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Superiority of blind over sighted listeners in voice recognition

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Abstract: The current study examined whether the blind are superior to sighted listeners in voice recognition. Three subject groups, including 17 congenitally blind, 18 late blind, and 18 sighted, showed no significant differences in the immediate voice recognition test. In the delayed test conducted two weeks later, however, both congenitally blind and late blind groups performed better than the sighted with no significant difference between the two blind groups. These results partly confirmed the anecdotal observation about the blind's superiority in voice recognition, which resides mainly in delayed memory phase but not in immediate recall and generalization phase.

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1. Introduction

It is a common belief that blindness may lead to enhanced ability in the other intact systems as a result of sensory compensation (Kupers *et al.*, 2011; Hötting and Röder, 2009). An increasing number of studies have shown that blind individuals perform better than sighted counterparts on a broad range of non-visual (primarily in the auditory modality) perceptual and cognitive tasks. For example, enhanced performance in the blind was observed in simple auditory tasks such as pitch discrimination (Gougoux *et al.*, 2004) and temporal resolution (Muchnik *et al.*, 1991), as well as in higher auditory skills such as sound localization (Lessard *et al.*, 1998; Voss *et al.*, 2004) and speech perception (Röder *et al.*, 2000; Hugdahl *et al.*, 2004), which also extends to musical rhythm perception (Zhang *et al.*, 2019), verbal memory performance (Amedi *et al.*, 2003; Röder *et al.*, 2001), and long-term memory for environmental sounds (Röder and Rösler, 2003).

Voice perception is amongst the most important functions of the human auditory system in support of social communication, allowing us to extract a wealth of information about the speaker's identity (Belin *et al.*, 2004). Even newborns are able to reliably differentiate their mother's voice from others (Beauchemin *et al.*, 2011). Unlike sighted individuals who can make use of both facial and vocal features for person identification, blind individuals do not have access to the visual input. Voice perception, therefore, is especially important for blind individuals in allowing them not only to readily recognize familiar persons, but also to gauge a speaker's sex, age, ethnicity, and social status (Kreiman and Sidtis, 2011). Interestingly, although some anecdotal observations suggest better voice recognition in the blind (James, 1890; Stankov and Spillsbury, 1978), empirical evidence for such a superiority is quite scarce and non-definitive. The reported results have been mixed with three studies showing superiority in the blind (Bull *et al.*, 1983; Föcker *et al.*, 2012; Hölig *et al.*, 2014) and three others revealing no significant difference between sighted and blind individuals (Winograd *et al.*, 1984; Günzburger *et al.*, 1987; Gougoux *et al.*, 2009). These studies adopted various tasks such as voice discrimination, matching and identification without a consistent control of participant characteristics in terms of degree of visual impairment (e.g., totally blind and those with partial vision), and musical experience (e.g., years of formal musical training). It remains to be further investigated whether blind individuals are superior to their sighted counterparts in voice perception.

One important caveat is that the onset age of blindness during development may determine the degree of auditory enhancement. For instance, congenitally and early blind individuals

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reportedly display superior performance over late blind individuals (Gougoux *et al.*, 2004; Voss *et al.*, 2008; Wan *et al.*, 2009). Neuroimaging studies have further demonstrated that individuals deprived of visual input from birth and early life are more susceptible to changes in brain function induced by blindness than those becoming blind late in life (Buchel *et al.*, 1998; Fieger *et al.*, 2006). However, not all behavioral findings support this notion (Röder and Rösler, 2003; Voss *et al.*, 2004).

The aim of the current study was to examine the possible superiority in voice perception of blind over sighted individuals. To ascertain whether the superior long-term memory for verbal and environmental sounds in the blind (Amedi *et al.*, 2003; Röder *et al.*, 2001; Röder and Rösler, 2003) also applies to voice perception, a delayed test was conducted two weeks after the immediate test. We were additionally interested in comparing individuals blinded at different phases in development (congenitally blind and late blind) with matched degree of vision to investigate the effects of onset age of visual loss. To our knowledge, previous studies on this topic have not made such a direct comparison.

