SHORT REPORT

Enhanced Memory for Vocal Melodies in Autism Spectrum Disorder and Williams Syndrome

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Adults and children with typical development (TD) remember vocal melodies (without lyrics) better than instrumental melodies, which is attributed to the biological and social significance of human vocalizations. Here we asked whether children with autism spectrum disorder (ASD), who have persistent difficulties with communication and social interaction, and adolescents and adults with Williams syndrome (WS), who are highly sociable, even indiscriminately friendly, exhibit a memory advantage for vocal melodies like that observed in individuals with TD. We tested 26 children with ASD, 26 adolescents and adults with WS of similar mental age, and 26 children with TD on their memory for vocal and instrumental (piano, marimba) melodies. After exposing them to 12 unfamiliar folk melodies with different timbres, we required them to indicate whether each of 24 melodies (half heard previously) was old (heard before) or new (not heard before) during an unexpected recognition test. Although the groups successfully distinguished the old from the new melodies, they differed in overall memory. Nevertheless, they exhibited a comparable advantage for vocal melodies. In short, individuals with ASD and WS show enhanced processing of socially significant auditory signals in the context of music. ***Autism Res*** *2021, 00: 1–7.* © 2021 International Society for Autism Research, Wiley Periodicals LLC.

Lay summary: Typically developing children and adults remember vocal melodies better than instrumental melodies. In this study, we found that children with Autistic Spectrum Disorder, who have severe social processing deficits, and children and adults with Williams syndrome, who are highly sociable, exhibit comparable memory advantages for vocal melodies. The results have implications for musical interventions with these populations.

Keywords: autism; Williams syndrome; vocalization; music; memory

Introduction

Musical behaviors are ancient [Conard, Malina, & Münzel, 2009], widespread [Mehr et al., 2019; Savage, Brown, Sakai, & Currie, 2015], and commonly incorporated into everyday life. Although various instruments can generate melodies, only vocal melodies are biological, conspecific signals with communicative consequences. Sung melodies, even without lyrics, elicit greater arousal than instrumental melodies in adult listeners [Weiss, Trehub, Schellenberg, & Habashi, 2016]. They are also more memorable than instrumental melodies for adults [Weiss, Schellenberg, & Trehub, 2017; Weiss, Trehub, & Schellenberg, 2012] and children [Weiss, Schellenberg, Trehub, & Dawber, 2015], who produce recognizable vocal songs by 2 or 3 years of age [Gudmundsdottir & Trehub, 2018].

It is possible, however, that populations with atypical neurodevelopment, especially those with atypical processing of vocalizations, or communicative signals more generally, would not exhibit the usual memory advantage for vocal melodies. Autism Spectrum Disorder (ASD) and Williams syndrome (WS) are neurodevelopmental disorders that have been linked to starkly different profiles of socio-communicative engagement [Tager-Flusberg, Skwerer, & Joseph, 2006].

Individuals with ASD show considerable heterogeneity in IQ and language ability [Courchesne, Girard, Jacques, & Soulières, 2019], but a core diagnostic feature is persistent difficulty with communication and social interaction (DSM-5; American Psychiatric Association, 2013). Many individuals with ASD do not respond to vocalizations with typical brain activity in the "Temporal Voice Areas" [Abrams et al., 2019; Bidet-Caulet et al., 2017; Boddaert

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et al., 2004; Gervais et al., 2004]. Moreover, they exhibit deficits in voice recognition [Schelinski, Borowiak, & von Kriegstein, 2016; Schelinski, Roswandowitz, & von Kriegstein, 2017] and vocal emotion recognition [Schelinski & von Kriegstein, 2019]. In the domain of music, individuals with ASD show typical or enhanced pitch and contour discrimination relative to age-matched controls [Bonnel et al., 2003; Chowdhury et al., 2017; Foxton et al., 2003; Germain et al., 2019; Heaton, 2003, 2005; Jamey et al., 2019; Mottron, Peretz, & Ménard, 2000; Stanutz, Wapnick, & Burack, 2014], but these studies used synthesized (e.g., pure tones) or instrumental (e.g., piano) sounds rather than voices.

