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Similar impressions of humanness for human and artificial singing voices in autism spectrum disorders

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ABSTRACT

People with autism spectrum disorder (ASD) exhibit impairments in the perception of and orientation to social information related to humans, and some people with ASD show higher preference toward human-like robots than other humans. We speculated that this behavioural bias in people with ASD is caused by a weakness in their perception of humanness. To address this issue, we investigated whether people with ASD detect a subtle difference between the same song sung by human and artificial voices even when the lyrics, melody and rhythm are identical. People without ASD answered that the songs sung by a human voice evoked more impressions of humanness (human-likeness, animateness, naturalness, emotion) and more positive feelings (warmth, familiarity, comfort) than those sung by an artificial voice. In contrast, people with ASD had similar impressions of humanness and positive feelings for the songs sung by the human and artificial voices. The evaluations of musical characteristics (complexity, regularity, brightness) did not differ between people with and without ASD. These results suggest that people with ASD are weak in their ability to perceive psychological attributes of humanness.

1. Introduction

Autism spectrum disorder (ASD) is a developmental disorder characterized by difficulties in social cognition and communication. People with ASD exhibit impairments in orientating to social stimuli, such as human faces (Jemel, Mottron, & Dawson, 2006; Nakano et al., 2010) and speech (Alcantara, Weisblatt, Moore, & Bolton, 2004; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). Instead, some of them show a strong affinity to robots and computers (Diehl, Schmitt, Villano, & Crowell, 2012). A previous study also reported that children with ASD automatically imitated the behaviour of a robot much better than they did that of a human (Pierno, Mari, Lusher, & Castiello, 2008). With regards to this preference for artificial objects rather than humans in autism, Baron-Cohen suggested that individuals with autism are attracted to systems of low variance (such as machines) and less sensitive to systems where there is maximal variance as is the case with human behaviour (Baron-Cohen, 2006).

In general, a human feels a stronger affinity toward another human than they do toward artificial objects. In particular, the subtle differences between a real human and a human-like object evoke an impression of a substantial qualitative difference between them that is accompanied by a negative feeling toward the human-like object. This is a well-known phenomenon known as the "uncanny valley phenomenon" (Mori, 1970). Research verifying the uncanny valley phenomenon clearly demonstrates that people perceive not only a physical difference but also a qualitative difference between humans and artificial objects. Haslam proposed that people have a unique sense of humanness, a special sense of "human nature," that involves emotion, warmth, and cognitive flexibility and is opposed to "mechanistic" dehumanization (Haslam, 2006). Thus, the dissociation between physical and psychological attributes of humanness evokes a feeling of repulsion as manifested by the "uncanny valley phenomenon". In contrast, the individuals with ASD do not show a preference bias toward human (Nakano et al., 2010) nor a repulsion toward the artificial objects rather than real humans (Diehl et al., 2012). We speculated that individuals with ASD face difficulties in perceiving the psychological aspects of humanness from human-related information, and thus they were unable to detect subtle differences between human and human-like objects. Therefore, they did not

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demonstrate any repulsion toward the artificial objects regardless of its degree of human resemblance. To test this hypothesis, the present study examined the impressions of humanness and feeling experienced by people with ASD upon hearing the same song sung by a real human voice and an artificial voice. Although many previous studies have explored the perception of humanness using humanoid robots or computer-generated 3D animation (such as Broadbent et al., 2013; Gray & Wegner, 2012; Thompson, Trafton, & McKnight, 2011), it is technically difficult to create artificial objects with the appearance and movements resembling those of an actual human. To address this problem, we focused on creating an artificial singing voice because the technology for synthesizing an artificial voice has advanced to a point that it can be used in daily life. Our previous study used the same auditory stimuli and demonstrated that a human singing voice evoked a sense of humanness and positive emotion much more strongly than an artificial singing voice did in typically developing adults, even though the lyrics, melody, and rhythm were identical (Tamura, Kuriki, & Nakano, 2015). We expected that if people with ASD had a weakness in their sense of humanness, they would not detect a subtle difference between the stimuli and would have similar impressions of humanness and positive feelings for the human and artificial singing voices.

