limited number of studies examining olfaction in ASD have also concluded that the ability to identify odours is impaired (Bennetto, Kuschner & Hyman, 2007; Suzuki, Critchley, Rowe, Howlin & Murphy, 2003).

Recently, Baron-Cohen et al. (2009) included sensory sensitivity as a critical component in the hyper-systematising theory, a theory which has been put forward with the aim of explaining savant skills in ASD. In line with the EPF theory (Mottron et al., 2009), these authors implicate atypical low-level perception in the emergence of special skills in autism. In concluding their detailed paper, Baron-Cohen et al. (2009) postulate that "the search for the association between autism and talent should start with the sensory hypersensitivity, which gives rise to the excellent attention to detail, and which is a prerequisite for hyper-systematising" (p. 1382). However, whilst hypersensitivity to sensory information is characteristic in ASD it is by no means clear whether or not individuals with ASD and talents show increased hypersensitivity in comparison to those with the same diagnoses but without savant skills. Bennett & Heaton (2012) did not observe significant differences between skilled and non-skilled individuals with ASD on questionnaire items assessing atypical sensory processing. Considering the link between savantism and unusual sensory processing, and the link between ASD and sensory sensitivity, it is of interest to investigate the sensory profiles of groups of savant and non-savant individuals with ASD. This will be probed as a third clinical factor in this chapter.

The predictions tested in this chapter were that savants would show increased socio-communicative impairment (measured by ADOS total and SCQ total scores), less impaired creativity (measured by ADOS Imagination/Creativity factor), increased repetitive behaviour (measured by ADOS Stereotyped Behaviours and Restricted Interests factor) and increased numbers of obsessions and greater intensity levels concerning their obsessional interests (measured using an adapted version of Baron-Cohen's obsessions questionnaire). Considering the limited amount of research into sensory processing in savant compared to non-savant populations, a prediction regarding sensory processing differences across groups was not made.

SYMPTOM SEVERITY

Methods

Participants

The groups of savant (n = 17) and non-savant (n = 19) children with ASD described in detail in chapter 2 participated in the three studies described in this chapter. In order to address the question of whether increased numbers of obsessions are associated with ASD or with savant syndrome, a group of age and intelligence matched TD children also took part in the obsessions study.

Materials

Two measures were employed to assess symptom severity. In order to examine current levels of symptomatology, both savant and non-savant children were administered module 3 of ADOS which is suitable for verbally fluent children/adolescents. ADOS measures core autistic symptoms in the domains of socio-communication, restrictive behaviours/interests and imagination. The lifetime version of the SCQ was employed as a brief questionnaire measure for parents to complete. This questionnaire assesses the presence of ASD symptoms across the child's developmental history. Considered together these assessments allow measurement of symptom severity, both currently and across early development. These measures are described in detail in chapter 2.

Procedure

ADOS assessments were conducted in a quiet room at the home of each participant. One child (the savant A.L.) had been assessed using ADOS for the purpose of clinical diagnosis prior to the study. As A.L.'s parents made his ADOS data available it was not deemed necessary to administer a second ADOS. None of the other children had been assessed using ADOS before. The SCQ was completed by the parent(s) of each participant independently.

Results

The means and standard deviations for savants and non-savants on measures of symptom severity are presented in Table 4–1.

Table 4–1. Means (M) and standard deviations (SD) for savant and non-savant groups on assessments of symptom severity

Measure of symptom severity	**Savants M (SD)**	**Non-savants M (SD)**
ADOS Total (autism cut-off = 10, ASD = 7)	8.65 (3.30)	6.95 (3.34)
Communication (autism cut-off = 4, ASD = 2)	2.53 (1.46)	2.00 (1.15)
Reciprocal Social Interaction (autism cut-off = 6, ASD = 4)	6.12 (2.15)	4.95 (2.48)
Imagination/Creativity	.47 (.51)	.95 (.85)
Stereotyped Behaviours and Restricted Interests	.59 (.71)	.58 (.61)
Other abnormal behaviours	.65 (1.06)	.58 (.77)
SCQ total (autism cut-off ≥ 22, PDD ≥ 15)	18.65 (7.78)	20.05 (6.76)

The initial analysis tested the hypothesis that savants would show increased symptom severity. Therefore ADOS total scores and SCQ total scores were compared across groups using independent samples (1-tailed) t-tests. The total ADOS scores did not differ across groups ($t(34) = 1.52$, $p > .05$) and a similar result emerged on the analysis of the SCQ data ($t(34) = -.58$, $p > .05$). This analysis showed that the two groups did not differ on the core social and communication symptoms characterising ASD. In order to determine whether groups differed on Imagination/Creativity and Stereotyped Behaviours and Restricted Interests, t-tests (1-tailed) with corrections for multiple comparisons were carried out ($p = .05/2 \leq .025$). These showed a significant difference between groups on Imagination/Creativity ($t(34) = -2.06$, $p < .05$) but not on Stereotyped Behaviours and Restricted Interests, ($t(34) = .042$, $p > .05$). Thus the two groups differed only on the imagination subscale with savants showing lower levels of impairment than non-savants.

OBSESSIONALITY

Methods

Materials

The parents of participants in all three groups completed an adapted version of the Cambridge University Obsessions Questionnaire which surveys the contents of an individual's obsessions (Baron-Cohen & Wheelwright, 1999). Parents were instructed to place a tick in yes/no boxes to indicate whether they consider their child to have an obsession within the domains specified by the questionnaire. Six core cognitive domains were probed (physics, mathematics, biology, psychology, language and taxonomy) as well as 8 other areas of everyday life (e.g., attachments to objects) and 1 autism-specific clinical domain (sensory phenomena). The authors suggest that this approach to questionnaire development has resulted in very broad categories (e.g. the category 'vehicles' includes trains, buses, planes, boats, model railways etc). In the original questionnaire 20 categories of obsessions are listed including a final category titled 'other' for any obsessions that parents do not feel have been represented by any of the previous 19 domains. In adapting the questionnaire for the study, 'other' was omitted and replaced with 'spatial information' – a category which was missing from the original list yet may be of importance in the context of savant skills. Although Baron-Cohen & Wheelwright (1999) suggested that it was "notoriously difficult" to define obsessions and that "parents would have their own notion of what this was" (p. 485) the adapted version of the questionnaire included a precise definition for the sake of consistency. Thus obsessions were defined as "any idea that haunts, hovers and constantly invades one's consciousness" (Reber & Reber, 2001). In addition to the inclusion of the spatial information domain a further adaptation was made; parents were asked to specify the extent of their child's obsessions by circling either slightly, moderately or highly obsessed for each category where they had reported an obsession. A key was provided to explain the differences in intensity at each level. At the least intense level, slight obsessions were defined as preoccupations that seem quite mild, are greater than an interest but do not interfere with thinking about or doing other things. Obsessions classified as moderately intense were described as apparent preoccupations but not all encompassing. Highly intense obsessions were defined as all encompassing: switching attention from the object of the obsession to something else is deemed extremely difficult. The adapted version of the obsessions questionnaire is included in Appendix D.

Analysis

Separate statistical analyses were carried out on the number of reported obsessions, content and extent. Where parents reported that their child had one or more specific obsessions in a particular category, a score of 1 was recorded to indicate a positive response in that domain (0 for no obsessions). Scores for the number of obsessions were calculated for each participant (maximum score = 20) and group means compared using one-way ANOVA. The content of obsessions across all 20 categories was analysed using the chi-square test. With regard to the extent of obsessionality, a scale of 1–3 was applied to the ratings of slightly obsessed (1), moderately obsessed (2) and highly obsessed (3). The number of 1's, 2's and 3's were then summed for each participant (maximum score = 60) and group means compared. The analysis of the numbers of obsessions had included the TD comparison children, but this revealed a very low level of obsessionality in this group. Therefore investigations into the content and extent of obsessions were confined to the ASD groups.

Results

Number of obsessions

The initial analysis tested the hypothesis that savants would show an increased number of obsessions compared to non-savants and TD comparisons. A one-way ANOVA (1-tailed) was used to compare the total number of obsessions for the three groups. A significant main effect was observed, $F(2,50) = 18.86$, $p < .05$. Post hoc comparisons using the Tukey HSD test showed that whilst the number of obsessions recorded for the savant group ($M = 7.94$, $SD = 4.02$) did not significantly differ from the non-savant group ($M = 7.42$, $SD = 2.32$), the TD comparison group were reported to have a significantly lower number of obsessions ($M = 2.06$, $SD = 2.84$) than both ASD groups ($p = .01$). Importantly, this finding shows that while TD children show fewer obsessions than those with ASD, savant children did not have greater numbers of obsessions compared to non-savant children.

Content of obsessions

In order to address questions concerning the content of obsessions, responses to the 20 categories were examined. These are presented in Table 4–2.

Table 4–2. Numbers of participants with reported obsessions across the 20 categories

Obsession category	**Savants** (*n* = 17)	**Non-savants** (*n* = 19)	**TD comparisons** (*n* = 17)
1. Machines	7	10	4
2. Systems	6	7	0
3. Sorting/categorising	9	11	2
4. Belief systems	2	5	0
5. Numerical information	9	5	0
6. Sports/games	6	11	4
7. Strong attachment to a particular item	7	12	2
8. Sensory experiences	9	13	1
9. Crafts	9	3	2
10. Factual information	7	6	1
11. Creative arts/fiction	10	10	5
12. Sciences	3	5	0
13. Animals	8	6	2
14. Collecting things	10	14	4
15. People	4	5	1
16. Vehicles	7	7	3
17. Spinning objects	5	0	0
18. Food & drink	9	6	3
19. Plants	1	0	0
20. Spatial information	6	5	1

Whilst the data analysis had shown that TD comparison children recorded fewer obsessions across all 20 categories than children with ASD, questions about how target domains might differ across ASD and TD groups was relevant to the aim of characterising savant skills in ASD. Domains where 20% or more of the total TD sample had recorded obsessions are shown in Figure 4–1.

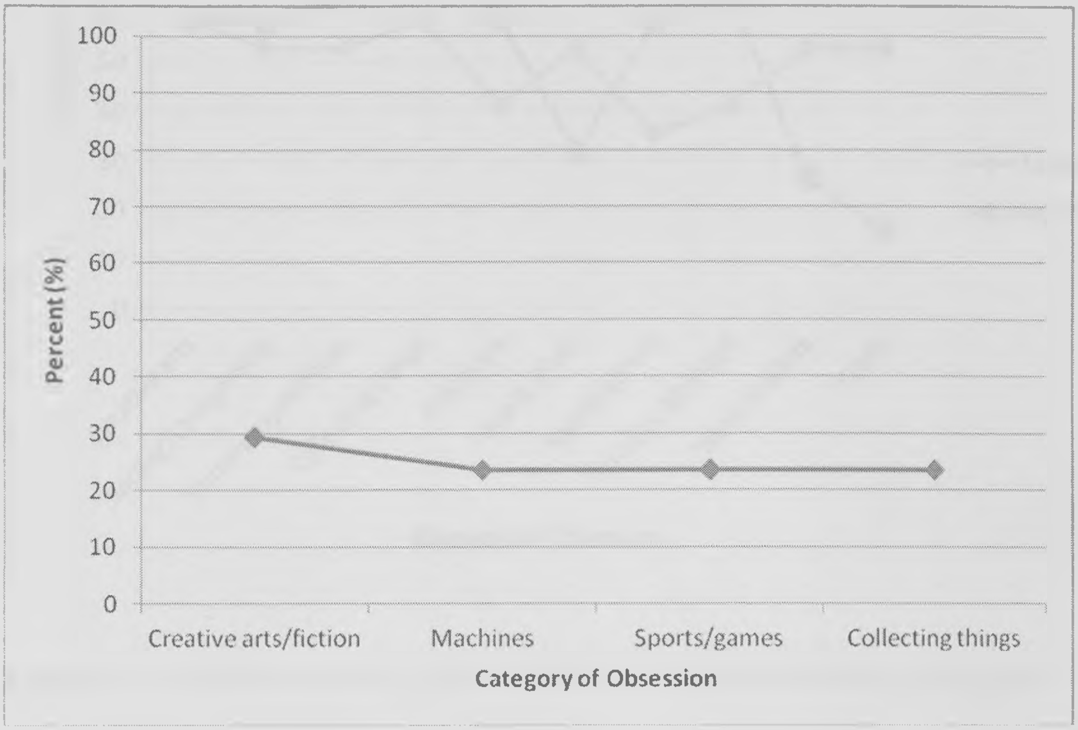


Figure 4–1. Obsessions totalling 20% or more of TD comparison participants

As can be seen, there were only four domains where 20% or more of TD comparisons were classed by their parents as obsessed: the creative arts/fiction (29%), machines (24%), sports/games (24%) and collecting things (24%). While TD comparison children shared some target domains with the ASD groups (creative arts/fiction, collecting things), there were domains that only elicited interest in individuals with ASD (sorting and categorising, sensory experiences).

In order to consider possible similarities and differences between savants and non-savants, obsessions where one or both of the ASD groups had targeted 50% or higher were isolated and examined. Figure 4–2 shows categories of obsessions where 50% of either/both ASD groups recorded an obsession.

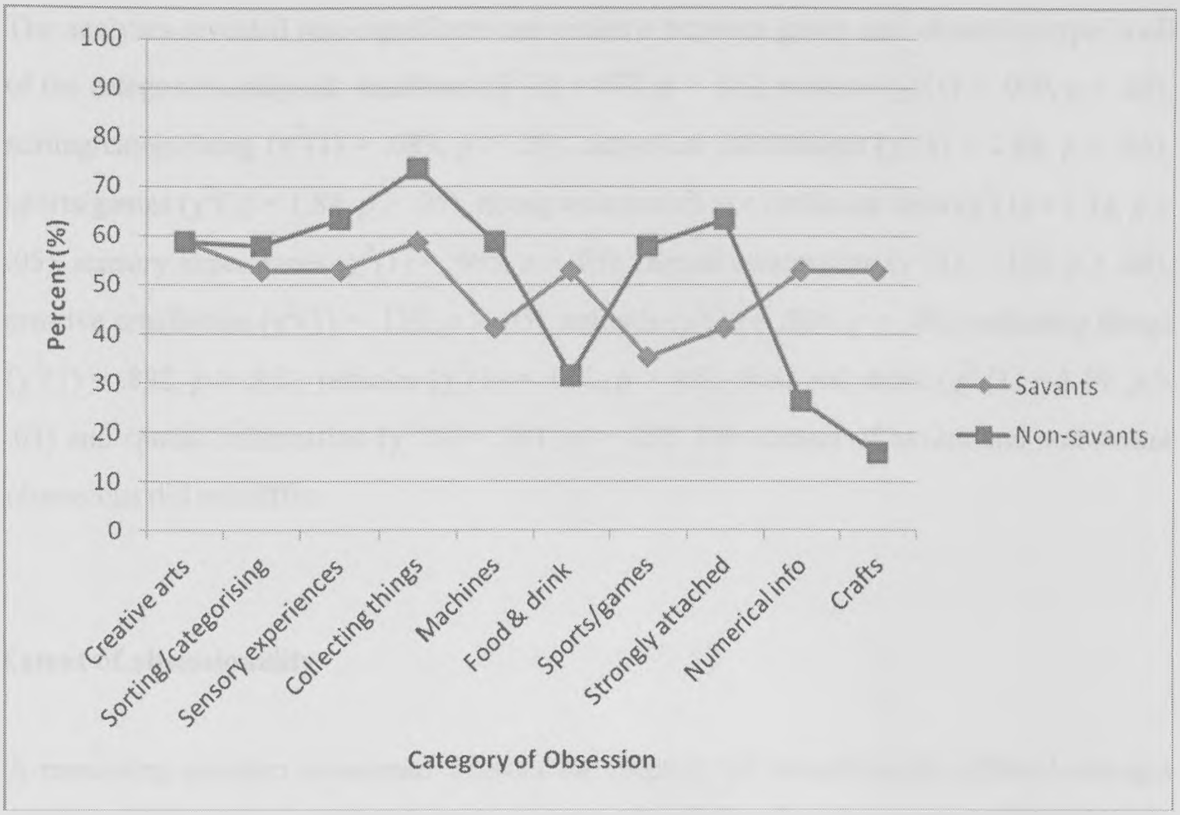


Figure 4–2. Obsessions totalling 50% or more of savant or non-savant participants

Figure 4–2 illustrates that the majority of savant and non-savant participants showed increased numbers of obsessions in the domains of creative arts/fiction, sorting/categorising, sensory experiences and collecting things. The majority of non-savant (but not savant) individuals showed increased numbers of obsessions in the domains of machines and sports/games. They were also more likely to be strongly attached to a particular item. While relatively low numbers of non-savant individuals were reported to have an obsession with numerical information (26%) and crafts (16%), the majority of savant individuals had obsessions in these areas (both at 53%). It therefore seemed that whilst savant and non-savant groups did not record significantly different total numbers of obsessions, they appeared to differ slightly in content. Chi-square analyses were conducted to test this. One assumption of the chi-square statistic states that expected frequencies should be greater than 5 in order to prevent against loss of statistical power. Therefore, the following categories were not analysed due to the fact that either or both ASD groups had four, or less, individuals scoring in these domains: belief systems, crafts, sciences, people, spinning objects and plants. Chi-square was performed on the remaining 14 categories.

The analyses revealed non-significant associations between group and obsession type in all of the categories analysed: machines ($\chi^2(1) = 472$, $p > .05$), systems ($\chi^2(1) = .009$, $p > .05$), sorting/categorising ($\chi^2(1) = .089$, $p > .05$), numerical information ($\chi^2(1) = 2.68$, $p > .05$), sports/games ($\chi^2(1) = 1.84$, $p > .05$), strong attachment to a particular item ($\chi^2(1) = 1.74$, $p > .05$), sensory experiences ($\chi^2(1) = .905$, $p > .05$), factual information ($\chi^2(1) = .358$, $p > .05$), creative arts/fiction ($\chi^2(1) = .139$, $p > .05$), animals ($\chi^2(1) = .905$, $p > .05$), collecting things ($\chi^2(1) = .892$, $p > .05$), vehicles ($\chi^2(1) = .071$, $p > .05$), food and drink (χ^2 $(1) = 1.69$, $p > .05$) and spatial information ($\chi^2(1) = .341$, $p > .05$). The content of savant and non-savant obsessions did not differ.

Extent of obsessionality

A remaining question concerned whether the intensity of obsessionality differed amongst savants and non-savants. To compare extent of obsessionality, the number of participants with slight, moderate and high obsessions was calculated by group. These are shown in Figure 4–3.

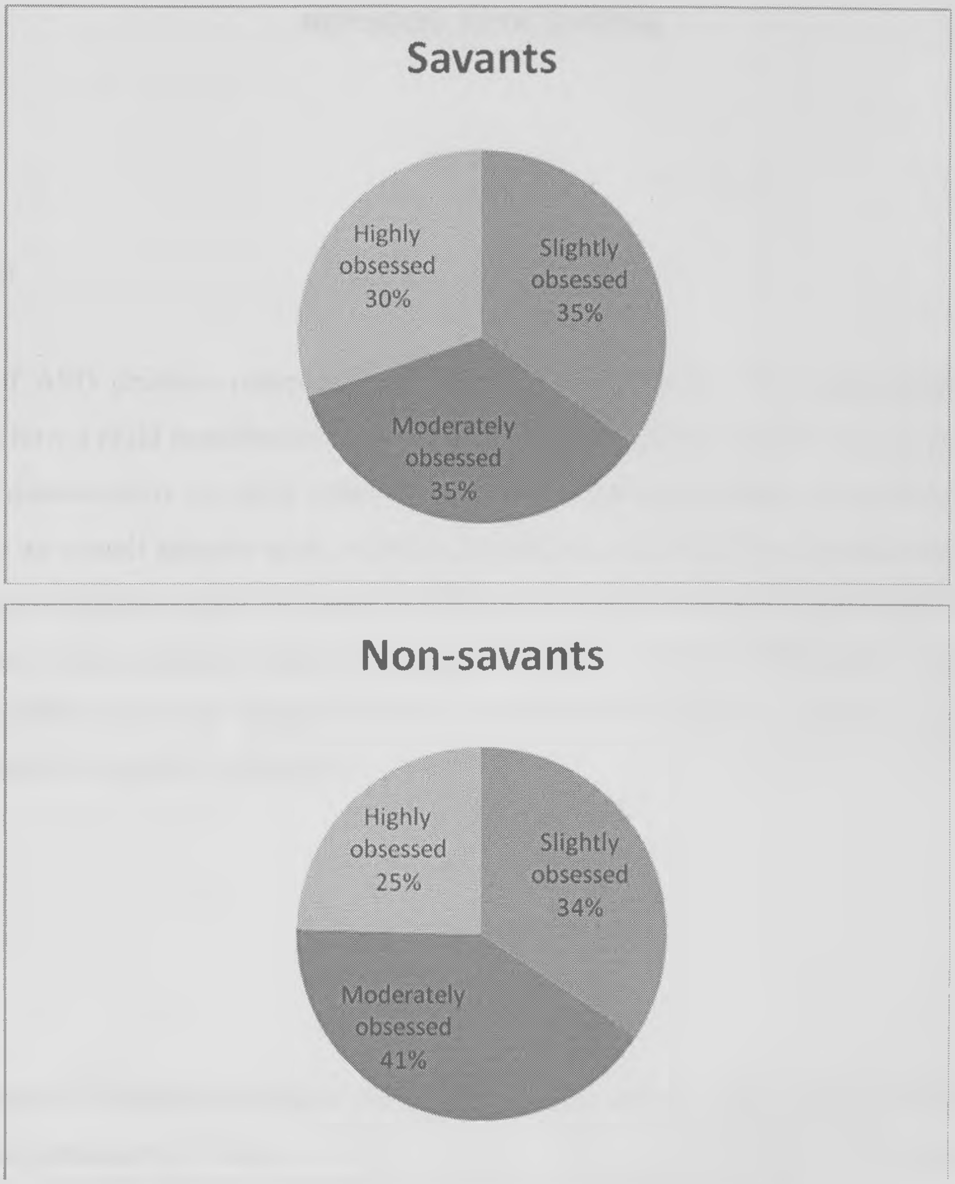


Figure 4–3. Number of particiants (in %) with slight, moderate and high obsessions for savant and non-savant groups

As can be seen from Figure 4–3, the extent of obsessionality did not appear to differ dramatically between the two groups. For savant children, intensity levels appeared to be relatively evenly distributed across slightly (35%), moderately (30%) and highly obsessed (30%) categories. Greater variation existed amongst the non-savant group with a higher proportion of moderate obsessions (41%) compared to slight (34%) or high (25%) obsessions.

