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Discriminating Autism and Language Impairment and Specific Language Impairment on a test of voluntary musical imagery

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Abstract

Deficits in auditory short-term memory have been widely reported in children with Specific Language Impairment (SLI), and recent evidence suggests that children with Autism Spectrum Disorder and co-morbid language impairment (ALI) experience similar difficulties. Music, like language relies on auditory memory and the aim of the study was to extend work investigating the impact of auditory short-term memory impairments to musical perception in children with neurodevelopmental disorders. Groups of children with SLI and ALI were matched on chronological age (CA), receptive vocabulary, non-verbal intelligence and digit span, and compared with CA matched typically developing (TD) controls, on tests of pitch and temporal acuity within a voluntary musical imagery paradigm. The SLI participants performed at significantly lower levels than the ALI and TD groups on both condition of the task and their musical imagery and digit span scores were positively correlated. In contrast ALI participants performed as well as TD controls on the tempo condition and better than TD controls on the pitch condition of the task. Whilst auditory short-term memory and receptive vocabulary impairments were similar across ALI and SLI groups, these were not associated with a deficit in voluntary musical imagery performance in the ALI group.

Autism Spectrum Disorder. Specific Language Impairment. Musical Imagery. Auditory Short-Term Memory

1. **Introduction**

Whilst cases of selectively impaired language and musical skills (Tzortzis, Goldblum, Dan, Forette & Boller, 2000; Ayotte, Peretz & Hyde, 2002) have been taken as evidence that music and language are independent cognitive domains, researchers have become increasingly interested in the extent to which they rely on shared cognitive and neural resources. The Shared Syntactic Integration Resource Hypothesis (Patel, 2008) draws a distinction between domain-specific representational networks, which are independent and may be selectively damaged, and domain-general resource networks that process both musical and linguistic information. Evidence for domain general resource networks comes from neuroimaging studies revealing activation in Broca's area during music processing (Maess, Koelsch, Gunter, & Friederici, 2001; Sammler, Koelsch, & Friederici, 2011) and results showing that linguistic and musical syntax rely on the same integration resources in this area (Kunert, Willems, Casasanto, Patel & Hagoort, 2015).

Models of memory are also relevant to questions about shared processing resources for music and language. The Working Memory Model (Baddeley & Hitch, 1974; Williamson, Baddeley & Hitch, 2010) explains the retention of words and tones, via the recruitment of the phonological loop, but does not explain the acquisition and retention of highly structured and complex syntax in language and music. In a recent experimental study Fiveash and Pammer (2014) presented participants with word lists and complex sentences that were accompanied by music that was syntactically congruent and incongruent. The rationale for the study was that single word recall relies on the phonological loop, whilst recall of complex sentences and musical syntax also relies on the semantic working memory system (Kljajevic, 2010). Consistent with their predictions, the authors reported an interference effect of syntactically incongruous music on recall of complex sentences, but not single words.

Research identifying shared cognitive resources involved in language and music processing has implications for our understanding of musical abilities in individuals with congenital language disorders. Specific Language Impairment (SLI) is a neurodevelopmental disorder that is characterised by clinically significant delays in receptive and expressive language, that cannot be explained by sensory, intellectual, and/or other neurological deficits (Bishop, 2003; Stark & Tallal, 1981). The pattern of language impairments in SLI varies across individuals and can change during development (Conti-Ramsden & Botting, 1999). However, difficulties on tasks of non-word repetition and sentence repetition, as well as errors of grammatical tense marking are characteristic across SLI subgroups (Williams, Botting & Boucher, 2008). Assessments of sound perception in this group have revealed slow and impaired auditory discrimination, impaired sensory memory (revoew artoc;e Luja;a & Leminen, 2017) and impairments in processing pitch (McArthur & Bishop, 2004), metre, and the temporal components of auditory stimuli (Corriveau & Goswami, 2009; Weinert, 1992). Studies specifically investigating music perception in SLI have reported poor performance on tests of melody and rhythm discrimination (e.g. Peretz et al., 2013) and singing (Clément, Planchou, Béland, Motte, & Samson, 2015). In one ERP study, Jentschke, Koelsch, Sallat, and Friederici (2008) presented children with SLI and typical language development with tests of music, language and memory in an ERP study. The authors reported that ERAN and N5 components were elicited during musical syntax processing in the TD but not in the SLI group. The results from the study also revealed impairments in musical memory and the authors discussed the interplay between syntactical processing and working memory mechanisms during musical encoding and retrieval.

Autism Spectrum Disorder (ASD) is diagnosed on the basis of socio-communicative impairments, alongside restricted and repetitive behaviours and interests (DSM-5, American Psychiatric Association, 2013). Although most children with ASD are delayed in reaching early language milestones (Tager-Flusberg, Paul & Lord, 2005), subsequent language development appears to show considerable variability. Studies have reported both accelerated language acquisition in the third or fourth year (Szatmari et al., 2000), and a loss of earlier acquired words during the second year (Pickles et al., 2009). Research using standardised tests to measure language skills in children with ASD has revealed considerable heterogeneity (Tager-Flusberg, Edelson & Luyster, 2011), with a minority of individuals scoring within the normal range on tests of phonological awareness, morphology, syntax, semantics and pragmatics (e.g. Kjelgaard & Tager-Flusberg, 2001). Some studies have reported a pattern of language impairment in ASD that is characteristic of children with a diagnosis of SLI (Kjelgaard & Tager-Flusberg, 2001; Lewis, Murdoch & Woodyatt, 2007; Rapin, Dunn, Allen, Stevens & Fein, 2009), although questions about the extent and specificity of overlapping language profiles in these groups are a subject of ongoing debate (Williams, Botting & Boucher, 2008).

Cognitive profiles in ASD and SLI appear to show clearer similarities. For example, Taylor, Maybury, Grayndler and Whitehouse (2014) reported impaired auditory working memory in children with SLI and language impaired children with ASD (ALI) but not children with ASD and normal language skills (ALN). A second study comparing the same groups (Hill, Santen, Gorman, Langhorst, & Fombonne, 2014), reported poorer memory performance in children with SLI than in children with ALI, though scores for both groups were lower than those of the ALN group. Results showing that individuals with ASD without co-morbid language impairment do not have significant impairments in auditory memory (Taylor et al., 2014) are consistent with results suggesting that perception of musical information is intact in ASD (Heaton, 2009). For example, experimental studies have revealed preserved perception of musical contour (Heaton, 2003, Mottron, Peretz & Menard, 2000), rhythm (Tryfon et al., 2017) and syntax (Heaton, Williams, Cummins & Happé, 2007; DePape, Hall, Tillmann & Trainor, 2012), and neuroimaging studies show that neural processing of musical stimuli is intact in ASD (Lai, Pantazatos, Schneider & Hirsch, 2012; Sharda, Midham Malik, Mukerji & Singh, 2015). Whilst it is plausible to suggest that auditory short term memory deficits in individuals with ASD and co-morbid language impairment (ALI) will impoverish musical encoding and maintenance, it should be noted that Kanner's original paper on autism (1946) made reference to children with highly atypical language abilities and exceptional memory for structured musical information.

