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Congenital amusia: A short-term memory deficit for non-verbal, but not verbal sounds

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ABSTRACT

Congenital amusia refers to a lifelong disorder of music processing and is linked to pitch-processing deficits. The present study investigated congenital amusics' short-term memory for tones, musical timbres and words. Sequences of five events (tones, timbres or words) were presented in pairs and participants had to indicate whether the sequences were the same or different. The performance of congenital amusics confirmed a memory deficit for tone sequences, but showed normal performance for word sequences. For timbre sequences, amusics' memory performance was impaired in comparison to matched controls. Overall timbre performance was found to be correlated with melodic contour processing (as assessed by the Montreal Battery of Evaluation of Amusia). The present findings show that amusics' deficits extend to non-verbal sound material other than pitch, in this case timbre, while not affecting memory for verbal material. This is in line with previous suggestions about the domain-specificity of congenital amusia.

1. Introduction

Congenital amusia (also named tone or tune deafness) refers to a lifelong disorder of music processing that occurs without brain damage, and is estimated to affect about 4% of the general population (see Peretz & Hyde, 2003 for a review). Individuals with congenital amusia have difficulty recognizing familiar tunes without lyrics and detecting a wrong or out-of-tune note. The musical disorder occurs despite normal performance on tests of intelligence, auditory processing, cognitive functioning, language processing, and verbal memory skills (see Ayotte, Peretz, & Hyde, 2002; Foxton, Dean, Gee, Peretz, & Griffiths, 2004; Peretz et al., 2002, for extensive testing).

This disorder has been recognised for a long time, but has only been systematically studied relatively recently (see Ayotte et al., 2002), mainly thanks to the development of the Montreal Battery for the Evaluation of Amusia MBEA (Peretz, Champod, & Hyde, 2003). In the MBEA, seven sub-tests address various components of music perception and memory, notably the pitch dimension (detection of an out-of-key note, a contour violation, or interval changes), the time dimension (rhythm and meter perception) and incidental memory (i.e., for melodies used in preceding sub-tests). Although some amusic individuals show deficits for rhythm perception, the major deficit concerns the pitch dimension (as assessed by the MBEA scale, contour and interval sub-tests).

The pitch deficit is not limited to musical contexts, it also affects basic pitch discrimination in unmusical tone material. Performance is impaired for the recognition of pitch direction, the perception of more complex pitch patterns and the detection of pitch changes in continuous and discrete sounds as well as in isochronous sequences (Foxton et al., 2004; Hyde & Peretz, 2004). Amusic individuals have difficulty detecting pitch changes smaller than two semitones (or even more, see Peretz et al., 2002). In earlier studies, normal performance has been reported for the processing of intonation in speech (Ayotte et al., 2002; Patel, Foxton, & Griffiths, 2005; Peretz et al., 2002), thus implying that the pitch deficit only affects music perception. Recent data suggest that for some amusics, the processing advantage for large pitch differences in speech might not be observed for gliding pitch changes at a slow rate (Patel, Wong, Foxton, Lochy, & Peretz, 2008).

The tasks revealing pitch deficits involved not only perception, but also memory components: Two melodies, tone pairs or tones have to be compared (same-different paradigms) or the odd-one out has to be found among three events (i.e., AAX versus AXA). It has been argued that memory and/or attention deficits cannot explain the poor performance because amusic individuals perform

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well for large pitch differences and show normal performance on standard memory tasks, such as the digit span from the Wechsler Adult Intelligence Scale III. However, another possibility might be that verbal and non-verbal memory differ (as suggested, for example, by Deutsch, 1970), with only the latter being impaired in congenital amusia. Recent research investigating pitch memory with variations in sequence length and intervening delay, provide direct evidence for short-term memory deficits for pitch in congenital amusia (Gosselin, Jolicoeur, & Peretz, 2008; Stewart, McDonald, Kumar, Deutsch, & Griffiths, 2008). However, up to now, no study has investigated memory performance for non-verbal material other than pitch. For non-verbal sound material, such as voices (i.e., of famous individuals) and environmental sounds (i.e., animal sounds, industrial sounds, human noises), Peretz et al. (2002) and Ayotte et al. (2002) have only shown that individuals with congenital amusia show normal performance in naming and recognition tasks (testing for access to knowledge stored in long-term memory, without testing for short-term memory).

Our present study investigated short-term memory for tones, musical timbres and words. Previous research using interference memory paradigms suggests the existence of short-term memory modules that are specialized for the retention of either pitch (without storing other attributes, Semal & Demany, 1991; Semal, Demany, Ueda, & Hallé, 1996) or timbre (Starr & Pitt, 1997). Timbre enables listeners to distinguish between different instruments or speakers, and plays a role in sequence perception as well as the separation of sound sources (Bregman, 1990). The Acoustical Society defines timbre with reference to the features that enable the distinction between two sounds of identical pitch, intensity, duration and location. Research has shown that timbre is a multidimensional set of auditory attributes based on the temporal and spectral features of sounds (cf. Krumhansl, 1989; McAdams, Winsberg, Donnadieu, DeSoete, & Krimphoff, 1995; Samson, Zatorre, & Ramsay, 1997). Models of timbre have been based on perceived similarity judgments and propose mental representations of timbre in three-dimensional spatial structures with axes representing attack time (the time to reach the maximum of the energy envelop), spectral centroid (or spectral center of gravity) and spectral flux (how the spectral envelope changes over time).