SENSORY PROCESSING

Methods

Materials

Parents of ASD children completed the Short Sensory Profile. This questionnaire briefly measures how a child experiences their world in terms of various sensations (e.g. touch, taste etc). The questionnaire provides information on individual components of sensory processing as well as an overall sensory score which is formulated from the total of these subscores. All scores are compared to specified cut-offs which indicate the extent to which a child's sensory processing in that domain differs from the norm (i.e. definite difference from normal, probable difference from normal, typical performance). Detailed information about this questionnaire is provided in chapter 2.

Results

The means and standard deviations for savant and non-savant groups on the Short Sensory Profile are presented in Table 4–3. Short Sensory Profile classifications are also shown for these group means. These classifications are based on performance of children without disabilities (n = 1,037) as specified in the test manual (Dunn, 1999).

Table 4–3. Means (M) and standard deviations (SD) for savant and non-savant participants on the Short Sensory Profile

Sensory factor	Savants M (SD)	Classification	Non-savants M (SD)	Classification
Short Sensory Profile Total	132.59 (24.03)	Typical	116.37 (23.99)	Definite
Tactile	25.65 (6.32)	Definite	23.68 (5.09)	Definite
Taste/smell	13.53 (6.19)	Probable	13.47 (5.81)	Probable
Movement	12.88 (2.76)	Probable	10.42 (2.91)	Definite
Under responsiveness/ seeks sensation	22.94 (6.64)	Definite	21.05 (6.05)	Definite
Auditory filtering	17.53 (4.30)	Definite	13.32 (5.21)	Definite
Low energy/weak	21.53 (4.68)	Definite	19.58 (9.52)	Definite
Visual/auditory sensitivity	18.53 (4.80)	Probable	14.84 (5.49)	Definite

Note: Definite = sensation is experienced in a way that is definitely different from normal. Probable = probable difference from normal. Typical = sensory processing as normal

Whilst it appears from Table 4–3 that the groups differed on total sensory scores in the direction of savants being less impaired, these scores very narrowly failed to reach statistical significance, $t(34) = 2.02$, $p = .051$. As the auditory filtering and visual/auditory sensitivity subscores measure factors associated with savant syndrome (i.e. sensitivity to auditory and visual information expressed in music and art), further comparisons were carried out on these two subscales. Two-tailed t-tests with adjustments for multiple corrections were carried out ($p = .05/2$; $p \leq .025$). Groups significantly differed on auditory filtering, $t(34) = 2.63$, $p < .05$. There was a trend toward significance on visual/auditory subscales, $t(34) = 2.13$, $p = .04$. These differences were in the direction that savants were less impaired on these factors than non-savants. However, it should be noted that both groups failed to achieve typical performance on these two items.

CHAPTER SUMMARY AND BRIEF DISCUSSION

This chapter examined possible clinical and behavioural differences between savant and non-savant children with ASD. The first study investigated possible symptom severity differences using ADOS and SCQ and showed that savant participants did not significantly differ from non-savant participants in terms of core socio-communicative impairment. The groups also did not differ on the ADOS factor measuring restrictive, repetitive behaviour and interests. However, savant individuals were found to be less impaired than those without skills on aspects of the ADOS measuring imagination/creativity.

The second study examined obsessionality in savant, non-savant and TD comparison children. While TD children were reported to have significantly lower numbers of obsessions compared to both ASD groups, savants did not possess greater numbers of obsessions compared to non-savants. This finding was in line with the results from the symptom severity study which did not reveal a difference between the ASD groups on the aspect of ADOS assessing restricted, repetitive behaviour. While savants were reported to have increased obsessions in two specific domains (numerical information, crafts) compared to non-savants, the profiles of obsessional content did not statistically differ for these two groups. Although slightly increased intensity ratings were observed within target domains for savants compared with non-savants, these data could not be analysed statistically and must therefore be interpreted with caution.

Finally, a small but interesting difference between savants and non-savants was observed on the measure of sensory processing. This was in the direction of reduced sensory impairment in the savant group. Examination of two subscales measuring factors associated with savant skills (music and art) showed that savants were significantly less impaired in the domain of auditory filtering and there was a marginal trend for reduced impairment in visual/auditory sensitivity. Taken together these results suggest that whilst severity of core social and communication deficits did not differentiate savant and non-savant groups, the savant group were less impaired in imagination and in sensory areas that could impact on savant skills. Whilst savants showed increased numbers of obsessions when compared with TD children, this is unremarkable in the context of ASD. Further, savants and non-savants did not differ in terms of the content of their obsessions or the extent of obsesisonality. Chapter 5 will explore cognitive correlates of savant syndrome, specifically with regard to attention and intelligence.

CHAPTER 5: EXPLORING THE COGNITIVE CORRELATES OF SAVANT SKILLS IN CHILDREN WITH ASD

ABSTRACT

Research into the savant syndrome has long aimed to uncover the cognitive mechanisms that may underpin extraordinary talents. Chapter 3 presented the case studies of three children with ASD and savant skills in art, mathematics and music, where commonalities on tests of attention and intelligence were revealed. Amongst the eight indices of the Children's Memory Scale, these savants performed best on the assessment of attention/concentration and performance for two out of three savants was in the very superior range. Other scores on this test were unremarkable and did not show convergence. Similarly, enhanced working memory was observed on the test battery assessing intellectual functioning. This was especially true for the Digit Span test, a test that has been implicated in the literature in other studies of savant syndrome. This chapter presents data testing attention/concentration in groups of savant and non-savant children with ASD, and examines intellectual profiles at composite and subtest levels. Participants completed the attention/concentration factor of the Children's Memory Scale and all 15 subtests from the Wechsler Intelligence Scales for Children.

In their quest to understand savantism researchers have considered potential abnormalities in attentional systems. Although attentional deficits are not such a salient aspect of the clinical symptomatology of ASD as is the case in ADHD, various abnormalities of attention have been noted in this group and indeed provided a main focus for some of the earliest cognitive theories of autism (Hutt, Hutt, Lee & Ounsted, 1965; Rimland, 1964). In speculating on the origins of savant talent, Rimland (1978, 1988, 1990) hypothesised that focussed attention might be a critical factor. For example, in 1978, he suggested that individuals with autism show an increased tendency to become "hooked" or locked onto the physical dimensions of objects. This tendency, termed "high fidelity", results in a strong interest in isolated details, and a reduced propensity for external information and higher level abstract thought (p. 56).

As an example, Rimland (1978) explained that a person given the task of studying a book for ten minutes could either memorise one or two paragraphs of text in exact detail or they could skim several chapters and extract conceptual gist of the text, but they could not do both. Where individuals characterised by typical cognitive processing have the ability to do either, depending on where they set their attentional dial, individuals with autism have an inability to 'zero-out'. As evidence, Rimland suggested the failure of infants with autism to orientate resulting in a state of hypodistractability (also supported by Casey, Gordon, Mannheim & Rumsey, 1993). Later on, children may focus their attention on "high fidelity" reproductions of the physical characteristics of stimuli, as opposed to abstract ideas, and in the autistic savant this may result in the ability to reproduce exact visual or auditory information following a single exposure. While this idea has merit and is supported by a number of reports of savants with photographic memory (Stephen Wiltshire; Sacks, 1995) and the ability to reproduce music precisely after a single hearing (Ockelford & Pring, 2005), it is surprising that the savant artist A.L. did not show remarkable visual memory in the tests carried out in chapter 3. However, as Nettelbeck & Young (1996) discussed, savants with superior drawing ability may demonstrate average or even poor visual recognition memory consistent with their overall IQ, whilst other researchers have suggested that superior visual recognition memory in artistic savants is restricted to (domain-specific) drawn responses only (O'Connor & Hermelin, 1987, Mottron & Belleville, 1993).

Anecdotal reports of focussed attention in individuals with ASD and special skills abound in the literature and indeed, detail-focussed attention has been described by several researchers (Casanova, Switala, Trippe, & Fitzgerald, 2007; Happé & Vital, 2009, Heaton & Wallace, 2004; Hill, 1978). Hou, Miller, Cummings, Goldberg, Mychack, Bottino & Benson (2000) reported on the commonalities of six savant artists with ASD, all of whom showed highly focussed attention when engaged in skill related activity. Of the Japanese artist Kiyoshi Yamashita the authors noted: "while working with many small pieces of paper, Yamashita demonstrated an exceptional ability to focus his attention for long periods of time" (p. 30). Yoshihiko Yamamoto, who produces paintings and prints, mostly of buildings, castles and ships, was described to concentrate equally well: "able to vigorously focus his attention, Yamamoto worked for many hours daily crafting meticulous realistic drawings… and he had the ability to focus on the same task for many hours" (p. 31). These descriptions are reminiscent of the artist A.L. whose mother reported that by the age of 3 years he was able to sit for hours at a time engrossed in producing series of drawings (see chapter 3). Several years later, A.L.'s capacity for focussed attention had not waivered and he was reported to have constructed a short animation film following two sessions of three hours of undivided attention.

Aside from art, focussed attention has been reported in other savant domains. In the domain of music, Heaton (2009) suggested that while TD children and those with autism learn about music through the same channel, by simple listening, some individuals with autism may show atypically focussed attention to, and perception of, music. Further, Heaton (2009) cited one of Kanner's (1943) original case study children as an example and suggested that it is inconceivable that this child could have remembered such a vast array of musical compositions without highly focussed attention. Elsewhere, Hill (1975) has tested a calendar calculating savant who concentrated on answering 168 date questions solidly for two hours; the 10 minute break near the middle of the testing period was for the sole benefit of the examiner (reported in Hill, 1978). The importance of focussed, intense attention in the development of special abilities and interests has been noted in other clinical groups (e.g. children with manic depression, DeLong & Aldershof, 1988) and also in young TD children (DeLoache et al., 2007). Further, Heaton & Wallace (2004) propose that traits predisposing individuals towards highly focussed attention within specific domains might facilitate high level achievement in those with both developmental (e.g. ASD) and late onset disorders (e.g. dementia). Lastly, the case study children presented in chapter 3 showed enhanced attention, yet scores on the other factors tested in the memory battery were unremarkable. Indeed, two out of three children performed at very superior levels on the attention/concentration factor and for all three children their score on this aspect of the test was their best from a set of eight indexes. Attention will be further investigated in group studies of savant and non-savant children with ASD, in the current chapter.

The extraordinary nature of the talents observed in savants is striking when contrasted with their overall cognitive profile and it is unsurprising that savantism is frequently invoked in discussion about the nature of intelligence (see Miller, 1999, and Nettelbeck & Young, 1996, for reviews). Traditional definitions of savant syndrome have presumed that remarkable talent (in normative terms) inevitably coexists with broad intellectual impairment. Indeed, Down (1887) explicitly postulated that savant individuals are characterised by low intellect when he coined the term "idiot-savant". According to this terminology, "idiot" refers to the clinical classification of IQ < 25 and is combined with a derivative of the French word "savoir" meaning "to know". Early reports of case studies appeared to be consistent with this understanding of low intelligence in savants. For example, Miller (1989) presented the case of a 6 year old child with musical talent whose limited language skills and severe visual impairment prevented standard intellectual assessment and only limited psychometric testing was possible for several of the artistic savants presented by Selfe (1983). While a number of researchers have followed Down (1887) in using the 'idiot-savant' terminology (e.g. Horwitz et al., 1965; Howe, Davidson & Sloboda, 1998; O'Connor & Hermelin, 1988; Rimland, 1978), the pejorative label 'idiot' has now been superseded by more neutral terms such as mono-savant (Charness, Clifton & MacDonald, 1988) or simply savant (Treffert, 1989, 2006, 2009).

Further, more recent work suggests that low intellect may not be a characteristic of all individuals with developmental disabilities and special skills, and it is becoming increasingly clear that early definitions of savantism need revising. A large body of evidence implies that individuals with ASD are not as intellectually impaired as has been traditionally thought and this is important considering that approximately half of all individuals with savant syndrome are diagnosed with the disorder (Treffert, 2009). A long-held view is that up to 75% of individuals with ASD are intellectually disabled (defined by global IQ < 70) and that this is coupled with functional impairments in everyday living (Charman, et al., 2011; Frith, 2003; Tsatsanis, 2005; Volkmar, Lord, Bailey, Schultz & Klin, 2004). Yet as Charman et al. (2011) have pointed out, such estimates have not been obtained in the context of epidemiological study. Moreover, with recent changes in diagnostic criteria widening to include a population of individuals who are more intellectually able (i.e. Asperger's syndrome) such estimates are likely outdated and not representative of the full spectrum. In presenting data collated from a large sample of children with ASD (n = 75), Charman et al. (2011) broadly concluded that ASD was less strongly associated with intellectual disability than had previously been assumed. Approximately half of all individuals with ASD had an intellectual disability and of these less than one in five had moderate to severe intellectual disability (IQ < 50). The proportion of children with average intelligence was approximately one quarter, and above average intelligence was observed in a few percent (Charman et al., 2011). These results confirm findings from other recent epidemiological studies (Bertrand, Mars, Boyle, Bove, Yeargin-Allsopp & Decoufle, 2001; Chakrabarti & Fombonne, 2005). In line with these findings showing that cognitive disability is not a necessary correlate of ASD are reports of savants with ASD and normal or high average IQ (Heavey et al., 1999; Treffert & Wallace, 2002; Young & Nettelbeck, 1995). Indeed there are even reports of savants with exceptional intellectual abilities. Daniel Tammet is one of the best examples of an autistic savant with high IQ. With a diagnosis of Asperger's syndrome and an IQ of 150, Tammet has an extraordinary facility with calculation and learning languages (e.g. he has the ability to recite Pi from memory to over 22,000 digits and he learned Icelandic in a week). Finally, data from the case study children presented in chapter 3 revealed full scale IQ scores that were in the average range for two children and superior for the third. This was consistent with findings presented by Bennett & Heaton (2012) in their questionnaire study which indicated that only 5% of individuals with a reported special skill were intellectually impaired (compared to 10% of those without reported skills). Currently it remains unclear whether IQ and savant skills are systematically connected. Cases of intellectually impaired savants clearly exist, yet intact (or elevated) intellectual abilities are reported in others. Further, studies have found a positive correlation between IQ and skill level (Hermelin & O'Connor, 1986; O'Connor, Cowan & Samella, 2000; Young, 1995) and this suggests that intelligence may play a role in supporting savant skills.

Miller (1998) and Heaton & Wallace (2004) postulate that findings of preserved intellectual abilities in ASD warrants a redefinition of the savant syndrome. In these authors view, intra-individual comparisons, especially with regard to adaptive functioning, could be of importance. As Heaton & Wallace (2004) suggest, deficits in adaptive behaviour, or difficulties in 'everyday' intelligence, are commonly reported in those with high functioning ASD (Klin, 2000) and this validates the inclusion of such persons within the savant classification. In the group of 17 savants presented in this thesis all individuals had clinical diagnoses of ASD and their skills stood in contrast to their socio-communicative impairments. As discussed in chapter 2, the mean full scale IQ score for the savant group was in the high average range and these individuals would not meet traditional savant criteria that assumed impaired IQ. Rather their savant status was defined by their overall intra-personal functioning (socio-communicative impairment) which contrasted with their high skills validated within a normative context. Similar criteria have been adopted in other studies of individuals with autism who have been considered to be savants, despite average, or above average, IQ (Heavey et al., 1999; Young, 1995; Young & Nettelbeck, 1995).

Moving away from global IQ scores, subtest performance profiles may be of importance in understanding the cognitive mechanisms implicated in ASD and savant skills. Despite the lack of norms for people with autism on standardised batteries such as Wechsler Intelligence Scales for Children (Wechsler, 2004) and Wechsler Adult Intelligence Scales (Wechsler, 2008), the findings from a number of studies have revealed a characteristic pattern of strengths and weaknesses on these tests (Charman et al., 2011; Frith, 2003; Happé, 1994, 1995; Harris, Handleman & Burton, 1990; Mayes & Calhoun, 2003; see Lincoln, Allen & Kilman, 1995, for review). On the Wechsler Scales of Intelligence, peaks are commonly reported on visuo-spatial tasks whereas troughs occur on tasks that assess communicative competence or social reasoning (e.g. high Block Design relative to Comprehension).

With regard to savant subtest performance, a similar spiky profile has been observed and it is interesting that globally gifted TD children also often show jagged profiles on standardised tests of intelligence, including those gifted in music and art (Winner, 2000). Hill (1982) compared intelligence test profiles in a sample of 19 adult savants compared to 111 non-savants with learning disabilities and equivalent full scale IQ. Savants were found to perform better than non-savant counterparts on four subtests: Block Design, Digit Span, Information and Arithmetic. Young (1995) replicated the Block Design and Digit Span finding in her sample of 51 savants with autism or autistic traits. She also reported a strength on the Object Assembly test and lower scores on Comprehension, Vocabulary and Coding. More recently, the intelligence profiles of savants and non-savants with ASD were compared in a sample of children and adults: again savants were found to perform best on Block Design, Digit Span, Information and Object Assembly, and worst on Comprehension and Picture Arrangement tests (Bölte & Poustka, 2004). However, the only test to statistically differentiate savants from non-savants in this study was the Digit Span test. Superior Digit Span relative to IQ in calendar calculating savants has also been noted by other research groups (Rumsey et al., 1992; Spitz & LaFontaine, 1973), although one study has failed to replicate this finding (Heavey et al., 1999). Bölte & Poustka (2004) discuss the importance of Digit Span as a correlate of savant syndrome and propose that less impaired working memory and executive functioning may be observed in this group, combined with enhanced rote memory and low-level processing. Recently, Dawson et al. (2007) raised important questions about how results showing subscale peaks and troughs on standardised intelligence tests should be interpreted in the context of ASD. In their study of 38 children with autism, scores on the Raven's Matrices, a test of general and fluid intelligence, were similar to their peak scores on the Wechsler Intelligence Scales, suggesting that these peaks provide a better measure of intelligence in this group than global IQ scores. As these authors observed strong Raven's

Matrices performance in individuals with Asperger's syndrome and peak abilities on verbal tests (Soulières, Dawson, Gernsbacher & Mottron, 2011) they concluded that the Raven's Matrices test measured a common mechanism in ASD that is important for all aspects of cognition. This question will be addressed in a comparison of Raven's Matrices scores across savant and non-savant groups.

In examining the full intelligence profiles of the three case study children presented in chapter 3, elevated working memory scores were observed in the context of unremarkable composite scores on the other factors of the intelligence test battery. In their review of working memory in ASD, Poirier & Martin (2008) discuss a number of early studies suggesting that immediate memory is intact. However in reviewing more recent findings these authors suggest that working memory deficits may be more likely in this group than was once considered. Poirier & Martin (2008) broadly conclude their review with the tentative suggestion that spatial working memory is impaired in ASD, while consensus on verbal working memory is unclear. Considering new ideas on the role of working memory, executive functions and rote memory ability as underpinnings of savant talent (Bölte & Poustka, 2004), an important question that remains outstanding is whether savants with high functioning ASD will show elevated working memory, over and above digit span, compared to those without savant talents. This will be investigated in the current chapter.

In research and clinical practise, intelligence is most commonly defined and measured by the concept of general intelligence ('g') as denoted by performance on standardised tests of IQ. However, as Dawson et al. (2007) point out, a reliance on 'g' may lead to an underestimation of autistic intelligence and it is possible that levels of intelligence in savants may well have been underestimated in the past. Similarly, Miller (1999) noted that the search for cognitive strengths in savants should not be restricted to those defined by conventional standardised tests of IQ. New definitions of savant syndrome (e.g. Heaton, 2010, 2012; Heaton & Wallace, 2004) allow for an absence of intellectual impairment and there are many reports of exceptional skills in intellectually able individuals with ASD. Much savant research has assumed that a common cognitive mechanism, independent of full scale IQ, explains the emergence of special talents and this chapter will seek to examine some of these mechanisms. The predictions tested in this chapter were that savants, relative to non-savants, would show superior performance on tests of attention, working memory, Block Design and analytical processing of matrix information (i.e. Raven's Matrices and Matrix Reasoning).

ATTENTION/CONCENTRATION

Methods

Participants

The groups of savant ($n = 17$) and non-savant ($n = 19$) children with ASD participated in the studies described in this chapter. In order to address the question of whether increased attention is associated with autism or with savant syndrome, a group age and intelligence matched TD children also completed the measure of attention.

Measures

The Children's Memory Scale measures a number of components of memory functioning and includes an Attention/Concentration factor. In order to examine possible group differences on measures of focus, subtests contributing to Attention/Concentration were used in isolation from the rest of the battery in the first study detailed in this chapter. The Attention/Concentration factor consists of two core subtests and one supplemental subtest. Numbers assesses the ability to repeat sequences of numbers that increase in length. The Sequences subtest assesses the ability to mentally order verbal information at speed. Together these two subtests equate a total Attention/Concentration score that is compared to age-appropriate norms for TD children. Picture Locations assesses immediate visual memory for the spatial locations of pictured objects. Administration of Picture Locations is not required to derive the Attention/Concentration factor score. However, this test was retained for two reasons: 1) the case study children performed similarly well on this subtest and 2) Picture Locations assesses visuo-spatial attention skills and this may be of import for savant talents (e.g. art). These subtests are described in further detail in chapter 2.

Procedure

Attention/Concentration tests were administered in a quiet room in the participants' homes.

None of the children had completed any aspect of the Children's Memory Scale prior to this. Standardised instructions as set out in the test manual were adhered to. Presentation of the subtests was randomised within participant testing sessions.

Results

Table 5–1 presents the means and standard deviations for the three groups on Attention/Concentration scores.

Table 5–1. Means (M) and standard deviations (SD) on Attention/Concentration scores for savant, non-savant and TD comparison groups

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Attention/Concentration (min. = 50, max. = 150)	129.29 (12.39)	108.32 (18.48)	128.12 (10.11)
Numbers (min. = 1, max. = 19)	17.35 (2.09)	13.42 (3.20)	16.59 (1.54)
Sequences (min. = 1, max. = 19)	12.29 (2.08)	9.32 (3.42)	12.53 (2.15)
Picture Locations (min. = 1, max. = 19)	12.94 (2.05)	10.53 (2.89)	12.24 (1.60)

The initial analysis tested the hypothesis that savants would show increased Attention/Concentration compared to non-savants. A one-way ANOVA (1-tailed) was used to compare the mean Attention/Concentration scores for the three groups. A significant main effect of group was observed, $F(2,50) = 12.40$, $p < .01$. Post hoc comparisons using the Games-Howell test revealed that whilst savants did not differ from TD comparisons (p = .951), they differed significantly from non-savants (p = .001). Non-savants differed from TD controls (p = .001). This analysis showed that savants achieved higher

Attention/Concentration scores compared to non-savants and performed at similar levels to TD children on this test. Indeed, both savant and TD groups achieved total Attention/Concentration scores in the superior range, whereas scores for the non-savant children were average. Figure 5–1 shows these results.