One aspect of music perception that has yet to be tested in groups with ASD and SLI is the ability to represent features of a piece of music (e.g., pitch, tempo, timbre) within voluntary musical imagery. Voluntary musical imagery involves the intentional generation of a mental musical image in the absence of a perceived external stimulus. It is differentiated from *involuntary* musical imagery in terms of its intentional initiation; involuntary musical imagery begins without purposeful intention to recall a tune and is generally associated with the "earworm" phenomenon of having a tune stuck in one's head. Early experimental work into voluntary musical imagery, carried out by Halpern (1988; 1989), showed that familiar melodies are represented in auditory images that tend to preserve the original melody's temporal pace and pitch contour. In a study of voluntary musical imagery carried out by Weir, Williamson, and Müllensiefen (2015), participants with varying levels of musical experience were told that they would hear a recording of a familiar song, in which a short section would be muted. They were instructed to carry on imagining the song in their 'mind's ear' during the silent period, after which the music continued at the correct or incorrect pitch or tempo. Participants' subsequent judgements about whether or not the music had been manipulated were strongly influenced by their familiarity with the song.

The overarching aim of the study was to extend research into music perception by investigating voluntary musical imagery in children with neurodevelopmental disorders. The specific aim was to investigate the impact of auditory short-term memory impairments on musical skills in children with ASD and language impairment (ALI) and compare their performance with that of children with SLI and typical development (TD). Research has shown that articulatory suppression lowers voluntary musical imagery performance (Smith, Wilson & Reisberg, 1995) implicating auditory working memory and the phonological loop (Baddeley & Hitch, 1974; Baddeley & Logie, 1992) in musical imagery. As memory impairments have been associated with impairments in music perception in SLI (Jentschke et al., (2008) we hypothesise that voluntary musical imagery performance will be poorer in this group than in age-matched typically developing children. Whilst short-term memory impairments are also characteristic in ALI, Kanner's (1946) clinical report suggests that poor structural encoding of music is not universal in individuals with autism and developmentally atypical language. Further evidence for a potential difference between SLI and ALI comes from studies showing poor discrimination of low level auditory stimuli (Tujala & Leminen, 2017) and enhanced pitch perception in individuals with ASD and language delay (Bonnel, McAdams, Smith, Berthiaume, Bertone, Ciocca, et al., 2010; Heaton, Davis & Happe, 2008a, b). As enhanced pitch discrimination may result in increased acuity of pitch information in long term memory, we hypothesise that the ALI group will show superior performance on the pitch condition compared with the SLI or TD control groups. In music, pitch information is highly salient and this effect may be increased in individuals with ASD and enhanced pitch memory (Heaton et al., 2008). Whilst auditory short term memory impairments in the ALI group might predict poor retention of auditory sequential information, information about tempo is yoked with pitch information during musical encoding, and we hypothesise that the ALI group will perform as well as TD controls on the tempo condition.

2..**Method**

2.1. Participants

Participants in the ALI and SLI groups were recruited via quota sampling from a school for children with special educational needs, where formal diagnosis by a qualified clinical team is mandatory for admittance. Inclusion criterion for the ALI group was a primary diagnosis of ASD with no secondary diagnosis of SLI, and inclusion criterion for the SLI was a primary diagnosis of SLI. A group of TD participants was recruited from a mainstream state school. Fifteen participants with ALI (11 males and 4 females), 14 participants with SLI (8 males and 6 females) and 16 TD participants (7 males and 9 females) participated in the study. Within the sample, age ranged between 12 and 15.67 years (M = 14.06, S.D = 0.97), and the three groups were matched on chronological age. Ethical consent was granted by the ethics committee at Goldsmiths, University of London.

2.2 Materials

Receptive vocabulary was measured using the British Picture Vocabulary Scale: Second Edition (BPVS-II; Dunn, Dunn, Whetton, & Burley, 1997) and auditory short-term memory capacity was measured using the digit-span subtest from the Child Memory Scale (CMS; Cohen, 1997). Research into early musical training has reported associated improvements in auditory, cognitive and motor abilities (Hyde, Lerch, Norton, Forgeard, Willianm Evans & Schlaug; Rose, Jones-Bartolli & Heaton, 2017) and data on numbers of hours of formal music or music related activity and parental musical training was collected using a parental report questionnaire (appendix 1). Non-verbal intelligence was measured in the ALI and SLI groups using the Raven's Progressive Matrices (Raven, 1981). Participants' age, psychometric and musical experience data are presented in Table 1.

Table 1: ***Participants' Psychometric Data***

	SLI Group	**ALI Group**	**TD Control Group**
Age (Years) - Mean (S.D)	14.10 (0.91)	14.78 (0.97)	13.79 (1.02)
RPM – Mean (S.D)	20.36 (6.20)	20.40 (6.20)	
BPVS score - Mean (S.D)	57.43 (7.13)	63.27 (13.11)	100.60 (12.27)
Digit Span score - Mean (S.D)	3.86 (2.35)	5.20 (3.03)	14.80(3.76)
Musical Experience– Mean (S.D)	10.14(3.82)	12.8 (5.19)	14.20 (3.61)

2.3. Stimuli: Musical Imagery Task

In consultation with the music teachers at the participating school, an initial group of ten songs taught in music class and featured in school concerts and plays was compiled. From these ten songs, each participant was invited to select the five songs he/she knew best for use as stimuli in the experiment (one for the practice trial, four for experimental trials). In order to avoid excessive use of the same musical stimuli in the experiment, two separate 25-second excerpts that retained memorable parts of the songs (e.g. first verse, chorus, hook) were cut from the songs. Five-second silences were then interjected at the 10-second mark of each excerpt. Accordingly, each trial began with the excerpt playing for 10 seconds, followed by a 5-second silence, then back into a continuation of the song that played for another 10 seconds. This latter continuation would play at either the correct or incorrect pitch or tempo. In the pitch condition, there were three levels of modifications, i) one semitone flat, ii) no pitch change and iii) one semitone sharp; in the tempo condition the three levels of modifications were i) 7 beats per minute (BPM) slower, ii) no tempo change and iii) 7 BPM faster. The pitch shifts and tempo manipulations were made using Adobe Audition CS6 editing software. The dimensions of change for both the pitch and tempo conditions were informed by pilot testing.

In order to control for potential distortions elicited by the process of pitch shifting or time stretching, a two-step audio manipulation was carried out (Jakubowski, Müllensiefen, & Stewart, 2016; Schellenberg & Trehub, 2013). For example, in a pitch condition where the continuation needed to be a semitone sharp: the audio before the silence would be shifted up one semitone, then back down one semitone to its original pitch, whereas the audio after the silence would be shifted up two semitones, then back down one semitone to reach the desired pitch level of one semitone sharp. Accordingly, rather than just manipulating the audio after the silence, every part of each trial underwent the same degree of interference and processing. During each condition, presentation of the songs was randomized using ‘shuffle’ on iTunes with the volume set at 75% on a Lenovo G400s laptop. Participants heard the stimuli through a pair of Sennheiser eH150 headphones. As the same 4 songs were used for both the pitch and tempo conditions, each with 3 levels, a condition would present in blocks of 12 (4 songs x 3 levels), with both pitch and tempo conditions, summing to 24 trials in total.