Individuals with WS exhibit reduced overall IQ and impaired spatial skills but relative strengths in verbal skills [Martens, Wilson, & Reutens, 2008]. They are highly sociable, even hyper-sociable or indiscriminately friendly, although they exhibit deficits in pragmatic language and social skills [Martens et al., 2008; Thurman & Fisher, 2015]. Their auditory profile reveals increased neural responses to auditory stimuli [Zarchi et al., 2015], including atypical responses to emotion in speech and instrumental music [Lense, Gordon, Key, & Dykens, 2014; Pinheiro et al., 2011]. They show a notable affinity for music, exhibiting stronger emotional responses to music than individuals with ASD and TD [Levitin et al., 2004; Thakur, Martens, Smith, & Roth, 2018]. In general, their performance on pitch and rhythm discrimination tasks is consistent with their mental age rather than chronological age [Deruelle, Schön, Rondan, & Mancini, 2005; Don, Schellenberg, & Rourke, 1999; Elsabbagh, Cohen, & Karmiloff-Smith, 2010; Hopyan, Dennis, Weksberg, & Cytrynbaum, 2001; Martens, Reutens, & Wilson, 2010].

For individuals with ASD, impaired processing of vocalizations and typical or enhanced processing of nonvocal music make their processing of vocal music of particular interest. When language is sung rather than spoken, it elicits greater engagement [Paul et al., 2015; Simpson, Keen, & Lamb, 2013; Thompson & Abel, 2018] and more typical patterns of fronto-temporal connectivity [Lai, Pantazatos, Schneider, & Hirsch, 2012; Sharda, Midha, Malik, Mukerji, & Singh, 2015] in individuals with ASD. These findings imply that atypical processing of vocalizations is limited to speech and other nonmusical contexts or that music engages a distinctive mode of processing in this population. Children with WS also show better memory for sentences that are sung rather than spoken [Dunning, Martens, & Jungers, 2015; Martens, Jungers, & Steele, 2011] and more typical neural responses to prosodic stimuli without semantic context rather than with such context [Pinheiro et al., 2011]. To our knowledge, however, no studies have compared the processing of vocal and instrumental melodies in individuals with ASD or WS.

The current study asks whether individuals with neurodevelopmental socio-communicative disorders—children with ASD as well as adolescents and adults with WS—exhibit enhanced memory for vocal over instrumental melodies, as observed in adults and in children with TD [Weiss et al., 2012, 2017; Weiss, Schellenberg, et al., 2015].

Method

Participants

Participants with ASD and TD were recruited from the general community in Montreal and Toronto, and participants with WS were recruited from a summer camp affiliated with Vanderbilt University. The ASD group (clinically diagnosed using DSM-IV criteria; American Psychiatric Association, 2000) included 26 children ($M_{age} = 11.1 \pm 1.4$, *range* = 7.9–12.9 years; 22 male). The TD group included 26 children ($M_{age} = 10.7 \pm 1.5$, *range* = 8.1–13.3 years; 23 male) who scored below the cut-off of 12 on the Social Communication Questionnaire [Rutter, Bailey, & Lord, 2003], a standard screening tool for ASD. The WS group (diagnoses confirmed genetically) included 26 adolescent or adult participants ($M_{age} = 26.8 \pm 8.0$, *range* = 15.9–53.5 years; 13 male). The WS group was older than the ASD and TD groups, Ps <0.001, but their verbal mental age on an abbreviated intelligence test (Kaufman Brief Intelligence Test, 2nd edition [KBIT-2]; Kaufman & Kaufman, 2004), $M = 11.7 \pm 2.5$, *range* = 8.3–18.5 years, did not differ significantly from the chronological age of TD, $P = 0.088$, or ASD participants, $P = 0.302$. Moreover, biological age did not correlate with recognition across all participants or within groups (see Supporting Information). All participants verbally confirmed that they understood the task.

Details on exclusions ($n = 6$), and measures of IQ, social responsiveness, and music lessons are included as Supporting Information. The research was approved by ethics committees at McGill University, Vanderbilt University, and the University of Toronto.

Stimuli

The stimuli were 24 excerpts (13–20 s) of unfamiliar but conventionally Western folk melodies from Ireland and the U.K., which had been used in previous research with adults and children [Weiss & Peretz, 2019; Weiss et al., 2012, 2017]. Each melody was recorded by amateur musicians in three timbres (voice, piano, and marimba) without accompaniment. Vocal renditions were performed by a female vocalist without lyrics (i.e., *la la*), and pitch-corrected note-by-note using the Melodyne software (Celemony). All renditions were normalized in RMS amplitude and exported as high-quality audio files (24 bit/44.1 kHz).

