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

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ARTICLE INFO

Article history:
Received 25 July 2014
Received in revised form 17 October 2014
Accepted 23 October 2014
Available online

Keywords:
Williams syndrome
Music
Verbal memory
Developmental disabilities

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.

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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, & Reuters, 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).
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 (Jarroll, 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 (Hoppyan, 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 & Schacter, 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
children were retested one year later, Ho and colleagues found that the verbal memory gains were still evident for those who continued their music training compared to those who stopped their music lessons. Of note, even those who discontinued their lessons showed an advantage in verbal memory compared to those who had never taken music lessons.

Kilgour, Jakobson, and Cuddy (2000) found that musically trained college students showed greater recall of sung and spoken lyrics compared to those without music training. Franklin et al. (2008) demonstrated that highly musically trained college students have superior verbal working memory skills compared to non-musicians, and suggested that enhanced rehearsal strategies in musicians may be mediating their increased verbal memory.

Only one study to date has examined if music training can enhance verbal memory in individuals with WS. A memory task of spoken or sung sentences that described an animal and its group name was used in two experiments, with the sung sentences presented to the familiar tune of “Twinkle, Twinkle, Little Star” (Martens et al., 2011). Findings revealed that participants who had participated in formal music lessons scored significantly better on the long-term verbal memory task when the sentences were sung rather than spoken. Those who did not have formal music lessons showed no such benefit.

The current experiment expands the previous experiment implemented by Martens et al. (2011) by examining whether novel music can benefit verbal memory in individuals with WS. Individuals with WS interact with music, broadly defined, differently than typically developing individuals. They are more likely to be engaged and respond emotionally when listening to music. The current study looks at music in several ways. First, the participants’ musical background, enjoyment of music, and experience with music lessons is characterized. Second, the study examines whether items set to music are remembered better than items that are spoken. Finally, the study investigates whether individuals with previous music lessons remember items better than those without lessons.

2. Methods

2.1. Participants

Forty-four participants with WS (27 females, 18 males), ranging in age from 8 to 48 years of age (mean age = 22.11 years), participated in the study. The participants were recruited locally and at a National Williams Syndrome Conference. All participants were administered the Kaufman Brief Intelligence Test, 2nd edition (Kaufman & Kaufman, 2004). The average Verbal IQ was 75.71 (SD = 10.39), Nonverbal IQ was 73.96 (SD = 18.38), and Composite IQ was 71.76 (SD = 13.30).

2.2. Music questionnaire

The parents/caretakers of the participants completed a Music Questionnaire that was designed for this study regarding the participants’ level of musical interest, type of musical interest, specific musical background, presence of musical abilities, and experience with formal music lessons (see Appendix A).

2.3. Design and procedure

The participants were first shown individual pictures of eight animals and asked to identify each animal by its name. The participants were then shown pictures of each animal group and taught the group name that corresponded to the picture (either sung or spoken) (see Fig. 1). None of the participants were familiar with any of the animal group names.

All sentences followed the example “A group of ____ is called a ____.” See Table 1 for a complete list of all of the sentences that were either sung or spoken.

The participants heard eight sentences, repeated 12 times each, teaching them the animal group name that corresponded to each picture. There were four stimulus sets, each with four spoken and four sung sentences. Both the sung and spoken sentence sets were presented at a similar rate by a female speaker/singer. The sentences were spoken in a natural manner (not rhythmic), while the sung versions were a cappella. Each stimulus set was randomized for order of stimuli and order of sung and spoken sentences, and each participant heard only one of the four stimulus sets. A novel melody was created for this study that included the same harmonic and rhythmic structure as “Twinkle, Twinkle Little Star,” which was the familiar tune used in the Martens et al. (2011) study (see Appendix B).

The participants’ memory for the stimuli was assessed immediately following the listening task using a direct recall format, followed by a multiple choice format. For the direct recall questions, participants were simply asked, “A group of ____ is called a what?” For the multiple choice questions, participants were asked to choose between three possible responses: “Is a group of ____ called a ____, a ____, or a ____?” The participants then completed a computerized distracter task for approximately 15 min. The participants’ memory for the animal group names was again assessed (delayed format) using direct recall and multiple-choice questions.

2.4. Data analysis

Level of musical interest as reported in the Music Questionnaire was examined using descriptive statistics. Mixed between-within subjects analysis of variance was used to compare the participants’ scores on the recall and multiple-choice
memory tests. The effects of age, IQ, and other types of musical experience on memory scores were examined using Pearson correlation coefficients.

