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Rhythm deficits in 'tone deafness'

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Abstract

It is commonly observed that 'tone deaf' individuals are unable to hear the beat of a tune, yet deficits on simple timing tests have not been found. In this study, we investigated rhythm processing in nine individuals with congenital amusia ('tone deafness') and nine controls. Participants were presented with pairs of 5-note sequences, and were required to detect the presence of a lengthened interval. In different conditions the sound sequences were presented isochronously or in an integer-ratio rhythm, and these were either monotonic or varied randomly in pitch. It was found that the 'tone deaf' participants exhibited inferior rhythm analysis for the sequences that varied in pitch compared to those that did not, whereas the controls obtained equivalent thresholds for these two conditions. These results suggest that the rhythm deficits in congenital amusia result from the pitch-variations in music.

Keywords: Congenital amusia; Tone deafness; Rhythm; Pitch; Auditory perception

1. Introduction

Recent reports have characterised a disorder where individuals describe lifelong, selective deficits in music processing (Ayotte, Peretz, & Hyde, 2002; Foxton, Dean, Gee, Peretz, & Griffiths, 2004). These individuals typically have great difficulty recognising music, and are unable to sing in tune, although, they themselves are not aware of this. This disorder is colloquially known as 'tone deafness,' but Ayotte and colleagues (2002) adopted the formal label 'congenital amusia,' to reflect the life-long, selective nature of the music deficits. Standardised music tests demonstrate that these individuals have deficits in processing the pitch changes in music and that a proportion of them also have deficits in processing musical rhythm (Peretz, Champod, & Hyde, 2003). It is estimated that around 4% of the population is affected by this disorder (Kalmus & Fry, 1980).

Recent studies have assessed the auditory perceptual abilities of participants with congenital amusia. These studies have demonstrated impairments in the detection of fine-grained pitch changes (Foxton et al., 2004; Peretz et al., 2002), and it has been proposed that this could underlie the impaired musical processing. However, these studies have largely neglected the deficits in rhythm analysis. This is of much importance as the majority of individuals with congenital amusia have difficulty dancing in time to music, and tapping along to the beat of a tune (Dalla Bella & Peretz, 2003).

One previous study assessed the deficits in rhythm analysis in congenital amusia in more detail (Hyde & Peretz, 2004). In this study, parallel assessments of pitch and rhythm processing were carried out. Participants were presented with monotonic and isochronous sound sequences, and were required to detect the presence of pitch or temporal changes. It was found that participants with congenital amusia were impaired at detecting the presence of small pitch changes, whereas they were able to detect the presence of temporal changes as well as control participants. This latter result conflicts with the rhythm deficits in individuals with congenital amusia. Hyde and Peretz (2004) proposed that deficits in rhythm analysis may only occur when sounds change in pitch. This would explain why deficits are present on musical tests of rhythm

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processing where the sounds change in pitch, but not on the tests that employed monotonic sounds. However, an alternative possibility is that deficits in rhythm analysis may only occur when sounds are presented in the form of a complex rhythmic pattern, where the intervals between successive notes are not held constant. This could also explain why deficits were not identified in Hyde and Peretz's study, where isochronous sound sequences were employed. This hypothesis would also predict deficits on musical rhythm tasks where the inter-note intervals are typically varied.

To assess the possibility that deficits in rhythm analysis only occur for complex rhythms, we administered tasks that required the detection of rhythmic changes in sound sequences that either had a constant inter-tone onset interval, or a variable inter-tone onset interval. It was hypothesised that if deficits in rhythm analysis only occur for complex rhythms, then deficits would only be observed for the variable-interval condition. To determine whether deficits in rhythm analysis only occur for sound sequences that contain random pitch variations, we administered the tasks twice: once with a constant pitch, and again with randomly varying pitches. It was hypothesised that if deficits in rhythm analysis only occur for sounds that vary in pitch, then performance would be normal for the monotonic sounds, whereas deficits would be observed for the sounds that vary in pitch.

2. Materials and methods

2.1. Participants

We tested nine individuals with congenital amusia, who all reported that when they sing their voices sound in tune to themselves but not to others. Their musical deficits were confirmed using the Montreal Battery of Musical Perception (Peretz et al., 2003), where their scores were found to fall in the impaired range, defined as two standard deviations below the mean level. All of these participants had previously taken part in a research study in this laboratory (Foxton et al., 2004), and had originally been recruited by means of a radio report and a newspaper advertisement.

Nine control participants were also tested, who all reported that they were able to sing in tune, despite having little or no musical training. All of these participants performed normally on the Montreal battery scale sub-test, which assesses the ability to detect differences between tunes that violate the melodic key. These participants matched the age and education levels of the congenital amusia group, with mean ages of 55 and 57 years, respectively, and a mean of 17 years spent in education for both groups. All but one of these control participants had previously taken part in a study in this laboratory (Foxton et al., 2004).

All of the participants gave informed consent to take part in this study and ethical approval was attained from the local research ethics committee for the University of Newcastle upon Tyne.

2.2. Auditory tests

Pairs of 5-note sequences were presented with a constant inter-tone onset interval (300 or 600 ms), or with variable inter-tone onset intervals (following the series: 300, 600, 300, and 600 ms, which creates a rhythmic pattern that most adults report being able to encode and recognise easily). For each pair, participants were required to detect the lengthening of an interval in either the first or the second sequence, and to respond by pressing keys 1 and 2 on the keyboard. The sequence containing the lengthened interval was randomised for each item. The use of this two-alternative forced choice task ensured that response bias did not affect the results. The tasks were administered twice in two separate sessions: once with a constant pitch (1000 Hz), and then again with randomly varying pitches (taken from 828.1, 914.3, 1009.4, 1114.5, 1230.5, 1358.6, and 1500 Hz, which correspond to notes on a non-musical scale where the octave is divided into seven logarithmically equal steps). For all of the conditions, the sounds were 100 ms pure tones with 20 ms onset and offset linear amplitude gating windows, and the two sets of five sounds were separated by a 1.5 s gap. The tasks are illustrated in Fig. 1.

For each task, participants were first presented with two practise items to ensure that they understood the tasks. For the test runs there were a total of 60 items (i.e., 60 pairs of 5-note sequences), presented in two runs out of 30. For the first item in each task, the interval between the third and the fourth sounds was lengthened by 60 ms for one of the sequences. Thereafter, the size of the lengthened intervals were altered following a two-down one-up procedure, whereby two consecutive correct responses led to a decrease in the lengthened interval duration, and one incorrect response led to an increase. These changes were 6 ms for each step, until there had been a total of four alternations in the difficulty level, or until the end of the first task run. Thereafter, the changes were 2 ms for each step. At the end of the runs threshold levels were determined by averaging the lengthened intervals at the last five points of the difficulty-level alternations.

The stimuli were created digitally at a sample rate of 44.1 kHz and 8 bit resolution. All of the auditory tests were conducted on a laptop computer with an external soundcard (Edirol: USB Audio Interface UA-3). Sounds were presented at a level of 80 dB SPL through Sennheiser HD 265 headphones (Sennheiser, Wedeburg, Germany).

At the end of the second session, the control group participants who had not already completed the full Montreal battery were administered the rhythm sub-test. This was to assess musical rhythm perception in these participants.

3. Results

3.1. Group differences

The thresholds obtained on the different rhythm tasks were all normally distributed (Shapiro–Wilk, $p > .05$), with