2. Method

2.1. Participants

Fourteen adults with ASD (10 male, 4 female; mean age, 27.6 years; range, 20–39 years) and fourteen adults without ASD (10 male, 4 female; mean age, 28.9 years; range, 21–37 years) participated in this study. The two groups were matched for sex and approximate age. ASD diagnoses were based on the clinical judgment of medical specialists according to the DSM-V criteria. All ASD participants were high functioning, with their full-scale IQ (Wechsler Adult Intelligence Scale, 3rd edition, WAIS-III) exceeding 89 (mean: 108.9, range: 89–120). The mean verbal IQ was 113.2 (range: 82–136), and the mean performance IQ was 101.4 (range: 82–114). All participants completed the Japanese version of the autism spectrum quotient (AQ) test (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The mean AQ score was 37.0 (range: 24–46) in the ASD group and 15.3 (range: 10–23) in the control group. The participants were chosen regardless of their musical experience. Before the experiment, the participants were asked about their musical preferences to ensure that they were not familiar with artificial voices in music. The study was approved by the review board of Osaka University, and all participants gave written informed consent before participation.

2.2. Auditory stimuli

We used the same 12 songs that were used in our previous study (Tamura et al., 2015). These songs were sung by an artificial voice created using the Vocaloid software (Yamaha Corporation, Japan) and were also covered by human singers. Vocaloid is a software package with a library that contains actual human voice samples of all phonemes in a given language (Japanese or English, depending on the library type). All songs were in a female voice with Japanese lyrics. We selected a 15-s segment that contained lyrics from each song and created a total of 24 WAVE files (sampling frequency, 44,100 Hz), each of which lasted 15 s, with a tapering effect on the first and last second. The average (root mean square) power was adjusted such that there was no difference in power between a human and an artificial voice singing the same song. The comparison of acoustic features between a human and artificial singing voices was described in our previous study (Tamura et al., 2015).

2.3. Procedure

Participants sat in front of a pair of speakers (Computer MusicMonitor, BOSE), through which the auditory stimuli were presented. Each of the 24 song segments was presented once and in random order, although a song sung by the human voice did not subsequently follow the same song in the artificial voice, and vice versa. The participants were not informed in advance that artificial singing voices were included in the stimuli.

After each song was presented, the participant completed a questionnaire in which he or she rated the song on a scale of 1–5 for ten items from three categories. The first category is the "human nature" dimension of humanness, which contrasts humans with machines and automata as proposed by Haslam (2006). The participants evaluated humanness (1 = mechanistic, 5 = humanlike), emotion (1 = lack of emotion, 5 = rich in emotion), animateness (1 = inanimate, 5 = animate), and naturalness (1 = unnatural, 5 = natural). The second category is the internal positive feelings elicited by the singing voice. As demonstrated by the uncanny valley phenomenon, people generally experience positive feelings toward actual humans but not robots. Thus, we expected that the evaluations of positive feelings would correlate with the evaluations of humanness. The participants were asked to rate familiarity (1 = unfamiliar, 5 = familiar), warmth (1 = cold, 5 = warm), and comfort (1 = irritating, 5 = comfortable). The third category is related to the musical character of the songs in the study according to the following: complexity (1 = simple, 5 = complex), regularity (1 = random, 5 = regular), and brightness (1 = dark, 5 = bright). These three items were included as contrast to the other seven items because they should not differ in the same song between human and artificial voices. Along with the rating task, the participants were asked whether they had heard the song before, to confirm that they were unfamiliar with artificial singing voices. After a participant completed the questionnaire, it was collected, and the next stimulus was presented. The experiment took a total of approximately 20 min for each participant.