3. Results

3.1. Music questionnaire

Thirty-eight (38) parents reported how often their child listened to music daily, with 66% of the children listening to music for 2 or more hours per day (30 min. to 8 h). Fourteen (14) of the participants had participated in music therapy, and 25 of the participants had participated in choir. According to parental ratings, 56.5% of the WS participants enjoy music “significantly more” than their peers (mean = 4.38 on a 0–5 Likert scale) (see Fig. 2), and 43.5% of children enjoy music “significantly more” than their siblings (mean = 4.12 on a 0–5 Likert scale) (see Fig. 3).

Just over half of the participants (n = 23) had taken formal music lessons for at least one year (average duration of lessons was 4½ years) and they started taking lessons at an average age of 9.17 years (SD 2.95). The formal music lessons included playing any type of instrument and/or taking voice lessons. Parents reported that 66.7% of participants played piano, 12.5% had voice lessons, 8.3% played the drums, 8.3% played the violin, and 4.2% played the guitar.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turtle</td>
<td>A group of turtles is called a bale</td>
</tr>
<tr>
<td>Duck</td>
<td>A group of ducks is called a raft</td>
</tr>
<tr>
<td>Giraffe</td>
<td>A group of giraffes is called a corps</td>
</tr>
<tr>
<td>Pig</td>
<td>A group of pigs is called a drove</td>
</tr>
<tr>
<td>Horse</td>
<td>A group of horses is called a band</td>
</tr>
<tr>
<td>Camel</td>
<td>A group of camels is called a train</td>
</tr>
<tr>
<td>Bear</td>
<td>A group of bears is called a sloth</td>
</tr>
<tr>
<td>Tiger</td>
<td>A group of tigers is called a streak</td>
</tr>
</tbody>
</table>
3.2. Memory for animal group names

Memory for the animal group names was evaluated using both direct recall and multiple choice formats. Findings from the direct recall format were analyzed first. A mixed between-within subjects analysis of variance was conducted to assess the impact of music training (formal lessons vs. no formal lessons) on participants’ direct recall scores across two stimuli types (sung vs. spoken) and two time periods (immediate and delayed). Thus, there were four conditions: (1) immediate recall of spoken stimuli, (2) delayed recall of spoken stimuli, (3) immediate recall of sung stimuli, and (4) delayed recall of sung stimuli. The between subjects variable was whether or not the participants had formal music training, and the within subjects variables were type of stimuli (spoken vs. sung) and timing (immediate vs. delayed). There was no significant interaction between condition and music training \[\text{Wilks Lambda} = .94, F(1, 40) = .91, p = .45\] and no main effect for condition \[\text{Wilks Lambda} = .93, F(1, 40) = .93, p = .43\]. There was a significant main effect for music training \[F(1, 42) = 4.53, p = .039, \text{partial eta squared} .097\], suggesting a moderately large effect of formal music lessons on direct recall of both sung and spoken stimuli in the immediate and delayed time periods (see Fig. 4).

Findings from the multiple choice format were then investigated. A mixed between-within subjects analysis of variance was conducted to evaluate the impact of music training (formal lessons vs. no formal lessons) on participants’ memory scores on the multiple choice items. Similar to the first analysis, there were four conditions: immediate and delayed spoken stimuli, and immediate and delayed sung stimuli. There was no significant interaction between condition and music training \[\text{Wilks Lambda} = .92, F(1, 40) = 1.16, p = .34\] and no main effect for condition \[\text{Wilks Lambda} = .90, F(1, 40) = 1.54, p = .22\]. There was also no significant main effect for music training \[F(1, 42) = 2.64, p = .112, \text{partial eta squared} .059\].

An examination of the graphical display of the data (see Fig. 5) revealed that the two groups (formal lessons vs. no formal lessons) performed similarly on the multiple choice sung items (immediate and delayed), but those who had formal lessons scored much higher on the multiple choice spoken items (immediate and delayed) than those who did not have formal lessons.

Therefore, separate mixed between-within ANOVAs were conducted on the multiple choice spoken and sung stimuli, using a Bonferroni adjusted \(p\) value of .025. For the analysis of the spoken stimuli, the between subjects variable was whether or not the participants had formal music training, and the within subjects variable was timing (immediate vs. delayed multiple choice score). There was no significant interaction between timing and music training \[\text{Wilks Lambda} = .99, F(1, 42) = .04, p = .84\]. Using the Bonferroni adjustment, there was a trend toward a main
effect for timing \( [\text{Wilks Lambda} = .90, F(1, 42) = 4.46, p = .04] \), with both groups (those who had formal music lessons and those who did not) scoring higher in the delayed format than in the immediate format. There was a significant main effect for music training \( [F(1, 42) = 6.41, p = .015, \text{partial eta squared} .13] \), suggesting a large effect of formal music lessons on the multiple choice spoken stimuli. As expected, based on the graphical display of the data, the analysis of the sung stimuli showed no interaction between timing and music training \( [\text{Wilks Lambda} = .99, F(1, 42) = .41, p = .53] \), no main effect for timing \( [\text{Wilks Lambda} = .99, F(1, 42) = .12, p = .74] \), and no main effect for music training \( [F(1, 42) = .10, p = .75] \).

