

# Musically tone-deaf individuals have difficulty discriminating intonation contours extracted from speech<sup>☆</sup>

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## Abstract

Musically tone-deaf individuals have psychophysical deficits in detecting pitch changes, yet their discrimination of intonation contours in speech appears to be normal. One hypothesis for this dissociation is that intonation contours use coarse pitch contrasts which exceed the pitch-change detection thresholds of tone-deaf individuals (Peretz & Hyde, 2003). We test this idea by presenting intonation contours for discrimination, both in the context of the original sentences in which they occur and in a “pure” form dissociated from any phonetic context. The pure form consists of gliding-pitch analogs of the original intonation contours which exactly follow their pattern of pitch and timing. If the spared intonation perception of tone-deaf individuals is due to the coarse pitch contrasts of intonation, then such individuals should discriminate the original sentences and the gliding-pitch analogs equally well. In contrast, we find that discrimination of the gliding-pitch analogs is severely degraded. Thus it appears that the dissociation between spoken and musical pitch perception in tone-deaf individuals is due to a deficit at a higher level than simple pitch-change detection.

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## 1. Introduction

While it has long been recognized that certain otherwise-normal individuals have great difficulties with music perception, only recently has systematic research begun on musical “tone-deafness” or “congenital amusia.” Such individuals are estimated to comprise about 4–5% of the population. Recent psychophysical research has demonstrated that tone deafness is associated with (1) abnormally large thresholds for detecting pitch changes between tones, (2) difficulty in judging the direction of pitch change between tones, and (3) difficulty discriminating short non-musical tone sequences on the

basis of pitch contour (Ayotte, Peretz, & Hyde, 2002; Foxton, Dean, Gee, Peretz, & Griffiths, 2004; Peretz & Hyde, 2003).

Given the growing interest in cognitive and neural relations between language and music, it is of considerable interest to know whether tone-deaf individuals have any deficits in intonation perception. Ayotte et al. (2002) tested the ability of 11 Canadian tone-deaf individuals to discriminate between sentences which differed only in intonation, and to discriminate non-linguistic tone sequences created from the intonation patterns of the sentences. The tone sequences were created by replacing each syllable of a sentence with a tone whose pitch was fixed near the mean fundamental frequency (Fo) of that syllable (see Patel, Peretz, Tramo, & Labrecque, 1998 for details). Ayotte et al. (2002) found a dramatic dissociation between performance on the linguistic and non-linguistic stimuli: tone-deaf individuals had no difficulty discriminating between sentences based on intonation,

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but had substantial difficulty with the tone sequences. Controls, in contrast, performed equally well in both domains. Peretz and Hyde (2003) made the reasonable suggestion that the dissociation in tone-deaf individuals was due to the fact that pitch contrasts in the sentences were coarser than in the tone sequences, and were thus large enough to overcome the tone-deaf participants' deficits in pitch-change detection.

This idea suggests that if the non-linguistic tone sequences followed the original Fo contours exactly, then tone-deaf individuals should be able to discriminate them without difficulty. Here we report an experimental test of this idea, using a population of seven tone-deaf individuals from the UK.

## 2. Methods

### 2.1. Participants

Seven tone-deaf individuals free of neurological and psychiatric disorders participated in this study. They were recruited via advertisements in Newcastle-upon-Tyne, UK. Their musical deficit was confirmed using Peretz's MBEA (Montreal Battery of Evaluation of Amusia, cf. Ayotte et al., 2002). Their ages ranged from 30 to 73 years (mean = 59.4,  $SD = 14.4$ ), and all had normal hearing in at least one ear, defined as a mean hearing level of 20 dB HL or less, measured by pure tone audiometry at 250, 500, and 1000 Hz (see Foxton et al., 2004 for the results of different pitch perception tasks).