2. Methods

2.1 Subjects

Seventeen congenitally blind (5 females; age range: 18–30 years), 18 late blind (6 females; age range: 18–27 years with onset age of blindness >5 years) participants and 18 sighted controls (7 females; age range: 18–26) took part in our study. In each case of blindness, the visual deficit resulted from anomalies in peripheral structures and resulted in total blindness except for minimal residual light sensitivity in seven congenitally blind and five late blind participants (see supplementary material for demographic characteristics of the blind participants[1]). All participants were native speakers of Mandarin Chinese and were undergraduate or postgraduate students with the blind participants from the Special Education College of Beijing Union University and the sighted controls from several universities in Beijing. As musical training can lead to enhanced auditory and cognitive abilities (Kraus and Chandrasekaran, 2010; Bogusz-Witczak *et al.*, 2015; Patel and Morgan, 2017), it is important to control for this potentially confounding factor. None of the participants received formal musical training and the three groups did not differ significantly in musical competence [$F(2, 50) = 1.876$, $p = 0.164$, partial $\eta^2 = 0.07$] assessed via Musical Ear Test (Wallentin *et al.*, 2010). No one had a history of neurological, psychiatric, or neuropsychological problems. They all passed a hearing screening at 25 dB hearing level for octave frequencies between 125 and 8000 Hz bilaterally with no significant between-group differences in the hearing thresholds at any frequencies [$F(2, 50) \leq 1.824$, $p \geq 0.172$, partial $\eta^2 \leq 0.068$]. Written informed consent was obtained from each participant on their first visit to the laboratory. The study was approved by the Institutional Review Board (IRB) of the State Key Laboratory of Cognitive Neuroscience and Learning at Beijing Normal University.

2.2 Stimulus materials

Stimuli for the voice recognition experiment consisted of 15 Chinese sentences which were from a corpus comprising 80 sentences in four languages used in our previous study (Zhao *et al.*, 2008). The sentences were short news-like declarative statements and each sentence was composed of 15 syllables. Five female native Chinese speakers who did not participate in the voice perception experiment read each of the sentences in a sound attenuated room. The sentences were recorded at a sampling rate of 44.1 kHz and digitized at 16 kHz. The mean duration of the sentences was 2725 ms (range: 2506–3067 ms) with 50 ms fade in and fade out in order to guarantee a smooth onset and offset of the voice stimuli. Sentences were checked for naturalness by two native Chinese speakers and all the sentences were perceived as having no discernible idiosyncratic talker characteristics (e.g., unusual phonetic or prosodic properties such as creaky voice).

2.3 Procedure

The current study adopted a well-established paradigm, i.e., voice identification task which consisted of a familiarization phase, a practice phase and a generalization phase (Perrachione *et al.*, 2011; Föcker *et al.*, 2012; Föcker *et al.*, 2015; Xin and Myers, 2015). Furthermore, we assessed delayed memory for voice which has never been examined in previous studies. The delayed memory test consisted of only a generalization phase and the participants were not informed that delayed voice memory would be tested. All participants were blindfolded during testing.

Participants were tested individually in a quiet room with ambient noise level below 45 dB(A). The auditory stimuli were presented over headphones at 70 dB sound pressure level (SPL) with equal phase and intensity at both ears. On each trial, each participant heard one of the five training sentences read by one of the five speakers followed by a number designating that speaker's voice (1, 2, 3, 4, or 5) spoken by a male speaker. This procedure was intended to familiarize the participants with the voices. The presentation order was blocked by sentences. Specifically, participants heard the same sentence read by all five speakers with two repetitions from each speaker. This procedure was repeated until listeners heard all five voices reading all five training sentences. The total number of sentences they heard was 5 sentences $\times$ 2 times $\times$ 5 talkers $=$ 50 trials. Participants were instructed to associate each number with the corresponding voice.

After familiarization, participants learned to identify the voice of each speaker. Stimuli were presented as in the familiarization phase, but participants were asked to respond with the number of the speaker by entering 1, 2, 3, 4, or 5 on the keyboard. Feedback was provided, and the correct number was indicated if the answer was incorrect. During the practice phrase, five repetitions of each of the five speakers reading five trained sentences were presented in randomized order. The total number of sentences they heard was 5 sentences $\times$ 5 times $\times$ 5 talkers $=$ 125 trials.

Generalization phase was conducted immediately after the practice phrase and the procedure was the same as in the practice phase except that no feedback was provided. Participants were required to identify the voices of ten novel sentences with one repetition of each of the five speakers reading the sentences, resulting in a total of 50 trials. This phase assessed the ability of the participants to transfer their voice-invariant knowledge to novel sentences.