Age, Verbal IQ, and length of participation in music lessons, music therapy, or choir did not impact performance on the sung or spoken stimuli \( (p > .05) \). Degree of music enjoyment and length of time listening to music per day also did not have an effect on memory scores for the sung or spoken stimuli \( (p > .05) \).

4. Discussion

The results of this study are noteworthy because they provide further evidence that music lessons may help individuals with WS more easily remember verbal information. Our findings indicate that individuals with WS who participate in music lessons have enhanced recall and recognition of spoken information. Those who participate in music lessons also show improved recall of verbal information that is taught to novel music. Both groups (those with and without music training) appear to benefit from information taught to novel music on easier recognition tasks, such as multiple-choice items. These findings were evident regardless of other musical experience, age, or Verbal IQ.

The finding that those with music training showed enhanced verbal memory supports previous research demonstrating that musicians show increased working and long-term memory for spoken stimuli compared to non-musicians \( (\text{Franklin et al., 2008}) \). Franklin and colleagues hypothesized that musicians may use more verbal rehearsal strategies than non-musicians, which benefit the temporary storage of the information in working memory, as well as create long-term memories. Ginsborg and Sloboda (2007) found that individuals with high levels of music expertise (either college music students and/or professional singers) had better recall of both words and melody of an unfamiliar song than individuals who had less or no musical expertise.

The memory benefit that music lessons has for both spoken and sung stimuli is well researched and has neurological underpinnings. Event-related brain potential demonstrated that both speech and pitch discrimination skills were increased in children who received music training \( (\text{Magne, Schön, & Besson, 2006; Moreno et al., 2009}) \). Jakobsen, Cuddy, and Kilgour (2003) showed that musicians had greater working memory skills than non-musicians and suggested that music training
may enhance temporal processing of auditory stimuli. Neurological evidence suggests that participation in formal music lessons may benefit verbal memory by impacting the pathways involved in processing and retaining verbal information. It is important to note that the influence of music training on neural pathways may not be the same between individuals with WS, who have atypical neuroanatomy, and typical individuals who may have limited or extensive musical expertise. However, whether or not the process is the same, music lessons can still show cognitive benefit to those with atypical neural development, such as those with dyslexia (Overy, 2003).

Evidence indicates that the brain processes music in neural networks within both hemispheres, and within the cerebellum, with variability associated with the level of musical expertise and the type of music processing (e.g. tonal knowledge, perception of pitch, temporal processing) (Hutchinson, Lee, Gaab, & Schlaug, 2003; Peretz & Zatorre, 2005; Schulze et al., 2011a, 2011b; Wilson, Lusher, Wan, Dudgeon, & Reutens, 2009; Zatorre et al., 1994). Functional magnetic resonance imaging demonstrates that cortical representation of auditory processing is increased 25% in the left hemisphere of musicians (Pantev et al., 1998). The left planum temporale, located in the temporal lobe and associated with language comprehension and aspects of pitch processing, shows increased size and activation in musicians (Ohnishi et al., 2001; Schlaug et al., 1995). Of note, left planum temporale volumes were enhanced in a group of musical individuals with WS (Martens et al., 2010). The process of music training may lead to a reorganization of brain connections, and increased development of the left temporal lobe, which facilitates verbal memory (Ho et al., 2003; Pantev et al., 1998). It is this reorganization that may give those with music training an advantage on verbal stimuli.

The findings from the music questionnaire revealed that a vast majority of participants reported heightened enjoyment of music and increased length of time listening to music compared to TD controls, which supports previous findings of enhanced music enjoyment in the WS literature (Don et al., 1999; Hopyan et al., 2001). Our findings indicate that presenting information with music would appear to be an important learning tool to use with individuals with WS given their heightened enjoyment of music, particularly on easier recognition items such as multiple choice.

The previous study examining the benefits of music training on verbal memory found a benefit for recall of sung stimuli, but not spoken stimuli (Martens et al., 2011). Martens and colleagues used a familiar melody to teach the information
(Twinkle, Twinkle), while the current study utilized a novel melody. There is evidence that novel music can be particularly beneficial in aiding verbal memory (Calvert & Tart, 1993; Crowder, Serafine, & Repp, 1990; McElhinney and Annett, 1996; Yalch, 1991).