Apparatus

Participants were tested individually in a quiet room with an experimenter present. The task was programmed using PsyScript (2.3; Slavin, 2007) on a MacBook Pro (Apple, Inc.). Stimuli were presented over portable speakers (Edifier M1250 or Alesis M1 Active 320) at a comfortable volume adjusted for each participant.

Procedure

The task was presented as two musical games. In the first game (exposure), participants heard half of the melodies (n = 12; four per timbre). To maintain their engagement, participants were required to respond to questions from Tito, a cartoon character, who asked how much they liked each melody (analysis of liking scores can be found in Supporting Information). Younger participants—those in the ASD and TD groups—responded by pointing to one of five ice-cream cones of increasing size (Fig. 1A). Participants in the WS group, who were older, responded by pointing to one of four cartoon faces (Fig. 1B), a response scale that was familiar to them. Each response was confirmed verbally and recorded by the experimenter. Each melody was presented twice, across two randomized blocks.

After a short break (5–10 min), participants completed an unexpected recognition test using the same 12 melodies (i.e., "old") intermixed with the remaining 12 melodies (i.e., "new"; four per timbre). Participants responded if they had heard the melody before by pointing to "Yes" or "No" images (Fig. 1C). The procedure lasted 25–30 min. Melodies were assigned to timbre and old/new status randomly, separately for each participant.

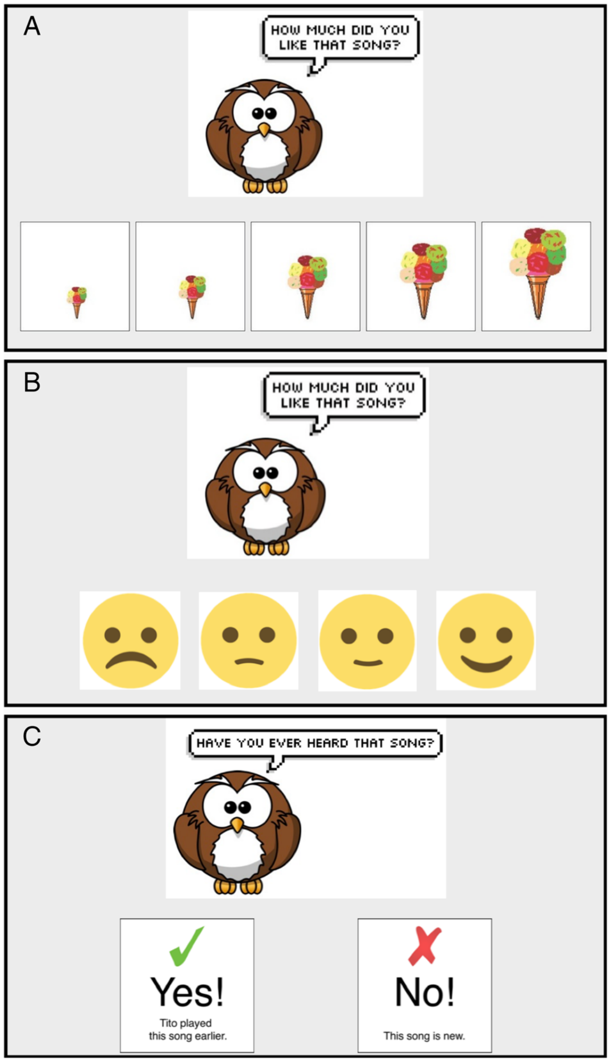

Figure 1. Panel (A) shows the response scale for the first phase of the task (exposure) for participants with ASD and TD. Panel (B) shows the response scale for the first phase of the task for participants with WS. The liking question was designed to keep participants engaged. Panel (C) shows the response options for the second phase of the task (recognition), which were the same across groups.

Results

Responses during the recognition task were coded as 1 (i.e., "old") or 0 (i.e., "new") and were averaged according to timbre (voice, piano, and marimba) and whether the melody was old or previously heard (i.e., yielding proportion hits) or new (i.e., yielding proportion false alarms). Descriptive statistics are visualized separately for each timbre and group in Figure 2A. Recognition memory, operationalized as hits minus false alarms, is visualized in Figure 2B.

