Discrimination of foreign speech pitch and autistic traits in non-clinical population

Lai-Sang Iao[a, *], Anna Wippich[a], and Yu Hin Lam[b]

[a]Department of Psychology, Nottingham Trent University, 50 Shakespeare Street, Nottingham, United Kingdom, NG1 4FQ

[b]Department of Educational and Psychological Studies, College of Education, University of South Florida, USA

[*]Corresponding author

Address for correspondence: Department of Psychology, Nottingham Trent University, 50 Shakespeare Street, Nottingham, United Kingdom, NG1 4FQ

E-mail: lai-sang.iao@ntu.ac.uk

Phone: +44 (0)115 848 2387

Conflict of Interest: Lai-Sang Iao declares that she has no conflict of interest. Anna Wippich declares that she has no conflict of interest. Yu Hin Lam declares that he has no conflict of interest.

Abstract

Individuals with Autism Spectrum Conditions (ASC) are widely suggested to show enhanced perceptual discrimination but inconsistent findings have been reported for pitch discrimination. Given the high variability in ASC, this study investigated whether ASC traits were correlated with pitch discrimination in an undergraduate sample when musical and language experiences were taken into consideration. Results indicated that the Social Skills subscale of the Autism Spectrum Quotient (AQ) was associated with foreign speech pitch discrimination, suggesting that individuals who were less sociable and socially skillful were less able to discriminate foreign speech pitch. Current findings have an implication in investigating individual differences in ASC and further investigation is needed for spelling out the relationship between the non-social and social aspects of ASC.

Keywords: Pitch discrimination, Autism Spectrum Quotient, Musical experience, Language experience, Individual differences

 Click here to view linked References

Discrimination of foreign speech pitch and autistic traits in non-clinical population

Abstract

Individuals with Autism Spectrum Conditions (ASC) are widely suggested to show enhanced perceptual discrimination but inconsistent findings have been reported for pitch discrimination. Given the high variability in ASC, this study investigated whether ASC traits were correlated with pitch discrimination in an undergraduate sample when musical and language experiences were taken into consideration. Results indicated that the Social Skills subscale of the Autism Spectrum Quotient (AQ) was associated with foreign speech pitch discrimination, suggesting that individuals who were less sociable and socially skillful were less able to discriminate foreign speech pitch. Current findings have an implication in investigating individual differences in ASC and further investigation is needed for spelling out the relationship between the non-social and social aspects of ASC.

Discrimination of foreign speech pitch and autistic traits in non-clinical population

Autism Spectrum Conditions (ASC) are characterized by impairments in social communication and interaction as well as restricted, repetitive interests and/or behaviors, in which hypersensitivity or hyposensitivity to sensory information are also included in the most recent Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013). Many research findings support the Enhanced Perceptual Functioning (EPF) theory that individuals with ASC show enhanced low-level perceptual processing (Mottron & Burack, 2001; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). Given that traits related to ASC are prevalent in relatives of individuals with ASC and in typically developing individuals (e.g., Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Dawson et al., 2007), individuals with higher ASC traits in the general population are also found to exhibit enhanced perceptual processing (e.g., Almeida, Dickinson, Maybery, Badcock, & Badcock, 2010; Grinter et al., 2009; Mayer, Hannent, & Heaton, 2016; Stewart, Griffiths, & Grube, 2015). However, this is not always the case in the auditory domain (for reviews, see Haesen, Boets, & Wagemans, 2011; O'Connor, 2012).

Superior pitch perception may be limited to children with ASC (Heaton, Hudry, Ludlow, & Hill, 2008b; Mayer et al., 2016; O'Riordan & Passetti, 2006), subgroups of children and adolescents with ASC (Eigsti & Fein, 2013; Heaton, Williams, Cummins, & Happé, 2008c) and subgroups of adults with ASC (Bonnel et al., 2010; Jones et al., 2009). Two recent studies even reported deficits in pitch discrimination in adolescents and adults with ASC (Boets, Verhoeven, Wouters, & Steyaert, 2015; Kargas, López, Reddy, & Morris, 2015). Neural sensitivity for speech pitch in Mandarin-speaking children with ASC was also found to be diminished (Yu et al., 2015). This discrepancy in findings may be due to the variability in ASC. For example, pitch discrimination is associated with general symptom severity in children with