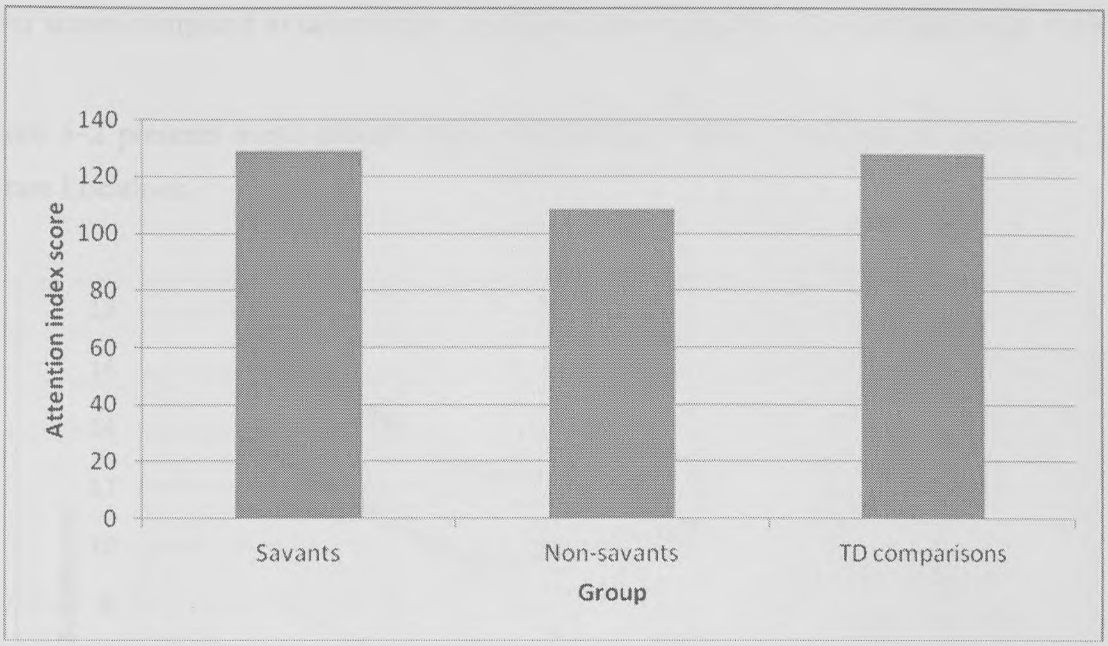


Figure 5–1. Attention/Concentration total scores for savant, non-savant and TD comparison groups

In order to determine where the group differences lie on the two subtests contributing to the Attention/Concentration total score, and to investigate possible group differences on the supplemental subtest Picture Locations, t-tests with corrections for multiple comparisons were carried out ($p = .05/3$; $p \leq .02$).

A significant main effect of Numbers was observed, $F(2,50) = 13.54$, $p < .05$. Post hoc comparisons using the Games-Howell test showed that whilst the savant group did not significantly differ from the TD group ($p = .455$), the non-savant group had significantly lower scores on this test compared to both savant ($p = .00$) and TD groups ($p = .00$).

A significant main effect of Sequences was observed, $F(2,50) = 8.29$, $p < .05$. Post hoc comparisons using the Games-Howell test showed that whilst the savant group did not significantly differ from the TD group ($p = .944$), the non-savant group had significantly lower scores compared to both savant ($p = .009$) and TD groups ($p = .005$).

A significant main effect of Picture Locations was also observed, $F(2,50) = 5.42$, $p < .05$. Post hoc comparisons using the Games-Howell test showed that whilst the savant group did not significantly differ from the TD group ($p = .509$), the non-savant group had significantly lower scores compared to savants ($p = .017$) but not compared to TD comparisons ($p = .084$).

Figure 5–2 presents mean subtest scores for the three groups on Numbers, Sequences and Picture Locations.

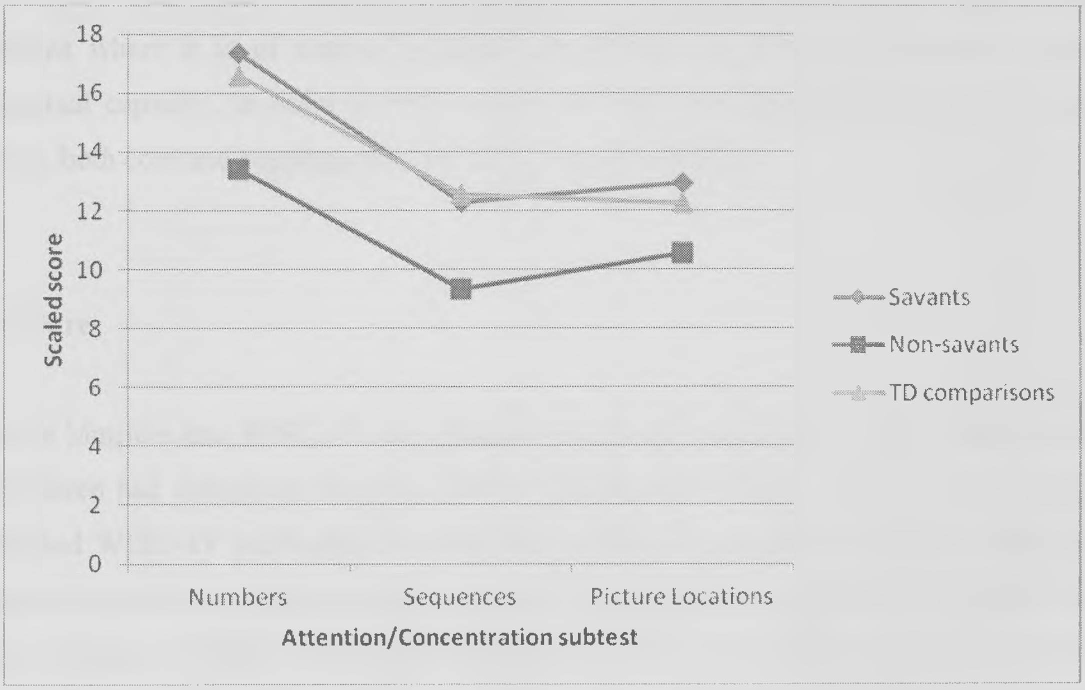


Figure 5–2. Mean Attention/Concentration subtest scores for savant, non-savant and TD comparison groups

INTELLIGENCE

Methods

Measures

Raven's Matrices assesses fluid and general intellectual functioning via the presentation of matrices with missing elements that the participant must reason with. WISC–IV measures five components of intellectual functioning, as described in chapter 2: VCI, PRI, WMI, PSQ and FSIQ. The test manual advises administration of both core and supplemental subtests in situations where it is of import to obtain the greatest amount of information regarding intellectual capacity. In order to fully explore the intellectual profiles of savants and non-savants, both core and supplemental subtests were administered.

Procedure

Raven's Matrices and WISC–IV was administered in the participants' homes. While none of the children had completed Raven's Matrices before, two children in the savant group had completed WISC–IV previously. For one child WISC–IV assessment had taken place three years prior and here re-administration was deemed appropriate considering the length of time that had elapsed. Another child had completed core WISC–IV subtests three months before taking part in the study. His results were used with parental permission and only supplemental subtests were administered to him. Considering the length of a full WISC–IV, children were typically administered this test over two testing sessions. Subtests were presented in the order specified by the test manual. Standardised instructions were adhered to and participants took breaks as required.

Results

Raven's Matrices

Table 5–2 presents the means and standard deviations for the three groups on Raven's Matrices raw scores. Scores are out of a possible maximum of 60.

Table 5–2. Means (M) and standard deviations (SD) on Raven's Matrices raw scores for savant, non-savant and TD comparison groups

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Raven's Matrices (raw score)	45.18 (8.87)	37.95 (9.03)	45.24 (5.90)

A one-way ANOVA (1-tailed) was used to compare the mean Raven's Matrices scores for the three groups. A highly significant main effect of group was observed, $F(2,50) = 4.89$, $p < .05$. Post hoc comparisons using the Tukey HSD test revealed that whilst savants did not differ from TD comparisons ($p = 1.00$), they differed significantly from non-savants ($p = .027$). Non-savants differed from TD controls ($p = .026$). This analysis showed that savants achieved higher Raven's Matrices scores compared to non-savants and performed at similar levels to TD children on this test.

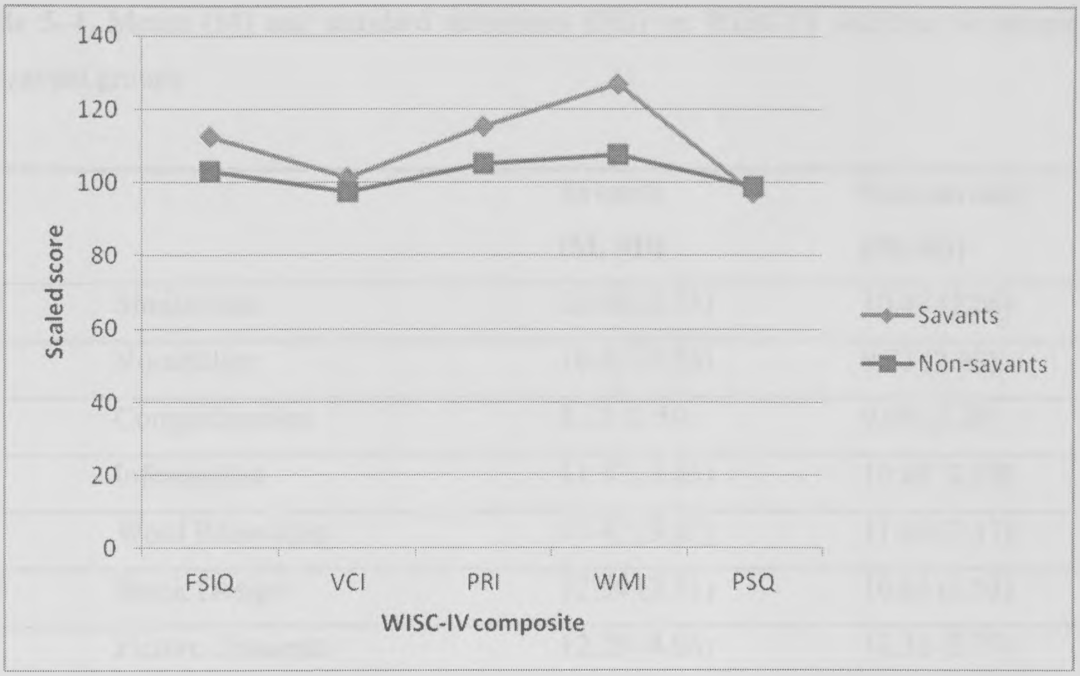
Wechsler Intelligence Scales for Children

Table 5–3 presents the means and standard deviations for both groups on WISC–IV composite scores. The range of scores for each composite is also presented. Scores are out of a possible maximum of 160.

Table 5–3. Means (M) and standard deviations (SD) on WISC–IV composites for savant and non-savant groups

	Savants (M, SD)	**Range**	**Non-savants (M, SD)**	**Range**
FSIQ	112.35 (19.13)	81 – 137	102.95 (13.90)	70 –120
VCI	101.29 (17.78)	67 – 134	97.26 (9.20)	77 – 110
PRI	115.12 (20.82)	75 – 149	104.95 (12.70)	75 – 119
WMI	126.76 (15.87)	80 – 148	107.63 (13.90)	88 – 132
PSQ	96.94 (14.72)	80 – 121	98.84 (17.27)	59 – 123

An independent samples t-test revealed that savants and non-savants did not significantly differ on FSIQ, $t(34) = 1.70, p > .05$. Indeed, the two groups were matched on FSIQ and this was discussed in chapter 2. Further tests were carried out to investigate group differences on VCI, PRI, WMI and PSQ, and this was done with corrections for multiple comparisons ($p = .05/4; p \leq .01$). A non-significant difference was observed on VCI ($t(34) = .840, p > .05$), PRI ($t(34) = 1.75, p > .05$) and PSQ ($t(34) = -.353, p > .05$). However, a significant difference was observed on WMI with savants scoring higher than non-savants, $t(34) = 3.86$, $p < .05$. Figure 5–3 presents these findings where group differences on WMI are clearly observed.



Note: FSIQ = Full scale IQ, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, WMI = Working Memory Index, PSQ = Processing Speed Quotient

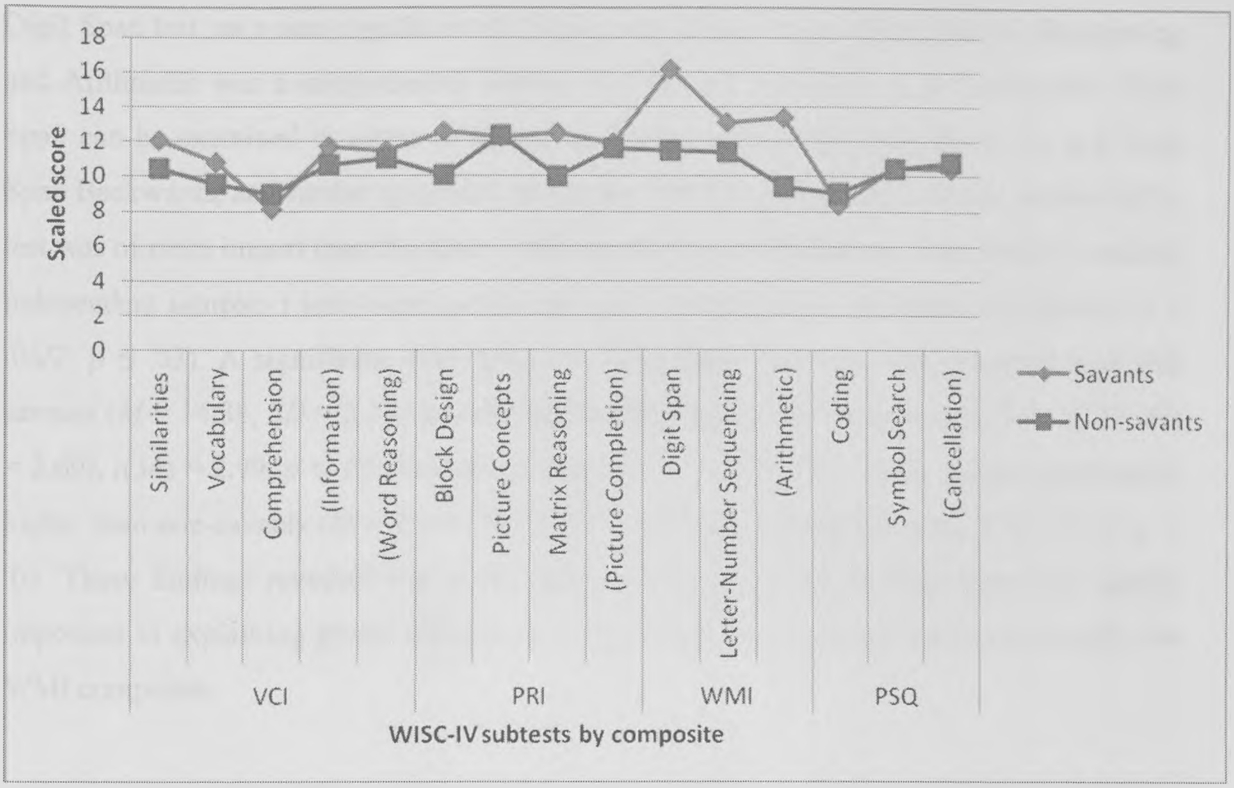
Figure 5–3. WISC–IV composite scores for savant and non-savant groups

Further investigation of the subtest profiles was carried out. Table 5–4 presents the means and standard deviations for savants and non-savants on intelligence subtests. Scores are out of a possible maximum of 19.

Table 5–4. Means (M) and standard deviations (SD) on WISC-IV subtests for savant and non-savant groups

		Savants (M, SD)	**Non-savants (M, SD)**
VCI	Similarities	12.06 (2.75)	10.47 (2.06)
	Vocabulary	10.82 (3.75)	9.53 (2.63)
	Comprehension	8.12 (3.50)	9.00 (2.29)
	Information	11.71 (3.65)	10.68 (2.69)
	Word Reasoning	11.47 (3.62)	11.05 (2.17)
PRI	Block Design	12.59 (3.71)	10.05 (2.55)
	Picture Concepts	12.29 (4.06)	12.32 (2.79)
	Matrix Reasoning	12.47 (4.00)	10.00 (3.06)
	Picture Completion	11.88 (2.98)	11.58 (3.52)
WMI	Digit Span	16.18 (2.96)	11.47 (2.57)
	Letter-Number Sequencing	13.12 (3.30)	11.42 (3.04)
	Arithmetic	13.35 (4.09)	9.42 (3.32)
PSQ	Coding	8.35 (2.23)	9.05 (3.31)
	Symbol Search	10.53 (3.16)	10.42 (3.32)
	Cancellation	10.47 (2.37)	10.79 (3.53)

Figure 5–4 presents these means via line graph where similarities and differences between the groups can be observed more readily. Supplemental subtests are denoted in brackets.



Note: VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, WMI = Working Memory Index, PSQ = Processing Speed Quotient

Figure 5–4. WISC–IV subtest scores for savant and non-savant groups

From consideration of Table 5–3 and Figure 5–4 savants and non-savants appear to be more similar than dissimilar on the majority of intelligence subtests. This is especially true for VCI and PSQ subtests. This is not surprising considering that groups did not statistically differ on these composites. The most noticeable discrepancies appeared on WMI subtests as predicted. Independent samples (1-tailed) t-tests were carried out on Digit Span, Letter-Number Sequencing and Arithmetic with corrections for multiple comparisons ($p = .05/3$; $p \leq .02$). A significant main effect of Digit Span was observed with savants scoring much higher than non-savants on this test, $t(34) = 5.10$, $p < .05$. Savants did not, however, differ from non-savants with regard to performance on Letter-Number Sequencing, $t(34) = 1.61$, $p > .05$. A significant main effect of Arithmetic was observed with savants scoring higher than non-savants, $t(34) = 3.18$, $p < .05$.

These results indicated that group differences on WMI were driven by performance on the

Digit Span test, as a non-significant difference was observed on Letter-Number Sequencing and Arithmetic was a supplemental subtest that did not contribute to the composite. Digit Span can be examined in terms of its two individual tests, Digit Span Forwards and Digit Span Backwards, and further questions concerned whether performance on one portion of the test was of more import than the other in driving the group differences. Two further (1-tailed) independent samples t-tests were carried out with corrections for multiple comparisons (p = .05/2; $p \leq .03$). A significant main effect of Digit Span Forwards was observed such that savants (M = 14.88, SD = 2.32) scored significantly higher than non-savants (M = 12.37, SD = 2.69), $t(34) = 2.99$, $p < .05$. Similarly, savants (M = 15.06, SD = 2.54) scored significantly higher than non-savants (M = 10.16, SD = 2.67) on Digit Span Backwards, $t(34) = 5.63$, $p < .05$. These findings revealed that performance on both portions of Digit Span was equally important in explaining group differences on the Digit Span subtest, and, more broadly, the WMI composite.

Lastly, it was predicted that savants would score higher than non-savants on two performance subtests, Block Design and Matrix Reasoning. Independent samples (1-tailed) t-tests were carried out with corrections for multiple comparisons (p = .05/2; $p \leq .03$). A significant main effect of Block Design was observed such that savants scored higher than non-savants on this test, $t(34) = 2.41$, $p < .05$. A significant main effect of Matrix Reasoning was also revealed with savants scoring higher than non-savants, $t(34) = 2.10$, $p < .05$. As performance on Block Design is reliant upon bonus points awarded for speed, a final question asked if savants would continue to out-perform non-savants once time bonuses had been omitted. An independent samples t-test was carried out on Block Design NTB scores and tested this hypothesis (see chapter 2 for details regarding this score). A significant main effect was observed: savants (M = 12.06, SD = 3.72) scored higher than non-savants (M = 10.00, SD = 2.47) on Block Design even after bonus points for speed had been removed from the calculation, $t(34) = 2.0$, $p < .05$. This suggested that savants have superior visuo-spatial construction abilities compared to non-savants, even when the effects of savants being faster are factored out.

CHAPTER SUMMARY AND BRIEF DISCUSSION

The findings from this group study investigating the cognitive correlates of savant skills were consistent with the results from the case studies presented in chapter 3. Savant children with ASD were characterised by greater attention spans in relation to other children with the same diagnoses but without savant skills. Similar results were observed on all three subtests probing Attention/Concentration: while savants did not differ in performance compared to TD comparisons, they significantly outperformed non-savants on all subtests of attention and this included a measure of visuo-spatial memory. The greatest between-group difference was observed on the Numbers subtest which is identical in nature to the Digit Span subtest from the Wechsler Intelligence Scales, where again savants outperformed non-savants. Indeed, significant group differences between savants and non-savants were observed on the working memory composite of the WISC–IV (but no other composite) and post hoc analyses revealed that this difference was driven by Digit Span alone. Further analysis revealed superior performance of savants on both forwards and backwards portions of Digit Span. This indicated that the additional cognitive load of manipulating and reorganising numerical information (Digit Span Backwards) was just as important in revealing group differences, as was simple rote memory of digits (Digit Span Forwards). Savants also outperformed non-savants on the Arithmetic subtest and this is in consistent with previous findings (e.g. Hill, 1982). Results showing superior Digit Span and Arithmetic are perhaps unsurprising considering that the majority of savants (12 out of 17) were skilled in numerical domains. However, it is worth noting that almost 30% of savants were not skilled in numerical domains and for four out of five of these children Digit Span scores were in the very superior range. In line with previous research investigating the subtest profiles of groups of savants compared to non-savants, superior performance on Block Design was observed as well as superior Matrix Reasoning and Raven's Matrices.

Group data presented in chapters 4 and 5 revealed some interesting differences between savant and non-savant children with ASD. The results from chapter 4 showed that savants were less impaired on the measure of imagination and creativity, but that they did not differ from non-savants on the other constructs of symptom severity (e.g. socio-communication, repetitive behaviour scores). Savants and non-savants were not found to differ across three levels of obsessionality: numbers of obsessions, content and extent of obsessional behaviour.

Savants were also less impaired in those areas of sensory processing that are related to their skills (e.g. auditory filtering, visual/auditory sensitivity). Chapter 5 has examined focussed attention and intelligence profiles and has revealed findings that are consistent with both previous research and the case studies presented in chapter 3. Savants were characterised by superior attention and working memory, especially with regard to Digit Span. Other intellectual strengths were recorded on specific non-verbal constructs, for example Block Design, Matrix Reasoning and Raven's Matrices. Groups were matched on full scale IQ and did not differ on verbal IQ, non-verbal IQ or processing speed factors. The finding showing superior Block Design in savants is consistent with WCC theory (e.g. Happé, 1999) and chapter 6 will investigate cognitive processing style in savant and non-savant groups. Dawson et al. (2007) have proposed that mechanisms underpinning superior Matrix Reasoning performance are implicated in talents in autism and this will be further discussed in chapters 7 and 8.