2.4. Procedure

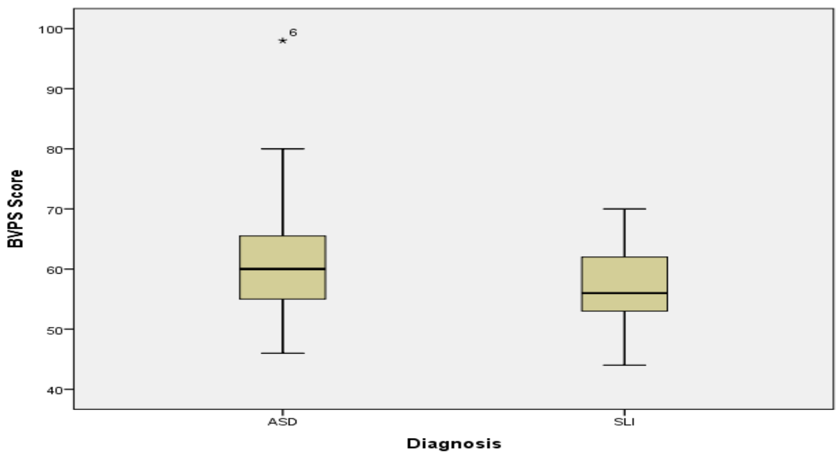
To avoid experimenter effects, the experimenter was blind to the diagnosis of the children in the special needs school during testing. The school music teacher was provided with the inclusion criteria (age, diagnosis) and selected participants, but did not disclose diagnostic information until data collection was completed. The experiment was carried out in quiet rooms at the participating schools. The children were given a simple description of the study and made aware of their right to withdraw from the study at any point. Once verbal consent was obtained, the BPVS-II and the CMS digit-span subtest were administered. In order to control for potential differences in non-verbal intelligence in the language impaired groups, the children in the ALI and SLI groups also completed the Raven's Matrices test (1981). The children were then asked which five of the ten prepared songs they knew best and these were selected for the experiment. One of the five songs was used for a practice trial in which children were familiarised with the experimental procedure and given an opportunity to distinguish a pitch or tempo manipulated continuation from a non-manipulated continuation. Once participants demonstrated understanding of the task requirements, they were told to make their own judgements about the manipulation in the remaining trials. Participants were requested to indicate 'change' or 'no change', either verbally or by use a pointing system, and responses were scored for accuracy. The pointing system involved the provision of two A4 size cards stating 'yes change' and 'no change'. Conditions (pitch or tempo manipulation) were randomised across participants and at the beginning of each block of trials, they were told to listen out for either pitch or speed changes. Upon task completion, participants were congratulated and thanked, then provided with a debrief form for their parents.

3. Results

3.1. Analysis of matching and background data

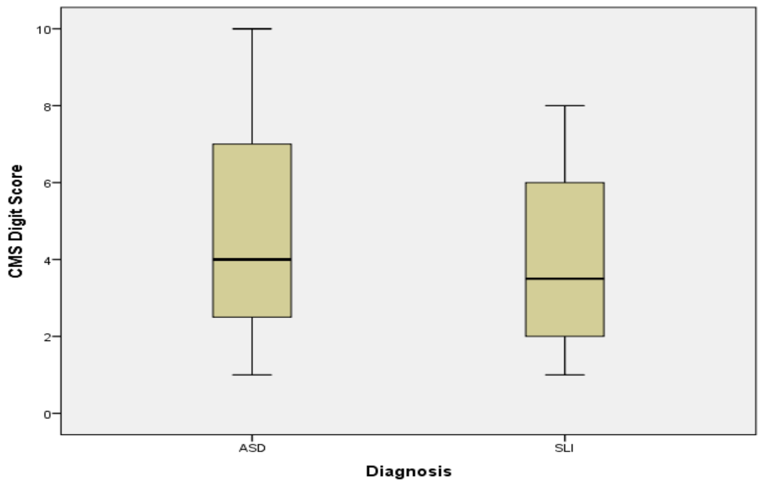
An initial analysis was carried out on the psychometric data shown in table one. A one-way ANOVA carried out on the data for the three groups failed to reveal significant differences on age ($F(2, 42) = 1.23$, n.s.) or musical experience ($F(2, 42) = 2.34$, n.s.). However, the three groups did differ on BPVS scores ($F(2, 42) = 46.40$, $p < .001$). Tukey's HSD post hoc test showed that the SLI and ALI groups achieved significantly lower scores than the TD group. An independent samples t-test, carried out on BPVS data for the SLI and ALI groups failed to reveal a significant group difference, $t(27) = 1.47$ (n.s.). As figure one shows, the SLI and ALI groups showed a very similar profile of performance on the BPVS test.

Figure one: *BPVS scores for SLI and ALI groups*



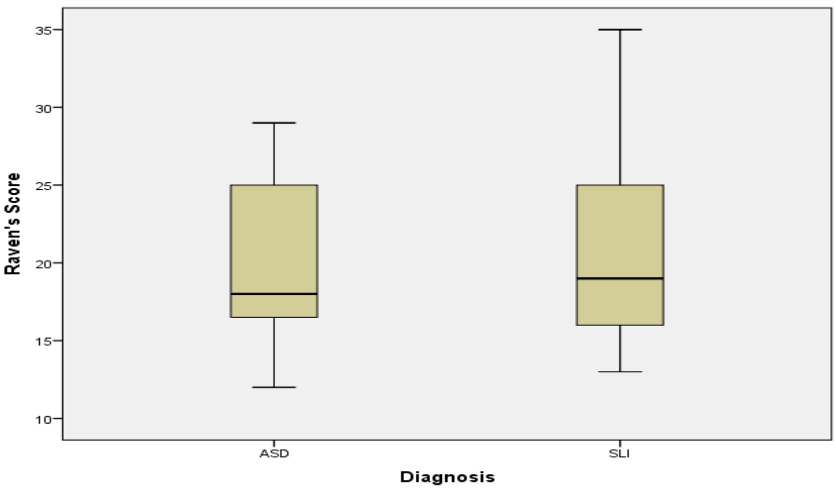
There was a significant between-group difference on the digit span test ($F(2, 42 = 51.66$, $p < .001$). Tukey's HSD post hoc test showed that SLI and ALI groups achieved significantly lower scores than the TD group. An independent samples t-test was carried out on digit-span scores for the SLI and ALI groups and failed to reveal a significant group difference, $t(27) = 1.33$ (n.s.). As figure 2 shows, the SLI and ALI groups showed a very similar profile of performance on the digit-span test.