ASC (Eigsti & Fein, 2013) and specific symptom severity on reciprocal social interaction and restricted and repetitive behaviours in adults with ASC (Kargas et al., 2015; Mayer et al., 2016). Thus, it might not be ASC in general but specific ASC symptoms/traits that were related to pitch discrimination. Given that it is still not clear whether ASC can be viewed as a single unitary spectrum or a multidimensional spectrum (Happé & Ronald, 2008; Happé, Ronald, & Plomin, 2006), investigating specific ASC symptoms/traits in relation to pitch discrimination and taking variabilities into account would provide further insight into the processing styles across the autism spectrum.

ASC traits have frequently been measured by the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001), which is a self-administered questionnaire. It provides a score, which is found to be high in individuals with ASC but lower in typically developing individuals on a continuum. It also provides five subscale scores corresponding to specific ASC traits: Social Skills, Attention Switching, Attention to Detail, Communication, and Imagination. So far, to our knowledge, only two studies examined the correlation between ASC traits and pitch discrimination. Stewart et al. (2015) found a correlation between AQ and pitch discrimination in a sample of 24 undergraduates while Mayer et al. (2016) reported a correlation between Attention to Detail and speech pitch discrimination in a sample of 38 individuals with and without ASC. Both were based on small samples and were not controlled for related variables, e.g., musical and language experiences, given that pitch is shared by both domains of music and language (Plack, Oxenham, & Fay, 2005).

Previous research has shown that musical experience is associated with pitch discrimination in both domains of music and language (Magne, Schön, & Besson, 2006; Marques, Moreno, Castro, & Besson, 2007; Schön, Magne, & Besson, 2004). For example, musicians are able to discriminate both musical pitch and speech pitch better than non-musicians. More importantly, musical experience could be referred to the amount of time spent on musical-related training (Besson, Schön, Moreno, Santos, & Magne, 2007; Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Moreno et al., 2009), suggesting that one does not necessarily have to be classified as musicians with extended years of training and expertise in order to show better pitch discrimination.

There is also evidence showing that language experience affects pitch discrimination in music and in language (Bent, Bradlow, & Wright, 2006; Bidelman, Hutka, & Moreno, 2013; Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). For example, native English speakers are less capable in discriminating pitch in music and in tone languages (e.g., Mandarin and Cantonese) than native tone-language speakers. It was also found that native Mandarin speakers have stronger subcortical pitch representation of Mandarin tones, even when a simulation of Mandarin tones without any speech context was used as stimuli, compared to native English speakers (Krishnan, Gandour, Bidelman, & Swaminathan, 2009; Krishnan, Xu, Gandour, & Cariani, 2005). Although, unlike tone languages, pitch variations in non-tonal languages (e.g., English) are not lexically relevant to word discrimination, they provide supra-lexical information such as stress and intonation (Krishnan & Gandour, 2014) so non-tonal language experience might also affect pitch discrimination. For example, pitch discrimination was superior in Finnish children with advanced English pronunciation skills than those with less-advanced English pronunciation skills (Milovanov, Huotilainen, Välimäki, Esquef, & Tervaniemi, 2008).

Therefore, there is a need to control for musical and language experience when investigating pitch discrimination. This study sought to do so by recruiting only native English speakers who did not know a second language and by testing pitch discrimination in an unknown foreign tone language rather than in English, English simulation or music to further control for native language and musical experience.

With a larger sample size than Stewart et al. (2015) and Mayer et al. (2016), it was predicted that foreign speech pitch discrimination would be correlated with ASC traits, even after controlling for self-reported musical experience, if ASC traits play a significant role in pitch discrimination.

Method

Participants

One hundred and two students (53 females; mean age = 21.65 years, *SD* = 3.51, range = 18–35) were recruited from a university in United Kingdom. All were native English speakers and were reported to have normal hearing and no history of learning a foreign language. They were not screened for any psychiatric or other characteristics. Ethical approval was obtained from university ethics committee before recruitment.

