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Perceiving sounds: analytic and synthetic listening, global-local processing and possible links with empathy and self-construal

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Abstract

In two experiments we examined the effects of training on auditory perception bias (Experiment 1), the relationship between auditory perception bias and global-local processing (Experiment 2), as well as the relationship between global-local auditory processing, empathy and self-construal (Experiment 2). The present findings are discussed in relation to their implications for research in auditory perception and the perception of others' emotional states.

Introduction

"*C'est quoi, le pitch?*" used to be the favorite question of the famous French TV talk show host, Thierry Ardisson, when he was interviewing writers, film makers and politicians alike. Knowing what the pitch is may not just be important on French television but plays an important role in our development of linguistic abilities as well. Starting in early infancy, our early auditory ability to process pitch and detect pitch contour deviations appears to be tightly linked to our ability to extract linguistic rules (Mueller, Friederici, & Männel, 2012). Pitch pattern perception has been shown to be an important predictor of reading performance both in skilled readers and children with developmental dyslexia (Foxton et al., 2003; Ziegler et al., 2012) and to play a role in L2 acquisition (Wong & Perrachione, 2007). However, pitch processing and production play an important social role in two ways: First, pitch modulation is a carrier of information about speakers' emotions and attitudes (Scherer et al., 1991; Juslin & Laukka, 2003). Second, pitch imitation is exploited in promoting social convergence and status accommodation (Gregory, 1983; Gregory & Hoyt, 1982; Gregory, Webster, & Huang, 1993; Gregory & Webster, 1996; Gregory, Dagan, & Webster, 1997; Gregory & Gallagher, 2002) and expressing ingroup-outgroup bias (Babel, 2009). In sum, an early assessment and training of a listener's ability to process rapid pitch changes in the speech signal could contribute to the development of tools for diagnosis and remediation of different types of language and communication disorders.

What makes pitch detection difficult? Pitch is, roughly, the perceptual correlate of fundamental frequency, produced primarily by the vibrations of vocal chords. It is both the most prominent and most elusive component of the complex sound produced by human articulators because its perception is influenced both at the level of primary auditory mechanisms in the ear (which, mainly due to the nonlinearities in the cochlea, may supply input in the fundamental frequency region; Moore, 2003) and at the level of neural processing in the auditory cortex (Schneider et al., 2005). Interestingly, the way complex sounds are perceived seems to differ systematically between individuals: Some listeners – known as f_0 or synthetic/holistic listeners - focus primarily on the region between 50-500 Hz, the region where the fundamental frequency can be found. Others – known as spectral/analytic listeners - rely on analyzing the harmonic constituents of the sound and focus on the spectrum "as a whole" (e.g. von Helmholtz, 1885). A neurological basis has been suggested for this difference, according to which there is a leftward vs. rightward asymmetry of the lateral Heschl's gyrus for synthetic and analytics listeners, respectively (e.g. Schneider et al., 2005). The auditory perception bias has been almost exclusively analyzed in the context of musical training, but the results of individual studies indicate that it may also affect linguistic performance (Wong & Perrachione, 2007; Wong et al., 2008), as well as pitch imitation (Postma-Nilsenová & Postma, 2012).

Most of the research on the synthetic and analytic listener types suggests that their auditory perception bias is a stable individual difference, possibly caused by genetic factors (Dediu & Ladd, 2007; Wong, Chandrasekaran, & Zheng, 2012). However, musical competence and training can affect the listening mode and lead to a shift from spectral to fundamental listening (Seither-Preisler et al., 2007). Also, repeated exposure to stimuli with a missing fundamental frequency over the course of several months appears to facilitate the synthetic listening mode and thus, presumably, to improve pitch perception (Seither-Preisler et al., 2007; Postma-Nilsenová & Postma, 2012).

In the first part of our study, we explore the possible effect of training on auditory perception bias. More specifically, we aim to find out whether training subjects into perceiving changes in pitch direction according to changes in fundamental frequency or changes in the spectrum can affect their subsequent listening mode. In the second part of the study, we explore the link between the auditory perception bias and listeners' sensitivity to local and global pitch changes, roughly mirroring local and global perception in the visual domain (Ziegler et al., 2012).

Simply put, global processing refers to the perception of a stimulus as a whole, whereas local processing corresponds to the perception of its parts. With respect to auditory stimuli, global processing corresponds to the perception of the pitch direction or contour, while local processing stands for the perception of the intervals between the notes comprising a sound (Bouvet et al, 2011; Justus & List, 2005; Sanders & Poeppel, 2007). Research in the visual domain has provided some support for stronger right hemisphere activation during global processing and stronger left hemisphere activation during local processing (e.g. Fink et al, 1996). So far, the link between auditory local and global processing and the auditory perception bias has not been explored experimentally.