Figure two: *Digit span scores for SLI and ALI groups*



Raven's Progressive Matrices test scores did not differ across the SLI and ALI groups (t (27) = .02, n.s.) Scores are shown in figure 3

Figure three: *Raven's Progressive Matrices scores for SLI and ALI groups*



3.2. A priori contrast analysis of Musical Imagery data

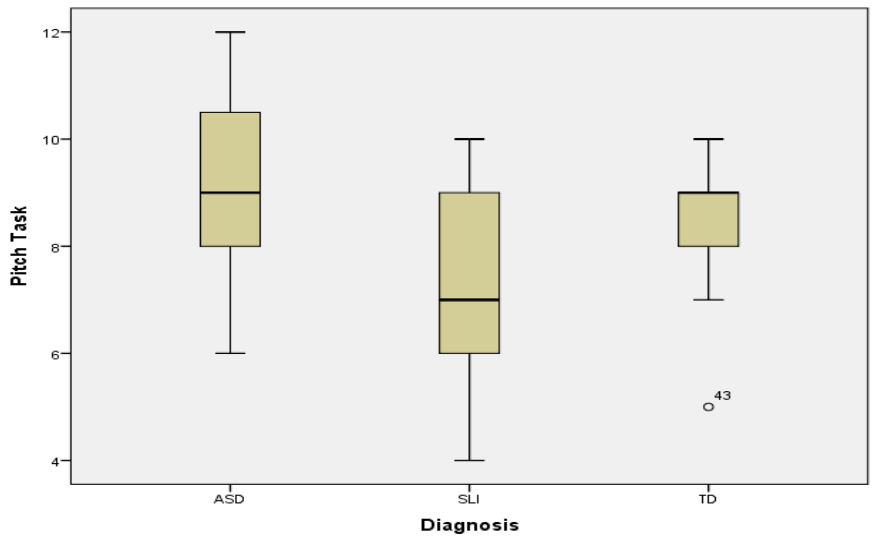
Means, standard deviations and ranges for performance on the pitch and tempo conditions of the voluntary musical imagery task are shown in Table 2.

Table 2: ***Means and standard deviations for task performance across diagnostic groups***

	SLI Group	**ALI Group**	**TD Group**
Pitch Task - Mean (S.D)	7.14 (1.75)	9.07 (1.75)	8.67 (0.98)
Range	6	6	5
Tempo Task - Mean (S.D)	6.64 (2.24)	8.47 (1.69)	8.40 (1.72)
Range	7	5	6

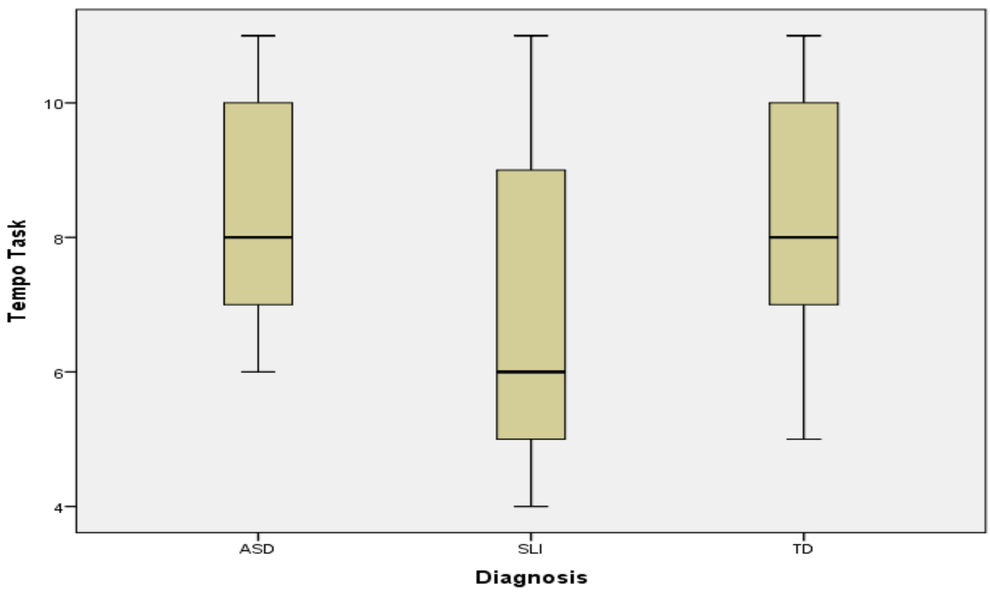
As previous research has suggested links between superior pitch processing and language delay in ASD, an *a priori* contrast analysis was carried out comparing the ALI group with the SLI and TD groups combined on this condition. This revealed superior performance in the ALI group: $t(42) = 2.51$, $p = .016$. This effect is shown in figure 4.

Figure four: *SLI, ALI & TD scores on the pitch condition*



For tempo, three separate contrast analyses were carried out, comparing one group with the remaining two. Of these, after a Bonferroni adjustment for the three comparisons, only the contrast comparing the combined ALI and TD groups with the SLI group was significant: $t(42) = 2.7$, $p = .01$, This effect is shown in figure 5.

Figure five: *SLI, ALI & TD scores on the tempo condition*



As sample sizes were relatively small for each group, the Shapiro-Wilk test was used to investigate normality of data. This failed to reveal significant results for either pitch or tempo conditions within groups (Pitch: ALI: p = 0.694; SLI: p = 0.598; TD: p = 0.07; Tempo: ALI: p = 0.271; SLI: p = 0.081; TD: p = 0.156). As Levene's test of homogeneity of variance was also non-significant for both pitch (p = 0.061) and tempo (p = 0.481), the statistical assumptions for ANOVA were met.

3.3. ANOVA analysis of Musical Imagery data

A 2x3 mixed ANOVA was carried out on the data, with musical imagery condition (2 levels: pitch/tempo) as the within-subjects variable, and diagnosis (3 levels: SLI/ALI/TD) as the between-subjects variable. This analysis failed to reveal a significant main effect of musical imagery condition ($F(1, 42) = 2.967$, $p = 0.092$, $\eta_p^2 = 0.067$), or a condition by diagnosis interaction, ($F(2, 42) = 0.142$, $p = 0.868$, $\eta_p^2 = 0.007$). However, the main effect of diagnosis was significant at the 0.01 level:
F (2, 42) = 4.378, $p = 0.003$, $\eta_p^2 = 0.250$. Post-hoc Bonferroni-adjusted multiple t-test comparisons showed that while total VMI scores did not differ between the ALI and TD groups, SLI group scores were significantly lower than these two groups combined.

3.4 Correlational analysis: investigating associations between musical imagery, memory and language data

In order to further explore the data, scores for pitch and tempo conditions were correlated. The correlation was highly significant for the SLI group (r = .76, p = .002) but not for the ALI (r = .40) or the TD group (r = .39). As scores for the two experimental conditions were highly correlated for the SLI group, pitch and tempo task scores were summed before examining correlations with the vocabulary and memory data. The analysis showed that total scores on the voluntary musical imagery task significantly correlated with the digit span scores ($r(14) = 0.661$, $p = 0.01$), but not with the BPVS scores ($r(14) = -0.152$, $p = 0.604$). As the correlations for the two experimental conditions were not significantly correlated for the ALI and TD groups vocabulary and memory data were correlated with each of the two experimental conditions. For the ALI group scores on the pitch condition did not significantly correlate with BPVS (r = -.32) or digit span scores (r = .36). Scores on the tempo condition did not correlate with BPVS (r = 004) or digit span (r = 16). For the TD group scores on the pitch condition were significantly correlated with scores on the BPVS (r = .59, p=.017) but not on the digit span test (r = .14). Scores on the tempo condition did not correlate with BPVS (r = 07) or digit span (r = 29).