2.4. Data analysis

To extract the factor structure underlying the questionnaire items, we analysed the correlation between each pair of questionnaire items for evaluations of 24 songs averaged for the control group. We then conducted the hierarchical cluster analysis using Ward's method from a dissimilarity matrix of all pairs based on the subtraction of the absolute value of the correlation coefficient from 1 for each pair. We determined the optimal cluster number based on the comparison of the silhouette values. The analysis was carried out using Matlab 2015a (Mathworks, USA). Then, we compared the evaluations averaged across 12 songs for each voice type between the ASD and control group in each extracted factor. Two-way Analysis of Variances (ANOVAs) with a factor of group (ASD vs control) and voice type (human vs artificial) were conducted for each factor. The post hoc multiple comparison test was conducted using a *t*-test with the Bonferroni correction.

3. Results

First, we compared the impressions of the songs sung by either a human or artificial voice for each questionnaire item in each group. In line with our previous study (Tamura et al., 2015), the control participants evaluated the songs sung by the human voice more highly than those sung by the artificial voice on the questionnaire items related to human-likeness and positive feelings but not on the items concerning musical characteristics (mean scores shown in Table 1). Compared with the control participants, the participants with ASD gave lower scores to the songs sung by the human voice regarding humanness and positive feelings, but the two groups' impressions of the songs sung by the artificial voice were similar. A three-way ANOVAs revealed significant interactions among the voice type, group (control and ASD) and questionnaire items ($F_{9,234} = 4.8$, $p < 0.0001$). A significant interaction between voice type and group was observed in human-likeness, naturalness, animateness, emotion and familiarity (statistical information is shown in Table 1).

Next, we extracted the factor structure underlying the questionnaire items using the hierarchical clustering analysis from a dissimilarity matrix calculated by the correlation between each pair of questionnaire items with a population of song segments in the control group. Based on the comparison of silhouette values, the two factors were optimally identified from ten questionnaire items (Fig. 1A). Factor 1 comprised items related to humanness (human-likeness, animateness, emotion, and naturalness) and the positive feelings elicited by the songs (familiarity, warmth, and comfort). Factor 2 comprised only the items related to the musical characteristics (brightness, complexity, and regularity). We then compared the mean score of each factor between the human and artificial singing voices for each group. The mean score of factor 1 was 3.8 ± 0.2 (mean ± s.d.) for the human voice and 2.9 ± 0.4 for the artificial voice in the control group, and 3.3 ± 0.5 for the human voice and 2.9 ± 0.5 for the artificial voice in the ASD group (Fig. 1B). The two-way ANOVAs revealed significant interaction between group (ASD vs control) and voice type (human vs artificial) in Factor 1 ($F1, 26 = 7.6$, $p = 0.01$). In the post hoc analysis, the mean score of factor 1 for the human voice was significantly higher than that for the artificial voice in the control group ($t_{13} = 7.0$, $p = 0.00001$, paired *t*-test), but difference between the voice types was not significant in the ASD group ($p = 0.07$, *Bonferroni corrected p-value thresholds was p = 0.05/4*). In addition, the mean score of factor 1 for the human voice was significantly higher in the control group than in the ASD group ($t_{22} = 3.4$, $p = 0.002$, two-sample *t*-test). In contrast, the mean scores of factor 2 were similar between the voice types in both groups (control: human voice, 3.1 ± 0.2; artificial voice 3.1 ± 0.2; ASD: human voice, 3.1 ± 0.2; artificial voice 3.1 ± 0.2), and there was no significant difference. We also analysed the correlation of ratings of factor 1 with the AQ scores across all participants. As shown in Fig. 1C, a significant negative correlation was observed ($r = -0.6$, $p = 0.0005$).

4. Discussion

The present study confirmed that the human singing voice evokes a sense of humanness and positive feelings to a much greater degree than an artificial singing voice in typically developing adults. In contrast, while adults with ASD showed slightly greater impressions of humanness and positive feelings toward the human singing voice than toward the artificial singing voices, the difference in responses to human and artificial singing voices was much smaller in adults with ASD as compared with typically developing adults. On the other hand, there was no difference in the impressions of musical characteristics (complexity, regularity, brightness) between adults with and without ASD. Therefore, the difference in the impressions of humanness and positive feelings for human singing voice between the groups did not result from

Table 1
Mean impression scores for the 10 items and the statistical results of interactions between group and voice type from three-way ANOVAs.