In the present study, participants (amusics and matched controls) listened to five-event sequences, with the events being either tones, words or timbres. The tones were played by the same instrument, but differed in pitch. The words were spoken by the same voice at the same pitch, but differed in the phonemes and semantic content. The timbres were played at the same pitch, but differed in spectro-temporal information. The five-event sequences were presented in pairs and were separated by a 3-s silent delay. They were either the same or differed in the order of presentation of the events (i.e., two events were exchanged). For the pitch memory task, the differences between the tones were altered according to the amusic participants' pitch perception thresholds. Based on previous findings on congenital amusia, we expected a memory deficit for tone sequences, but normal performance for word sequences. It was reasoned that if the memory deficit is restricted to pitch, performance should be normal for the timbre sequences. If, however, the deficit more generally affects memory for non-verbal sounds, impaired performance should be observed for the timbre sequences. The present paradigm has previously been tested on healthy students with varying sequence lengths (Schulze & Tillmann, 2007), and we expected matched control groups to replicate the students' data for the five-event sequences.[1] With the aim of investigating potential memory deficits in amusic listeners, the present study focused on comparisons between amusic and control participants for each of the materials.

2. Method

2.1. Participants

The amusic group consisted of 10 adults (six women) with a mean age of 33.6 years (SD = 10.3). Their level of education was on average 15.2 years (SD = 1.87), and the average musical training was 0.85 years (SD = 1.67). The matched control group consisted of 10 adults (six women) with a mean age of 36.2 years (SD = 10.3), a reported level of education of 13.9 years (SD = 1.56) and an average musical training of 0.3 years (SD = .95). All participants performed the MBEA: The average score for the amusic group (21.07; SD = 1.59) differed significantly from the score for the control group (27.23; SD = 1.18), $t(18) = 9.85$, $p < .0001$. All amusics obtained scores below the cut-off score (23, which is two standard deviations below the norm), except for one participant who obtained a score of 23.67. This amusic was included because of low performance on the scale sub-test (18, with a cut-off at 22), which has been shown to be strongly diagnostic (Peretz et al., 2008). All controls performed above the cut-off score (see Table 1 of Supplementary material).

2.2. Pretest: pitch difference detection thresholds

2.2.1. Method and procedure

To determine perceptual thresholds for detecting differences in pitch, a two-alternative forced choice task was employed. Participants were presented with two pairs of pure tones: One pair of tones that had the same pitch, and a second pair of tones that differed in pitch. Participants were asked to decide whether the first or the second pair contained the pitch difference. Adaptive tracking using a two-down, one-up staircase procedure was employed to determine the perceptual threshold, targeting 70.7% correct performance. The sound pairs consisted of two 100 ms pure tones, gated with 10 ms amplitude ramps, and separated by a silent interval of 150 ms. The frequency of the same-pitch pairs was 512 Hz; the different-pitch pairs always contained one tone of 512 Hz and another tone of a higher frequency that was randomly presented first or second within the pair. During the task, there was no time limit for the response, and the next sound pair was presented 650 ms after the response. The order of the same-pitch and different-pitch pairs was randomized. The test was administered in three runs of 30 trials, and the pitch difference at the beginning of the first run was set at 2.0 semitones. The step size in the adaptive track was 0.1 semitones. Thresholds were determined by averaging the last six changes in the direction of the adaptive track. Prior to the task, participants completed a short practice run of six items, where they were given error feedback. No feedback was given during the three adaptive runs.

2.2.2. Results

Thresholds for the amusic group ranged from 0.2 to 4 semitones (mean = 1.32, SD = 1.17) and for the control group from .07 to 1.67 (mean = 0.57, SD = .61) (see Table 1 of Supplementary material). This difference was statistically significant using a one-tailed *t*-test, $t(18) = 1.80$, $p = .045$. For the amusics, five participants had thresholds below one semitone (average threshold of .54), three had thresholds above one semitone (average threshold of 1.28) and two above 2 semitones (thresholds of 2.6 and 4, respectively). For the controls, seven participants had thresholds below one semitone (average threshold of 0.22), and three participants had thresholds above one semitone (with respectively 1.2, 1.3 and 1.7 semitones). For the amusics only, these results were used to define the tone sequences of the short-term memory task, as detailed be-

[1] For the five-event sequences, students' performance level for timbres was as good as for words (i.e., Hits – False Alarms of .43 and .45, respectively), while performance was best for tones (i.e., Hits – False Alarms of .61).