4 Discussion

The results from the study revealed striking differences between groups of children with ALI and SLI on a test of musical imagery. Children with SLI performed at significantly lower levels than children with ALI and TD on both tempo and pitch conditions of the task. In contrast children with ALI performed as well as TD children on the tempo condition and at a significantly higher level than TD children on the pitch condition of the task. Previous studies comparing children with ALI and SLI have reported similar levels of auditory short term memory impairments in the two groups (Hill et al., 2004) and this was observed in current the study. Auditory short term memory scores did not differ across groups and both groups were very impaired when compared with age matched TD controls. The analysis of the receptive vocabulary data revealed the same pattern, although a small minority of participants in the ALI group achieved BPVS scores that were within the normal range. This is consistent with research showing that receptive vocabulary scores may be relatively preserved in individuals with ASD who show significant impairments in high-order language skills (e.g. syntax, semantics, pragmatics) (e.g. Kjelgaard & Tager-Flusberg, 2001). In the study the correlation between BPVS and experimental scores was not significant for the ALI group and individuals with relatively intact receptive vocabulary were not advantaged on the musical task. As the comparison of the Raven’s matrices data failed to reveal significant differences between SLI and ALI groups, difference on the music task could not be explained by differences in levels of non-verbal intelligence or receptive vocabulary.

The pattern of correlations between measures of auditory short term memory and musical imagery showed a marked difference across groups and raised questions about the cognitive and memory processes involved in task performance. In the task the participants heard an incomplete section of familiar music, then after a short break, heard a congruent or incongruent final phrase. Poor identification of congruent phrases could then reflect an impoverished long-term memory representation of the musical excerpt and/or the demands of the task on auditory short-term memory. For TD children the correlation between experimental and digit span scores was not significant and this suggests that short-term auditory memory does not play a major role in the task of accessing and assessing well learned musical material in children without language impairment. In contrast to the pattern reported for the TD group, auditory short-term memory scores were significantly correlated with both conditions of the musical task for participants with SLI. However whilst digit span scores were low in the ALI group, they performance as well or better than TD controls and their digit span scores did not correlate with their musical imagery scores.

Low digit span scores have been implicated in the language impairment in SLI. For example, in a recent study, Lukács, Ladányi, Fazekas and Kemény (2016) showed that significant differences in discriminating groups with SLI and TD on verbal measures of executive functioning, were eliminated when digit span scores were covaried in the data analysis. In the current study SLI particiapnts performed poorly on the musical imagery task and their scores were significantly correlated with this digit span scores. Whilst this suggests a causal link between digit span and musical imagery performance in the SLI group, this explanation cannot hold for the ALI group, for whom the correlation was not significant. One possibility is that the musical impairment in the SLI group is causally linked with another variable that correlates with digit span but was not measured in the study. In a recent experiment Conti-Ramsden, Ullman and Lum (2015) investigated the contribution of the working, procedural and declarative memory systems on receptive grammar skills in children with TD and SLI. The results showed that whilst procedural memory alone predicted levels of receptive grammar for TD children, children with SLI relied on the sub-optimal declarative memory system. Neuroimaging studies have shown that linguistic and musical syntax rely on similar neural mechanisms in TD persons (Maess, Koelsch, Gunter, & Friederici, 2001; Sammler, Koelsch, & Friederici, 2011; Kunert, Willems, Casasanto, Patel & Hagoort, 2015) and Jentschke et al., (2008) reported abnormalities in musical syntax processing in SLI. However, sensitivity to musical syntax develops over time and in response to the musical environment. Impairments in low-level auditory discrimination, sensory memory (Kujala & Leminen, 2017) and auditory short term memory (Lukács et al., 2016), reported in SLI are likely to curtail the child's ability to engage with the musical environment and develop and understanding of musical syntax. Language intervention studies have reported improvements in speech-sound discrimination in SLI (Pihko et al., 2007) and music therapy may plan an important role in improving auditory discrimination and sensory memory in this group. Research using musical tasks that rely on early perceptual and short-term memory abilities will be important in informing our understanding of musical impairments in SLI and will also provide a scientific basis for music therapists working this these children.

Whilst the comparison of the SLI and ALI groups showed strikingly different patterns of performance, TD/ALI group differences were considerably less marked. There was no significant difference between the groups on the tempo condition of the musical imagery task, and the pattern of correlations across conditions and between musical and background data also showed similarities. For example, correlations across pitch and tempo conditions were not significant and auditory short term memory scores did not correlate with performance on either conditions for ALI or TD groups. The correlation between receptive vocabulary and tempo scores were also not significant for the ALI or TD groups. Whilst speech and music are both rhythmically patterned stimuli, temporal organisation is considerably more specific in music than in speech and temporal identifications skills may not generalise across music and language domains. One very interesting difference between the ALI and TD groups was that performance on the pitch conditions was significantly correlated with receptive vocabulary scores for the TD but not the ALI group. Good pitch discrimination is likely to advantage acquisition of both linguistic and musical information at the early stages of development and this may explain the positive correlation reported for the TD group. However, for the ALI group superior pitch processing skills appeared to be independent of receptive vocabulary skills and this merits further consideration. Previous findings showing enhanced pitch perception in individuals with ASD and impaired or delayed language skills (Bonnel et al., 2010; Heaton et al., 2008a, Heaton et al., 2008b) have been interpreted in the context of the Enhanced Perceptual Functioning model of ASD (Mottron, Dawson, Soulieres, Hubert & Burack, 2006). However, differences in the correlates of pitch perception in ALI and TD raise questions about the function and development of pitch perception in these groups.

An assumption of cognitive neuroscience approaches to development, is that the infant's patterns of attention or interests, facilitates access to new sources of information that result in increasing neural specialisation over time (Johnson, 2011). According to this framework, atypical development, may reflect altered constraints, for example in perceptual, cognitive and/or memory ability, that limit the infant's exposure to inputs necessary for the development of brain specialisations. Infants with ASD show reduced attention to social stimuli in the period when the foundations of language are normally established (Boucher, 2012) and Kuhl and colleagues (2013) showed that severe impairments in the ability to attend to linguistically relevant information in social contexts, results in reduced neural specialisation for speech stimuli. Whilst relatively preserved language skills are observed in some children with ASD (Kjelgaard & Tager-Flusberg, 2001; Tager-Flusberg et al., 2005; Szatmari et al., 2000; Pickles et al., 2009), social/communication impairment in ASD do not provide optimal conditions for language acquisition. However, the effects of these constraints are likely to differ across functional domains. Music and speech show similarities at the psychoacoustic and structural levels (Patel, 2008), but differ in ways that may help explain the pattern of impairment language and spared musical skills in ASD. Music is perceptually rich, highly structured, emotionally powerful and less specified in semantic meaning than language (Cross, 1999). Speech acts require a socially contextualised response from listeners whilst music can be experiences without such social demands, In addition to differences in the social/communication aspects of music, psychoacoustic differences across domains may also play a role in explaining spared musical skills in ALI. Musical timbre refers to the use of different musical instruments or voices for colouristic purposes whilst timbre in speech results from the alternation of consonants and vowels in rapid succession. Work by Kuhl et al., (2013) has shown that the ability to decode complexity in speech is compromised by an early inattention to social stimuli in ASD and this is consistent with neuro-constructivist models of development. In two recent neuroimaging studies, children with ASD showed atypical neural processing of speech stimuli and typical neural processing of song (Lai et al., 2012; Sharda et al., 2015), and this suggests that social, communication impairments, characterising ASD, do not constrain music in the same way as language.