These findings highlight the need for future studies to examine whether a specific type of formal music lesson is most beneficial in aiding verbal memory (Calvert & Tart, 1993; Crowder, Serafine, & Repp, 1990; McElhinney and Annett, 1996; Yalch, 1991).

Fig. 5. Multiple choice scores (out of 4) for those with and without formal music lessons across stimuli type (sung, spoken) and time of multiple choice questions (immediate, delayed).

Acknowledgements

This research was supported in part by The Ohio State University at Newark Student Research Grant. The authors would like to thank the individuals with Williams syndrome and their parents who participated in this study. We would also like to thank Daniel Martens for creating the novel melody used in this experiment.
Appendix A

Music Questionnaire

NAME: ___________________________________ DATE OF BIRTH: ___________

Please answer the following questions about your child by checking the appropriate response.
Thank you for your time!

Musical Interest:

1. How much does your child appear to enjoy music compared to his/her siblings?

   ____Significantly   ____A Little   ____About the   ____A Little   ____Significantly
   Less                Less           Same            More              More

2. How much does your child appear to enjoy music compared to his/her peers?

   ____Significantly   ____A Little   ____About the   ____A Little   ____Significantly
   Less                Less           Same            More              More

3. Does your child emotionally react to certain songs or types of music?

   ____No unusual reaction   ____Cries or appears sad   ____Becomes happy or
   ____                ____                            overly excited

4. If your child cries when he/she hears certain songs, please list the songs that bring about this
   response:

   _______________________________ _______________________________
   _______________________________ _______________________________
   _______________________________ _______________________________

5. Does your child specifically prefer one style or type of music? If they enjoy more than one
   style, please number their preferences (1, 2, 3, etc.).

   ____Country   ____Classical   ____Instrumental   ____Hip-Hop
   ____           ____           ____              ____
   ____Rap       ____Rock       ____Alternative   ____Blues
   ____           ____           ____              ____

   ____Other (specify) ____________________________________________
6. Please list any particular style/type of music that your child dislikes.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

7. If your child becomes happy or overly excited when he/she hears certain songs, please list the songs that bring about this response:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

8. Please list any other emotional reactions that your child may have in response to music:

________________________________________________________________________

Musical Background:

9. How often did your child listen to music as a baby (1st year)?

___ Less than siblings  ___ Same as siblings  ___ More than siblings

10. How often did your child listen to music between the ages of 1 to 5?

___ Less than siblings  ___ Same as siblings  ___ More than siblings

11. How often did someone sing to your child when they were a baby?

___ Never  ___ Rarely  ___ Occasionally  ___ Often  ___ Everyday

12. How many hours of the day does your child listen to music? __________

What type of music do they listen to? ______________________________________

13. Has your child ever had formal music lessons?  ___ No  ___ Yes

If yes,

- What instrument (e.g. piano, guitar, drums, etc.) or voice?

________________________________________________________________________

- Age lessons began: _______________________________________________________

- Frequency and duration of lessons (e.g. once a week for 30 minutes):

________________________________________________________________________

- How long did they take the lessons? (Number of months or years):

________________________________________________________________________
14. Was your child involved in music therapy?  ____No  ____Yes

If yes,
- Age music therapy began: ______________________________
- Frequency and duration of therapy (e.g. once a week for 30 minutes):
  ______________________________
- How long did they have music therapy? (Number of months or years):
  ______________________________

15. Has your child sung in a choir? (School or religious organization)
  ____No  ____Yes

If yes,
- Age they began choir: ______________________________
- Frequency and duration of choir (e.g. once a week for 30 minutes):
  ______________________________
- How long did they participate in choir? (Number of months or years):
  ______________________________

16. If your child plays an instrument or sings, how many hours of the day do they play or sing?

(Not including lessons) ______________________________

Musical Ability:

17. Does your child seem to display any particular musical abilities?

__________________________

__________________________

__________________________
18. Any other comments you wish to add regarding your child’s musical interests or abilities?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

19. Does your child appear to be particularly sensitive to any other types of sounds?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

If so, has this sensitivity changed since childhood? __________________________

Thank you!!!

Appendix B

novel melody

\[ \text{\includegraphics[width=\textwidth]{novel-melody.pdf}} \]


Wengenroth, M., Blatow, M., Bendzus, M., & Schneider, P. (2010). Leftward laterORIZATION of auditory cortex underlies holistic sound perception in Williams syndrome. *PLoS ONE, 5* [http://dx.doi.org/10.1371/journal.pone.0012326](http://dx.doi.org/10.1371/journal.pone.0012326)