Materials and Procedure

Participants were tested individually in a laboratory setting. They were first asked to rate their musical experience on a 4-point scale: no training at all, 1- to 2-year training, 3- to 5-year training, or more than 5- year training. This was because participants found it hard to recall and report the exact amount of time spent on musical training. Participants then filled in the AQ (Baron-Cohen et al., 2001). It consists of 50 items, to which participants indicate how much they agree or disagree on a 4-point scale: Definitely Agree – Slightly Agree – Slightly Disagree – Definitely Disagree. The items are grouped into five subscales, each involving ten items. Each item was coded as either 0 or 1. Thus, the total score ranges from 0 to 50, and each subscales score ranges from 0 to 10. The higher the score the higher level of ASC traits the individual possesses. Baron-Cohen et al. (2001) reported good test-retest reliability (r = .70) and adequate internal consistency (α = .69).

Participants then took part in a foreign speech pitch discrimination task, in which they determined whether there were pitch differences between pairs of monosyllabic Cantonese words. These words were *bui*, *dyun*, *jau*, *ngoi*, *ziu*, and *zoeng*. All were produced by an adult male, who is a native Cantonese speaker, with a high-level tone in Cantonese. Each recording was 150-msec long. Using PRAAT (Boersma & Weenink, 2001), the pitch contour of each word was then shifted to lower levels, equivalent to 1, 2 and 3 semitone(s) away from the original.[1]

Each original word was paired with the same word at a different pitch level, comprising 18 word pairs that differed by 1, 2 or 3 semitone(s). The order of the two pitch levels in these 18 "different" trials were counterbalanced, making 36 "different" trials. Words at each pitch level were also paired with themselves, comprising 24 word pairs that were at same pitch. Six of these 24 "same" trials consisted of the original words, which were equally distributed in all 3 "different" conditions. Thus, repeating these 6 trials should not affect the findings but would make up a total of 30 "same" trials, reducing the difference between the numbers of the "same" and "different" trials so that participants were not biased toward the "different" response.[2]

All trials had an inter-word pause of 250 ms so that the words were temporally distinguishable. They were played with the E-prime software on a standard computer through the speakers to each participant in a randomised order. Participants were told that different sound pairs would be presented and they were asked to indicate whether the two sounds in each pair were same or different by pressing "1" for same or "2" for different.[3] The entire task lasted about 10 minutes.

---

[1] One semitone lower is a decrease in frequency of 6%. We used "1, 2 and 3 semitones" instead of "2, 3 and 6 semitones" that were used in Heaton et al. (2008b) and Mayer et al. (2016) because we reasoned that a harder task was needed to avoid an overall ceiling effect given that we tested university students rather than children, and had no restriction on musical experience.

[2] In Heaton et al. (2008b) and Mayer et al. (2016), this bias was not controlled and there were 20 more "different" trials than the "same" trials.

[3] Participants were never asked to compare pairs that differed in pitch contour. The contrast was always of different pitch levels (i.e., frequencies).

Results

Descriptive statistics for foreign speech pitch discrimination, AQ scores and musical experience rating are presented in Table 1. In order to compare with previous research, participants' task performance was analyzed before investigating the relationship between task performance and ASC traits. Participants' task performance was significantly above chance for 0, 1, 2 and 3 semitone differences, *t*s(101) > 9.27, *p*s < .001, *d*s > 1.84. A repeated measures analysis of variance (ANOVA) revealed a significant main effect of semitone difference, $F(2.05, 207.27) = 45.54$, $p < .001$, $\eta_p^2 = .31$. Post hoc tests suggested that correct discrimination significantly improved with increases in semitone differences (all comparisons *p*s < .001 except the comparison between 1 and 2 semitone differences, $p = .41$).