Delayed memory phase was conducted two weeks later in order to examine the possible difference in voice memory ability among the three groups. The stimuli and procedure were the same as in the generalization phase.

3. Results

Percent-correct values were obtained based on the raw scores (number of correct responses) (see Fig. 1). A 3 $\times$ 2 repeated measures analysis of variance was then carried out with participant group (congenitally blind, late blind, and sighted) as the between-subject factor and test phase (immediate generalization phase and delayed memory phase) as the within-subject factor. The main effects of participant group [$F(2, 50) = 3.432$, $p = 0.04$, partial $\eta^2 = 0.121$] and test phase [$F(1, 50) = 47.105$, $p < 0.001$, partial $\eta^2 = 0.485$] were both significant, indicating that the three groups performed differently on voice recognition and that performance in the immediate generalization phase was better than that in the delayed memory phase. LSD *post hoc* tests on the main effect of participant group showed that both blind groups performed better than the sighted group ($p = 0.02$ for the congenitally blind versus the sighted; $p = 0.043$ for the late blind versus the sighted), but the two blind groups performed similarly ($p = 0.717$).

More importantly, the results revealed a significant interaction effect between participant group and test phase [$F(2, 50) = 3.76$, $p = 0.03$, partial $\eta^2 = 0.131$], indicating that group difference in voice recognition was modulated by test phase. Further simple effect analyses revealed that the three groups had similar performance in the immediate generalization phase [$F(2, 50) = 1.26$, $p = 0.293$, partial $\eta^2 = 0.048$], but had significantly different performance in the delayed memory phase [$F(1, 50) = 4.34$, $p = 0.018$, partial $\eta^2 = 0.148$] with the two blind groups performing similarly [LSD *post hoc* test, $p = 0.843$] but both better than the sighted group [LSD *post hoc* test, $p = 0.011$ for the congenitally blind versus the sighted; $p = 0.017$ for the late blind versus the sighted].

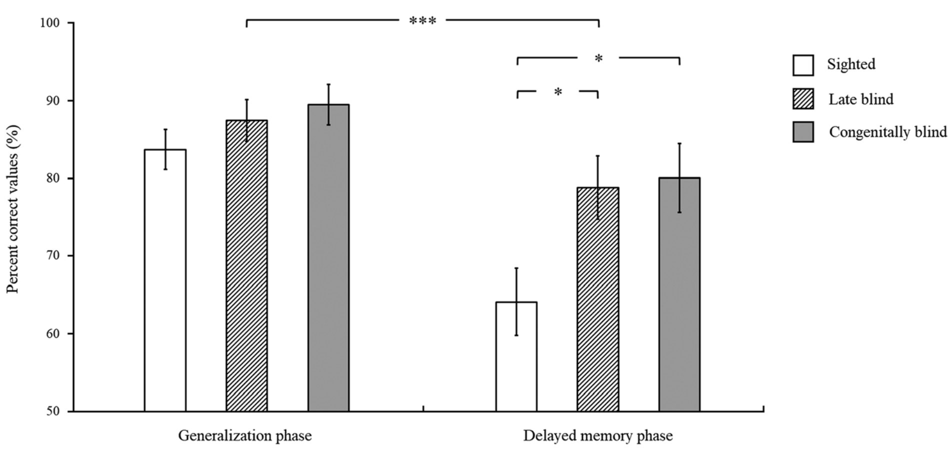

Fig. 1. Percent-correct values of voice recognition by the congenitally blind, late blind, and sighted groups in the generalization and delayed memory phases. ***: significant at $p < 0.001$, *: significant at $p < 0.05$. Error bars represent standard deviation across subjects.

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4. Discussion

In the present study, we examined the anecdotal observation that the blind are superior to the sighted in voice recognition. The superiority was confirmed by the significant main effect of participant group and *post hoc* analyses, indicating that both congenitally and late blind individuals recognize voices of native speakers better than sighted counterparts. More importantly, the significant interaction between participant group and test phase revealed that the blind's superiority in voice recognition resides mainly in delayed memory phase but not in immediate generalization phase.

