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Music lessons are associated with increased verbal memory in individuals with Williams syndrome

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ABSTRACT

Williams syndrome (WS) is a genetic disorder characterized by intellectual delay and an affinity for music. It has been previously shown that familiar music can enhance verbal memory in individuals with WS who have had music training. There is also evidence that unfamiliar, or novel, music may also improve cognitive recall. This study was designed to examine if a novel melody could also enhance verbal memory in individuals with WS, and to more fully characterize music training in this population. We presented spoken or sung sentences that described an animal and its group name to 44 individuals with WS, and then tested their immediate and delayed memory using both recall and multiple choice formats. Those with formal music training (average duration of training 4½ years) scored significantly higher on both the spoken and sung recall items, as well as on the spoken multiple choice items, than those with no music training. Music therapy, music enjoyment, age, and Verbal IQ did not impact performance on the memory tasks. These findings provide further evidence that formal music lessons may impact the neurological pathways associated with verbal memory in individuals with WS, consistent with findings in typically developing individuals.

1. Introduction

Williams syndrome (WS) is a neurodevelopmental disorder characterized by a deletion of 26–28 genes on chromosome 7q11.23, with a prevalence of 1 in 7500 births (Peoples et al., 2000; Strømme, Bjørnstad, & Ramstad, 2002). Individuals with WS have mild to moderate cognitive delays, with an average Full Scale IQ of 55 (Martens, Wilson, & Reutens, 2008). Visuospatial abilities are quite delayed (Farran & Jarrold, 2004; Pezzini, Vicari, Volterra, Milani, & Ossella, 1999; Porter & Coltheart, 2006), while receptive vocabulary skills are relatively strong (Mervis & Klein-Tasman, 2000; Robinson, Mervis, & Robinson, 2003). Individuals with WS show typical (but delayed) language development in verbal comprehension, word fluency, and semantics (Bello, Capirci, & Volterra, 2004; Jarrold, Hartley, Phillips, & Baddeley, 2000) while grammatical comprehension and morphosyntax appear to develop atypically (Karmiloff-Smith et al., 1997; Vicari, Caselli, Gagliardi, Tonucci, & Volterra, 2002; Volterra, Capirci, Pezzini, Sabbadini, & Vicari, 1996).

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Most research indicates that memory impairments in individuals with WS are not generalized, but that dissociations exist between short and long term memory, or between verbal and visual modalities, depending in part on the tasks administered. Initial findings suggested that short term verbal memory skills (as measured by digit span and word span) were spared in WS (Klein & Mervis, 1999; Vicari, Brizzolara, Carlesimo, Pezzini, & Volterra, 1996; Wang & Bellugi, 1994), while long term verbal memory was more significantly impaired (Vicari et al., 1996; Nichols et al., 2004). More recent research indicates that both verbal and visual memory may show evidence of impairment (Brock, Brown, & Boucher, 2006; Sampaio, Sousa, Fernandez, Henriques, & Goncalves, 2008). Sampaio et al. (2008) sought to confirm that individuals with WS have impairments in multiple memory systems and their results indicated impairments in both the phonological loop and visuo-spatial sketchpad. Furthermore, they found an equal impairment in both short and long-term memory. Although long term memory is not described as a cognitive strength for individuals with WS, it is not more delayed than what would be anticipated taking into account visuospatial abilities (Jarrold, Baddeley, & Phillips, 2007). Individuals with WS have also been shown to display deficits in aspects of executive functioning, including visual working memory, particularly with delays longer than five seconds (Rhodes, Riby, Park, Fraser, & Campbell, 2010). These combined findings suggest that memory abilities in WS would be an appropriate focus of intervention.

In contrast to their memory deficits, another important aspect of the WS phenotype is their responsiveness to music. Individuals with WS are highly drawn to music in terms of enjoyment and emotional reaction (Don, Schellenberg, & Rourke, 1999; Levitin et al., 2004; Martens, Jungers, & Steele, 2011). Levitin and colleagues found that compared to typically developing (TD) control participants, individuals with WS had higher ratings of musical engagement and interest and experienced significantly more emotion when listening to music. Based on parental ratings, children, adolescents, and adults with WS appear to enjoy music significantly more than their peers or siblings (Martens et al., 2011).