[Table 1]

Correlations were not found between task performance and the AQ total, *r*s(102) = -.19–.05, *p*s > .06, nor the subscale scores of Attention Switching, Attention to Detail, Communication and Imagination, *r*s(102) = -.18–.10, *p*s > .07. However, the Social Skills subscale score was marginally correlated with performance on 1 semitone difference, $r(102) = -.19$, $p = .05$, and was significantly correlated with performance on 3 semitone difference, $r(102) = -.28$, $p < .01$. After controlling for musical experience, the correlation coefficients improved , *r*s(99) = -.26 and -.32 for 1 and 3 semitone difference respectively, and both were significant, *p*s < .01. These findings suggested that participants who scored high on the Social Skills subscale (i.e., less sociable and less socially skillful) were less capable in pitch discrimination.

Discussion

With a larger sample size and better controls, the current study investigated the relationship between pitch discrimination and ASC traits when musical and language experiences were taken into account. It replicated previous findings (Heaton et al., 2008b; Mayer et al., 2016) that correct discrimination was near ceiling for 0 semitone difference, dropped significantly for small semitone differences and improved gradually with increases in semitone differences although the pitch discrimination task we used was more difficult and has controlled for response bias. This replication provided a basis for the main finding that pitch discrimination was negatively correlated with the Social Skills subscale score only even when self-reported musical experience was further controlled, indicating that participants who were less sociable and less socially skillful were less capable in pitch discrimination. Although this finding was inconsistent with those in Mayer et al. (2016) and Stewart et al. (2015), it could be explained by several possibilities.

The first possibility is that the stimuli used to test pitch discrimination in each study were different. This study used foreign speech whereas Stewart et al. (2015) used pure tones and Mayer et al. (2016) used native speech and its analogue. While different stimuli might sufficiently lead to different findings, there is also a possibility that Stewart et al. and Mayer et al.'s findings were contaminated by participants' musical and language experience. By using foreign speech as stimuli, this study controlled for both musical and native language experiences. Musical experience was further controlled using statistical methods and foreign language experience was controlled by including only participants who did not know a second language. Although language delay, which was suggested to be related to pitch discrimination in ASC (Bonnel et al., 2010; Eigsti & Fein, 2013; Heaton et al., 2008a, b, c; Jones et al., 2009), was not considered and may be suggested as a limitation of the current study, it was assumed that language delay was not prevalent in a non-clinical undergraduate sample. Together with a larger sample size, the current findings may thus be more convincing than those in Stewart et al. and Mayer et al.

Nevertheless, the current study was not the first to demonstrate a relationship between pitch discrimination and sociability. Using analogue tones derived from native speech, Mayer et al. (2016) reported a similar finding that pitch discrimination was negatively correlated with and independently predicted by the reciprocal social interaction subscale of the Autism Diagnostic Observation Schedule (ADOS) in adult participants with ASC. Previous research on children with ASC also showed that some children with ASC did not preferentially attend to social speech and failed to show typical neural changes to vowel pitch changes (Kuhl, Coffey-Corina, Padden, & Dawson, 2005). Moreover, social interest and social interaction play a role in learning and discriminating speech (Kuhl, 2003; Kuhl, Tsao & Liu, 2003). Infants readily learned and discriminated characteristics in speech, no matter of whether they were native or foreign, during natural social interaction but not via audio or video tape. Although pitch discrimination is a non-social capacity, its relation to social capacities is therefore not unexpected and this relationship extends across typically developing individuals and individuals with ASC.

While there has not been a single account that entirely explains all the features of ASC, the current finding that pitch discrimination was negatively correlated with autistic social traits failed to support the EPF theory (Mottron & Burack, 2001; Mottron et al., 2006). This was in line with previous studies which used group measures and reported diminished pitch discrimination in individuals with ASC across lifespan (Boets et al., 2015; Kargas et al., 2015; Yu et al., 2015). Although this study did not test individuals with ASC, its findings have an implication in investigating individual differences in pitch discrimination and specific ASC traits rather than ASC in general, reflecting the high variability and complexity across the autism spectrum. Further investigation is still warranted to spell out the relationship between non-social and social aspects of ASC (for reviews, see Leekam, 2016; Valla & Belmonte, 2013) given its importance in our understanding of ASC.

References

Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2010). A new step towards understanding embedded figures test performance in the autism spectrum: The radial frequency search task. *Neuropsychologia, 48*, 374-381.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: American Psychiatric Association.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5-17.