Global vs. Local Precedence and its Correlates

In the visual domain, processing at the global level usually takes precedence over processing at the local level, a tendency described as the Global Precedence Effect (GPE) (Navon, 1977). A similar pattern has been demonstrated in the auditory domain as well (Bouvet et al., 2011; List, Justus, Robertson & Bentin, 2007). Contrary to this general effect, processing at the local level can also precede global processing when stimuli features are altered (e.g. Kimchi, 1992), or, even more importantly, in case of developmental differences. For instance, in the auditory domain, children with developmental dyslexia show a stronger tendency for local auditory processing (Ziegler, Pech-Georgel, George, & Foxton, 2011); in the visual domain, individuals diagnosed with Autistic Spectrum Disorders, such as autistic children (Jollife & Baron-Cohen, 2006) and women diagnosed with Anorexia Nervosa (Southgate et al, 2008) show a local processing bias as well. In the case of autism, Baron-Cohen (2002) describes the tendency for local processing as systemizing and differentiates it from empathizing, which reflects the ability to share others' mental and emotional states. Autistic children perform poorly in tasks requiring Theory of Mind (ToM) and show empathic deficits from a very early age (Baron-Cohen, 1995; Yirmiya, Sigman, Kasari, & Mundy, 1997, a.o.). Impaired ToM is also itself associated with low empathy scores (Shamay-Tsoory et al., 2005). The above findings indicate that the presence of a local processing bias is, in autism at least, accompanied by the presence of impaired empathy. A more direct examination of the link between global-local visual processing and empathy in normal subjects has shown, on the contrary, a link between local processing and greater empathy (Woltin, Corneille, Yzerbyt, & Förster, 2011). This last finding was attributed to the facilitating role that local processing plays in self-other awareness, a prerequisite for the experience of empathy (Decety & Jackson, 2004).

In the present research, we also aim to examine the relationship between empathy and global-local auditory processing. In the auditory domain, personal distress, an affective component of empathy, has been associated with the ability to perceive prosody (Aziz-Zadeh, Sheng, & Gheytanchi, 2010). Prosody perception is impaired in children diagnosed with the Asperger syndrome (Korpilahti et al., 2007). Furthermore, autistic children have difficulties in inferring mental states from the other's voice (Rutherford, Baron-Cohen, & Wheelwright, 2002). If we take into account the processing preferences of autistic individuals, impaired prosody perception and decreased empathy seem to accompany the local processing bias. Considering that similar processing types are exhibited across modalities, we might expect a local processing preference to be accompanied by impaired prosody perception and empathy in the auditory domain as well.

To strengthen the proposed relationship between global-local processing and empathy, we will also examine the role of self-construal (Markus & Kitiyama, 1991). Interdependent self-construal has been associated with global processing, whereas independent self-construal with local processing (Kühnen & Oyserman, 2002; Lin et al, 2008, 2009). Moreover, interdependent self-construal is related to higher empathy (Cross et al., 2000). In addition to these two types of self-construal, we are also considering the relational-interdependent self-construal, a type of interdependence found in rather individualistic cultures (Cross et al., 2000). According to the above, we expect interdependent and relational-interdependent self-construal to be positively related to global auditory processing and empathy, while independent self-construal to be negatively related.

Current Study

Experiment 1

Participants

Sixty-eight students (15 males and 54 females) from Tilburg University were recruited for an experimental session in exchange for course credit. Participants' age ranged from 17 to 27 years old (mean = 22.2, ± 2.6). One participant reported non-normal hearing ability; the participant was not excluded from the analyses given that (s)he performed similarly to the rest of the participant group. The participants were randomly divided into the three between-participant experimental conditions.

Stimuli and procedure

A total of 72 pairs of complex harmonic tones consisting of two, three or four harmonics were constructed for the pitch discrimination task, following the procedure described in Laguitton et al. (1998), including the addition of noise in order to minimize the effects of combination tones (which arise at the cochlear level and may interfere with the measurements of individual differences on the neural level). Thirty-six tone pairs were ambiguous, meaning that the second tone sequence would be judged as higher vs. lower than the first one depending on the participant's listening mode. For 18 ambiguous tone pairs, the second sequence would be judged as lower-higher based on a fundamental frequency listening mode. For the rest of 18 tone pairs, the second sequence would be judged as higher-lower based on a spectral listening mode. The remaining 36 tone pairs were unambiguous and were used as control stimuli. Each tone pair was 2000 ms long. All stimuli were displayed using E-Prime (Psychology Software Tools, Inc., **www.pstnet.com**).