	Human voice		Artificial voice		Interactions	
Impression of songs	Control	ASD	Control	ASD	F	p
Humanness	4.0 ± 0.1	3.3 ± 0.2	2.7 ± 0.2	2.5 ± 0.1	15.4	0.0001
Naturalness	3.8 ± 0.1	3.3 ± 0.2	3.0 ± 0.2	2.7 ± 0.1	11.2	0.0009
Animateness	3.8 ± 0.1	3.2 ± 0.2	2.6 ± 0.2	2.6 ± 0.1	8.1	0.005
Emotion	3.8 ± 0.07	3.4 ± 0.2	3.0 ± 0.2	2.8 ± 0.1	5.7	0.02
Familiarity	3.8 ± 0.07	3.1 ± 0.2	3.0 ± 0.2	3.1 ± 0.1	6.2	0.01
Comfort	3.7 ± 0.08	3.3 ± 0.1	3.2 ± 0.1	3.2 ± 0.1	3.5	0.06
Warmth	3.5 ± 0.08	3.2 ± 0.09	3.1 ± 0.1	3.1 ± 0.1	1.3	0.3
Brightness	3.2 ± 0.1	3.1 ± 0.08	3.3 ± 0.1	3.0 ± 0.09	2.6	0.1
Complexity	2.9 ± 0.1	3.0 ± 0.1	2.7 ± 0.2	2.8 ± 0.1	0.6	0.5
Regularity	3.2 ± 0.1	3.3 ± 0.1	3.3 ± 0.2	3.5 ± 0.09	0.9	0.3

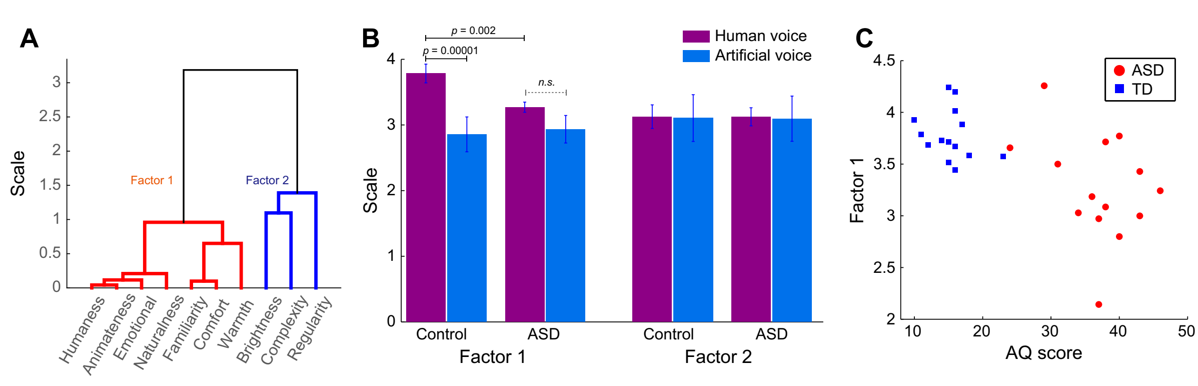

Fig. 1. Behavioural results from the factor analysis. (A) A graphical representation of the two factors analysed with the 10 questionnaires using factor analysis. (B) Comparison of the mean rating for each factor between human and artificial voices in each group. The error bar represents the standard error. (C) Negative correlation between the AQ scores and the ratings of factor 1.