Bent, T., Bradlow, A. R., & Wright, B. A. (2006). The influence of linguistic experience on the cognitive processing of pitch in speech and nonspeech sounds. *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 97-103.

Besson, M., Schön, 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.

Bidelman, G. M., Hutka, S., & Moreno, S. (2013). Tone language speakers and musicians share enhanced perceptual and cognitive abilities for musical pitch: Evidence for bidirectionality between the domains of language and music. *PLoS One*, *8*, e60676.

Boersma, P., & Weenink, D. (2001). PRAAT, a system for doing phonetics by computer. *Glot International, 5*, 341-345.

Boets, B., Verhoeven, J., Wouters, J., & Steyaert, J. (2015). Fragile spectral and temporal auditory processing in adolescents with autism spectrum disorder and early language delay. *Journal of Autism and Developmental Disorders, 45*, 1845-1857.

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

Dawson, G., Estes, A., Munson, J., Schellenberg, G., Bernier, R., & Abbott, R. (2007). Quantitative assessment of autism symptom related traits in probands and parents: Broader phenotype autism symptom scale. *Journal of Autism and Developmental Disorders*, *37*, 523-536.

Eigsti, I. M., & Fein, D. A. (2013). More is less: pitch discrimination and language delays in children with optimal outcomes from autism. *Autism Research*, *6*, 605-613.

Giuliano, R. J., Pfordresher, P. Q., Stanley, E. M., Narayana, S., Wicha, N. Y. (2011). Native experience with a tone language enhances pitch discrimination and the timing of neural responses to pitch change. *Frontiers in psychology, 2*, 146.

Grinter, E. J., Maybery, M. T., Van Beek, P. L., Pellicano, E., Badcock, J. C., & Badcock, D. R. (2009). Global visual processing and self-rated autistic-like traits. *Journal of Autism and Developmental Disorders, 39*, 1278-1290.

Haesen, B., Boets, B., & Wagemans, J. (2011). A review of behavioural and electrophysiological studies on auditory processing and speech perception in autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*, 701-714.

Happé, F., & Ronald, A. (2008). The ‘fractionable autism triad’: A review of evidence from behavioural, genetic, cognitive and neural research. *Neuropsychology Review*, *18*, 287-304.

Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature Neuroscience, 9*, 1218-1220.

Heaton, P., Davis, R. E., & Happé, F. (2008a). Research note: 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. (2008b). Superior discrimination of speech pitch and its relationship to verbal ability in autism spectrum disorders. *Cognitive Neuropsychology, 25*, 771-782.

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

Jones, C. R. G., Happé, F., Baird, G., Simonoff, E., Marsden, A. J. S., Tregay, J., ... Charman, T. (2009). Auditory discrimination and auditory sensory behaviours in autism spectrum disorders. *Neuropsychologia, 47*, 2850-2858.

Kargas, N., López, B., Reddy, V., & Morris, P. (2015). The relationship between auditory processing and restricted repetitive behaviors in adults with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 45*, 658-668.

Krishnan, A., & Gandour, J. T. (2014). Language experience shapes processing of pitch relevant information in the human brainstem and auditory cortex: Electrophysiological evidence. *Acoustics Australia/Australian Acoustical Society*, *42*, 166-178.

Krishnan, A., Gandour, J. T., Bidelman, G. M., & Swaminathan, J. (2009). Experience-dependent neural representation of dynamic pitch in the brainstem. *Neuroreport, 20*, 408-413.

Krishnan, A., Xu, Y., Gandour, J., & Cariani, P. (2005). Encoding of pitch in the human brainstem is sensitive to language experience. *Cognitive Brain Research, 25*, 161-168.

Kuhl, P. K. (2003). Human speech and birdsong: communication and the social brain. *Proceedings of the National Academy of Sciences*, *100*, 9645-9646.

Kuhl, P. K., Coffey-Corina, S., Padden, D., & Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: Behavioral and electrophysiological measures. *Developmental Science, 8,* F1–F12.

Kuhl, P. K., Tsao, F.-M., & Liu, H.-M. (2003). Foreign language experience in infancy: effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences*, *100*, 9096-9101.