CHAPTER 6: EXAMINING THE COGNITIVE PROCESSING STYLE OF SAVANT SKILLS IN CHILDREN WITH ASD

ABSTRACT

The term weak central coherence (WCC) was coined to refer to the tendency of persons with ASD to process information according to local detail, at the expense of global meaning (Frith, 1989). Whilst it has been postulated that WCC is the preferred cognitive processing style in individuals with ASD, it has also been used to explain the overlap between ASD and savant syndrome. The results from the case studies presented in chapter 3 failed to reveal high levels of WCC, but a number of published studies have observed WCC in savants and the next step in the research was to extend the investigation of WCC in a group study. The current chapter therefore presents data for savants, non-savants and TD comparison participants on a small number of tests of local processing. Happé (1999) described WCC at different levels and in the study described in this chapter the theory was tested using traditional markers of visuospatial-constructional and verbal-semantic coherence. As the three children described in chapter 3 excelled on the Pseudoword Decoding test, this was also included in the test battery.

The WCC theory of autism (Frith, 1989, 2003; Happé, 1999, 2005; Happé & Frith, 2006) was proposed to account for the non-social deficits observed in the disorder and to explain experimental findings not accounted for by previous deficit models (Frith & Happé, 1994). The theory postulates that those with ASD process information in a manner that is fundamentally different to that seen in typical development. While typical information processing is characterised by central coherence, defined as a drive to process information for overall gist and meaning, ASD is characterised by 'weak' central coherence. This then predisposes detail-focussed information processing, where individual elements possess increased salience and the importance of global context is reduced. The inability to see the wood for the trees is the example often given when describing WCC (Frith, 1989, Wolman, 2010). Frith (1989, 2003) proposes that the notion of WCC maps directly onto one of the diagnostic criterion for autistic disorder: persistent preoccupation with parts of objects (DSM–IV, APA, 1994). It is also reminiscent of Kanner's (1943) early reports of children who could not "experience wholes without full attention to the constituent parts" (as cited in Frith, 2003, p. 168). In 1999 Happé suggested that this piecemeal processing characteristic of ASD is best regarded as a cognitive style and this was important in complementing existing deficit models (e.g. Theory of Mind, Baron-Cohen, Leslie & Frith, 1985; Executive Dysfunction, Hill, 2004) that could not explain talents and skills in ASD. A major strength of WCC theory is that it is able to explain both deficits and assets in ASD. As an example, the model predicts poorer performance on tasks requiring an appreciation of global meaning but enhanced performance on tasks requiring attention to local information.

Support for WCC has been drawn from a number of studies of participants with ASD and matched controls using cognitive tests where attention to local detail results in superior performance. Indeed, Happé (1999, 2005) collected evidence for WCC across three levels of processing, namely in the domains of perceptual, visuo-spatial and verbal-semantic coherence. Further support for the studies has also been drawn from biological studies (see Frith, 1997, for a brief review) and studies examining the cognitive processing style of parents of individuals diagnosed with ASD (e.g. Bölte & Poustka, 2006; Briskman, Happé & Frith, 2001). However, a number of studies have failed to show autism superiority on tests of local processing whilst other research has failed to reveal autism-specific deficits in global processing (e.g. Brian & Bryson, 1996, Ozonoff, Pennington & Rogers, 1991, Plaisted, Dwettenham & Rees, 1999, Ropar & Mitchell, 1999, 2001). A detailed review of empirical data investigating WCC in ASD has been provided by Frith & Happé (2006) and will not be further discussed here. Instead the following section is focussed on those studies that are of direct relevance to the experiments presented in this chapter and the association between a local bias and savant skills in ASD.

It has been suggested that performance peaks on tests such as Block Design and Embedded Figures reflect a preference for segmental over holistic processing (Frith, 1997). The underlying premise is that successful completion of both tasks requires that larger geometric shapes are mentally segmented into smaller units (Frith, 2003; Rajendran & Mitchell, 2007). For example, one test (Block Design) requires that visually presented designs are mentally segmented into their constituent components before they can be reconstructed using a set of patterned blocks. In the other task (Embedded Figures) participants are asked to locate a small target shape that is embedded in images of everyday items (e.g. a pram) that are composed of different lines and shapes. In this way these tests rely upon an ability to resist the overall global form in order for the constituent parts to be teased apart from the Gestalt. As such it is not surprising that these tests have traditionally been considered markers for WCC (Frith, 1989, 2003, Frith & Happé, 2006).

In one of the first experimental studies to examine autistic performance on the Block Design test, Shah & Frith (1993) presented a systematic variation of this task to two groups of individuals with autism (high IQ and low IQ) and two control groups (TD and learning-disabled). While conditions of spatial orientation yielded non-significant results, those in the autism groups performed better than controls when presented with un-segmented designs and this was irrespective of ability or age. Following pre-segmentation, however, such group differences disappeared and the control groups performed as well as those with autism. Shah & Frith (1993) concluded that prior-segmentation of the designs provided no further benefit to those with autism who had likely processed the designs in terms of individual segments to begin with. The authors proposed that their results revealed an autism-specific asset in piecemeal processing thereby providing support for WCC theory. Superior performance on the Block Design test has now been observed in a number of studies (e.g. Dawson et al., 2007, Happé, 1994, Lincoln, et al., 1995, Rumsey, 1992).

The initial study using the Embedded Figures test observed increased levels of accuracy amongst low functioning children with autism compared to controls (Shah & Frith, 1983) and it became widely assumed that that the ability to disembed figures was a universal strength in ASD. However, White & Saldaña (2011) reviewed studies comparing the performance of participants with ASD and different control groups on different versions of the Embedded Figures test and concluded that this assumption might be unwarranted. Reporting on 16 papers published since the time of Shah & Frith's (1983) original study, they highlighted the fact that only two studies have replicated the accuracy difference reported in the Shah & Frith (1983) study. Whilst seven studies have reported that ASD participants are faster (but not more accurate) at locating Embedded Figures compared to controls, six studies have failed to observe any difference and one study reported lower accuracy scores for participants with ASD compared with controls. Indeed, White & Saldaña's (2011) own data contributed to the pool of studies failing to observe superior Embedded Figures performance in ASD. They tested two relatively large samples of high functioning participants with ASD who were matched to TD controls on gender, chronological age, verbal IQ and non-verbal IQ and found no group differences on either accuracy or reaction time scores (for both correct items and all items). The authors suggested that inconsistent results from studies using the Embedded Figures test might result from any combination of methodological or sampling issues and that caution should be exercised in future studies employing the Embedded Figures test as a measure of WCC. In a recent study not reviewed by White & Saldaña (2011), Pring et al. (2010) explored local processing in savant artists with ASD and compared them to ASD, MLD and TD adults. Their study also included a group of artistically talented TD students. Results indicated that the savant artists, with and without ASD, obtained higher scores on the Block Design test than the groups of ASD and MLD participants without savant talent. However, no group difference was observed for the Embedded Figures test. Pring et al. (2010) attributed the discrepancy across the Embedded Figures and Block Design tests to differences in task requirements (passive recognition vs. active construction, respectively) and suggested that "local processing alone is not sufficient to produce superior performance in savant artists; the task must also incorporate a motor element" (p. 1102). No studies to date have investigated the relationship between these two tasks across savant and non-savant children with ASD and this will be addressed in the current study. Questions about the importance of motor elements in savant skill will be addressed in the studies described in chapter 7.

While it has been proposed that WCC theory can explain splinter skills (Treffert, 1989), for example proficiency with jigsaw puzzles (Frith & Hermelin, 1969), it has also been put forward to account for more highly developed savant skills. A focus on elements or parts, may serve to equip the fledgling savant with the building blocks essential for more elaborated hierarchical knowledge. For example, Heavey et al. (1999) described how an early interest in dates precedes the emergence of calendar calculating skills in savants. Enhanced performance on visual and auditory tasks requiring segmentation skills are of particular importance in that they may provide insights into abilities sufficient for the development of savant skills in art and music. A limited number of studies have investigated this.

In the domain of music, Heaton et al. (1998) showed that musically untrained children with ASD were better than matched controls at learning labels for individual musical tones. This is the ability that underlies absolute pitch, a skill that is universally reported in musical savants

(Miller, 1989, Treffert, 2009). Interestingly, the study revealed a strong association between superior pitch memory and performance on the Block Design test. In reviewing research into absolute pitch, Takeuchi & Hulse (1993) concluded that TD children experience a developmental shift from perceiving individual features to perceiving the relations amongst features after the age of 6 years old and that acquisition of absolute pitch is rarely, if ever, observed after this time period (cited in Happé, 1999). But as Happé (1999) suggested, individuals with ASD who process information at the local level will be less affected by these developmental constraints and so their ability to learn labels for pitches may be maintained until later developmental stages. A subsequent study by Heaton (2003) noted that children with autism, who could associate a pitch with a picture for later recall, were also able to segment Gestalt musical configurations. Similar results were obtained by Mottron et al. (2000) in a study showing that musically untrained individuals with autism obtained higher accuracy scores than TD controls when asked to make same/different judgements about pairs of melodies that were manipulated at local and global levels.

It has been suggested that a diminished awareness of global information and a focus on local elements could help to account for the precision of detail in ASD art. Hou et al. (2000) reported on the commonalities of six artistic savants with autism and described how each person's art work showed remarkable attention to detail, regardless of the medium used (e.g. pencil drawings, paper art etc). Mottron & Belleville (1993) reported the case of E.C., a savant graphic artist diagnosed with autism, who showed fragmented perception and local bias on a number of tests. It was reported that E.C. did not begin compositions by sketching in their global outlines, and instead produced drawings by working from one detail to the next. Mottron & Belleville (1993) termed this strategy "construction by local progression" (p. 29). Such a drawing style has been described elsewhere (Booth, Charlton, Hughes & Happé, 2003; Low et al., 2009) and was witnessed in the child artist, A.L. described in chapter 3 of this thesis. Further support for a local processing bias in savant artists was put forward by Pring et al. (1995). These authors hypothesised that superior segmentation skill, as evidence in good performance on the Block Design test, might facilitate skill development in individuals with ASD who are graphically talented. The results from their study revealed superior Block Design performance in participants who were gifted for art compared with similarly diagnosed individuals without such skills. A control group of artistically gifted TD children also performed at high levels on the task and thus it was concluded that superior segmentation might be a general characteristic of artists, whether diagnosed with ASD or not.

More recently, Winner and colleagues observed a local processing bias, defined by superior performance on both Block Design and Embedded Figures tests in TD children gifted in realistic drawing (Drake, Redash, Coleman, Haimson & Winner, 2009).

Whilst these findings appear to provide strong evidence for a local processing bias in individuals gifted for art, results from a study by Sheppard, Ropar & Mitchell (2009) suggested an alternative theoretical account. In a study of drawing strategy in large groups of individuals with ASD and matched controls, these authors observed how participants with ASD showed a greater tendency to begin reproductions of 3D line drawings by copying the outline of the figure, compared to controls. This finding was consistent with previous studies carried out by this group (e.g. Ropar & Mitchell, 2002) suggesting that perception is less conceptual but not necessarily less global in ASD.

In addition to art, calendar calculating skills are frequently reported in ASD and as previously mentioned they have also been explained within the context of WCC. Heavey et al. (1999) observed that all of a group of 8 calendar calculating savants tested (7 of whom were diagnosed with autism) showed a strong preoccupation with specific dates, such as birthdays and events of personal significance. These authors proposed that an initial interest in particular dates served to increase exposure to day-date pairings and regularities and repetitions that are inherent in calendars. Indeed, Frith (2003) suggested that savants build upon a knowledgebase of calendar information in a piecemeal way, starting with single days and then going onto weeks, months and finally years: "just like crystals, small units of information can grow into systems from a single seed in self-replicating structures to large and beautiful patterns" (p. 164). Taken together the results from the studies described above suggest that a local information processing style is advantageous for individuals with ASD developing savant skills in domains characterised by high-levels of hierarchical information, such as music, art and calendar calculating.

In addition to describing enhanced local processing, the original formulation of WCC theory outlined a reduced tendency to process information at the global level (Frith, 1989). Studies have attempted to operationalise and test this aspect of the model within savant domains or with individuals with savant skills, but these have largely failed to reveal abnormalities in global processing. Global processing of musical stimuli appears to be intact in ASD (Heaton, 2005, Heaton, Williams, Cummins & Happé, 2007; Mottron et al., 2000) and the autistic savant draughtsman, E.C. (described above) showed an excellent ability to reproduce the proportions of presented objects, an ability that would appear to be reliant upon intact global processing. Mottron & Belleville (1993) interpreted the results from their study of E.C. as evidence of either a local or a global processing bias. They suggested that E.C. focussed on local features because local features are generally more abundant than global features. It therefore appears that whilst a local processing bias conveys an initial advantage in facilitating the acquisition of elements or details that provide building blocks for musical or artistic skills, it is not necessarily yoked to a global processing impairment. Other domains also presume intact global domain-specific knowledge. For example, whilst calendar calculating savants might initially be advantaged by a tendency to focus in on specific dates (e.g. birthdays) calendar calculating skill requires the ability to understand where these specific dates stand in relation to other dates that are a part of the same structured system. Similarly, memory for travel routes (an idiosyncratic skill which is sometimes reported in individuals with ASD) relies upon a cognitive representation of an extensive system of inter-connected routes, and spatial skills, also involved in route knowledge, relies on global processing at the perceptual level. In response to findings challenging the suggestion that ASD is characterised by a global processing deficit, Frith (2003) acknowledged that there must be a "limit" to which local processing takes precedence (p. 154) and Happé (2005) suggested that WCC may be better conceptualised as a cognitive style, in which global processing is possible, but is not the preferred processing style. This account moved closer to the account proposed by Mottron & Belleville (1993). Ropar & Mitchell's (2002) results showing that conceptual information has reduced salience in ASD should be studied in the context of savants. The mathematical savants described in chapter 2 were assessed using the WIAT–II (Wechsler, 2005) and this test includes measures of conceptual understanding within the domain. Whilst it is currently difficult to understand how conceptual understanding should be defined and operationalised within the domains of art and music, qualitative differences between talented, intellectually able individuals with and without ASD may emerge on studies testing conceptual understanding.

Given that research studies have consistently observed a local processing bias in savants with ASD, the results from the case studies described in chapter 3 are surprising. Whilst all three children obtained high test scores on the Embedded Figures test their performance on the other tests traditionally used to test WCC were mixed. For example, although the musician obtained a very superior Block Design score, scores for the other two talented individuals were in the average range. One child achieved a high score on the Picture Completion test. None of the three children obtained high scores on the Object Assembly test, and the results from the Sentence Completion Task yielded similar findings. Although the results for these case studies failed to provide strong evidence for a local processing bias in individuals with savant skills such a bias has been revealed in a substantial number of group studies into savant syndrome so will be further investigated. In this study the small battery of WCC tasks used in chapter 3 was used to test groups of savant and non-savant participants with ASD, as well as a group of TD controls. Tasks included three subtests from standardised measures of intelligence (Block Design, Object Assembly and Picture Completion), a test of hidden figures (Children's Embedded Figures Test) and a brief test of verbal coherence requiring global sentence completions (Sentence Completion Task). A test of decoding ability (Pseudoword Decoding) was also included in the battery. Decoding relies on an ability to break whole words down into their constituent parts and individuals who show attention to local information may be advantaged on this test. All three case study children performed well on this activity during individual achievement testing, and this motivated the decision to include this test as a new measure of WCC.

The hypothesis to be tested in this chapter was that children with ASD and savant skills would exhibit a stronger local processing bias than both children with ASD without savant skills and TD control children.

Methods

Participants

The groups of savant (n = 17), non-savant (n = 19) and TD (n = 17) children described in chapter 2 participated in this study. As some the tasks used in the local processing test battery were not standardised tests, data from the TD control group was included in the analysis described in this chapter.

Materials

Six individual tests were utilised to assess WCC at visuo-spatial and verbal-semantic levels across the groups: Block Design, Object Assembly, Picture Completion, Children's Embedded Figures Test (CEFT), Sentence Completion Task (SCT) and Pseudoword Decoding. While the majority of these tests have been used in previous research to investigate WCC, Pseudoword Decoding was included as a new measure. Details of the tests are presented in chapter 2.

Procedure

All tests were administered in a quiet room in the participants' homes. With the exception of two savants, none of the participants had been tested on any of these tasks prior to the study. Two savants had previously completed Block Design. As this had been fairly recent for one, his scores were used with parental permission. The test was re-administered to the second savant (see procedure of chapter 5 for further details). The tasks were presented in a random order and the instructions set out in the test manuals were followed for all activities. With regard to the CEFT, the procedure described by the test manual (Witkin et al., 1971) was followed but with the addition of imposing a time limit of 30 sec per trial. This procedure was advocated by Pellicano et al. (2006) and followed by Low et al. (2009). It was adopted in the current study in order for reaction time data to be compared across groups (see section on CEFT in chapter 2 for further information). Analysis of CEFT results were carried out on accuracy (number of correctly identified targets within 30 sec across all 25 trials) as well as average reaction time data (calculated for correct responses only).

Results

One-way (1-tailed) ANOVA's tested the hypothesis that savants would show a greater local processing bias compared to control groups on all six tests of WCC. Statistical analyses are presented under individual headings below.

Subtests from the WISC

Table 6–1 presents the means and standard deviations for the three groups on tests of WCC extracted from the WISC. Scores are out of a possible maximum of 19.

Table 6–1. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on tests of WCC taken from the WISC

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Block Design	12.59 (3.71)	10.05 (2.55)	12.41 (2.12)
Object Assembly	9.82 (3.23)	8.16 (3.47)	11.65 (3.67)
Picture Completion	11.88 (2.98)	11.58 (3.52)	12.94 (1.56)

Block Design

The groups significantly differed on Block Design, $F(2,50) = 4.48$, $p < .05$. Post hoc comparisons using the Tukey HSD test revealed that whilst scores for the savant group and the TD group did not differ ($p = .982$), the non-savant had significantly lower Block Design scores than both the savant ($p = .028$) and the TD group ($p = .044$).

Object Assembly

The groups also significantly differed on the Object Assembly test, $F(2,50) = 4.56$, $p < .05$. A closer inspection of the data using post hoc comparisons (Tukey HSD) failed to reveal a significant difference between savants and non-savants ($p = .328$), or between savants and TD comparison participants ($p = .283$). The only significant difference to emerge was between non-savants and TD comparison participants ($p = .011$) with higher scores in the latter group.

Picture Completion

The groups did not significantly differ on Picture Completion, $F(2, 50) = 1.12$, $p > .05$. Savants did not identify more missing details from pictures than non-savants or TD participants.

Children's Embedded Figures Test

Table 6–2 presents the means and standard deviations for the three groups on the CEFT. Accuracy scores are out of a possible maximum of 25.

Table 6–2. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on CEFT accuracy and detection time scores

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Accuracy	21.29 (2.82)	20.32 (3.22)	21.65 (2.18)
Mean detection time per item (in sec)	6.12 (1.55)	7.56 (1.84)	6.54 (1.81)

As can be seen from Table 6–2, accuracy scores for identifying Embedded Figures were similar across the groups. The groups did not significantly differ in their ability to detect Embedded Figures, $F(2,50) = 1.11$, $p > .05$. However, it should be noted that all three groups were able to correctly locate the target shape 80% or more of the time. This suggests that performance on this task was not hindered by strong central coherence for any of the groups. An additional question concerned whether savants were faster when identifying target shapes compared to the two control groups. A significant difference was observed when the reaction time data were analysed, $F(2,50) = 3.24$, $p < .05$. Post hoc comparisons using the Tukey HSD test revealed that the savant group identified target shapes faster than non-savants ($p = .045$) although they did not differ from TD comparison participants ($p = .763$). The non-savant and TD groups did not differ from each other ($p = .202$).

Sentence Completion Task

Table 6–3 presents the means and standard deviations for the three groups on SCT data.

Table 6–3. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on SCT scores

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Completion score (max score = 20)	15.71 (3.80)	16.58 (3.20)	17.24 (2.75)
Number of local endings (max score = 10)	1.88 (1.69)	1.05 (1.08)	1.18 (1.19)

The analysis failed to reveal a significant difference between groups on the completion score, $F(2,50) = .932, p > .05$. When the number of local endings were analysed separately a non-significant difference was also observed, $F(2,50) = 1.96, p > .05$. Savants did not make more local endings than non-savants or TD comparison participants.

Pseudoword Decoding

Table 6–4 presents the means and standard deviations for the three groups on Pseudoword Decoding. Scores are out of a possible maximum of 190.

Table 6–4. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on Pseudoword Decoding scores

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Total score	110.88 (9.79)	100.42 (14.77)	114.18 (4.22)

The groups significantly differed in their ability to decode pseudowords, $F(2,50) = 8.18$, $p < .05$. Post hoc comparisons using the Games-Howell test revealed that while savants did not significantly differ from TD comparison participants ($p = .424$), non-savants obtained significantly lower scores than both savants ($p = .043$) and TD comparison participants ($p = .002$).

CHAPTER SUMMARY AND BRIEF DISCUSSION

Consistent with the results from the case studies presented in chapter 3, the findings from this group study investigating local processing as a construct for discriminating savants and non-savants with ASD were somewhat mixed. While savants performed significantly better than non-savants on the Block Design and Pseudoword Decoding tests, and were faster than non-savants in detecting Embedded Figures, the two groups did not significantly differ on the other measures of local processing. It is also important to note that savants did not significantly differ from TD comparison participants on any of the local processing measures. Indeed, whilst few group differences between savants and non-savants were observed, no significant differences were observed between savants and TD controls. This is in line with Pring et al. (2010) who found that artistic adult savants with ASD did not differ from TD comparison groups on their two measures of local processing (Block Design, Embedded Figures).

Although the savants were faster at detecting Embedded Figures than the participants in the control groups, group differences were not observed on CEFT accuracy scores. This result is consistent with a growing body of evidence (Pring et al., 2010; White & Saldaña, 2011) challenging early findings (Shah & Frith, 1983) showing autism superiority on this task. Indeed, in the current study, the TD children achieved the highest group mean on the CEFT task. Further, the TD group achieved the highest group means on the Object Assembly and Picture Completion tests, although the group difference only reached statistical significance for Object Assembly.

