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Research Report

Does tonality boost short-term memory in congenital amusia?

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ARTICLE INFO

Article history:
Accepted 5 September 2013
Available online 13 September 2013

Keywords:
Tone deafness
Auditory short-term memory
Pitch
Implicit processing
Musical structure
Response time

ABSTRACT

Congenital amusia is a neuro-developmental disorder of music perception and production. Recent findings have demonstrated that this deficit is linked to an impaired short-term memory for tone sequences. As it has been shown before that non-musicians' implicit knowledge of musical regularities can improve short-term memory for tone information, the present study investigated if this type of implicit knowledge could also influence amusics' short-term memory performance. Congenital amusics and their matched controls, who were non-musicians, had to indicate whether sequences of five tones, presented in pairs, were the same or different; half of the pairs respected musical regularities (tonal sequences) and the other half did not (atonal sequences). As previously reported for non-musician participants, the control participants showed better performance (as measured with d') for tonal sequences than for atonal ones. While this improvement was not observed in amusics, both control and amusic participants showed faster response times for tonal sequences than for atonal sequences. These findings suggest that some implicit processing of tonal structures is potentially preserved in congenital amusia. This observation is encouraging as it strengthens the perspective to exploit implicit knowledge to help reducing pitch perception and memory deficits in amusia.

1. Introduction

Congenital amusia is a lifelong disorder of music perception and production that has been estimated to affect about 4% of the general population (Ayotte et al., 2002; Peretz and Hyde, 2003; Peretz et al., 2002; Stewart, 2006, 2008, 2011). Amusic individuals are unable to recognize a familiar tune (without the help of lyrics) or to detect that someone (including themselves) sings out of tune. This deficit, which affects individuals in their everyday life (McDonald and Stewart, 2008), cannot be explained by peripheral hearing loss, brain lesions, or general cognitive or social impairments (Ayotte et al., 2002).

Seminal studies of congenital amusia (Foxton et al., 2004; Peretz and Hyde, 2003; Peretz et al., 2002) have led to the

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http://dx.doi.org/10.1016/j.brainres.2013.09.003

assumption that this condition is based on a disorder of fine-grained pitch processing, with amusic individuals exhibiting elevated pitch discrimination thresholds. Pitch discrimination difficulties in amusics were observed in simple tone sequences (for changes smaller than two semi-tones, whereas controls detected changes of a quarter of a semi-tone; Hyde and Peretz, 2004) and with various psychoacoustic approaches (Foxton et al., 2004). Recent studies have extended these findings by showing that amusic individuals may display impaired short-term memory for pitch, even in the absence of elevated pitch discrimination thresholds (Albouy et al., 2013; Gosselin et al., 2009; Tillmann et al., 2009; Williamson et al., 2010; Williamson and Stewart, 2010).

Evidence for a short-term memory deficit in congenital amusia was obtained using pitch comparison tasks both for single tones and for tone sequences. For single tones, a stronger sensitivity to interference (irrelevant tones presented during the silent retention period between to-be-compared tones) in short-term memory tasks was observed in amusic participants in comparison to controls (Gosselin et al., 2009; Williamson et al., 2010). Further support for a short-term memory deficit for single tones was provided by Williamson et al. (2010) who showed that amusic participants had a steeper decline in performance with increasing retention delay between two tones than did controls.

Amusics' short-term memory deficit for pitch was also shown for tone sequences, where amusics showed a greater decrease in performance, relative to controls, with increasing length of the to-be-remembered sequences, thus revealing amusics' sensitivity to memory load (Gosselin et al., 2009). The specificity of the short-term deficit for musical material was shown by Tillmann et al. (2009) who compared short-term memory performance for sequences of tones, timbres, and words. The results indicated that amusic participants performed worse than controls for tone and timbre sequences (see also Marin et al., 2012), but not for words, thus providing evidence that amusics' memory deficit is selective to the musical domain.

Importantly, the pitch changes used in the aforementioned short-term memory studies exceeded the amusics' psychophysically measured pitch discrimination thresholds. The findings therefore point to a memory-based deficit for pitch that extends beyond a perceptual impairment. In addition, it is relevant to note that while some amusics exhibited normal pitch discrimination thresholds (Albouy et al., 2013; Foxton et al., 2004; Tillmann et al., 2009), all amusic participants displayed impairments in pitch memory tasks. These observations have led to the working hypothesis that the core deficit in congenital amusia is an impairment of short-term memory for pitch, and that this impairment may be accompanied by an impairment of fine-grained pitch processing at the perceptual level.

Interestingly, despite explicit processing deficits, recent behavioral data have provided evidence for some spared implicit pitch processing in congenital amusia. Using a priming paradigm, Tillmann et al. (2012a) revealed that some musical knowledge is indeed preserved in congenital amusia, in particular about the syntactic-like functions of chords in the Western musical system (see also Omigie et al., 2012). Similarly, a recent study investigating amusics' perception of musical emotions has also suggested some spared musical structure processing related to mode (major, minor) (Paquette et al., 2011). Further evidence for implicit tonal processing in amusia has been provided by Tillmann et al. (2012b), showing that amusic individuals can differentiate between tonal and atonal musical pieces. Taken together, these studies reveal that amusics might possess more tonal knowledge than previously thought on the basis of their performance in tasks requiring explicit judgments, such as the detection of a single (out-of-key) tone or the memory-storage of melodies. These data sets thus suggest that congenital amusics might have acquired some knowledge about musical structures by mere exposure to music that obeys to tonal rules, as previously reported for non-musician listeners (Bigand and Poulin-Charronnat, 2006; Tillmann et al., 2000).

In light of the recent evidence for some spared implicit knowledge of tonal structures in congenital amusia, the question arises as to whether amusics' tonal knowledge might also benefit their short-term memory for tone sequences (i.e., for tonal sequences in comparison to atonal sequences). For other materials, such as verbal material or spatial patterns (Bor et al., 2003; Savage et al., 2001), it has been shown that material that is structured leads to better short-term and working memory performance than unstructured material. Similarly, the inherent structure of music, as based on the regularities of the Western tonal system, improved the maintenance of tone sequences in short-term memory for musician and non-musician listeners (in comparison to atonal sequences, Schulze et al., 2012).

The present study investigated amusics' short-term memory for tonal and atonal sequences using the five-tone (tonal and atonal) melodies of Schulze et al. (2012). By comparing the processing of structured and unstructured musical material, we aimed to investigate amusics' implicit tonal knowledge and its impact on short-term memory. Eleven amusic participants and eleven matched controls (all non-musicians) were recruited based on prior testing with the Montreal Battery of Evaluation of Amusia (MBEA, Peretz et al., 2003). Before the short-term memory task, all participants were tested with a two-alternative forced-choice task (using a staircase procedure) to determine their pitch discrimination thresholds (PDT, see Tillmann et al., 2009). Participants' short-term memory abilities for sequences of digits were evaluated using classic forward and backward digit span tests (Wechsler, 1997) to ensure that participants' performance did not differ for non-musical auditory material. For the main musical short-term memory test, we used a delayed matching-to-sample paradigm where participants had to determine whether tonal or atonal melodies (of five tones) presented in pairs were the same or different.

2. Results

2.1. *Pre-tests*

2.1.1. *Montreal battery of Evaluation of amusia (MBEA)*

All participants were tested with the MBEA (Peretz et al., 2003). To be considered as amusic, participants had to obtain an average score on the MBEA below the cut-off score (23 on