Studies of early musical abilities in TD infants and children have revealed surprisingly sophisticated early musical abilities that increase in response to informal (listening) as well as formal (musical training) musical exposure over time (McPherson, 2015). Such findings are consistent with evidence suggesting that postnatal structural and functional development is influenced by the environment

(Johnson, 2011). Although ASD is characterised by reduced attention to social stimuli (Jones & Klin, 2013), children with ASD display a strong interest in music (Blackstock, 1978; Kolko, Anderson & Campbell, 1980; Thaut, 1987) and experimental studies (e.g. Heaton et al., 2007; DePape et al., 2012) suggest that the structure of their musical knowledge is similar to that of TD children. However, there are several reasons for thinking that the trajectory of musical leaning in ASD and ALI in particular, will differ from that of a TD child. In the current study, participants with ALI performed at a similar level to TD participants on the tempo condition of the musical imagery task, but their performance on the pitch condition was superior. Second, the association between receptive vocabulary and pitch scores seen in the TD participants was absent for this group. In TD populations increased exposure to music results in enhanced discrimination of pitch in both music and speech (Schon, Magne & Besson, 2014) possibly reflecting improved perceptual discrimination of soud. However, there are important domain-specific difference in pitch organisation and function across music and speech domains. In music pitch information is systematically organised (in octaves) into discrete entities (semitones, tones) and changes in timbre, for example occurring when the note is played on a clarinet rather than on a flute, do not make the pitches more difficult to distinguish. Information in speech is conveyed through formants which represent the timbral elements of speech. Pitch is of secondary importance in speech and functions to convey emphasis and affective information. Experimental studies have shown the children with ASD are exceptionally sensitive to arbitrary pitch change sin speech stimuli (Heaton, Hudry, Ludlow & Hill, 2008; Jarvinen-Pasley, Wallace, Ramus, Happe & Heaton, 2008) although they are less sensitive to communicative intent in prosody that TD children (Jarvinen-Pasley, Peppe, King-Smith & Heaton, 2008). According to Johnson's (2011) model, development is a self-organizing and activity-dependent process, with neural specialisations resulting from attention to specific stimuli and competition between these stimuli. We therefore hypothesise that fine-grained pitch discrimination in ALI is a downstream effect of early impoverished attention to language but not music. An assumption of our hypothesis is that musical skills in ALI result from an interaction between early and atypical patterns of attention and neural specialisation and the psychoacoustic, structural and motivating characteristics of music. Although social/communication difficulties vary in their severity in ASD, they nevertheless impact on the individual's ability to interpret other people's communicative intentions. Experimental and neuroimaging studies show that s=musical skills are spared in ASD and we propose that our developmental account offers an explanation that accounts for enhanced pitch and music skills in ALI and in the wider population of individuals on the autism spectrum.

Several limitations to the current study should be considered. First, group sizes were relatively small and the study should be replicated using larger samples. A second limitation concerns the comparison of the data from the SLI and ALI groups. The groups were closely matched on non-verbal intelligence, auditory short-term memory and receptive vocabulary. However children with language difficulties may show much less marked deficits on tests of receptive vocabulary than on tests probing higher-order language skills and future studies comparing ALI and SLI should include a broader range of language tests. Outstanding questions about the impact of deficits in auditory discrimination and memory mechanisms on music perception in SLI should also be addressed in future studies. A third potential limitation in the study is that the three participant groups were matched on chronological age, and it might have been useful to have included a verbal mental age matched TD group for comparison with the SLI and ALI groups. However, a methodological problem that frequently arises in studies of children with language impairments is that the chronological/verbal mental age discrepancy may be large, and verbal mental age controls may be very young and unable to meet experimental task demands. Musical experience rapidly shapes perceptual skills in childhood and very young TD controls may be particularly disadvantaged in studies of music perception. Nevertheless, the question of whether deficits in musical imagery will be less marked in SLI than in mental age matched TD children is interesting and could be explored in future research. One strength of the matching procedure used in the study was that it enabled us to reveal skills in the ALI group that were superior to, or commensurate with chronological age. An interesting outstanding question that could be explored in future studies, is whether children with ALI will differ from children with ASD and intact language skills on tests of musical imagery.

Conclusions. This is the first study to compare groups of children with SLI, ALI and TD on a test of voluntary musical imagery. Whilst participants in the ALI group showed a similar profile of receptive vocabulary, non-verbal intelligence and auditory short term memory impairments as participants with SLI, the results revealed strikingly different musical phenotypes. Children with SLI performed at significantly lower levels than ALI and TD groups on the task, and causal factors, implicated in musical deficits in SLI where discussed. For children with ALI, pitch acuity in voluntary musical imagery was superior to that of TD children and tempo of acuity was preserved. We propose that findings from studies of music perception in neurodevelopmental disorders should be interpreted in the context of developmental models that take account of early attentional processes and the development of domain specific neural processing mechanisms.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5*. American Psychiatric Association.

Ayotte, J., Peretz, I., & Hyde, K. (2000). Congenital amusia: a group study of adults afflicted with a music-specific disorder, *Brain, 125*, 238–51.

Baddeley, A..D., & Hitch, G. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 8, pp. 47–89). New York: Academic Press.

Baddeley, A. D., & Logie, R. H. (1992). Auditory imagery and working memory. In D. Reisberg (Ed.), *Auditory imagery* (pp. 179–197). Hillsdale, NJ: Erlbaum.

Besson, M., Schon, D., Moreno, S., Santos, A. & Magne, C. (2007). Influence of musical expertise and musical training on pitch processing in music and language. *Restorative Neurology and Neuroscience*, 25, 399–410.

Bishop, D. V. M. (2003). Autism and specific language impairment: Categorical distinction or continuum? In *Autism: Neural basis and treatment possibilities* (pp. 213–234). Chichester: Wiley.

Blackstock, E. G. (1978). Cerebral asymmetry and the development of early infantile autism. *Journal of Autism and Childhood Schizophrenia, 8,* 339–353.

Bonnel, A., McAdams, S., Smith, B., Berthiaume, C., Bertone, A., Ciocca, V., et al. (2010). Enhanced pure-tone pitch discrimination among persons with autism but not Asperger syndrome. *Neuropsychologia, 48*(9), 2465-2475.

Boucher, J. (2012)1 Research review: structural language in autistic spectrum disorder - characteristics and causes. *Journal of Child Psychology and Psychiatry,* 53(3):219-33

Benasich, A.A. (2011) Maturation of auditory evoked potentials from 6 to 48 months: prediction to 3 and 4 year language and cognitive abilities. *Clinical Neuropohysiology,* 122 (2) 320-38.

Clément, S., Planchou, C., Béland, R., Motte, J., & Samson, S. (2015). Singing abilities in children with specific language impairment. *Frontiers in Psychology, 6*, 420.

Cohen, M. J. (1997). Children's memory scale. *Pearson Clinical Assessments.*

Conti-Ramsden, G. & Botting, N. (1999). , Classification of children with specific language impairment: longitudinal considerations. *Journal of Speech, Language Hearing Research,* 5, 1195-204.

Conti-Ramsden, G., Ullman, M. T., & Lum, J. A. G. (2015). The relation between receptive grammar and procedural, declarative, and working memory in specific language impairment. *Frontiers in Psychology*, 6, 1090.