Thus far findings from group study data presented in chapters 4, 5 and 6 have revealed that individuals with ASD who possess savant skills differ from non-savant individuals with similar diagnoses in a number of ways. Chapter 4 revealed that whilst the groups did not differ on measures of social-communication impairment, repetitive behaviours or obsessionality, individuals with savant skills appeared to be less impaired on the measure of imagination and creativity. Savants were also less impaired than non-savants in sensory areas pertaining to skill development (e.g. auditory filtering, visual/auditory sensitivity). Chapter 5 examined cognitive correlates of savant syndrome and revealed that savants, but not non-savants, were characterised by superior attention/concentration and working memory, especially evidenced by performance on the Digit Span test. Other intellectual strengths were recorded on specific non-verbal constructs (e.g. Block Design, Matrix Reasoning). The two ASD groups did not differ on full scale, verbal, non-verbal intelligence or on processing speed and the group differences were taken as evidence for qualitatively different cognitive profiles in savant and non-savant groups. The results from the current chapter again highlighted the importance of Block Design in discriminating savants from non-savants. However, whilst savants were superior to non-savants on the Block Design and Pseudoword Decoding tests, significant differences between ASD groups were not observed on the majority of local processing tests. Recent theoretical accounts outlined by Baron-Cohen and colleagues (2009) and Mottron and colleagues (2009) have proposed that an ability to detect patterns may be implicated in savant syndrome and the studies described in chapter 7 will extend the investigation into cognitive profiles by testing pattern perception in savants, non-savants and TD children. This chapter will include an investigation into the relationship between Block Design performance and pattern perception.

CHAPTER 7: TESTING PATTERN PERCEPTION OF SAVANT SKILLS IN CHILDREN WITH ASD

ABSTRACT

Whilst early theoretical accounts of savant syndrome made reference to an enhanced ability to extract patterns, research has largely focussed on intelligence test profiles and perceptual abilities, for example in testing a local processing bias (WCC). Chapter 6 revealed mixed findings across a battery of tests assessing WCC in groups of savant and non-savant participants. However one test that revealed savant superiority was Block Design and this is consistent with findings from a number of previous studies into savant syndrome. Whilst the Block Design test has been characterised as a disembedding test, theoretical accounts of talent in ASD have specified the role of enhanced pattern perception in the emergence of savant skills. Therefore, the studies presented in this chapter explicitly tested pattern perception ability in groups of savant, non-savant and TD participants. Two newly developed tasks are introduced which assess pattern perception across two levels: extraction (recognising patterns) and production (generating pattern information). In devising pattern perception tests that mapped closely onto Block Design, a direct comparison between WCC theory (scores on Block Design) and other models implementing superior pattern skills (scores on the pattern tests) would be enabled.

In an early theory of giftedness Waterhouse (1988) hypothesised that special talents have a unique neuroanatomical underpinning and made specific reference to superior pattern perception. Waterhouse (1988) proposed a model in which special abilities are qualitatively different from general intellectual functioning. According to this model, special abilities are based on a set of skills that involve preconscious memory and processing. Specifically these skills involve 1) the ability to hold precise representations of visual images and sounds in memory and 2) recognition and manipulation of patterns involving those visual and auditory stimuli. As Waterhouse (1988) explained, a wide range of special talents (e.g. music, art, mathematics) "spring from the same global, preconscious, specific set of skills, namely, the ability to generate accurate and elaborate mental representations of images and/or sounds, and to store, manipulate, and recall these sounds – and more important – the ability to "see" or "hear" complex patterns in those mental sights and sounds" (p. 496). Hence those with special talents, including savants, are able to generate or elaborate upon complex mental representations to the extent of being able to detect complex patterns embedded within these representations. According to this model it is these precise cognitive mechanisms that give rise to unusual talents. Waterhouse (1988) discussed the principal claims of her model under seven distinct conceptualisations and used evidence to support her ideas, for example, by elaborating on the cortical mechanisms potentially supporting these processes. As the notion of superior pattern processing is of chief importance to the studies presented in this chapter, the following discussion will be focussed on this aspect of Waterhouse's model.

To support the contention that pattern recognition and pattern generation of visual and auditory representations form the core of special abilities in both savants and eminent non-disabled people, Waterhouse (1988), and later Waterhouse, Fein & Modal (1996), present data from single cases and group studies. As Waterhouse (1988) discussed, some musical savants report that they hear polyphonic patterned sounds in memory, while artistic savants have reported that they see vast patterned images in their mind's eye (Sacks, 1985). Sacks (1985) further presented the cases of calendar-calculating twin savants who generated prime numbers from a visual-mental array. Non-disabled individuals with special talents have also presented with enhanced visual and auditory recognition of patterns, and this is consistent with the data from savant case studies (Waterhouse, 1988). It has been reported that by the age of 2 years, the composer Igor Stravinsky was capable of immediate verbatim recall of songs (Gardener, 1983) and the inventor Nikola Tesla was reported to possess a capacity for mental imagery that was so outstanding that he could build and test complex machines in his mind alone (Gardner, 1985). In the domain of musical talent, both Mozart and Beethoven were reported to have said that music was always in their head (Beethoven described that music "thundered in") and this is reminiscent of the statement made by the musical savant D.B. who stated that he can hear constant drumming in his head (see chapter 3). Furthermore, a number of other outstandingly talented individuals (e.g. van Gogh, Matisse, Galton, Einstein and Proust) have been reported to possess prodigious memory for forms of mental representation, particularly visual images and auditory patterns. These gifted people may have possessed the underlying skill of pattern recognition for visual and auditory representations, but they also possessed the ability to be creative with such patterns (Waterhouse, 1988). This is an idea that was later elaborated on by Mottron et al. (2009) and will be discussed below. Waterhouse's (1988) original model was highly speculative, and in 1996 she and her colleagues revised it and provided a more in-depth account of the perceptual nature of talent, with especial regard to savant skills in ASD. In support of this they described more recent evidence suggesting that pattern identification and memory are crucial to autistic savant skill (Pring et al., 1995; Young & Nettelbeck, 1995).

Two recent theoretical accounts proposed by Baron-Cohen and colleagues (2009) and Mottron and colleagues (2009) have also moved beyond enhanced perceptual discrimination or local processing accounts to implicate higher order processes and enhanced perception of patterns in those with ASD who possess savant skills. Given the nature of classical savant skills (e.g. music, numbers) that typically involve generative output from a hierarchally organised domain-specific information base, it is plausible to suggest that these more complex explanations may shed light on savant abilities. Baron-Cohen et al. (2009) present an extended model of Baron-Cohen's (2006, 2008) systematizing account in which strong systematizing, attention to detail and sensory hypersensitivity are put forward as factors which work together to underpin talent. As the authors explain, systematizing represents the mechanism allowing information, knowledge or stimuli to be classified and interpreted within the context of a given system. A system requires the implementation of certain rules, which, when followed, enable the individual to recognise repeat patterns, in order to predict regularity: "the general formulation of what happens during systematizing is one looks for laws of the form 'if p, then q'" (Baron-Cohen et al., 2009, p. 1378). Baron-Cohen et al. (2009) provide several examples of the domains in which savants commonly excel, and explain how proficiency in all of these areas could be predisposed by hyper-systematizing ability. Savants with musical skills are fairly commonly reported and these individuals typically possess the ability to look for repeat patterns in auditory stimuli, perhaps by analysing the sequence of notes in a melody or the harmonic structure in a piece of music. Mathematical savants use systematizing when solving maths problems, as this relies on the understanding of various mathematical systems and rules in areas such as multiplication, division and square roots. Those gifted in prime number calculation operate according to the system of recognising whether a number is, or is not, a prime, and those with calendar calculating skills demonstrate their recognition of repeat patterns and regularities in calendars when they name the day of the week on which a given day will fall. Even those with excellent drawing skills can be seen in terms of their systematizing, for example in analysing space into geometric shapes or understanding the laws of perspective. The key to savant talent then lies in the ability to understand and manipulate domain-specific systems and in noting regularities and rules in the stimuli of interest, in order to make predictions about outcomes. In this way, Baron-Cohen et al. (2009) describe hyper-systematizing as a cognitive style, similar to Happé's (1999) formulation of WCC.

While hyper-systematizing is important in understanding why savants excel in certain domains (i.e. those based on a system of following rules and identifying patterns), Baron-Cohen et al. (2009) do not consider hyper-systematizing sufficient for the emergence of talent in ASD. Indeed, these authors suggest that the association between autism and talent begins at the sensory level where attention to detail arises in response to sensory hypersensitivity. Hyper-systematizing, characterised as a cognitive style, exists in conjunction with increased attention to detail in savants. Baron-Cohen et al. (2009) discuss a number of studies investigating sensory processing in various domains (e.g. visual, auditory and tactile modalities) and conclude that the research broadly suggests increased sensory sensitivity and/or discrimination in ASD compared to typical development. Within the context of hyper-systematizing and excellent attention to detail, the authors pinpoint this abnormal and heightened sensory functioning as a salient clinical factor that affects information processing from an early age and which may cause distress in some whilst giving rise to specific talents in others. It is interesting however that the results from sensory profiles of groups of savant and non-savant children presented in chapter 4 did not reveal greater sensory sensitivity in the savants and this was in line with earlier findings from the questionnaire study carried out by Bennett & Heaton (2012). In the study described in chapter 4, a small difference was observed between savant and non-savant groups on the sensory sensitivity measure, but this was in the direction of reduced sensory impairment in the savant group. Examination of the two subscales measuring factors associated with savant skills (music and art) showed that savants were significantly less impaired in the domain of auditory filtering and there was a marginal trend for reduced impairment in visual/auditory modalities. Whilst this evidence suggests that the types of sensory sensitivities that impact on everyday functioning in ASD are less severe in savants than non-savants the test used could not address questions about attention to detail and this will be further discussed in chapter 9. Whilst evidence for systematizing ability in ASD clearly exists (Baron-Cohen, Leslie & Frith, 1986; Baron-Cohen, Richler, Bisarya, Gurunathan & Wheelwright, 2003; Baron-Cohen, Wheelwright, Scahill, Lawson & Spong, 2001) to date no studies have investigated possible systematizing differences in groups of savant and non-savant individuals with ASD. Systematizing explicitly requires a faculty with law-based pattern recognition systems and the studies presented in the current chapter will investigate pattern recognition in savants and non-savants with ASD.

Mottron and colleagues (Mottron & Burack, 2001) have proposed the Enhanced Perceptual Functioning (EPF) model of autism, recently updated to include eight new principles of autistic perception (Mottron, Dawson, Soulières, Hubert & Burack, 2006). The basic premise of this early model is that individuals with ASD demonstrate an over-development of low level (domain-specific) perceptual abilities at the expense of higher level (domain-general) processing. This theory is supported by evidence of superior ASD perception on cognitive tasks assessing visual and auditory modalities, atypically high use of perception in complex cognitive tasks and in the orientation of behaviours that are perceptually based in day-to-day life (discussed in Mottron et al., 2006). The model also fits well with the characteristic profile of savants who, by nature of the syndrome, show specific concentrated expertise in very narrow areas of interest. The most recent account of EPF (Mottron et al., 2009) includes an additional component to the model based on ideas concerning enhanced pattern detection in savant cognition. This represents a clear gain in theoretical thinking considering that abilities like calendar calculation are not well understood within the context of a local bias or enhanced perception model. Mottron et al. (2009) speculate that pattern recognition in structured material is uniquely preserved in ASD and, as such, the perceptual mechanisms that underpin pattern recognition play a key role in the interests and skills of autistic people. Hence pattern detection mechanisms are thought to be especially active in ASD and the recognition of perceptual similarities amongst stimuli may provide the "root" of savant ability (p. 1386). Moreover, the detection of similarity amongst perceptual patterns may orient savants toward their principal materials of interest – those that consist mainly of structured stimuli governed by rules and patterns (e.g. pitches for musicians, numerical codes for mathematicians). In their model Mottron et al. (2009) discuss the new idea of one-to-one, or veridical, mapping in savants and suggest that this results from their perception of structural similarity between two units of information. For example, calendar calculation maps days of the week to dates and perfect pitch maps pitch labels to specific tones. Mottron et al. (2009) suggest that a substantial proportion of savant talents may be underpinned by this ability for between-code mapping and they elaborate with specific examples. Pattern processing rests on the ability to integrate related information.

From this it follows that EPF views the pattern detection skills of autistic savants as a domain-general trait that allows them to recognise organisation and structure in their domains of interest. Mottron et al. (2009) discuss findings that those with autism are less efficient in detecting the relational properties of features (i.e. grouping) (e.g. Dakin & Frith, 2005), but present data from their own lab suggesting that grouping processes can be superior in ASD, at least under some conditions (Caron, Mottron, Berthiaume & Dawson, 2006). Further, redintegration is put forward as a superior mechanism in savant cognition. The idea is that structural domain-specific knowledge is extremely stable in savants and as such little information is needed in order to retrieve whole systems of information from long-term memory. For example, a calendar calculating savant can quickly access calendar knowledge with relatively few details (e.g. a person's date of birth) and very short musical cues allow a savant musician to retrieve a whole sonata. Such completions are flexible in that exposure to any part of the configuration can prompt recall of missing elements. Mottron et al. (2009) suggested that pattern completion on this scale may also account for the ability of autistic artists to complete any part of a drawing beginning from any local element (see chapter 6). However, considering the range of creative skills shown by savants with ASD, a general concept of pattern or information completion is needed. In sum, from Mottron et al.'s (2009) perspective atypical perception underlies pattern detection skills where specific principles of between-code mapping and reintegration, in conjunction with a preference for structured material, facilitate the acquisition of talent in ASD.

In order to investigate whether individuals with ASD and savant skills are characterised by superior pattern perception as recent models suggest, two new paradigms were developed to test both pattern recognition and pattern production ability in groups of savant and non-savant participants. These tests were modelled on the Block Design subtest of the WISC–IV in featuring red and white pattern elements. As Block Design has been considered a salient marker for assessing a local processing bias presumed to characterise those with ASD and savant skills, it was anticipated that pattern perception tasks closely mapped onto the Block Design test would enable a direct comparison between WCC theory (scores on Block Design) and newer models implementing superior pattern skills (scores on the pattern tasks). As recent findings have implicated motor skills in local processing for savant artists with ASD (Pring et al., 2010), one of these pattern tasks implemented a motor element very similar to that in the Block Design task while the other task did not. This chapter will test the hypothesis that savant children with ASD will be more accurate in extracting patterns and producing pattern elements than non-savants. Reaction time data will investigate group differences in processing speed during the discrimination and completion of pattern information.

Methods

Participants

The groups of savant (n = 17) and non-savant (n = 19) children with ASD participated in the studies in this chapter. In order to address the question of whether increased pattern skills are associated with savant syndrome or with ASD, a group of age and intelligence matched TD children also completed these experiments.

Materials

Pattern Extraction task

The task probes the child's ability to understand a pattern rule in order to correctly predict how a sequence may be concluded. In the experiment the child was asked to look at a presented pattern that was made up of a string of four or five elements. The last element in the pattern sequence was missing and was replaced by a question mark. A set of four options are displayed underneath the pattern for consideration (each option labelled 1–4) and the child is instructed to identify the piece that should be next in sequence. Children were timed during this activity (time recorded is in sec per test item) but no time limit was imposed. Children were informed that they could take as much time as they needed to work out their answer and were explicitly advised that it was important to be confident about their choice and not make a quick guess about which option was the correct one. The child practised with two sample items before beginning the first test item. The Pattern Extraction task included a total of 14 test items that were presented one after the other from a stimulus book. Examples of the stimulus are given below in Figure 7–1, 7–2 and 7–3.

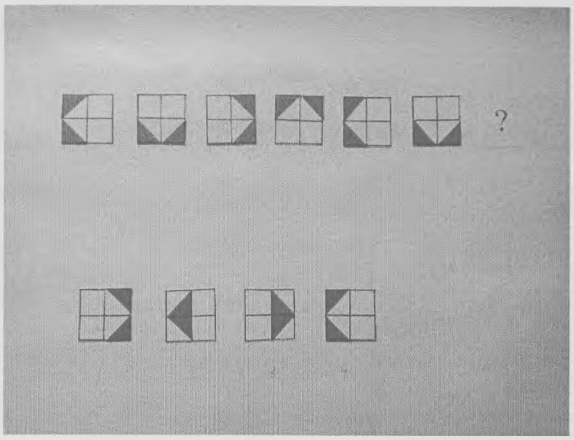


Figure 7–1. Item 5 of Pattern Extraction

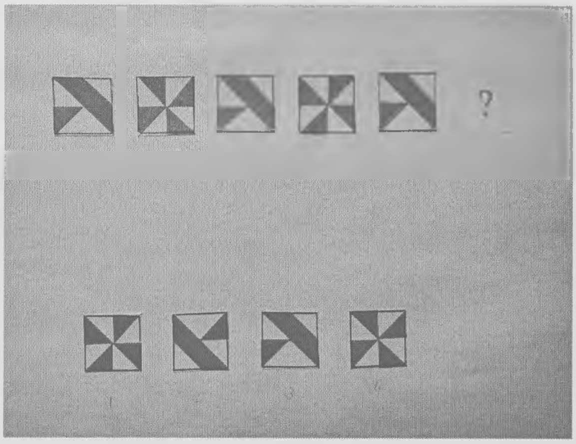


Figure 7–2. Item 10 of Pattern Extraction

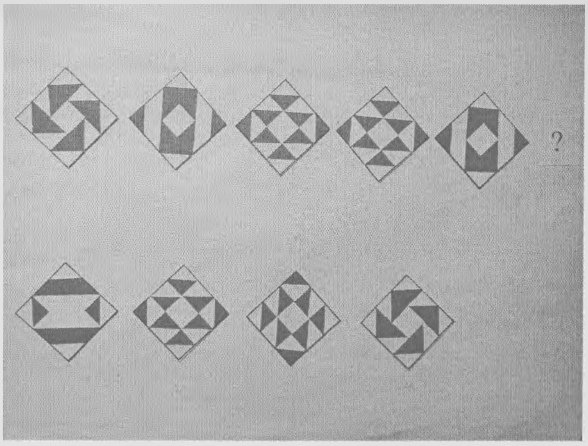


Figure 7–3. Item 14 of Pattern Extraction

Pattern Production task

The Pattern Production task differed from the Pattern Extraction task in requiring participants to build the final (completion) pattern with a set of blocks (those from Block Design). Unlike Pattern Extraction, there were no given options and in this way the Pattern Production task imposed a greater cognitive load. A distinction can be made between the two pattern tasks in terms of 1) the child's ability to understand pattern rules and predict a missing element (Pattern Extraction) and 2) the ability to understand pattern rules and to build upon this knowledge to generate pattern elements requiring use of motor skills (Pattern Production). Children were timed per item (in sec) but again, no time limit was imposed. Prior to testing the child was encouraged to practise with two sample items and this enabled them handle the blocks. The Pattern Production task included 14 test items that were presented in a stimulus book. Figure 7–4, 7–5 and 7–6 present examples of the stimulus.

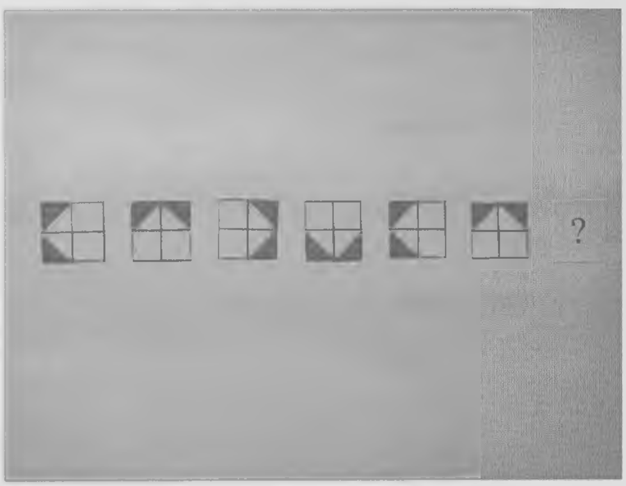


Figure 7–4. Item 5 of Pattern Production

Figure 7–5. Item 10 of Pattern Production

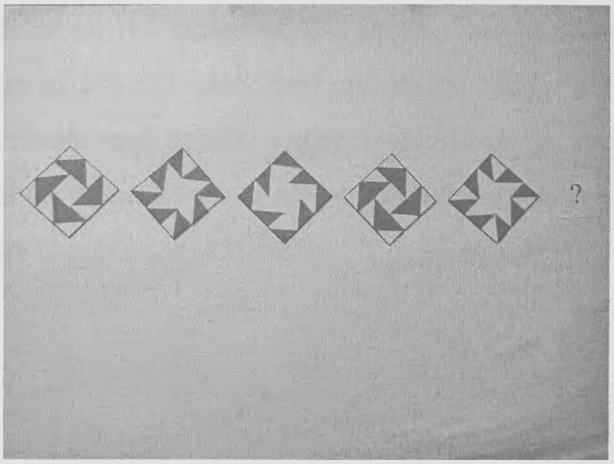


Figure 7–6. Item 14 of Pattern Production

Development of pattern perception tasks

Pattern Extraction and Pattern Production tasks were explicitly modelled on the Block Design subtest of the WISC–IV. First, both pattern tasks presented original Block Design items as the first element of each new pattern item. For example, item 5 of Block Design features a 4-block design with two white blocks arranged vertically and a white arrow made from half white/half red blocks placed to the left. Item 5 of both Pattern Extraction and Pattern Production tasks began with this exact design as the first element starting the sequence (see Figure 7–1 and 7–4, above). All 14 items of both sets of tasks began with the corresponding item from Block Design and in this way these two new tasks mapped directly onto the specifics of the images shown in Block Design. Second, the pattern tasks increased in difficulty in line with increases in difficulty in the Block Design task. The first 6 items of the two pattern tasks presented segmented pattern elements, the remaining 8 items presented pattern elements that were unsegmented. Third, in line with Block Design the first item of Pattern Production required use of 2-blocks, items 2–10 used 4-blocks and items 11–14 used 9 blocks. In imitating Block Design in these ways, the pattern tasks adhered to some of the fundamental design guidelines implemented by this classic test. Across the two pattern tasks corresponding items were similar in the patterns that they presented but they were not exact and this was to prevent simple learning of pattern rules from one task to the other. For example, note that item 10 of Pattern Production (Figure 7–5) is not the exact same pattern presented for item 10 of Pattern Extraction (Figure 7–2), rather it is a variation. All stimuli were designed and created by the author of this thesis. Pattern elements were individually made using small pieces of red and white card cut out by hand. Fine black ink was used to outline the pattern elements and denote segmentation lines on items 1–6 of both tasks. Patterns were presented on white A4 paper and presented in two separate stimulus books for each task. Separate score sheets were also made.

Procedure

Full instructions for the administration of Pattern Extraction and Pattern Production are presented in Appendix D and E, respectively. The order of administration for Pattern Extraction, Pattern Production and Block Design tests was randomised for each participant. Participants completed these tests in a quiet room of their family home. While administration time of Pattern Extraction was typically brief, the testing time for Pattern Production tended to vary depending on how quickly children were able to extract patterns and construct the missing elements. Pattern Extraction was typically completed in 5 mins, Pattern Production in 10–20 mins.