A 3-way mixed-model ANOVA compared recognition scores as a function of the within-subject factors of timbre (voice, piano, marimba) and exposure level (old, new), and the between-subjects factor of group (ASD, TD, and WS). There was a robust main effect of exposure level, $F_{(1,75)}$ = 392.42, $P < 0.001$, η_P^2 = 0.84, indicating successful differentiation of old and new melodies, and a main effect of group, $F_{(2,75)}$ = 3.82, P = 0.026, η_P^2 = 0.09, indicating that groups differed in the rate of "old" responses overall. However, those main effects were qualified by an interaction between group and exposure level, $F_{(2,75)}$ = 6.73, P = 0.002, η_P^2 = 0.15, indicating differences in overall memory (i.e., regardless of timbre) across groups. Pairwise comparisons (Holm–Bonferroni) of overall hits minus false alarms showed that the TD group (M = 0.63 $\pm$ 0.20) outperformed the ASD group (M = 0.45 $\pm$ 0.24), $t(50)$ = 2.81, P = 0.014, Cohen's d = 0.78, and the WS group (M = 0.41 $\pm$ 0.22), $t(50)$ = 3.60, P = 0.002, d = 1.00, in overall memory, while the latter two groups did not differ, $t(50)$ = 0.60, P = 0.550. Moreover, there was a main effect of timbre, $F_{(2,150)}$ = 7.04, P = 0.001, η_P^2 = 0.09, which was qualified

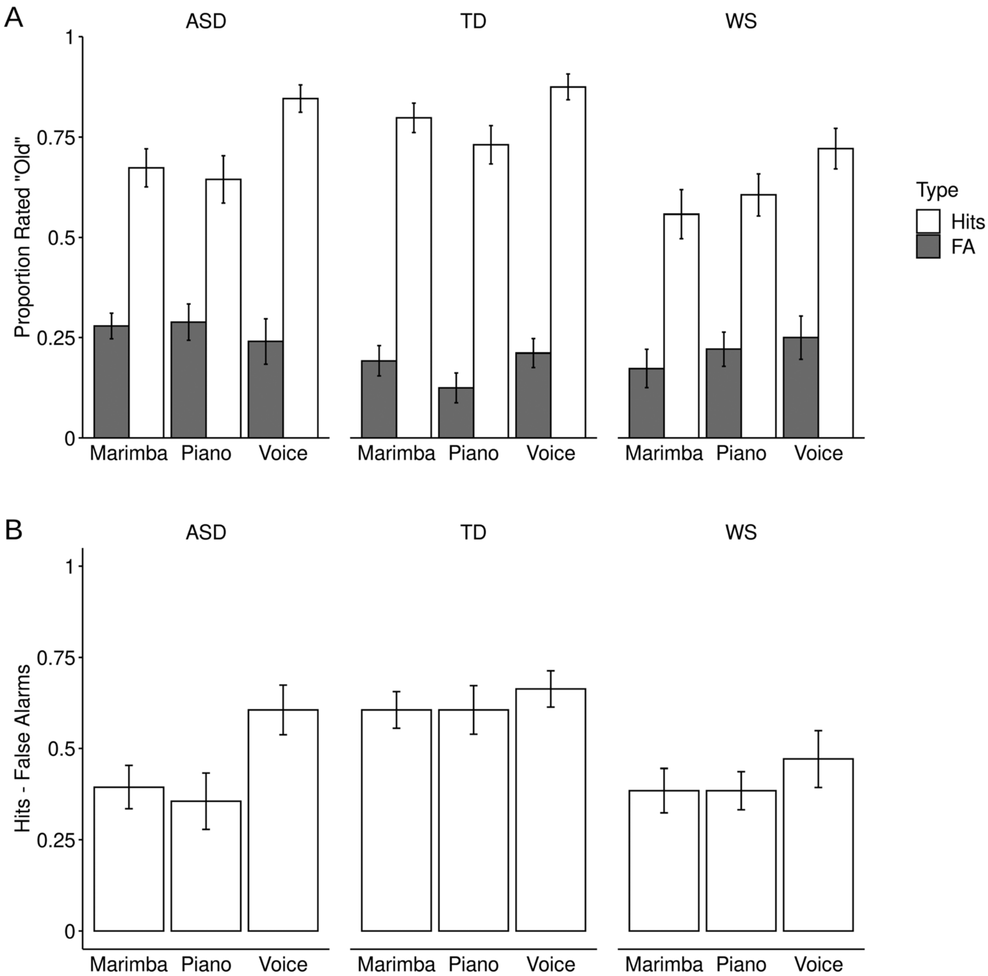

Figure 2. Panel A shows the proportion of items rated as heard previously (i.e., "old") separately by timbre, group, and whether the item was actually heard previously (hit) or not (false alarm) (range = 0–1, chance = 0.5). Panel B shows recognition memory (hits minus false alarms; perfect = 1, chance = 0) separately for each timbre and group. Across all participants, there was a significant advantage for vocal melodies compared to marimba or piano melodies. The memory advantage for voice did not differ significantly across groups, but overall memory did. Error bars are S.E.M.