Training phase: During the training phase, participants were presented with 36 ambiguous tone pairs. They were instructed to listen to the tone pair and were asked to indicate whether they perceived the tone pair as rising or falling. After each response, they were provided with feedback about the tonal progression, aiming to train their listening mode. In the fundamental frequency mode condition, participants were told that the tone pair was rising (falling) according to rises (falls) of the fundamental frequency. In the spectral listening mode condition, the feedback depended on rises (falls) of the spectrum. In a control condition, no feedback was provided. The response key order was counterbalanced between the participants.

Testing phase: During the testing phase, participants were presented with 18 ambiguous and 18 non-ambiguous tone pairs. Similarly to the training phase task, they were instructed to indicate whether they perceived the tone pair as rising or falling, they were not provided with feedback about the tonal progression.

Measurements

Based on the participants' answers, we calculated their individual ‘Coefficient of Sound Perception Preference’ (∂_p) using the formula ∂_p = (F-Sp)/(F+Sp), where F is the number of virtual fundamental classifications and Sp the number of spectral classifications in the testing phase. We calculated the ‘Listener Attention Coefficient’ (∂_A) as the proportion of correctly categorized unambiguous stimuli.

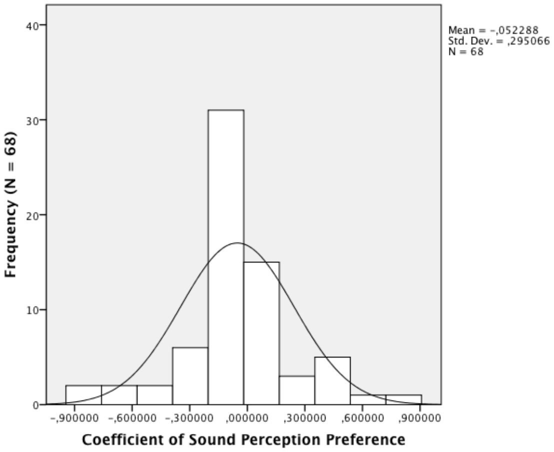

Figure 1: Distribution of the Coefficient of Sound Perception Preference across the three experimental conditions.

Results

A one-way analysis of variance showed no effect of training on the Coefficient of Sound Perception Preference in the testing phase. The participants in the fundamental frequency mode condition, the spectral mode condition and the control condition also did not differ with respect to their mean reaction times and correct responses to the non-ambiguous stimuli. The distribution of the ∂_p values across the three conditions is shown in Figure 1.

Discussion

The results of the first experiment indicate that simple feedback is not sufficient to train participants in such a way that they focus either on the fundamental frequency in the signal or on its harmonic components. The results confirm the findings of Ladd et al. (2013) and others who found that auditory perception bias is robust in test-retest. Contrary to their study, we found a relatively normal distribution of listener types in our experimental group, compared to the prevalence of holistic (fundamental) listeners in their experiment. The difference is most likely due to the use of masking noise in our stimulus material which helped to exclude effects of combination tones (Plomp, 1976).

Experiment 2

Participants

Forty-nine students (7 males and 42 females) from Tilburg University, drawn from the same participant group as in Experiment 1, were recruited for an experimental session in exchange for course credit. Participants’ age ranged from 18 to 27 years old (mean = 22.5, ± 1.8).

Stimuli and procedure

Auditory global-local processing task

To measure global-local auditory processing, a total of 96 pairs of 4-tone sequences (48 same and 48 different) stimuli were used. The stimuli were constructed following the procedure suggested by Ziegler, Pech-Georgel, George, & Foxton (2011). The sequences contained pure tones, each of 250 ms duration with 20 ms gating windows, with frequencies from an atonal scale taken from a division of an octave into seven equally spaced logarithmic steps. The starting frequencies were taken from the interval between 250 to 354 Hz. The third or fourth note in the second sequence was altered so that it was two steps lower or higher than the note in the first sequence (see Figure 2). In the local stimuli, the second sequence would remain rising/falling, in the global stimuli, the global melody would change. Each tone pair was 1000 ms in duration. All stimuli were displayed using E-Prime (Psychology Software Tools, Inc., www.pstnet.com) in a random order.

Auditory affective processing task

To measure participants’ performance in auditory affective processing, we used the Montreal Affective Voices stimuli (Belin, Fillion-Bilodeau, & Gosselin, 2008). The corpus includes 90 vocal affect bursts (expressed as the vowel /a/), which express the emotions of anger, disgust, fear, happiness, pain, pleasure, sadness, surprise and a neutral expression. Participants heard each vocal expression once and were asked to select one of the above emotions.