### 2.2. Stimuli

The stimuli were based on an English version of the prosody-music battery originally described by Patel et al. (1998). One part of that battery involves same–different discrimination of sentence pairs which are lexically identical but differ in intonation. These sentence pairs are of two types: statement-question pairs, where the critical pitch difference is at the end of the sentence (such as “The telephone doesn't work” spoken as a statement or a question), and focus-shift pairs, where contrastive focus and its associated pitch movement is on a different word within the sentence (such as “I like BLUE ties on gentlemen” vs. “I like blue TIES on gentlemen”). Computer editing of sentence pairs is used to ensure that the timing of syllables is the same and that perceived loudness differences are minimized, so that the only salient cue for discrimination is pitch. This report concentrates on focus-shift pairs in language and their non-linguistic tone sequence analogs.

Two types of non-linguistic analogs were made from the focus-shift pairs. In one type, each syllable was replaced by a tone of fixed pitch set to the Hz value midway between the maximum and minimum Fo values

within that syllable: these are referred to as the “discrete-pitch” analogs. In the other type of analog, each tone's pitch exactly followed the Fo contour within the syllable, gliding up and/or down just as the Fo did: these are referred to as the “gliding-pitch” analogs. These gliding-pitch analogs dissociated the intonation contour from any trace of phonetic information, to minimize the chance that they would be processed in a “speech mode.” In both types of sequences, tone onsets occurred at the vowel onset times of corresponding syllables, and tone offsets were determined by the offset of Fo within each syllable. Thus each tone sequence had the same temporal rhythm as the syllables in the parent sentence. All tones had a complex frequency structure consisting of a fundamental and seven odd harmonics of decreasing amplitude, giving the analogs a clarinet-like quality.

There were 12 focus-shift linguistic pairs (see Appendix B of Nicholson et al., 2003 for a list). Participants heard each of the 12 pairs in a *same* configuration (contrastive focus on the same word) and in a *different* configuration (contrastive focus on a different word), as well as four randomly chosen sentence pairs repeated in each of these configurations, for a total of 32 sentence pairs. Similarly, there were 32 pairs of discrete-pitch analogs and 32 pairs of gliding-pitch analogs.

### 2.3. Procedure and scoring

The three types of stimuli (speech, discrete-pitch analogs, and gliding-pitch analogs) were presented in separate blocks. The order of the blocks was the same (speech, discrete pitch, and gliding pitch), but the blocks were not always run in the same session, as the tests were part of a larger study which required multiple visits (Foxton et al., 2004). Within each block members of a pair were separated by 2 s and pairs were separated by 5 s. Participants were instructed to listen to each pair and indicate with a button press if the members of the pair sounded identical or if they sounded different in any way. Practice items were given before each block. Participants were tested in a quiet room in the School of Neurology at the University of Newcastle upon Tyne.

Scoring of performance was based on percentage of hits minus percentage of false alarms, in accordance with the procedure of Ayotte et al. (2002). A hit was defined as a *different* configuration pair which was classified as different, while a false alarm was defined as a *same* configuration pair classified as different. (Note: a *different* configuration pair classified as same was scored as a miss, while a *same* configuration pair classified as same was scored a correct rejection. Thus the responses of a participant to the 16 *different* configurations pairs were divided into hits and misses, and responses to the 16 *same* configuration pairs were divided into false alarms and correct rejections.)

### 3. Results

Fig. 1 shows the results on the three tasks. Consistent with the findings of Ayotte et al. (2002), tone-deaf individuals are far better at discriminating sentences based on intonation than they are at discriminating discrete-pitch analogs of the intonation contours (compare Ayotte et al., 2002, Fig. 3). This difference is statistically significant ( $p = .023$ , Wilcoxon signed rank test). Surprisingly, however, tone-deaf individuals also have difficulty discriminating gliding-pitch analogs which exactly mimic the intonation patterns of the sentences. In fact, performance on the discrete and gliding-pitch analogs is indistinguishable. Thus as one would expect, performance on the latter is significantly worse than on the sentences ( $p = .026$ , Wilcoxon signed rank test).