by an interaction between timbre and exposure level, $F_{(2,150)} = 4.95$, $P = 0.008$, $\eta_P^2 = 0.06$, indicating that memory differed by timbre. Pairwise comparisons (Holm-Bonferroni) of hits minus false alarms showed better memory for vocal melodies ($M = 0.58 \pm 0.34$) than piano ($M = 0.45 \pm 0.35$), $t(77) = 2.61$, $P = 0.022$, $d = 0.38$, or marimba ($M = 0.46 \pm 0.30$) melodies, $t(77) = 2.81$, $P = 0.019$, $d = 0.37$, which did not differ, $t(77) = 0.28$, $P = 0.777$. There was no three-way interaction between group, timbre, and exposure level, $F < 1$.

In summary, we found a memory advantage for vocal melodies, as in previous research with populations with TD [Weiss & Peretz, 2019; Weiss et al., 2012, 2016, 2017; Weiss, Schellenberg, et al., 2015; Weiss, Vanzella, Schellenberg, & Trehub, 2015], which did not differ across groups that differed in overall memory. An ANOVA limited to ASD and WS groups yielded a nearly identical pattern of results, except for the absence of an interaction between group and exposure level (i.e., no difference in overall memory, as reported in the pairwise tests above). In other words, the TD group was not responsible for the observed voice advantage. Additional analyses investigating individual differences in recognition with liking ratings, IQ, social responsiveness, and age can be found in Supporting Information.

Discussion

We found enhanced memory for vocal over instrumental melodies in two populations with atypical socio-communicative profiles: children with ASD and adolescents and adults with WS. The magnitude of the voice advantage in the ASD and WS groups did not differ from that of children with TD in the current sample. Moreover, the vocal melody advantage mirrored that observed in previous research with children with TD [Weiss, Schellenberg, et al., 2015], adults with TD [Weiss et al., 2012, 2017], adults with congenital amusia [Weiss & Peretz, 2019], and expert musicians, including pianists [Weiss, Vanzella, et al., 2015]. The present findings add to the evidence of superior memory for vocal melodies across a range of typical and atypical populations.

Differences in other aspects of vocal processing have been observed in ASD [Abrams et al., 2019; Bidet-Caulet et al., 2017; Boddaert et al., 2004; Gervais et al., 2004; Järvinen et al., 2016; Schelinski et al., 2017] and WS [Järvinen et al., 2012, 2016; Järvinen-Pasley et al., 2010; Plesa-Skwerer, Faja, Schofield, Verbalis, & Tager-Flusberg, 2006] relative to typically developing samples. In those cases, the vocalizations were speech tokens or isolated sounds (e.g., laughter, gasps) rather than singing. In typically developing individuals, vocal melodies engage different aspects of neural processing relative to speech [Angulo-Perkins & Concha, 2019] and elicit a greater degree of neural phase-locking to the signal under time-compressed listening conditions [Vanden Bosch der Nederlanden, Joanisse, & Grahn, 2020]. The processing of sung language in ASD involves typical patterns of connectivity in fronto-temporal networks [Sharda et al., 2015]. Whether the processing of vocal melodies involves common pathways for individuals with ASD, WS, and TD remains to be established.

Our findings are relevant to evidence-based music therapies in children with neurodevelopmental disorders [Lense & Camarata, 2020; Sharda et al., 2019]. Music therapy can include various forms of music-making, especially singing, because vocal melodies are more memorable than other melodies, as shown here and elsewhere, and because they are inherently engaging [Weiss et al., 2016]. Other research has shown a greater degree of socio-communicative engagement for sung words than for spoken words in children with ASD [Paul et al., 2015; Thompson & Abel, 2018]. In short, we recommend the inclusion of vocal music in therapeutic interventions, where feasible, rather than assuming that voice processing difficulties in nonmusical contexts preclude productive use of the voice in musical contexts.

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Conflict of interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1: Supporting information