Corriveau, K., & Goswami, U. (2009). Rhythmic motor entrainment in children with speech and language impairment: Tapping to the beat. *Cortex, 45,* 119–130.

Cross, I. (1999).Is music the most important thing we ever did? Music, development and evolution. In: Suk Won Yi, (Ed.), Music, mind and science, pp.10-39. Seoul:Seoul National University Press.

DePape, A., Hall, G., Tillmann, B., & Trainor, L. (2012). Auditory Processing in High-Functioning Adolescents with Autism Spectrum Disorder. *PLoS ONE 6*(9).

Dunn, L. M., Dunn, L. M., Whetton, C., & Burley, J. (1997). The British picture vocabulary scale: Second edition. *National Foundation for Educational Research.*

Fiveash, A., & Pammer, K. (2014). Music and language: Do they draw on similar syntactic working memory resources? *Psychology of Music*, *42*(2), 190-209.

Halpern, A. R. (1988). Perceived and imaged tempos of familiar songs. *Music Perception*, *6,* 193–202.

Halpern, A. R. (1989). Memory for the absolute pitch of familiar songs. *Memory & Cognition, 17,* 572–581.

Heaton, P. (2005). Interval and contour processing in autism. *Journal of Autism and*

Heaton, P. (2009). Assessing musical skills in autistic children who are not savants. *Philosophical Transactions of the Royal Society B. 364*, 1443-1447.

Heaton, P., Davis, R., & Happe, F. (2008). Exceptional Absolute Pitch Perception for spoken words in an able adult with autism. *Neuropsychologia* 46, 2095–2098.

Heaton, P., Hudry, K., Ludlow, A. & Hill, E. (2008). Superior pitch processing is unrelated to verbal ability in autism spectrum disorders. *Cognitive Neuropsychology,* **25** (6), 771 – 782.

Heaton, P., Williams, K., Cummins, O., & Happé, F. (2007). Beyond perception: Musical representational processing in autism. *Journal of Autism and Developmental Disorders, 37*(7), 1355–1360.

Heaton, P., Williams, K., Cummins, O., & Happé, F. (2008). Autism and pitch processing splinter skills: A group and subgroup analysis. *Autism, 12*(2), 203-219.

Hill, A. P.,van Santen, J., Gorman, K., Langhorst, B. H.,& Fombonne, E. (2015). Memory in language-impaired children with and without autism. *Journal of Neurodevelopmental Disorders 7*(15).

Hyde, K.L., Lerch, J., Norton,A., Forgeard,M., Winner,E., Evans, A.C. & Schlaug, G. (2009). The effects of musical training on structural brain development: a longitudinal study. *Journal of Neuroscience*, 29 (10) 3019-3025.

Jakubowski, K.,Mullensiefen, D. & Stewart, L. (2016). A development study of latent absolute pitch memory. *The Quarterly Journal of Experimental Psychology* 434-443

Järvinen-Pasley, A., Peppé, S., King-Smith, G. & Heaton, P**.** (2008). The relationship between form and function level receptive prosodic abilities in autism. *Journal of Autism and Developmental Disorders,* **38,** (7), 1328 – 40.

Järvinen-Pasley, A.M., Wallace, G.L. Ramus, F., Happe, F. & Heaton, P. (2008). Enhanced perceptual processing of speech in autism. *Developmental Science,* **11**, (1), 109 – 121.

Jentschke, S., Koelsch, S., Sallat, S., & Friederici, A. D. (2008). Children with specific language impairment also show impairment of music-syntactic processing. *Journal of Cognitive Neuroscience, 20*(11), 1940–1951.

Johnson, M. (2011). Interactive Specialization: A domain-general framework for human functional brain development? *Developmental Cognitive Science*, 1, 1, 7-21.

Jones, W. & Klin, A: (2013) Attention to eyes is present but in decline in 2–6-month old infants later diagnosed with autism. *Nature,* 504:427–431.

Kanner, L. (1943), Autistic Disturbances of Affective Contact, *Nervous Child,* 2, .217-250.

Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes, 16,* 287–308.

Kljajevic, V.(2010).Is syntactic working memory language specific? *Psihologija*, 43,85–101.

Kolko, D. J., Anderson, L., & Campbell, M. (1980). Sensory preference and overselective responding in autistic children. *Journal of Autism and Developmental Disorders, 10,* 259–271.

Kuhl, P.K, Coffey-Corina S, Padden D, Munson J, Estes A, & Dawson G (2013) Brain Responses to Words in 2-Year-Olds with Autism Predict Developmental Outcomes at Age 6. *PLoS ONE* 8(5): e64967. https://doi.org/10.1371/journal.pone.0064967

Kujala T & Leminen M (2017). Low-level neural auditory discrimination dysfunctions in specific language impairment-A review on mismatch negativity findings. *Developmental Cognitive Neuroscience,* 28, 65-75.

Kunert, R., Willems, R.M., Casasanto, D., Patel, A.D., Hagoort, P. (2015). Music and language syntax interact in Broca's area: an fMRI Study. *PLoS ONE 10*(11): e0141069. doi: 10.1371/journal.pone.0141069

Lai, G.,Pantazatos, S.P.,Schneider, H. & Hirsch J.(2012). Neural systems for speech and song in autism.*Brain*, 135, 961-75.

Lewis, F. M., Murdoch, B. E., & Woodyatt, G. C. (2007). Linguistic abilities in children with autism spectrum disorder. *Research in Autism Spectrum Disorders, 1,* 85–100.

Lukács, Á, Ladányi, E., Fazekas, K. & Kemény, F. (2016). Executive functions and the contribution of short-term memory span in children with specific language impairment. *Neuropsychology*. 30 (3):296-303.

Maess, B., Koelsch, S., Gunter, T., & Friederici, A. D. (2001). Musical syntax is processed in the Broca's area: An MEG study. *Nature Neuroscience, 4,* 540–545.

McArthur, G. M., & Bishop, D. V. (2004). Frequency discrimination deficits in people with specific language impairment: reliability, validity, and linguistic correlates. *Journal of Speech, Language, and Hearing Research, 47,* 527–541.

McPherson, G.E. (ed)- 2015. The Child as Musician: A Handbook of Musical

Development. Oxford University Press

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J., 2006. Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, *36*, 27–43

Mottron, L., Peretz, L., & Menard, E. (2000). Local and global processing of music in high-functioning persons with autism: Beyond central coherence? *Journal of Child Psychology and Psychiatry*, *8*, 1057–1065.

Patel, A. (2008). *Music, Language, and the Brain*. *Oxford: Oxford University Press.*

Peretz, I., Gosselin, N., Nan, Y., Caron-Caplette, E., Trehub, S. E., & Béland, R. (2013). A novel tool for evaluating children's musical abilities across age and culture. *Frontiers in Systems Neuroscience*, *7*, 30

.

Pickles, A., Simonoff, E., Conti-Ramsden, G., Falcaro, M., Simkin, Z., Charman, T. & Baird, G. (2009). Loss of language in early development of autism and specific language impairment. *Journal of Child Psychology and Psychiatry*, 50, 843– 852.