Analysis

Participants were awarded 1 point for each correct answer and totals out of 14 were summed for each test. Mean response time was calculated for correct answers only, per test. One-way ANOVA's were carried out on the data for the three groups to investigate 1) accuracy in the ability to extract and produce pattern information and 2) reaction time data. Initially, separate analyses were carried out on the Pattern Extraction and Pattern Production tests.

Results

Pattern Extraction

Table 7–1 presents the means and standard deviations for the three groups on Pattern Extraction. Scores are out of a possible maximum of 14.

Table 7–1. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on Pattern Extraction accuracy scores and mean completion time

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Pattern Extraction score	12.29 (2.08)	10.00 (2.92)	12.47 (1.18)
Mean time per item (in sec)	7.48 (1.99)	8.54 (6.85)	7.19 (1.90)

The initial analysis tested the hypothesis that savants would show increased accuracy in solving patterns compared to non-savants. A one-way (1-tailed) ANOVA was used to compare mean Pattern Extraction scores by group. Significant group differences were revealed, $F(2,50) = 7.06$, $p < .05$. Post hoc comparisons using the Games-Howell test revealed that savants and non-savants differed from each other ($p = .027$): savants correctly extracted more patterns than non-savants. Savants and TD comparison participants did not differ ($p = .950$) but the TD participants correctly extracted more patterns than the non-savants ($p = .007$). This analysis showed that savants were superior in extracting pattern information compared to non-savants, but they did not differ from TD children.

An additional question asked whether savants would be faster in extracting patterns compared to the control groups. However, a non-significant difference was observed when the reaction time data for Pattern Extraction were compared across groups, $F(2,50) = .477, p > .05$.

Pattern Production

Table 7–2 presents the means and standard deviations for the three groups on Pattern Production. Scores are out of a possible maximum of 14.

Table 7–2. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on Pattern Production accuracy scores and mean completion time

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Pattern Production score	10.29 (3.00)	8.05 (3.22)	10.71 (1.93)
Mean time per item (in sec)	35.48 (11.87)	35.10 (22.38)	48.35 (26.10)

A one-way (1-tailed) ANOVA was used to compare Pattern Production scores for the three groups. Significant group differences were revealed, $F(2,50) = 4.77$, $p < .05$. Post hoc comparisons using the Tukey HSD test revealed a strong marginal trend toward group differences between savants and non-savants ($p = .051$) in the direction of savants correctly producing more pattern elements than non-savants. Savants and TD comparisons did not differ from each other ($p = .903$) but TD participants produced more correct pattern elements than non-savants ($p = .017$).

A further analysis investigated whether savants were faster in producing pattern information compared to the control groups. Significant group differences were not revealed, $F(2,50) = 2.23, p > .05$.

Pattern Processing composite

Post hoc results from these two experiments appeared to confirm that pattern perception distinguished savants from non-savants. A clear significant difference was observed between savants and non-savants on Pattern Extraction, and a very strong trend was revealed on Pattern Production (p = .051). It was therefore of interest to investigate whether performance on these two tasks correlated. Pearson's correlations revealed that savants who had higher Pattern Extraction scores also tended to have higher Pattern Production scores, $r(17) = .746, p < .01$. A similar pattern was observed for non-savants, $r(19) = .625, p < .01$, and TD children, $r(17) = .449, p < .05$.

Considering these significant positive correlations, the decision was made to total the accuracy scores for both pattern tasks and to investigate group differences on this new variable: a pattern processing composite. Table 7–3 presents the means and standard deviations for the three groups on the composite score. Scores are out of a possible maximum of 28. Reaction time data was not further investigated as this had twice revealed non-significant findings.

Table 7–3. Means (M) and standard deviations (SD) for savant, non-savant and TD comparison groups on Pattern Processing composite scores

	Savants (M, SD)	**Non-savants (M, SD)**	**TD comparisons (M, SD)**
Pattern Processing composite	22.59 (4.76)	18.05 (5.54)	23.18 (2.67)

A one-way (1-tailed) ANOVA was used to compare pattern processing composite scores for the three groups. A significant main effect was observed, $F(2,50) = 6.98, p < .05$. Post hoc comparisons using the Tukey HSD test revealed that savants and non-savants significantly differed (p = .012): savants extracted and produced more correct patterns than non-savants. Savants and TD comparisons did not differ (p = .924) but TD children scored higher than non-savants (p = .004). This analysis confirmed superior pattern processing abilities in savants compared with non-savants.

Pattern Processing and Block Design

As the pattern perception tasks were explicitly modelled on Block Design, it was of interest to investigate whether performance on the Pattern Processing composite was correlated with Block Design performance. Pearson's correlations were carried out individually for the three groups. This revealed that savants who had higher Pattern Processing scores also tended to have higher Block Design scores, $r(17) = .539$, $p < .01$. However, performance on Pattern Processing and Block Design was not correlated for non-savants, $r(19) = .263$, $p > .05$, nor for TD children, $r(17) = .317$, $p > .05$. The significance of this result will be discussed below and in chapter 9.

CHAPTER SUMMARY AND BRIEF DISCUSSION

The findings from this chapter have added empirical weight to theoretical models that implement enhanced pattern recognition in individuals with savant skills and ASD. Savants were more accurate than non-savants on the test assessing pattern extraction and there was a very strong marginal trend for savant superiority on the test assessing pattern production. Once scores for both tasks were summed, savants were shown to perform at higher levels overall on assessments of pattern perception compared to non-savants matched on age and global IQ. Group differences in reaction time were non-significant and this indicated that while savants were superior in their ability to understand and manipulate pattern information, they did not show increased processing speed whilst doing so. While significant differences emerged between savant and non-savant groups, savants did not significantly differ from TD comparison participants in their ability to accurately detect or produce pattern information. Indeed, this finding showing similar performance between savants and TD controls mirrored those findings reported in previous chapters. Observed similarities between savant and TD groups will be further discussed in chapter 9. Interestingly, performance on Pattern Processing and Block Design tasks were significantly correlated for the savant group but not for either of the two control groups. Block Design has traditionally been characterised as a test of disembedding (Shah & Frith, 1993). However, a reconsideration of what this test measures may be required considering the positive correlation with Pattern Processing in the savants tested here. This will be discussed further in chapter 9.

Investigations into the cognitive abilities of the savant and non-savant groups tested in this thesis have revealed a number of significant differences and these were described in chapters 5–7. Chapter 5 probed intellectual profiles using a standardised IQ battery. Savant superiority was recorded on working memory, but no other differences were found on composite scores, and post hoc analyses revealed that this group difference was largely explained by the Digit Span subtest. Savant superiority was also observed on Block Design and Arithmetic subtests, as well as on tests of non-verbal fluid reasoning as measured by Raven's Matrices and Matrix Reasoning. The savant group were further characterised by enhanced attention and they also achieved significantly higher scores on Picture Locations, a measure of visuo-spatial memory. The results from the battery of tests assessing local processing in chapter 6 again highlighted the importance of Block Design in discriminating savants from non-savants and revealed savant superiority on Pseudoword Decoding – a new measure of local processing. This chapter investigated pattern perception as a cognitive marker for savantism and indicated that savants were more accurate than non-savants in analysing and producing pattern information. Chapter 8 isolates the cognitive tests where savant/non-savant group differences emerged and will further explore the relative importance of these tests for predicting savant syndrome in ASD.

CHAPTER 8: WHAT COGNITIVE CHARACTERISTICS DEFINE SAVANTS WITH ASD?

ABSTRACT

Theories tested in chapter 7 hypothesised that enhanced pattern processing skills are fundamental to savant syndrome in ASD. The results from the study described in that chapter were consistent with these accounts in revealing superior pattern processing in savants compared to non-savants matched on diagnosis, age and global IQ. The studies carried out in chapters 5 and 6 also revealed a number of differences between groups of savants and non-savants on cognitive tasks assessing attention, intelligence and a local processing bias. The analyses presented in this chapter will therefore utilise logistic regression analysis to determine how well savant and non-savant group membership can be predicted by the scores on these different tasks.

The results of cognitive testing detailed in chapters 5–7 revealed that savants performed superiorly to non-savants on a number of tests. It was observed that these tests roughly fell into two broad categories. The first of these tested basic working memory and included Attention/Concentration, Picture Locations, Working Memory Index, Digit Span and Arithmetic subtests. The second category included the new pattern processing tasks, Raven's Matrices and three subtests from the Wechsler assessments: Matrix Reasoning, Block Design and Pseudoword Decoding. Considering that performance on the Working Memory Index was found to be driven by the Digit Span test alone, the decision was made to examine Digit Span in isolation from the composite for the remainder of the thesis. Due to the high number of savants with numerical skills in the present sample, the decision was made to omit Arithmetic from further analyses as inclusion of this test may be sensitive to expertise effects. Whilst the savants were also superior on the Matrix Reasoning subtest, this tests the same construct as Raven's Matrices so was not analysed as an independent item. Logistic regression analyses were carried out with group (savant, non-savant) as the dependent variable, and the seven tests as individual predictors of group membership. The research questions addressed in this chapter asked how well savant syndrome is predicted in ASD as a function of 1) basic working memory processes and 2) pattern disembedding and perception. Although most empirical group studies of savants have revealed superior working memory in this group, this has not been ascribed a role in current theoretical models of savant syndrome (e.g. Happé, 1999; Baron-Cohen et al., 2009; Mottron et al., 2009). In contrast, superior pattern perception is an important pillar of the new models and the data analysis will directly test the extent that pattern processing predicts savant group membership. The chapter concludes by briefly considering these results in the broader context of theoretical models of savant skills in ASD.

BASIC WORKING MEMORY PROCESSES

Attention/Concentration

The Attention/Concentration index of the Children's Memory Scale primarily assesses competency in sustaining and directing attention as a function of auditory working memory and processing speed. The Numbers subtest assesses the ability to repeat random digit sequences of graduated length forward and backward, while Sequences tests the ability to order and manipulate more general verbal information (e.g. letters, days of the week, months of the year) at speed. Performance on both tests relies upon an ability to mentally manipulate and sequence information. Ultimately, these tasks were designed to place a significant demand upon the ability to attend and focus. Logistic regression analysis was conducted to investigate group membership using Attention/Concentration as a predictor. Table 8–1 presents the classification percentages for Attention/Concentration.

Table 8–1. Classification table for predicted group as a function of Attention/Concentration

Observed			Predicted		
			Group		Percentage Correct
			Savants	Non-savants	
Step 1	Group	Savants	15	2	88.2
		Non-savants	4	15	78.9
	Overall Percentage				83.3

A test of this model using the single predictor was statistically significant, indicating that Attention/Concentration reliably distinguished between savants and non-savants (chi square = 13.43, $p < .01$ with $df = 1$). Nagelkerke's R^2 of .416 indicated a very large relationship between prediction and grouping. Prediction success overall was 83.3%. The Wald criterion demonstrated that Attention/Concentration made a significant contribution to prediction (p = .004). Exp(B) value indicated that for every one unit increase in Attention/Concentration, the likelihood of being a savant increased by 1.1 times (or 8%).

Picture Locations

The Picture Locations subtest of the Children's Memory Scale assesses immediate visual memory for the spatial locations of pictured objects/subjects. The author of the Children's Memory Scale proposed that this test is highly sensitive to deficits in sustained attention and visual working memory (Cohen, 2003). As such superior performance assumes an enhanced ability to concentrate on visually presented information, to encode and hold this representation in short-term memory and to reproduce an exact reproduction of what was presented immediately after exposure. Normal right hemisphere functioning is required at minimum for successful performance and it is possible that perfect scores may relate to what has been termed photographic memory. Logistic regression analysis was conducted to examine the predictive value of Picture Locations for group membership. Table 8–2 presents the classification percentages for this variable.

Table 8–2. Classification table for predicted group as a function of Picture Locations

Observed			Predicted		
			Group		Percentage Correct
			Savants	Non-savants	
Step 1	Group	Savants	9	8	52.9
		Non-savants	7	12	63.2
	Overall Percentage				58.3

This model was statistically significant, indicating that Picture Locations reliably distinguished between savants and non-savants (chi square = 7.9, $p < .01$ with $df = 1$). Nagelkerke's R^2 of .263 indicated a large relationship between prediction and grouping. Prediction success overall was 58.3%. The Wald criterion demonstrated that Picture Locations made a significant contribution to prediction ($p = .02$). Exp(B) value indicated that for every one unit increase in Picture Locations, the likelihood of being a savant increased by 1.5 times (or 52%).

Digit Span

Digit Span is a measure of verbal short-term memory, sequencing skills, attention and focus. The forward portion of the test involves rote learning and memory, concentration, encoding and auditory processing. The backward portion rests on these same cognitive mechanisms but additionally requires competence in transforming and manipulating information. Visuo-spatial imaging may further contribute to enhanced performance, for example in the ability to "see" the digits as they are being presented and then reading them off forward or backward (Hale, Hoeppner & Fiorello, 2002). The shift from the forwards portion of this task to the backward portion requires mental alertness and cognitive flexibility. Logistic regression analysis was conducted to predict group membership using Digit Span as a predictor. Table 8–3 presents the classification percentages for this variable.

Table 8–3. Classification table for predicted group as a function of Digit Span

Observed			Predicted		
			Group		Percentage Correct
			Savants	Non-savants	
Step 1	Group	Savants	15	2	88.2
		Non-savants	4	15	78.9
	Overall Percentage				83.3

A test of this model was significant, indicating that Digit Span reliably distinguished between savants and non-savants (chi square = 18.5, $p < .01$ with $df = 1$). Nagelkerke's R^2 of .536 indicated a very large relationship between prediction and grouping. Prediction success overall was 83.3%. The Wald criterion demonstrated that Digit Span made a significant contribution to prediction ($p = .001$). Exp(B) value indicated that for every one unit increase in Digit Span, the likelihood of being a savant increased by 1.7 times (or 72%).

PATTERN DISEMBEDDING AND PERCEPTION

Pattern Processing

The Pattern Processing composite score was formed from the summation of total scores on the two newly developed pattern tests. The first test assessed the ability to extract pattern rules and to select the missing pieces from given options in order to correctly complete the pattern sequences. The second test assessed the ability to extract pattern rules, to predict the missing pieces in sequence, and to make these missing elements using 3D blocks. Successful completion of these tasks relies on the ability to detect a visual rule in order to predict what is absent. In the second task children are additionally required to use motor skills in order to produce pattern information. Logistic regression was conducted to predict group membership using the Pattern Processing composite as a predictor. Table 8–4 presents the classification percentages for Pattern Processing.

Table 8–4. Classification table for predicted group as a function of Pattern Processing

Observed			Predicted		
			Group		Percentage Correct
			Savants	Non-savants	
Step 1	Group	Savants	13	4	76.5
		Non-savants	6	13	68.4
	Overall Percentage				72.2

A test of this model using a single predictor was significant. This indicated that Pattern Processing reliably distinguished between savants and non-savants (chi square = 6.73, $p < .01$ with $df = 1$). Nagelkerke's R^2 of .228 indicated a large relationship between prediction and grouping. Prediction success overall was 72.2%. The Wald criterion demonstrated that Pattern Processing made a significant contribution to prediction ($p = .024$). Exp(B) value indicated that for every one unit increase in Pattern Processing, the likelihood of being a savant increased by 1.2 times (or 20%).

Raven's Matrices

Traditionally Raven's Matrices has been regarded as a culture-fair measure of fluid or overall general intelligence. It tests the ability to detect patterns and sequences in visually presented matrices in order to predict the element that is missing from each design. There has been some suggestion that analysis of early matrices in sets A and B requires perceptual reasoning, while the more difficult matrices (those from set C onward) depend on a greater cognitive capacity to encode and understand information at more analytical levels (Mackintosh & Bennett, 2005). Logistic regression was conducted to predict group using Raven's Matrices as a predictor. Table 8–5 presents the classification percentages for this variable.

Table 8–5. Classification table for predicted group based on Raven's Matrices

Observed			Predicted		
			Group		Percentage Correct
			Savants	Non-savants	
Step 1	Group	Savants	13	4	76.5
		Non-savants	6	13	68.4
	Overall Percentage				72.2

This model was significant, indicating that Raven's Matrices reliably distinguished between savants and non-savants (chi square = 5.88, $p < .05$ with $df = 1$). Nagelkerke's R^2 of .201 indicated a large relationship between prediction and grouping. Prediction success overall was 72.2%. The Wald criterion demonstrated that Raven's Matrices made a significant contribution to prediction ($p = .036$). Exp(B) value indicated that for every one unit increase in Raven's Matrices, the likelihood of being a savant increased by 1.1 times (or 11%).

Block Design

Block Design measures a number of non-verbal and perceptual abilities. Completion of this test involves the core ability of analysing and synthesising abstract visual information. Other cognitive mechanisms implicated in this test include non-verbal concept formation, visual organisation, learning and the ability to separate figure and ground in visual stimuli. The ability to process two streams of information simultaneously is also required, for example in integrating visual and motor processes (visual-motor coordination). More low-level mechanisms utilise visual observation, matching and disembedding. Logistic regression was carried out to predict group membership using this test as a predictor. Table 8–6 presents the classification percentages for this variable.

Table 8–6. Classification table for predicted group as a function of Block Design

Observed			Predicted: Group: Savants	Predicted: Group: Non-savants	Predicted: Percentage Correct
Step 1	Group	Savants	11	6	64.7
		Non-savants	5	14	73.7
	Overall Percentage				69.4

A test of this model was statistically significant, indicating that Block Design reliably distinguished between savants and non-savants (chi square = 5.58, $p < .05$ with $df = 1$). Nagelkerke's R^2 of .192 indicated a large sized relationship between prediction and grouping. Prediction success overall was 69.4%. The Wald criterion demonstrated that Block Design made a significant contribution to prediction ($p = .031$). Exp(B) value indicated that for every one unit increase in Block Design, the likelihood of being a savant increased by 1.3 times (or 30%).

Pseudoword Decoding

Psuedoword Decoding measures awareness of phonemes and requires use of a phonological decoding mechanism to correctly pronounce a list of non-words. While the non-words can be decoded on the basis of spelling-phoneme relationships, it is not possible to use sight-word knowledge to decode the non-words (indeed, the words are not real words). Non-words that are visually similar to real words allow individuals to read by analogy (e.g. ched, pragment), however complex non-words require the blending of multiple units in order for correct pronunciation (e.g. unfrodding, tomingly). As such the test relies on an ability to decode newly presented reading material according to its individual components and phonological rules. Logistic regression was conducted to investigate group membership as a function of Pseudoword Decoding. Table 8–7 presents the classification percentages for this variable.

Table 8–7. Classification table for predicted group as a function of Pseudoword Decoding

Observed			Predicted: Group: Savants	Predicted: Group: Non-savants	Predicted: Percentage Correct
Step 1	Group	Savants	13	4	76.5
		Non-savants	8	11	57.9
	Overall Percentage				66.7

A test of this model was significant, indicating that Pseudoword Decoding reliably distinguished between savants and non-savants (chi square = 6.14, $p < .05$ with $df = 1$). Nagelkerke's R^2 of .209 indicated a large sized relationship between prediction and grouping. Prediction success overall was 66.7%. The Wald criterion demonstrated that Pseudoword Decoding made a significant contribution to prediction ($p = .033$). Exp(B) value indicated that for every one unit increase in Pseudoword Decoding, the likelihood of being a savant increased by 1.1 times (or 8%).

These analyses have revealed the relative importance of the various tests and their associated cognitive mechanisms in predicting group membership. Both Attention/Concentration and Digit Span explained an equal share of the variance when utilised as single predictors, 83%. The Raven's Matrices and Pattern Processing composite also explained an equal proportion, 72%. Block Design explained 69% of the variance and Pseudoword Decoding 67%. Lastly, Picture Locations explained 58% of the variance.

INDEPENDENT CONTRIBUTION OF ATTENTION AND PATTERN PROCESSING

In discerning savant group membership at the cognitive level, the two most important predictors were Attention/Concentration (83%) and Pattern Processing (72%). These factors were isolated and entered into hierarchical regression analyses in order to investigate the relative and independent contribution of these variables.

The first model tested Attention/Concentration (block 1) followed by Pattern Processing (block 2). A test of the model following block 1 (Attention/Concentration) was significant (chi square = 13.43, $p < .05$ with $df = 1$). Nagelkerke's R^2 of .416 indicated a large sized relationship between prediction and grouping and overall prediction success was 88.3%. The Wald criterion indicated that this relationship was significant ($p < .05$). A test of the model at block 2 (Attention/Concentration and Pattern Processing) was also significant (chi square = 15.01, $p < .05$ with $df = 2$). When Pattern Processing was entered into the second block, Nagelkerke's R^2 increased to .455 representing an increase in explaining the variance by approximately 4%. However, prediction success with this model decreased to 77.8%. While the contribution of Attention/Concentration remained significant ($p < .05$), Pattern Processing no longer significantly contributed to explaining the variance ($p > .05$).

The second model tested Pattern Processing (block 1) followed by Attention/Concentration (block 2). A test of the model following block 1 (Pattern Processing) was significant (chi square = 6.73, $p < .05$ with $df = 1$). Nagelkerke's R^2 of .228 indicated a large sized relationship between prediction and grouping and overall prediction success was 72.2%. The Wald criterion indicated that this relationship was significant ($p < .05$). When Attention/Concentration was entered into the second block, Nagelkerke's R^2 increased to .455 representing an increase in explaining the variance by approximately 23%. Prediction success increased to 77.8% indicating that Attention/Concentration contributed to explaining the variance over and above Pattern Processing. Whilst the contribution of Attention/Concentration in the second block was significant ($p < .05$), Pattern Processing no longer significantly contributed to explaining the variance ($p > .05$).

In utilising Attention/Concentration and Pattern Processing as single variables, both predictors were shown to significantly differentiate savants from non-savants at the cognitive level. However, in examining the combined predictive value of Attention/Concentration and Pattern Processing the results from these final analyses showed that Attention/Concentration was a stronger predictor of savant status than Pattern Processing.

CHAPTER SUMMARY AND BRIEF DISCUSSION

The analyses carried out in this chapter provided further support for the suggestion that savants and non-savants differ at the cognitive level. The group comparisons had revealed differences across broad working memory and pattern processing categories and the regression analysis further showed that these factors were important in determining group membership. Thus whilst the analysis of global intelligence test scores failed to reveal a significant difference between savants and non-savants, important differences at the subtest level were observed and were associated with savant talent. Consistent with the results from previous studies (e.g. Spitz & LaFontaine, 1973; Young, 1995) superior working memory was an important factor distinguishing savants from non-savants. Indeed, attention was found to be the most important predictor of savant status within the current sample and a role for these mechanisms should be incorporated in future theories of savant syndrome. Further the test of visuo-spatial memory, Picture Locations, distinguished savants from non-savants. These findings are important within the context of pinpointing the nature of exceptional memory in savant syndrome: it might be that savant memory is characterised by specific peaks in working memory and visuo-spatial memory. Interesting findings emerged from the tests probing the second category that distinguished savants and non-savants in the group studies. Whilst chapter 6 largely failed to show that WCC is characteristic of savants, the regression analysis using Block Design and Pseudoword Decoding was significant and the inclusion of a local bias in theoretical models of savant syndrome is clearly justified. Performance on Raven's Matrices and tests of Pattern Processing distinguished savants from non-savants in the current analysis and this lends empirical weight to current models of savant skills in ASD (Baron-Cohen et al., 2009; Mottron et al., 2009). These results will be discussed in chapter 9.