Although blindness may enhance voice perception ability in accordance with the sensory compensation account, many empirical studies demonstrated that blind persons generally showed no advantage in voice identification or discrimination tasks (Winograd *et al.*, 1984; Günzburger *et al.*, 1987; Gougoux *et al.*, 2009). Furthermore, blind and sighted persons did not differ in their voice-based estimation of relative heights of men (Pisanski *et al.*, 2016), or in the assessment of competence or warmth (Oleszkiewicz *et al.*, 2017). Our finding that the sighted, congenitally and late blind individuals performed similarly in the immediate voice recognition test is therefore consistent with results of the previous studies, indicating that the superiority of blind individuals in some auditory processing skills does not apply to voice perception. The lack of significant difference between blind and sighted individuals might be due to the modulatory effect of linguistic cues on voice perception because speakers and listeners always share the same native languages in the current and above studies. Traditional views of speech perception separate the features and processes used to encode voice attributes from those used to perceive the linguistic contents (Halle, 1985; Laver and Trudgill, 1979). That is, the acoustic features representing vocal quality are linguistically irrelevant. However, recent findings have revealed that vocal characteristics and linguistic properties are perceived independently and that listeners rely heavily on linguistic cues when perceiving voices of native language speakers as demonstrated by the language familiarity effect (Perrachione *et al.*, 2010; Xin and Myers, 2015). As the perception of nonnative speakers' voices by the blind has never been examined, it remains to be investigated whether blind individuals are superior to sighted counterparts in discriminating and identifying voices of nonnative speakers in comparison with native language speakers' voices.

The blind and sighted individuals performed better than their sighted counterparts in the delayed memory test, indicating that the blind have superior long-term memory for voice information of native language speakers. Our finding is consistent with the findings of previous research that the blind have better memory than the sighted for verbal materials and environmental sounds (Röder *et al.*, 2001; Amedi *et al.*, 2003; Hötting and Röder, 2009). The performance of the two blind groups, however, did not differ. This finding is consistent with the result of Bull *et al.* (1983) that the onset age and number of years of blindness both failed to relate to voice recognition accuracy. All the late blind participants in the current study had been totally blind after the age of 5 years old, indicating that the blind's superiority in delayed memory for voice information is likely to be not linked to the critical period associated with changes in brain function induced by blindness. When identifying other people, blind individuals rely much more on voices compared to sighted individuals who use both facial and vocal features. Therefore, even short-term visual loss in blind adults may lead to enhanced ability to retain and retrieve voice information in long-term memory so that a speaker encountered occasionally can be recognized successfully later. The superiority of blind individuals in auditory memory is always ascribed to the inter-modal plasticity of the primary visual brain area. For example, Amedi *et al.* (2003) found that blind individuals had better long-term memory for words compared with sighted counterparts and that the memory performance was positively correlated with activation in the primary visual brain area among the blind but not the sighted. By contrast, voice perception in congenitally blind individuals mainly recruited the superior temporal sulcus reflecting intra-modal plasticity (Gougoux *et al.*, 2009). Whether the superiority of congenitally and late blind individuals over sighted counterparts in delayed memory for voice is ascribed to inter- or intra-modal plasticity can be further investigated through neuroimaging studies.

It is noteworthy that a previous study adopted similar experimental procedures showed that congenitally blind individuals performed better than their sighted counterparts in the generalization phase (Föcker *et al.*, 2012). Different stimuli were used in the study of Föcker *et al.* and the present study. Specifically, the study of Föcker *et al.* used 20 disyllabic pseudo-words spoken by 12 speakers (young women/men and old women/men with each group consisting of 3 speakers), while the current study used 15 sentences spoken by 5 young women. The differences in phonetic richness between the sentence and pseudo-word stimuli and the differences in task difficulty and complexity in terms of age, sex, and number of target speakers might have collectively led to the discrepancy. Although recognizing the voices of 5 speakers would presumably be easier than recognizing 12 voices, the lack of significant group difference in the generalization phase in the present study cannot simply be ascribed to the ceiling effect as the scores were in the range of 58%–98% with no participant achieving a perfect score. Further studies are needed to clarify how various experimental tasks and stimuli affect voice recognition and the related cognitive processes such as short-term and long-term memory among the blind and sighted individuals.

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[1]See supplementary material at https://doi.org/10.1121/10.0001804 for demographic characteristics of the blind participants.

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