Pihko, E., Mickos, A., Kujala,T., Pihlgren, A., Westman, A., Alku, P., Byring, R., & Korkman, M. (2007) Group intervention changes brain activity in bilingual language-impaired children. *Cerebral Cortex*,17, 849-858.

Rapin, I., Dunn, M. A., Allen, D. A., Stevens, M. C., & Fein, D. (2009). Subtypes of language disorders in school-age children with autism. *Developmental*

Neuropsychology, 34, 66–84.

Raven, J. (1981). *Manual for Raven's Progressive Matrices and Vocabulary Scales. Research supplement no. 1: The 1979 British standardisation of the Standard Progressive Matrices and Mill Hill Vocabulary Scales, together with comparative data from earlier studies in the UK, US, Canada, Germany, and Ireland.* Oxford, England: Oxford Psychologists Press.

Rose, D., Jones Bartoli, A. & Heaton, P. (2018). Measuring the impact of musical learning on cognitive, behavioural and socio-emotional wellbeing development in children. *Psychology of Music* Advanced online publication. doi: 10.1177/0305735617744887

Sammler, D., Koelsch, S., & Friederici, A.D., (2011). Are left fronto-temporal brain areas a prerequisite for normal music-syntactic processing? *Cortex*, 47(6), 659-673.

Schellenberg, E. G., & Trehub, S. E. (2013). Good pitch memory is widespread. *Psychological Science, 14*(3), 262-266.

Schon, D., Magne, C. & Besson, M. (2004). The music of speech: Music training facilitates pitch processing in both music and language. *Psychophysiology*, 41, 341–349

Sharda, M.,Midha, R., Malik, S.,Mukerji, S.,Singh, N. C. (2014). Fronto-temporal connectivity is preserved during sung but not spoken word listening, across the autism spectrum. *Autism Research,* 8, 174–186

Smith, J. D., Wilson, M., & Reisberg, D. (1995). The role of subvocalization in auditory imagery. *Neuropsychologia*, *33,* 1433–1454.

Stark, R. E., & Tallal, P. (1981). Selection of children with specific language deficits. *Journal of Speech and Hearing Disorders, 46,* 114–122.

Szatmari, P.,Bryson, S.E.,Streiner, D.L.,Wilson, F.,Archer, L. & Ryerse, C. (2000). Two-year outcome of preschool children with autism or Asperger's syndrome. *American Journal of Psychiatry*, *157*(12):1980-7.

Tager-Flusberg H., Paul R, & Lord C, (2005). Language and Communication in Autism, *Handbook of Autism and Pervasive Developmental Disorders* (pp. 650-681)

Tager-Flusberg, H.,Edelson, L.,Luyster, R., 2011. Language and communication in autism spectrum disorders. In: *Handbook of Autism and Pervasive Developmental Disorders* (pp.650-681). Amaral, D., Dawson, G., Geschwind, D. (Eds.).

Taylor, L. J., Maybery, M. T., Grayndler, L., & Whitehouse, A. J. O. (2013). Evidence for distinct cognitive profiles in autism disorders and specific language impairment. *Journal of Autism and Developmental Disorders, 44,* 19-30.

Thaut, M. (1987). Visual versus auditory (musical) stimulus preferences in autistic children: A pilot study. *Journal of Autism and Developmental Disorders, 17,* 425–432.

Tryfon, A., Foster, N.E., Ouimet, T., Doyle-Thomas, K., Anagnostou, E., Sharda, M. & Hyde, K.L. (2017. Auditory-motor rhythm synchronization in children with autism spectrum disorder. Research in Autism Spectrum Disorders, 35:51-61

Tzortzis,C.,Goldblum, M. C., Dang, M.,Forette,F., & Boller,F. (2000). Absence of amusia and preserved naming of musical instruments in an aphasic composer. *Cortex*, 36, 227-242.

Weber,C., Hahne, H., Friedrich, M., & Friederici, A.D. (2005) Reduced stress pattern discrimination in 5-month-olds as a marker of risk for later language impairment: neurophysiologial evidence. *Cognitive Brain Research*, 25, 180-187.

Weinert, S. (1992). Deficits in acquiring language structure: the importance of using prosodic cues. *Applied Cognitive Psychology*, *6,* 545–571.

Weir, G., Williamson, V. J., & Müllensiefen, D. (2015). Voluntary but not involuntary musical mental activity is associated with more accurate musical imagery. *Psychomusicology: Music, Mind, and Brain.* 25 (1) 48 – 57.

Williams, D., Botting, N., & Boucher, J. (2008). Language in Autism and Specific Language Impairment: Where Are the Links? *Psychological Bulletin, 134*(6), 944-963.

Williamson, V. J., Baddeley, A. D., & Hitch, G. J. (2010). Musicians' and nonmusicians' short-term memory for verbal and musical sequences: comparing phonological similarity and pitch proximity. *Memory and Cognition, 38*(2), 163-175.

Appendix 1

1 (a) Have you had any formal musical training (for example, individual music lessons) ?

Yes No (please tick)

(b) If yes, for how long? (*Please circle*)

0–1 year   2–4 years   5–10 years   more than 10 years

2 (a) Has your partner had any formal musical training (for example, individual music lessons)?

Yes No (please tick)

(b) If yes, for how long? (*Please circle*)

0–1 year   2–4 years   5–10 years   more than 10 years

3 (a) Has your child had any formal musical training?

Yes No (please tick)

(b) If yes, for how long? (*Please circle*)

Less than 1 year   1–2 years   2–3 years   3–4 years   4+years

4 Does your child engage in any of the following musical activities?

If yes, please say how much time this takes during a typical school week.

(a) Individual music lesson (instrumental or singing)

1⁄2 hour 1 hour 1 1⁄2 hours 2+hours

(b) Class music lessons

1⁄2 hour 1 hour 1 1⁄2 hours 2+hours

(c) Music therapy

1⁄2 hour 1 hour 1 1⁄2 hours 2+hours

(d) Dance/movement classes

1⁄2 hour 1 hour 1 1⁄2 hours 2+hours

4Is your child able to access music on his/her own (i.e.using an ipad)

Yes No (please tick)

If yes, please say how often s/he does this (please circle)

Rarely	Moderately	Frequently	Very frequently
Once a week	2 – 4 times a week	Most days	Several times on most days

6 If your child cannot access music on her/his own does

s/he ask you to play music to him/her? Yes No (please tick)

If yes, please say how often s/he does this (please circle)

Rarel**y**	Moderately	Frequently	Very frequently
Once a week	2 – 4 times a week	Most days	Several times on most days

7 How would you rate your child's *reaction* to music

(e.g. music played live or on the radio)? (please circle)

Strong dislike Strong liking

1……………2……….. 3…………..4……….5……… 6……………7

8 a) Does you child show a strong reaction to particular sounds (e.g. specific musical instruments or particular singers

Yes No (Please tick)

b) If, yes please say which instruments or singers

…………………………………………………………………………

…………………………………………………………………………

…….

c) If yes, please rate the strength of your child's reaction

Strong dislike Strong liking

1……………2……….. 3…………..4……….5……… 6……………7

9 Does your child quickly memorize new tunes s/he hears?

Yes No (*Please tick*)

10 a) Does your child sing songs/melodies to her/himself

or other people Yes No (*Please tick*)

b) If so, how often? ……………………………………