an impairment of music perception in the ASD group. This is in line with a previous study reporting that the perception of music is intact in individuals with ASD (Heaton, Allen, Williams, Cummins, & Happe, 2008; Heaton, Hermelin, & Pring, 1999). In fact, both children and adults with ASD correctly understand musical emotion and show a strong preference and brain response toward music (Gebauer, Skewes, Westphael, Heaton, & Vuust, 2014; Molnar-Szakacs & Heaton, 2012; Molnar-Szakacs et al., 2009). Therefore, the present results suggest that adults with ASD have difficulties in perceiving humanness and experiencing positive feelings from human-related social information but not music per se. Haslam (2006) suggested that humanness has two distinct characteristics: characteristics that are uniquely human and separate human beings from other animals and human nature that is comprised essentially of psychological attributes not present in objects or mechanics. Since the present study used auditory stimuli that physically resembled human singing, different impressions might be invoked by the human and artificial singing voices regarding human nature. Thus, the present findings suggest that individuals with ASD could not extract qualitative information from the human singing voice related to such psychological attributes of human nature. The perception for psychological attributes of human nature might be equivalent with a perception of human-mind (Gray, Gray, & Wegner, 2007). Converging with the previous report that individuals with ASD showed reduced perception of agency in humans (Gray, Jenkins, Heberlein, & Wegner, 2011), a weakness in perception for psychological attributes of humanness in ASD suggests that individuals with ASD are insensitive for other's mind state, resulting their lack of interest toward others and their impairments of perceiving other's theory of mind.

It is worth noting that there was no difference in the impressions of an artificial singing voice on any of the questionnaire items between adults with and without ASD. Our result implies that the seeming preference toward robots in individuals with ASD, which was previously reported (Diehl et al., 2012), is due not to the extraordinary perception of positive feelings from robots but to an impairment of the typical perception of positive feelings from humans. In line with the present findings, Gray et al. reported that higher scores on the AQ scale were associated specifically with reduced perceptions of agency in adult humans (Gray et al., 2011). However, no change in perception was observed for robots in their study. Converging with the present findings that the AQ scale was associated with the sense of humanness for a human singing voice, autistic traits correlate negatively with an ability to perceive humanness from human-related information. To put the present findings into context, future study is expected to replicate these findings with more standard diagnoses and assessment scales of autism such as the Autism Diagnostic Observation Schedule (ADOS) rather than the AQ scale.

The present study demonstrates that human beings seem to have a unique sense of humanness in auditory processing and that this sense may be impaired in individuals with ASD. This could be a reasonable explanation for some characteristics typical of ASD, such as the low orientation to social stimuli and the tendency to prefer robots to humans. Our previous study, which compared brain activation between human and artificial singing voices using functional magnetic resonance imaging, revealed that the left posterior insula is involved in evaluating the quality of human vocalization and eliciting a positive emotional sensation (Tamura et al., 2015). An electrophysiological study using monkeys also reported that this region responded to conspecific vocalization rather than the vocalization of other animals (Remedios, Logothetis, & Kayser, 2009). A recent functional neuroimaging study reported that the activity of the left insula is correlated with the score of alexithymia, which is a dysfunction of emotional awareness (Bird et al., 2010). Moreover, the insula has dense reciprocal connection with the amygdala, which has been implicated in emotional processing (Bamiou, Musiek, & Luxon, 2003). Converging these lines of evidence, the left insula is involved not only in evaluating the ecological quality of a conspecific voice but also in evoking positive feelings toward it. Therefore, there is a possibility that a dysfunction of the left insula induces impairment in perceiving humanness and evoking positive feelings for a human singing voice in individuals with ASD. This hypothesis is supported by the evidence of high prevalence of alexithymia in the autism spectrum disorders (Bird & Cook, 2013). In contrast, recent studies have suggested that deficits in emotional perception and lack of empathy in autism are mediated by alexithymia per se (Allen, Davis, & Hill, 2013; Bird & Cook, 2013; Bird et al., 2010). Future research is expected to verify whether the activity of the left insula in response to a human singing voice is associated with the scores of autistic symptoms or alexithymia.

The current study used only a narrow set of singing voice stimuli created by the specific software as cited herein. Thus, it is important to replicate the present findings using a broader array of voice stimuli including speaking and singing voices across genders. In addition, further research may also be done with other types of stimuli, such as visual stimuli, to investigate whether the impairment in the sense of humanness observed for auditory stimuli in people with ASD is consistent in other senses.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2016.04.004.

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