### 4. Discussion

Tone-deaf individuals have difficulty perceiving musical and non-musical tone sequences built from discrete pitches, yet they seem to discriminate intonation contours in a normal fashion (Ayotte et al., 2002; Foxton et al., 2004). The observation that such individuals have abnormally large psychophysical thresholds for detecting pitch changes in sequences of tones naturally leads to the idea that intonation perception is spared because it relies on pitch contrasts which are coarse enough to exceed these elevated thresholds (Peretz & Hyde, 2003). We have tested this idea by using non-linguistic analogs of intonation contours which exactly

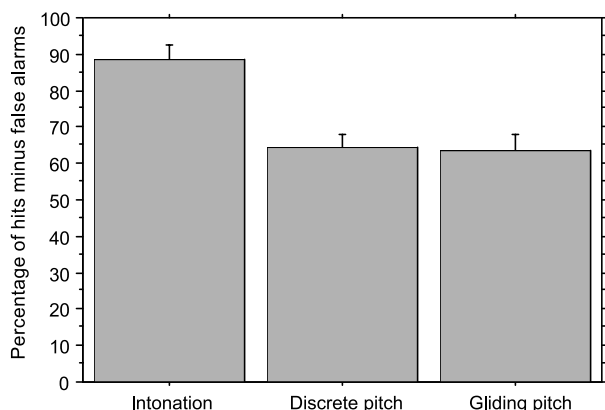


Fig. 1. Performance of tone-deaf individuals (means + SE) on discrimination of three different types of pitch patterns: intonation contours in speech, non-linguistic analogs of intonation contours based on discrete pitches, and non-linguistic analogs of intonation contours based on gliding-pitch movements which exactly replicate the pitch pattern of intonation. Mean %hits – %false alarms: intonation = 88.4% (SE 4.2%); discrete pitch = 64.3% (SE 3.5%); and gliding pitch = 63.4% (SE 4.6%).

reproduce the gliding-pitch movements and temporal patterns of speech intonation. If the difference between speech and music is due to the coarser pitch contrasts of speech, then such gliding-pitch analogs should be discriminated just as well as actual intonation contours embedded in speech.

We find, rather surprisingly, that tone-deaf individuals have severe difficulties discriminating gliding-pitch analogs of intonation, and that their performance on these analogs is no different than their discrimination of analogs based on discrete pitches. This finding is especially striking in light of a particular psychophysical finding of Foxton et al. (2004) on the same tone-deaf individuals studied here. Foxton et al. examined thresholds for detecting a pitch change between two successively presented pure tones under two circumstances. In one condition (“segmented pitch-change detection”), the tones were separated by a silent interval of 100 ms. In another condition (“gliding pitch-change detection”), this interval was filled by a linear frequency ramp that bridged the pitch difference between the tones. For all seven participants in the current study, the threshold for pitch-change detection was *smaller* when pitches were connected by an intervening glide. For the segmented condition the mean threshold for 75% correct discrimination was 0.56 semitones (st) (SD 0.36), while for the glide condition it was only 0.21 st (SD 0.08); this difference is significant by a Wilcoxon signed rank test ( $p = .018$ ). For controls ( $n = 10$ ), the mean for the segmented condition was 0.19 st (SD 0.08) and the mean for the gliding condition was 0.12 st (SD 0.03).

Thus not only do tone-deaf individuals have difficulty discriminating gliding-pitch analogs of intonation, they have these difficulties *despite* the fact that they have substantially smaller thresholds for detecting pitch changes in gliding-pitch patterns than in segmented pitch patterns. It therefore appears that the relatively normal intonation perception of tone-deaf individuals cannot be explained by the idea that intonation uses coarse pitch contrasts which exceed their psychophysical thresholds for pitch-change detection. While a satisfying explanation awaits future research, it seems clear that the key factors lie at a higher processing level than simple pitch-change detection.

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