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Discriminating autism and language impairment and specific language impairment through acuity of 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 conditions 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.

1. Introduction

Whilst cases of selectively impaired language and musical skills (Tzortzis, Goldblum, Dang, 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

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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 processing in SLI have revealed slow and impaired auditory discrimination, impaired sensory memory (review article Kujala & 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. 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 et al., 2008).

Cognitive profiles in ASD and SLI appear to show clearer similarities than language profiles. For example, Taylor, Maybery, 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, van 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 short-term memory (Taylor et al., 2013) are consistent with results showing that perception of musical information is intact in ASD (Heaton, 2009). For example, experimental studies have revealed preserved perception of musical contour (Heaton, 2005; Mottron, Peretz, & Menard, 2000), rhythm (Tryfon et al., 2017) and syntax (DePape, Hall, Tillmann, & Trainor, 2012; Heaton, Williams, Cummins, & Happé, 2007), and neuroimaging studies show that neural processing of musical stimuli is intact in ASD (Lai, Pantazatos, Schneider, & Hirsch, 2012; Sharda, Midha, 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 (1943) original paper on autism 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.