Research also suggests that some individuals with WS may have specific musical skills. Children and adolescents with WS performed similarly to chronological age-matched controls on tasks of melodic imagery and musical expressiveness (Hopyan, Dennis, Weksberg, & Cytrynbaum, 2001) and are more likely to take instrumental music lessons and show greater musical skill than individuals with other developmental disabilities (Dykens, Rosner, Ly, & Sagun, 2005). Individuals with WS show an earlier interest in music and spend more time per week playing a musical instrument than TD controls (Levitin et al., 2004). It should be noted, however, that not all individuals with WS show strengths in musicality. Lense, Shivers, and Dykens (2013) reported that 11% of their WS participants showed significant impairment in their ability to perceive pitches.

Aspects of music processing occur in both the right and left hemispheres (Peretz & Zatorre, 2005; Schulze, Mueller, & Koelsch, 2011; Schulze, Zysset, Mueller, Friederici, & Koelsch, 2011; Zatorre, Evans, & Meyer, 1994), with some evidence indicating structural differences in the left hemisphere between musicians and nonmusicians. Research among TD controls demonstrates that musicians with absolute pitch show increased leftward asymmetry in the planum temporale than either nonmusicians or musicians who do not have absolute pitch (Schlaug, Jäncke, Huang, & Steinmetz, 1995). Individuals with WS show a strong leftward asymmetry in their auditory evoked responses and their left primary auditory cortical volumes are significantly larger than in TD controls (Wengenroth, Blatow, Bendszus, & Schneider, 2010). Interestingly, Martens, Reutens, and Wilson (2010) noted that left planum temporale volumes were significantly larger in a group of musical individuals with WS compared to either TD controls or non-musical individuals with WS.

Given that individuals with WS demonstrate impaired verbal memory, enhanced musical interest, and perhaps a structural and functional neuroanatomy that is receptive to processing musical stimuli, it is logical to examine whether music can be used to help counter the verbal memory delays noted in WS. While there are undoubtedly neurological differences between individuals with Williams syndrome and neurotypical individuals, there is certainly a wealth of evidence indicating that music can enhance verbal memory in TD individuals, as well as in those with learning difficulties (McElhinney and Annett, 1996; Register, Darrow, Standley, & Swendberg, 2007; Ross, 1971; Shehan, 1981; Wallace, 1994). Text that is sung is more accurately recalled than text that is spoken in a rhythmic tone (McElhinney and Annett, 1996; Wallace, 1994). Music has also been shown to improve memory and reading skills in children with learning difficulties (Register et al., 2007; Shehan, 1981). In addition, children with mild intellectual delay showed improvement in verbal memory following just six weeks of Kodály training, which emphasizes singing and listening, learning music notation, and rhythm (Ross, 1971). It may be that music enhances cognitive performance, in part, due to increased emotional and physiological arousal (Blood & Zatorre, 2001; Khalfa, Peretz, Blondin, & Manon, 2002; Orini et al., 2010; Schellenberg, 2001). Neural regions in the reward pathway and limbic region of the brain are activated during euphoric music (Blood & Zatorre, 2001), and verbal recall appears to be enhanced during times of emotional arousal (Cahill, Gorski, & Le, 2003). Music may also benefit cognition through 'priming,' which can occur when one type of learning experience sets the stage for a similar type of learning to occur more readily (Tulving & Schachter, 1990).

There is ample evidence suggesting that individuals who have had music training show increased verbal memory compared to those with no music training, even if the stimuli are spoken versus sung (Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003; Roden, Kreutz, & Bongard, 2012; Roden, Grube, Bongard, & Kreutz, 2013). Ho et al. (2003) found that children who had taken music lessons for at least one year, or had continued lessons, performed significantly higher on a verbal recall memory task (immediate and delayed up to 30 min) than those who had not taken music lessons. In their large sample of 90 children/adolescents, a positive correlation was noted between duration of music training and verbal memory performance. When the