CHAPTER 9: GENERAL DISCUSSION

ABSTRACT

The studies presented in this thesis have investigated the clinical and cognitive factors that are associated with savant syndrome in children with high functioning ASD. Group studies have attempted to pinpoint the cognitive constructs that are associated with talent acquisition and in doing so have revealed a number of differences between the two ASD groups. In this chapter, the results presented in the thesis will be discussed in the context of current theories of savant syndrome. In addition, limitations of the current work will be explored as well as directions for future research.

The studies described in this thesis were motivated by questions about the clinical, cognitive and behavioural substrates of savant skills in high functioning children with ASD. These questions were especially timely in the light of 1) recent redefinitions of savant syndrome which do not preclude persons without intellectual impairment if they have special skills and ASD and 2) new theoretical accounts proposing that specific cognitive abilities, relating to pattern construction or systematising will be observed in individuals with ASD and special skills. A number of differences distinguishing savants and non-savants emerged in the case and group studies described and these will be discussed in turn.

The first study described in the thesis built on results from a pilot screening study (Bennett & Heaton, 2012) that highlighted a number of factors discriminating savants and non-savants. However, these data were based on parental reports and so detailed case studies of three children with ASD and validated skills in the classic savant domains of art, mathematics and music were carried out. Assessments of symptom severity in these children revealed ADOS scores in the ASD range for two children (the mathematician and the artist), while the third child met criterion for autism. These results were consistent with results from the special skills screening questionnaire indicating that savant skills are not limited to one PDD subtype (Bennett & Heaton, 2012). Further, scores on the stereotyped behaviours factor of ADOS revealed an absence of any abnormality in these children. In order to further address questions about obsessionality, six items were drawn from SCQ and ADOS assessments and these also suggested that the children did not show exceptionally high levels of obsessional behaviour. The question of whether highly focussed attention, suggested by the screening and case studies, might better explain motivation in savant syndrome than obsessionality was discussed.

Exceptional memory has been highlighted in savants with ASD and the case study children therefore completed a standardised battery of memory tasks. However, the results from this test did not reveal exceptional general memory abilities in these children and for one child (the artist) general memory abilities were in the borderline range (between impaired and low average). In contrast to unremarkable general memory, all three children excelled on tests of working memory. Two children achieved very superior scores on the working memory index of the intelligence test battery, while for the third child working memory scores were in the high average range. The analysis of the intelligence composite scores revealed strikingly similar profiles across the three cases and a cognitive peak on the working memory composite score was observed for each child. This peak was largely driven by very superior Digit Span scores, and for two out of three children (the musician and the mathematician) performance on this test was at ceiling. Considering that two children possessed savant skills outside of the context of numerical brilliance (i.e. skills for music and art), this finding suggested that superior Digit Span may be a domain-general characteristic of individuals with ASD and savant skills. This will be discussed below within the context of the group studies.

The results from the pilot screening study (Bennett & Heaton, 2012) indicated that individuals with ASD and reported talents show a strong tendency to become absorbed in topics of interest. Indeed, this finding was also shown in a study by O'Connor & Hermelin (1991). This suggested a role for enhanced attention and motivation in the emergence and maintenance of savant skills. When tested for attention and concentration skills, two out of three case study children achieved scores in the very superior range. For the third child (the artist), attention/concentration scores were in the average range. However, performance on this element of the memory battery yielded the highest test scores for each child suggesting enhanced attention skills in these children. Results showing enhanced attention/concentration but not high levels of obsessionality were consistent with the findings from the Bennett & Heaton (2012) study and challenged current beliefs about the role of obsessions in the emergence of savant talent. This was later investigated in studies carried out with larger participant samples.

Previous research has proposed that information processing in savants is characterised by a local processing bias. However, on the tests of local processing, results for the three cases were largely mixed. Only one child achieved very superior Block Design performance (the musician) whilst scores for the other two cases were in the average range. A trend for enhanced Embedded Figures performance was revealed, but this stood in contrast to largely unremarkable scores on the Object Assembly, Picture Completion and Sentence Completion tests where it was hypothesised that a local processing bias would also convey a test advantage. The only component of the individual achievement battery that revealed elevated performance was the Pseudoword Decoding test. As it is possible that a local reading strategy may aid performance on this task it was isolated from the rest of the individual achievement battery and included in the local processing test battery administered in the group studies comparing savants and non-savants.

The findings from the case studies were used to inform group studies presented in chapters 4–7. The first group of studies described in chapter 4 examined key clinical factors that have been implicated in savant skills in ASD. In the first of three studies presented in this chapter, savants and non-savants matched on diagnosis, age and global IQ completed ADOS. ADOS is considered the gold standard by clinicians and researchers for assessing current ASD symptomatology and was selected as a comprehensive instrument for assessing each child's socio-communication deficits, repetitive behaviour and creativity. The results did not reveal a significant difference between savant and non-savant groups on the core diagnostic features of ASD. For example, group differences were not observed on ADOS total scores (a combination of communication and social interaction scores) or stereotyped repetitive behaviour scores. However, savants were significantly less impaired than non-savants on the component of ADOS that measures creativity. It was also noted that savants scored in both the ASD and autism ranges on ADOS and this was consistent with the results from the case studies and other reports suggesting that savants are not drawn from a single diagnostic subtype. Some theoretical accounts of savant syndrome have suggested that impaired social and communication skills may help explain savant skills claiming that reduced social engagement allows more time for skill related activity (Hoffman, 1971; Nurcombe & Parker, 1964; Tredgold, 1914; Viscott, 1970). Whilst intense engagement in skill related activity appears to be characteristic in savants, the results from the study failed to reveal clear associations between the presence of a savant talent and the degree of ASD symptom severity. In order to further explore questions about the behavioural correlates of savant skills obsessionality was then probed, using a parental report questionnaire study.

In this second study further investigating the clinical correlates of savant syndrome in ASD, parents of ASD participants were asked to complete an extended version of the obsessions questionnaire developed by Baron-Cohen & Wheelwright (1999). In order to determine whether obsessionality is a function of savant syndrome or of ASD, a group of intelligence and age matched TD children were included in this study. Baron-Cohen & Wheelwright's (1999) questionnaire measures numbers of obsessions and was adapted to probe both the number and the extent (i.e. high, moderate, mild) of reported obsessions. Twenty categories of obsessions were probed and these included obsessions with transport, media, sensory experiences and sorting/categorising, amongst others. As predicted, both ASD groups were reported to have greater numbers of obsessions compared to TD children although the savants and non-savant groups did not differ. Analysis of the content of obsessions revealed some overlap between the two ASD groups, showing for example that more than 50% of both ASD groups were reported to have obsessions in the areas of creative arts/fiction, sorting/categorising, sensory experiences and collecting things. However, there was a tendency for savants to be more obsessed than non-savants in functional areas. For example, almost 53% of savants were reported to be obsessed with numerical information (compared to approx. 26% of non-savants) and again almost 53% of savants were reported to be obsessed with crafts (relative to approx. 16% of non-savants). The extent, or intensity, of obsessions did not appear to differ dramatically between ASD groups. Compared to non-savants, savants achieved a slightly increased mean percentage on the highly obsessed category (30% vs. 25%). However, in order to test for statistical differences larger samples of savants and non-savants would be required. Taken together, these findings suggest that savants showed increased intensity in functional areas, although they were not more obsessional per se. Savants were reported to be interested in information that equips them to understand art and maths, both skills that were in evidence in the participants. Whilst these findings are promising, firm conclusions about the content and extent of savant obsessions could only be made on the basis of a questionnaire study with increased power. A detailed section on obsessionality may be integrated into the screening questionnaire under development (Bennett & Heaton, 2012) and validated in a future project.

In the final study investigating the clinical correlates of savant syndrome in ASD, parents of savants and non-savants completed a brief measure of sensory processing. This questionnaire probed sensory functioning across several domains. Analysis of the results revealed that the savants as a group performed in the normal range on the total sensory score, and this was in contrast to the non-savants who scored in the range of definite impairment. Whilst this finding narrowly failed to reach statistical significance the trend for reduced sensory impairment in the savant group merited further investigation. Considering the direct links between artistic and musical skills and the visual and auditory modalities, two items of the sensory questionnaire were considered in further analyses. Again the results suggested that the savants were less impaired, although it was noted that neither group performed in the normal range on these two items. These results were interesting considering that models of savant syndrome in ASD (e.g. Baron-Cohen et al., 2009) pinpoint hyper-sensory processing as a precursor for talent. However, the measure used in the study aims to identify the negative consequences of atypical sensory processing and theoretical accounts largely discuss the advantages that atypical sensory processing conveys.

Chapters 5–7 investigated the cognitive correlates of savant syndrome in children with ASD, and this was carried out with regard to a number of distinct factors. In the first study described in chapter 5, savant, non-savant and TD comparison children completed assessments of Attention/Concentration. The three case study children presented in chapter 3 had been observed to perform especially well on this aspect of the standardised memory test and it was of interest to investigate whether this finding would be replicated across groups of savants and non-savants. Whilst the savant and TD groups performed in the superior range on this test, scores for the non-savant group were in the average range. Further, savants performed better than non-savants on the supplementary Attention/Concentration test which probed visuo-spatial memory, a strength previously highlighted in the case studies. These findings revealed that savant children with ASD were characterised by higher levels of focussed attention relative to age and intelligence matched non-savant peers. Whilst questions concerning the cause and effect relationship of focussed attention cannot be addressed by the current study, the results from the screening study, the case studies and the group comparison studies all suggest that those with a specific validated talent and ASD have the ability to concentrate to significantly higher levels than their non-gifted counterparts. As Dawson & Mottron (2011) point out, strongly focussed interests in ASD have often been described as pathological and traditional notions of savantism have often presumed a high degree of obsessionality and repetitive behaviour in these individuals. However, these characteristics were not in evidence in the savants tested in this study and evidence showing superior attention in this group suggests that an alternative explanation for skill engagement in savants is warranted. An important step for future studies will be to study motivation and particularly focussed attention in autistic savants. The results from the studies suggest that savants possess a faculty for ordering and manipulating numbers, and sequencing information. This will be further discussed in the context of intelligence test profiles and pattern perception abilities in savants and in current theories of savant syndrome.

The second study presented in chapter 5 investigated intellectual profiles in savant and non-savant groups. Composite profiles revealed that these two groups did not differ on measures of verbal, non-verbal, processing speed or full scale intelligence. Indeed the groups were matched on the basis of global IQ scores and group differences on verbal and non-verbal composites were not then expected. However, one composite revealed clear between-group differences. Compared to non-savants, the savant group achieved superior working memory indexes and this was consistent with the elevated working memory scores found in the case studies presented in chapter 3. Further analysis revealed that savant superiority on working memory was largely due to group differences on the Digit Span test. Superior Digit Span is not ASD specific (Poirier et al., 2011) and indeed other investigations into savant syndrome have revealed superiority on this task (Bölte & Poustka, 2004; Rimland & Hill, 1984; Rumsey et al., 1992; Spitz & LaFontaine, 1973; Young & Nettelbeck, 1995). Such findings would seem to support a rote memory account of savant syndrome, but as other authors have discussed (Heaton & Wallace, 2004; Pring, 2008) rote memory is not a sufficient explanation for the degree of flexibility shown by savants in musical performance and artistic expression. Further, the backwards component of the Digit Span test was as important in driving the group difference as the forward component. This suggests that the manipulation and recasting of information is as important as rote memory measured by the forwards component of the test, in distinguishing savants and non-savants. It is important to note here that the majority of savants (12 out of 17) possessed validated skills in numerical domains (e.g. mathematics, calendar/prime number calculation) and that this could have biased results in the direction of savant superiority. However, five of the savants in the current sample did not possess numerical skills, and for 4 out 5 of these children Digit Span was still in the very superior range. This suggests the importance of Digit Span for savant syndrome as a domain-general cognitive skill, regardless of the specifics of the skill itself. Savant superiority was further revealed on subtests assessing Arithmetic, Matrix Reasoning and Block Design. Block

Design performance will be further discussed within the context of local processing, below.

Analysis of Raven's Matrices scores and the Matrix Reasoning scores from the WISC–IV revealed savant superiority. Matrices tests probe fluid intelligence this result implies a superior faculty with analytical, non-verbal problem solving and understanding of pattern information in savants. It is important to note that the general intelligence of savants and non-savants as measured by the more comprehensive Wechsler full scale IQ did not reveal a significant difference between the groups. Dawson et al. (2007) have observed that persons with ASD often perform better on Raven's Matrices than on measures of intellectual functioning which include verbal competency in addition to non-verbal reasoning. However, it is interesting that savants with ASD should outperform other autistic individuals on the Raven's Matrices test whilst not differing on full scale IQ. These results suggest a qualitatively different type of intelligence in those with ASD and savant skills. It has been suggested that the ability to detect patterns in stimuli is of primary importance for explaining savant syndrome in ASD and this will be discussed in more detail.

The studies described in chapter 6 investigated the cognitive style of savants and non-savants using a number of tests of local processing. In order to determine whether any local processing bias observed was characteristic of savant syndrome or of ASD, a TD comparison group also completed the tasks. The results failed to reveal significant differences between savants and non-savants on the Object Assembly, Picture Completion or Sentence Completion tests. Indeed, this finding supported those of chapter 3 in revealing largely unremarkable scores on these tests in the case study children. While savants were faster than non-savants at detecting Embedded Figures, they did not show increased levels of accuracy. However, savants did perform at significantly higher levels than non-savants on two tests: Block Design and Pseudoword Decoding. A previous study carried out by Pring et al. (2010) reported a similar discrepancy with savant superiority on Block Design but not Embedded Figures. The authors of this work concluded that local processing alone was not sufficient to produce superior performance in their group of savants; rather the addition of a motor element was required. However, savant superiority on Object Assembly, a task with a clear motor component, was not observed in the study described in chapter 6 and this challenges Pring et al.'s (2010) conclusion. Further, if Block Design and Embedded Figures tests are measuring the same cognitive mechanisms (i.e. a faculty with parts, or a local processing bias), as is often assumed, the question of why enhanced performance on both tests was not observed in chapter 6 or in the study carried out by Pring et al. (2010) is of theoretical interest. In chapter 7, new pattern processing tests were described and correlations between the composite score for these and the Block Design test were statistically significant for the savant group. It is therefore here suggested that the Block Design test may assess pattern perception in savants. In completing this test the participant is required to reconstruct patterned designs from their individual parts. Whilst good local processing is undoubtedly required to mentally segment the presented designs in the initial stage, the task can only be successfully completed if the individual knows how to piece the elements together to formulate a global patterned design. By contrast, an understanding of pattern stimuli is not required in the Embedded Figures test; rather this is a test of visual search facilitated by attention to local details. It is possible that good performance on Block Design might be explained in terms of an existing theory of pattern perception in ASD. Baron-Cohen's systematizing theory proposes the principle "if p, then q" (i.e. manipulating variables to predict the outcome). It is suggested that this is exactly what is required of the child when completing Block Design: s/he manipulates the blocks and uses trial and error to see how they fit together to make the presented designs. Indeed Baron-Cohen et al. (2009) make reference to the Rubik's cube and draw parallels between this and the Block Design test in their explanation of hyper-systematizing.

Finally, in order to directly address specific assumptions in theoretical accounts of savant syndrome outlined by Baron-Cohen et al. (2009) and Mottron et al. (2009), assessments of pattern perception were conducted. This study investigated pattern extraction (recognising patterns) and pattern production (generating pattern information) in savants and non-savants using two newly developed tests. In order to determine whether any superior pattern processing skills emerging in the study were associated with savants or with ASD, a group of matched TD children also participated in the study. While group differences were not observed in reaction times to pattern information, analysis of the pattern processing composite (a combination of pattern extraction and production scores) revealed savant superiority compared to non-savants. The results from a number of other tests involving the analysis of patterns (Raven's Matrices, Matrix Reasoning, Sequences subtest and Block Design) had revealed savant superiority and taken together the results from the cognitive studies described in the thesis offer empirical support to the recent models of savant syndrome proposed by Baron-Cohen et al. (2009) and Mottron et al. (2009). Considering the importance of working memory and attentional skills for characterising the group of savants studied here, it is recommended that future models of savant syndrome incorporate pattern recognition in conjunction with working memory as cognitive factors associated with this syndrome.

Before proceeding to a more general discussion of the findings outlined in this thesis, a note on the TD comparison participants is required. For some research questions, it was important to disentangle the contribution of ASD and savant syndrome and TD comparison participants were included in those studies. For example, whilst questions about the contribution of ASD symptom severity did not require the inclusion of a TD control group, it was important to know whether savants would be more obsessional than age and intelligence matched TD children. Similarly, whilst the comparison of cognitive profiles across ASD groups was carried out using a standardised test with norms, the pattern processing tasks were new and it was important to obtain data on how TD children would perform. An interesting finding to emerge from the study was that savants were not superior to matched TD participants on any of the cognitive measures that distinguished savants and non-savants. Thus in addition to Raven's Matrices on which the groups were matched, savants and TD controls did not significantly differ on measures of Attention/Concentration, Picture Locations, Pattern Processing, Block Design and Pseudoword Decoding. Whilst this might suggest that there are no qualitative differences between talented autistic children and typical children it should be noted that at least for tests of attention/working memory the savants were superior when considered in the context of group norms from the Children's Memory and Wechsler Intelligence Scales. This suggests that the savant cognitive profile encompasses spared as well as enhanced cognitive skills. An important consideration is that despite these similarities, the savants differed from the TD controls in meeting criteria for ASD and in showing significantly higher levels of obsessionality. Such factors are likely to influence the behavioural manifestation of cognitive strengths. The TD children were not screened for special skills and the possibility that some may have possessed such skills cannot be ruled out. The studies described in the thesis have identified a number of cognitive factors associated with special skills in ASD and it may be interesting to see whether a similar cognitive profile is associated with special skills in TD.

The observation of savant superiority on various assessments of cognition can in part be explained within current theoretical models of savantism in ASD. Baron-Cohen et al. (2009) and Mottron et al. (2009) discuss principles such as hyper-systematizing and between-code mapping, both of which rest upon explicit mechanisms of pattern recognition. For example, hyper-systematizing suggests that those with ASD and savant skills have an ability to understand repeat patterns in stimuli of interest (e.g. rules and regularities of the calendar). Between-code mapping suggests that information from one domain is mapped onto another. For example, in absolute pitch tones are mapped with verbal codes. Both models specify enhanced perception or a local bias and the process of redintergration, detailed in the Mottron et al. (2009) model, suggests an unusually stable knowledge structure that can be easily cued. A prediction from both models is that savants will demonstrate an unusual faculty with pattern processing. In the study described in chapter 7 the savants performed at higher levels than the non-savants on the new tests of pattern processing and this adds support to the suggestion that pattern processing skills are central to the development and maintenance of specific savant talents. Further, superior local processing was revealed on the Block Design and Pseudoword Decoding tasks, though not on the other measures of WCC. Whilst these findings are important in supporting the models proposed by Happé & Frith (2006), Baron-Cohen et al. (2009) and Mottron et al. (2009), other findings from the thesis suggest that these models are incomplete. Many studies of savant syndrome have observed superior working memory in this group (Rimland & Hill, 1984; Rumsey, Mannheim, Aquino, Gordon & Hibbs, 1992; Spitz & LaFontaine, 1973; Young & Nettelbeck, 1995) and the logistic regression analyses conducted in chapter 8 showed that scores on the Attention/Concentration and Digit Span tests strongly predicted savant group membership. Indeed at 83%, these tests were stronger predictors than Pattern Processing or Block Design. Future models of savant syndrome should include superior working memory as a precursor for talent.

In discussing limitations of the thesis and future directions for work in this field, one point to highlight is that the types of skills in the current sample were not represented equally amongst savants and this should be addressed in future large scale studies. While 5 out of 17 savants were gifted in art and music, 12 out of 17 savants possessed validated skills in numerical domains. It is assumed that the behavioural and clinical correlates of savant syndrome are the same for all domains. However this assumption currently lacks strong empirical support and future studies should represent different skills more evenly within samples in order to investigate similarities and differences amongst cross-domain profiles. It is recommended that such work be conducted with children and adults in order to observe how such cognitive correlates change over time. While it is noted that ASD and savant syndrome are both characterised by a disproportionate number of males to females, the studies presented in this thesis did not include any female savants. One outstanding question is whether female savants with ASD would show the same cognitive profile of enhanced working memory and pattern detection that was observed in the male savants tested here. Further, it has been suggested that savant skills may play a role in enabling researchers to genetically distinguish subgroups within the autism spectrum (Nurmi, Dowd, Tadevosyan-Leyfer, Haines & Folstein, 2003). Whilst proposed changes in the forthcoming DSM–V will move the focus away from ASD subtypes in favour of adopting an all encompassing autism spectrum diagnosis, the idea that there may be genetic correlates of savant syndrome in ASD has important implications for our understanding of ASD and therefore merits further investigation. Finally, while the aim of the current thesis was not to examine special skills in TD populations an outstanding question, highlighted by the results from the TD/savant comparison, is whether the cognitive profile associated with special skills in TD individuals is similar to that of a talented person with ASD. If special skills in TD populations rely upon the same cognitive mechanisms as special skills in ASD, then such persons may resemble talented individuals with ASD more closely than their non-gifted TD peers. Such a study would increase our understanding of talents in general and may highlight interesting similarities across gifted individuals with and without developmental disabilities.

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APPENDIX A: Special skills screening questionnaire

Special Skills Questionnaire

We are interested to collect basic information about diagnosis and talent in children with Autism Spectrum Disorders (ASD). We would be grateful if you would complete the following questionnaire. Section A asks basic questions about your child and his/her diagnosis. Section B looks at any specific talents that your child may or may not have.

SECTION A

Please answer these questions about your child and his/her diagnosis. Please circle your answer where appropriate. If your answer is OTHER for any of the questions, please specify.