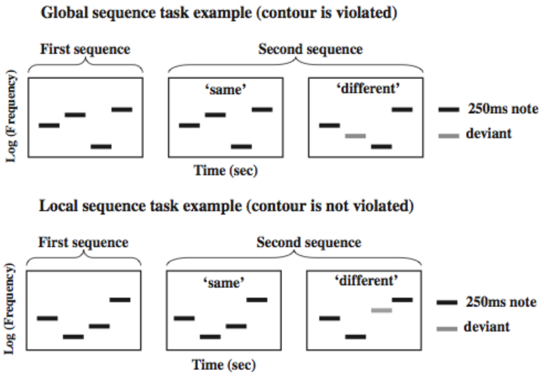

Figure 2: Illustration of the local and global types of stimuli used in Experiment 2 (from Ziegler et al. (2011)).

Empathy measurement

To measure empathy, we used the Interpersonal Reactivity Index, developed by Davis (1980). It measures individual differences in empathy and consists of four dimensions (perspective taking, fantasy scale, empathic concern and personal distress) each one tapping a different aspect of empathy. Participants were asked to indicate, on a five-point scale, to what extent each statement described themselves.

Self-construal measurement

To assess the role of self-construal, we used the Self-Construal Scale developed by Singelis (1994). The scale consists of 24 items which measure the interdependent and independent images of the self. We also included the relational-interdependent self-construal scale (Cross et al., 2000). The scale consists of 11 items. For both measures, participants were asked to indicate their agreement or disagreement on a seven-point scale.

Measures

Following Ziegler et al. (2011), we used d' measures to calculate the participants' performance in the auditory global-local pitch processing task (d'_G and d'_L, respectively). Both measures were not normally distributed with Md_G = .427, Md_L = .312. For the auditory affective processing task, we calculated the scores as the total number of correctly identified emotions (*Aff*). The mean score of correctly identified emotions (90 in total) was 61.6 (SD = 9.3, Md = 64); the distribution of answers was not normal with most participants performing above chance ($t(47) = 36.56$, $p < .001$). For the empathy measurement, the Cronbach's alpha coefficient was .73; the items were reduced to a single empathy score (*Emp*) for further calculations. For self-construal, we constructed three subscales: relational self-construal (Cronbach's alpha (11) = .76), interdependent self-construal (Cronbach's alpha (12) = .47) and independent self-construal (Cronbach's alpha (12) = .73).

Table 1: Nonparametric Spearman's correlations for measures collected in Experiment 1 and 2.

	d'_G	d'_L	∂_P	∂_A	*Aff*	*Emp*	*Rel*	*Inter*	*Indep*
d'_G		.45**	.10	-.02	.34*	-.02	.07	.11	.06
d'_L			-.02	-.03	.07	-.07	-.04	.06	-.06
∂_P				.04	.07	.24	.03	-.02	-.98
∂_A					-.15	-.04	-.15	-.13	-.19
Aff						-.04	-.30	.06	.00
Emp							.10	.39**	-.08

Note: * $p < .05$, ** $p < .001$

d'_G = *Global pitch processing (d'),* d'_L = *Local pitch processing (d')* , ∂_P = *Coefficient of Sound Perception Preference,* ∂_A = *Listener Attention Coefficient, Aff = Affective Voices, Emp = Empathy Measurement, SC = Self-Construal.*

Results

The Shapiro-Wilk test of normality showed a significant non-normal distribution for several of the measures, therefore, we used non-parametric tests throughout. In Table 1, the results of nonparametric correlations for the measures of global and local pitch perception, emotion perception, affective empathy and self-construal are reported, including the Coefficient of Sound Perception Preference collected in the first experiment. The analysis shows a significant relation between global pitch perception processing and the auditory affective processing measure: participants who were better in perceiving changes in the global pitch contour were also better in identifying vocalized emotions.

Discussion

The results of the second experiment indicate that global auditory processing is related to auditory affective processing. This suggests that being able to identify emotions in voice is associated with the ability to perceive pitch globally.

General discussion and Conclusion

The present studies aimed to: a) investigate the possibility of altering individuals' auditory perception bias through training, b) to illustrate experimentally the existence of a relation between auditory global-local processing and auditory perception bias, and c) to examine the link between global-local auditory processing on one hand and empathy and self-construal on the other hand. Our findings show that auditory perception bias cannot be altered by simple training/feedback. This finding adds to the existing evidence according to which the mode of listening (synthetic or analytic) constitutes a rather stable individual difference. With respect to its relation with auditory global-local processing, our findings cannot support an association between processing type and perception bias. We do find, though, an association between global auditory processing and auditory affective processing. To put it differently, perceiving the contour in sounds is related to the ability to recognize emotions in voice. No evidence is provided for the link of empathy with processing when using self-report measures. It is quite possible that, especially for perceived emotions, behavioral measures of emotional empathic responses may yield different results.

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