Leekam, S. (2016). Social cognitive impairment and autism: What are we trying to explain? *Philosophical Transactions of the Royal Society, Series B: Biological Sciences, 371*, 20150082.

Magne, C., Schon, D., & Besson, M. (2006). Musician children detect pitch violations in both music and language better than nonmusician children: Behavioral and electrophysiological approaches. *Journal of Cognitive Neuroscience*, *18*, 199-211.

Marques, C., Moreno, S., Castro, S. L., & Besson, M. (2007). Musicians detect pitch violation in a foreign language better than nonmusicians: behavioral and electrophysiological evidence. *Journal of Cognitive Neuroscience, 19*, 1453-1463.

Mayer, J. L., Hannent, I., & Heaton, P. F. (2016). Mapping the developmental trajectory and correlates of enhanced pitch perception on speech processing in adults with ASD. *Journal of Autism and Developmental Disorders, 46,* 1562-1573.

Micheyl, C., Delhommeau, K., Perrot, X., & Oxenham, A. J. (2006). Influence of musical and psychoacoustical training on pitch discrimination. *Hearing Research, 212,* 36-47.

Milovanov, R., Huotilainen, M., Välimäki, V., Esquef, P. A. A., & Tervaniemi, M. (2008). Musical aptitude and second language pronunciation skills in school-aged children: neural and behavioral evidence. *Brain Research, 1194*, 81-89.

Moreno, S., Marques, C., Santos, A., Santos, M., Castro, S. L., & Besson, M. (2009). Musical training influences linguistic abilities in 8-year-old children: more evidence for brain plasticity. *Cerebral Cortex, 19,* 712-713.

Mottron, L., & Burack, J. (2001). Enhanced perceptual functioning in the development of autism. In J. A. Burack, T. Charman, N. Yirmiya, & P. R. Zelazo (Eds.), *The development of autism: Perspectives from theory and research*. Mahwah, NJ: Lawrence Erlbaum Associates.

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.

O'Connor, K. (2012). Auditory processing in autism spectrum disorder: A review. *Neuroscience and Biobehavioral Reviews, 36*, 836-854.

O'Riordan, M., & Passetti, F. (2006). Discrimination in autism within different sensory modalities. *Journal of Autism and Developmental Disorders, 36*, 665-675.

Plack, C. J., Oxenham, A. J., & Fay, R. R. (Eds.). (2005). *Pitch: Neural coding and perception* (Vol. 24). New York: Springer.

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

Stewart, M. E., Griffiths, T. D., & Grube, M. (2015). Autistic traits and enhanced perceptual representation of pitch and time. *Journal of Autism and Developmental Disorders*, 1-9.

Valla, J. M., & Belmonte, M. K. (2013). Detail-oriented cognitive style and social communicative deficits, within and beyond the autism spectrum: Independent traits that grow into developmental interdependence. *Developmental Review*, *33*, 371-398.

Yu, L., Fan, Y., Deng, Z., Huang, D., Wang, S., & Zhang, Y. (2015). Pitch processing in tonal-language-speaking children with autism: An event-related potential study. *Journal of Autism and Developmental Disorders, 45,* 3656-3667.

Table 1

Descriptive Statistics for the Foreign Speech Pitch Discrimination Task Performance, the AQ Scores and Musical Experience Rating

Variable	Mean	*SD*	Min	Max
Foreign speech pitch discrimination				
0 semitone difference	.96	.07	.70	1
1 semitone difference	.75	.28	0	1
2 semitone difference	.76	.27	0	1
3 semitone difference	.85	.22	.08	1
AQ				
Total	15.07	6.25	2	34
Social Skills	1.84	1.87	0	9
Attention Switching	4.27	2.18	0	9
Attention to Detail	4.54	2.15	0	10
Communication	2.03	1.91	0	10
Imagination	2.40	1.71	0	9
Musical experience[a]	1.92	.85	1	4

[a]Rated on a 4-point scale: No training at all (1), 1- to 2-year training (2), 3- to 5-year training (3), or more than 5- year training (4).