Today's date: ____________________ Your child's name: ___________________________

Your child's gender: ____________ Date of birth: ___________________ Age: ____________

Your child's formal diagnosis (please circle): Autism ASD Asperger's Syndrome High Functioning Autism Developmental Delay Moderate Learning Difficulties Severe Learning Difficulties Other (please specify): _________________________________

Who diagnosed your child? (please circle): Paediatrician Clinical Psychologist Educational Psychologist Speech & Language Therapist Psychiatrist GP Other (please specify): ____

When was the diagnosis made (please specify the year or child's age): ____________________

Were any of the following used with you or your child for the diagnosis (please circle):
Autism Diagnostic Interview (ADI) Autism Diagnostic Observation Schedule (ADOS)
Pervasive Developmental Disorder Behavior Inventory (PDDBI)
Developmental, Dimensional and Diagnostic Interview (3Di)
Other (please specify):____

Have any other family members ever been diagnosed with autism, ASD or Asperger's Syndrome? YES NO
If YES, please specify whom in relation to your child: ___________________________________

SECTION B

Please answer these questions with regard to any particular talent that your child may or may not have currently. By talent we mean the presence of any *outstanding skill (or skills) that you* consider to be markedly better than your child's general skills and/or those of same aged children. Examples of skill might be, but are not limited to, musical skills (e.g. playing the piano by ear, perfect pitch), art (e.g. painting, drawing) or mathematics (e.g. performing mental calculations). Please circle either YES or NO to each question. If your answer is YES, please specify the exact nature of the skill (or skills).

1. Does your child have any musical skills that you consider to be markedly better than his/her general skills and those of same aged children? (e.g. musical performance, perfect pitch, musical recognition, musical composition etc) YES NO

If YES, please specify: ______________________________

2. Does your child have any art skills that you consider to be markedly better than his/her general skills and those of same aged children? (e.g. drawing, painting, sculpting, clay modeling, paper art etc) YES NO

If YES, please specify: ______________________________

3. Does your child have any mathematical skills that you consider to be markedly better than his/her general skills and those of same aged children? (e.g. mental arithmetic, calculating prime numbers etc) YES NO

If YES, please specify: ______________________________

4. Does your child have any memory skills that you consider to be markedly better than his/her general skills and those of same aged children? (e.g. accurate memory for detail, dates, facts, time-tables, personal events etc) YES NO

If YES, please specify: ______________________________

5. Does your child have any mechanical skills that you consider to be markedly better than his/her general skills and those of same aged children? (e.g. constructing or repairing machines, building models, advanced Lego/Meccano construction etc) YES NO

If YES, please specify: ______________________________

6. Does your child have any spatial skills that you consider to be markedly better than his/her general skills and those of same aged children? (e.g. map/route memorising, computing distances, navigation skills, jigsaw puzzles, recognising shapes/patterns etc) YES NO

If YES, please specify: ____

7. Does your child calendar calculate (e.g. is s/he able to specify the day that a person was born on for a given date)? YES NO

If YES, please specify how far forwards/backwards in time s/he can approximately calculate:

____

8. Does your child have any skill (or skills) that are not covered by the other categories? (e.g. unusual language skills, exquisite sensory discrimination, perfect appreciation of passing time without access to a clock face, outstanding knowledge in specific fields such as history or biology etc) YES NO

If YES, please specify: ____

____

____

____

APPENDIX B: Skill validation results for the savant D.U.

Calendar calculating

D.U. had the reported ability to calendar calculate for up to 4 years forwards/backwards. This was tested by asking D.U. to name the day of the week for dates from 2007 – 2015. Two dates were selected per year with a total of 18 questions presented in random order.

1. 28th February 2007 – Wednesday (correct)
2. 20th September 2007 – Thursday (correct)
3. 29th January 2008 – Monday (correct)
4. 14th June 2008 – Saturday (correct)
5. 17th April 2009 – Friday (correct)
6. 26th October 2009 – Monday (correct)
7. 31st July 2010 – Sunday (correct)
8. 7th December 2010 – Tuesday (correct)
9. 10th March 2011 – Thursday (correct)
10. 23rd September 2011 – Friday (correct)
11. 1st February 2012 – Wednesday (correct)
12. 12th May 2012 – Saturday (correct)
13. 19th June 2013 – Wednesday (correct)
14. 3rd December 2013 – Tuesday (correct)
15. 25th October 2014 – Saturday (correct)
16. 8th August 2014 – Friday (correct)
17. 16th November 2015 – Monday (correct)
18. 5th January 2015 – Monday (correct)

Total: 18/18 questions answered correctly

Prime number calculation

D.U. was asked to name as many prime numbers as possible starting from 0. He successfully named the first 500 prime numbers, as listed below.

2	3	5	7	11	13	17	19	23	29
31	37	41	43	47	53	59	61	67	71
73	79	83	89	97	101	103	107	109	113
127	131	137	139	149	151	157	163	167	173
179	181	191	193	197	199	211	223	227	229
233	239	241	251	257	263	269	271	277	281
283	293	307	311	313	317	331	337	347	349
353	359	367	373	379	383	389	397	401	409
419	421	431	433	439	443	449	457	461	463
467	479	487	491	499	503	509	521	523	541
547	557	563	569	571	577	587	593	599	601
607	613	617	619	631	641	643	647	653	659
661	673	677	683	691	701	709	719	727	733
739	743	751	757	761	769	773	787	797	809
811	821	823	827	829	839	853	857	859	863
877	881	883	887	907	911	919	929	937	941
947	953	967	971	977	983	991	997	1009	1013

General London Transport route knowledge

a) D.U. was asked 10 questions designed to assess his knowledge of public transport routes in London, using any means of public transport (e.g. bus, tube, London Overground etc).

1. West to north: How do I get from Hammersmith to Camden?
   - Piccadilly line to Kings Cross, Northern line to Camden Town (correct)
2. North to east: How do I get from Finchley Central to West Ham?
   - Northern line to London Bridge then Jubilee line to West Ham (correct)
3. East to south: How do I get from Stepney Green to Brixton?
   - District line to Westminster then 159 bus to Brixton (correct)
4. South to West: How do I get from Lambeth North to Ealing Broadway?
   - 159 bus from Lambeth North to Westminster tube station then District line to Ealing Broadway (correct)
5. North-west to north-east: How do I get from Harrow-on-the-Hill to Seven Sisters?
   - Bakerloo line to Oxford Circus then Victoria line to Seven Sisters (not quite correct, the Bakerloo line does not stop at Harrow-on-the-Hill)
6. North-east to south-east: How do I get from Leytonstone to New Cross Gate?
   - Central line to Bethnal Green then walk and take 242 to Dalston Junction, then Overheard to New Cross Gate (correct)
7. South-east to south-west: How do I get from Canada Water to Wimbledon Park?
   - Overhead to Crystal Place then 417 to Streatham, the 319 to Clapham Junction, Overhead to Wimbledon (correct)
8. South-west to north-west: How do I get from Fulham Broadway to Uxbridge?
   - District line to Ealing Common, then Piccadilly line to Uxbridge (correct)
9. North-west to south-east: How do I get from Wembley Central to Elephant & Castle?
   - Bakerloo line (correct)
10. South-west to north-east: How do I get from West Brompton to Caledonian Road?
    - District line to Gloucester Road then Piccadilly line to Caledonian Road (correct)

b) D.U. was asked 10 questions designed to assess his knowledge of bus systems serving north and south London only.

1. What is the last stop on the 150? Becontree Heath (correct)
2. What is the name of the station that the W15 will pass by? Walthamstow Central (correct)
3. Where does the 491 go? Waltham Cross to North Middlesex (correct)
4. Which night bus starts at Tottenham Court Road and ends at Aldgate? N253 (correct)
5. What bus will take me from King's Cross to Streatham Hill? 59 (correct)
6. Is the 159 a single bus, Double Decker or a bendy bus? Double Decker (correct)
7. What buses go to Thornton Heath? 198, 250 (correct)
8. Name 5 buses that go to Brixton? 109, 250, 159, 133, 159 (correct)
9. Name a night bus that goes to Elephant & Castle? N133 (correct)
10. If I were at Westminster and wanted to go to Paddington Station at night, what bus would take me there? 159 (correct)

Total: 20/20 questions answered correctly

APPENDIX C: Skill validation results for the savant K.M.

K.M. was asked to name the day of the week for dates presented from the years 1905–2299. Two dates were selected per decade. Questions were presented in a random order.

1. 13th September 1905 – Wednesday (correct)
2. 26th March 1909 – Friday (correct)
3. 10th October 1914 – Saturday (correct)
4. 21st November 1917 – Wednesday (correct)
5. 30th April 1922 – Sunday (correct)
6. 29th January 1927 – Saturday (correct)
7. 6th August 1931 – Thursday (correct)
8. 24th July 1933 – Monday (correct)
9. 19th March 1945 – Monday (correct)
10. 15th April 1948 – Thursday (correct)
11. 4th September 1950 – Monday (correct)
12. 22nd July 1956 – Sunday (correct)
13. 31st August 1961 – Thursday (correct)
14. 27th May 1967 – Saturday (correct)
15. 20th February 1974 – Wednesday (correct)
16. 13th December 1977 – Tuesday (correct)
17. 3rd June 1985 – Monday (correct)
18. 11th February 1989 – Saturday (correct)
19. 25th November 1990 – Sunday (correct)
20. 7th June 1998 – Sunday (correct)
21. 17th January 2003 – Friday (correct)
22. 1st May 2010 – Saturday (correct)
23. 18th July 2012 – Wednesday (correct)
24. 2nd August 2018 – Thursday (correct)
25. 31st October 2021 – Sunday (correct)
26. 12th December 2026 – Saturday (correct)
27. 1st February 2034 – Wednesday (correct)
28. 16th September 2035 – Sunday (correct)

29. 5th May 2044 – Monday (correct)
30. 23rd April 2049 – Friday (correct)
31. 10th November 2052 – Sunday (correct)
32. 21st July 2057 – Saturday (correct)
33. 18th April 2060 – Sunday (correct)
34. 25th June 2066 – Friday (correct)
35. 4th May 2073 – Thursday (correct)
36. 5th August 2078 – Friday (correct)
37. 20th January 2080 – Saturday (correct)
38. 9th November 2088 – Tuesday (correct)
39. 14th September 2091 – Friday (correct)
40. 27th June 2099 – Saturday (correct)
41. 30th March 2100 – Tuesday (incorrect answer given: Wednesday)
42. 29th October 2105 – Thursday (incorrect answer given: Friday)
43. 10th February 2200 – Monday (incorrect answer given: Tuesday)
44. 13th January 2299 – Friday (incorrect answer given: Sunday)

Total: 40/44 questions answered correctly

APPENDIX D: Adapted version of the Cambridge University Obsessions Questionnaire (Baron-Cohen & Wheelwright, 1999)

Obsessions Questionnaire

Today's date: ________________ Your child's name: ________________________

Your child's gender: __________ Date of birth: ___________ Age: __________

We are interested to collect basic information on obsessions. **Obsessions can be defined as "any idea that haunts, hovers and constantly invades ones consciousness".** We would be grateful if you would answer the following questions. For each category of obsession, please tick whether your child has ever had an obsession in that category. If so, please specify the exact nature of the obsession and the extent by circling either highly obsessed, moderately obsessed or slightly obsessed. Use the following key to mark your responses:

Highly obsessed: A preoccupation that is all encompassing. The person is not able to switch attention from the object of their obsession to think about or do something else.

Moderately obsessed: A preoccupation that is apparent but not all encompassing. With effort or a change of environment, the person is able to switch attention to something else.

Slightly obsessed: A preoccupation that seems quite mild. It is greater than an interest, but does not interfere with thinking about or doing other things.

1. MACHINES (how things work) (e.g. computers, radios, TVs, washing machines, clocks, burglar alarms, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

2. SYSTEMS (e.g. toilet flushing, drains, light switches, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

3. SORTING/CATEGORISING (e.g. lining objects up, arranging objects in alphabetical order or by size, shape, colour, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

4. BELIEF SYSTEMS (e.g. religion, politics, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

5. NUMERICAL INFORMATION (e.g. timetables, number plates, calculators, charts or tables of information, calculations, prime numbers, calendars, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

6. SPORTS/GAMES (e.g. football, tennis, walking, mountain climbing, swimming, cycling, ice skating, snooker, playing cards, board games, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

7. STRONGLY ATTACHED TO A PARTICULAR ITEM (e.g. an article of clothing, a rag, a bottle top, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

8. SENSORY EXPERIENCES (e.g. touching things, hearing specific sounds, lights, smells, tearing paper, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

9. CRAFTS (e.g. model making, knitting, sewing, cooking, carpentry, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

10. FACTUAL INFORMATION (e.g. writing, reading or memorising lists of things, writing letters, reading encyclopedias, newspapers, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

11. THE CREATIVE ARTS/FICTION (e.g. theatre, cinema, art work, opera, watching drama on TV/videos, playing an instrument, listening to music, writing/reading fiction, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

12. THE SCIENCES (e.g. astronomy, chemistry, geography, physics, engineering, biology, geology, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

13. ANIMALS (e.g. pets, wild or farm animals, dinosaurs, insects, fish, birds, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

14. COLLECTING THINGS (e.g. bottles, matchboxes, stamps, catalogues, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

15. PEOPLE (e.g. talking to people, a specific person, etc.)

YES ☐ NO ☐

If YES, please specify...

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

16. VEHICLES (e.g. trains, buses, planes, boats, model railways, etc.)

YES ❑ NO ❑

If YES, please specify..

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

17. SPINNING OBJECTS (e.g. tops, wheels, plates, Frisbees, coins, etc.)

YES ❑ NO ❑

If YES, please specify..

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

18. FOOD AND DRINK (e.g. consuming particular food and drink, etc.)

YES ❑ NO ❑

If YES, please specify..

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

19. PLANTS (e.g. gardening, house plants, woodland plants, seaweed, etc.)

YES ❑ NO ❑

If YES, please specify..

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

20. SPATIAL INFORMATION (e.g. maps/routes, distances, navigation, jigsaw puzzles, shapes, patterns, etc.)

YES ❑ NO ❑

If YES, please specify..

If YES, what is/was the extent of this obsession?

Highly obsessed Moderately obsessed Slightly obsessed

APPENDIX E: Instructions for the administration of Pattern Extraction

Overview

The child looks at a pattern whereby the next piece in the sequence is missing, denoted by a question mark. The child selects the missing piece in the pattern sequence from four response options.

Materials

Instructions
Score sheet
Pattern Extraction stimulus book
Stopwatch
Pen or pencil

Start

All children (regardless of age) begin with the sample items A and B, followed by item 1.

Discontinue

Administer all items. Do not discontinue. If a child experiences difficulty instruct him/her to do their best or say: **Give me your best guess**.

Timing

Accurate timing is essential. Children should be instructed to work as quickly as possible. Begin timing for each item after saying the last word of the instructions. Stop timing when it is clear from the child's words or gestures that s/he has made their selection (1, 2, 3 or 4). Record how long it took the child to complete the item (in sec).

General Directions

- Make sure instructions are clarified by pointing to the pattern, the question mark, and the response options, as you speak to the child
- The child is required to indicate their answer either by pointing to or verbally naming the number of the piece that is missing. If the child responds with any other type of verbalisation (e.g. names the picture), say: **Show me what you mean**
- Provide assistance with the sample items only

Administration

Sample A

Place the stimulus book in front of the child and turn to Sample A. Say: **Look here is a pattern** (point to the first piece of the pattern and run your finger all the way along to the end of the pattern). **The next piece of the pattern is missing** (point to the question mark). **Which one here** (point across the four response options) **comes next in the sequence?**

If the child's response is correct, say: **That's right. Let's try another one.** Proceed to Sample B.

If the response is incorrect, say: **Let's look again. The blocks are in this order** (point to each piece as you say): **white, red, white, red, white, red, white...** (pause to allow the child the opportunity to finish the sequence).

If the child answers correctly, say**: That's right – the piece that comes next is red** (point to response option 1. Proceed to Sample B.

If the child answers incorrectly or does not respond, say: **The piece that comes next is red.** If the child looks confused, re-phrase and explain why the red block comes next. Proceed with Sample B.

Sample B

Look here is another pattern (point to the first piece of the pattern and run your finger along to the end of the pattern). **The next piece of the pattern is missing** (point to the question mark). **Which one here** (point across the four response options) **comes next in the sequence?**

If the child's response is correct, say: **That's right. Let's try another one.** Proceed to Item 1.

If the child's response is incorrect, say: **Let's look again. The blocks are in this order** (point to each piece as you say): **white on the top/red on the bottom, red on the top/white on the bottom, white on the top/red on the bottom, red on the top/white on the bottom, white on the top/red on the bottom...** (pause and allow the child the opportunity to finish the sequence).

If the child answers correctly, say**: That's right – the piece that comes next has red on the top and white on the bottom** (point to response option 2). Proceed to Sample B.

If the child answers incorrectly or does not respond, say: **The piece that comes next is this one** (and point to response option 2). If the child looks confused, re-phrase and explain why this piece comes next. Proceed with Item 1.

Items 1–14

Now that we've practised, let's try some more. On the next few pages are some more patterns. Each pattern is missing the next piece in the sequence. I would like you to

work out which piece comes next. You can have as long as you need to work out your answer, but try to work as quickly as you can because I am timing you. When you have worked out which piece comes next you can either show me by pointing to the piece that comes next, or you can tell me by calling out the number – either 1, 2, 3 or 4. Make sure the child understands what s/he is supposed to do and then turn to item 1. **Which one here** (point across the response options) **comes next in the sequence?** Start timing. Record the child's response (1, 2, 3 or 4) and his/her response time. Proceed to the next item. Administer all 14 items and record the child's response and time for each.

Answers

The correct responses are listed below and on the scoring sheet.

1. 1
2. 3
3. 4
4. 2
5. 1
6. 4
7. 2
8. 3
9. 1
10. 4
11. 3
12. 2
13. 1
14. 4

Scoring

Sample items are not scored. Each item is scored either 1 (correct) or 0 (incorrect). A total out of 14 is calculated. Mean response time should be recorded for correct answers only.

APPENDIX F: Instructions for the administration of Pattern Production

Overview

The child looks at a pattern whereby the next piece in the sequence is missing, denoted by a question mark. The child uses red-and-white blocks to build the missing piece.

Materials

Instructions
Score sheet
Pattern Production stimulus book
Blocks (from Block Design)
Stopwatch
Pen or pencil

Start

All children (regardless of age) begin with the sample items A and B, followed by item 1.

Discontinue

Administer all items. Do not discontinue. If a child experiences difficulty instruct him/her to do their best or say: **Give me your best guess**.

Timing

Accurate timing is essential. Children should be instructed to work as quickly as possible. Begin timing for each item after saying the last word of the instructions. Stop timing when it is clear from the child's words or gestures that s/he has finished. Record how long it took the child to complete the item (in sec).

General Directions

- Ensure that the child sits opposite the examiner (as is the case for administering Block Design) with the stimulus book facing the child
- The designs illustrated on the score sheet represent the correct answer from your (the examiner's) perspective (upside down), with shaded areas representing the red portions of the designs
- Provide assistance with the two sample items only
- Item 1 requires the child to assemble two blocks, items 2–10 require four blocks and items 11–14 nine blocks
- Remove all unnecessary blocks from the child's view and only provide the number of blocks necessary to complete each item

Administration

To introduce the test, place two blocks in front of the child. Hold up one of the blocks and let the child examine the other block if s/he wishes. Say: **Look at these blocks. They are all alike. On some sides they are all red** (show red side); **on some sides, all white** (show white side) **and on some sides, they are half red and half white** (show red-and-white side).

Sample A

Place the stimulus book in front of the child and turn to Sample A. **Look. Here is a pattern using our red and white blocks** (point to the first piece of the pattern and run your finger along until the end of the pattern). **The next piece of the pattern is missing** (point to the question mark). **Can you make the missing piece using these blocks?** (gesture toward the two blocks)

If the child's response is correct, say: **That's right. Let's try another one.** Proceed to Sample B.

If the child's response is incorrect, say: **Let's look again. The blocks are in this order** (point to each piece as you say): **red/white, white/red, red/white, white/red, red/white…** (pause and allow the child the opportunity to finish the sequence).
If the child answers correctly, say**: That's right – the piece that comes next is white/red** (gesture for the child to build this design if s/he has not done so already by this point). Proceed to Sample B.

If the child answers incorrectly or does not respond, say: **The piece that comes next is white/red.** If the child looks confused, re-phrase and explain why this piece comes next. Assist the child to build the next piece if needs. Proceed with Sample B.

Sample B

Look here is another pattern (point to the first piece of the pattern and run your finger along all the way along the line up). **The next piece of the pattern is missing** (point to the first piece of the pattern and run your finger all the way along to the end of the pattern). **Can you make the missing piece using these blocks?** (gesture toward the two blocks)

If the child's response is correct, say: **That's right. Let's try another one.** Proceed to item 1.

If the child's response is incorrect, say: **Let's look again. The blocks are in this order** (point to each piece as you say): **red on the top/white on the bottom, white on the top/red on the bottom, red on the top/white on the bottom, white on the top/red on the bottom, red on the top/white on the bottom…** (pause and allow the child the opportunity to finish the sequence).

If the child answers correctly, say**: That's right – the piece that comes next has white on the top and red on the bottom** (gesture for the child to build this design if s/he has not done so already by this point). Proceed to item 1.

If the child answers incorrectly or does not respond, say: **The piece that comes next has white on the top and red on the bottom.** If the child looks confused, re-phrase and explain why this comes next. Assist the child to build the next piece if needs. Proceed with item 1.

Item 1

Now that we've practised, let's try some more. On the next few pages are some more patterns. Each pattern is missing the next piece in the sequence. I would like you to work out which piece comes next and try to make that piece using the blocks. You can have as long as you need to make the next piece, but try to work as quickly as you can because I am timing you. When you have finished let me know. Make sure the child understands what s/he is supposed to do and then turn to item 1. **Can you make the next piece using these blocks?** Start timing. When it is clear that the child has finished, record the child's response (either correct or incorrect) and the response time. Proceed to the next item.

Items 2–10

Place two more blocks in front of the child (four blocks altogether). Turn to item 2 (point to the question mark) and say: **Can you make the missing piece using these blocks? Work as quickly as you can and tell me when you have finished.** Start timing. When it is clear that the child has finished, record the child's response and the response time. Proceed to the next item.

Items 11–14

Place the remaining blocks in front of the child (nine blocks altogether). Turn to item 11 (point to the question mark) and say: **Can you make the missing piece using these blocks? Work as quickly as you can and tell me when you have finished.** Start timing. When it is clear that the child has finished, record the child's response and the response time.

Correcting Errors

- Any pronounced rotation of 30° or more is considered an error.
- Correct only the first rotation that occurs by rotating the blocks to the correct position and say: **See it goes this way.** Continue administration accordingly and provide no further assistance should rotation errors occur.
- Points are not awarded for otherwise correct responses that are rotated at 30° or more.

Correct Responses

The correct designs are displayed on the score sheet and are shown from the examiner's perspective (upside down).

Scoring

Sample items are not scored. Each item is scored either 1 (correct) or 0 (incorrect). A total out of 14 is calculated. Mean response time should be recorded for correct answers only.