Neuropsychologia 77 (2015) 128–136

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Conveying the concept of movement in music: An event-related brain potential study

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ARTICLE INFO

Article history:
Received 27 February 2015
Received in revised form
7 July 2015
Accepted 29 July 2015
Available online 5 August 2015

Keywords:
Music
Movement
Conceptual processing
N400
ERP

ABSTRACT

This study on event-related brain potential investigated whether music can convey the concept of movement. Using a semantic priming paradigm, natural musical excerpts were presented to non-musicians, followed by semantically congruent or incongruent pictures that depicted objects either in motion or at rest. The priming effects were tested in object decision and implicit recognition tasks to distinguish the effects of automatic conceptual activation from response competition. Results showed that in both tasks, pictures that were incongruent to preceding musical excerpts elicited larger N400 than congruent pictures, suggesting that music can prime the representations of movement concepts. Results of the multiple regression analysis showed that movement expression could be well predicted by specific acoustic and musical features, indicating the associations between music per se and the processing of iconic musical meaning.

1. Introduction

Music and language are important information systems for human beings as both convey meaning. In language, majority of words bear a symbolic link between mental lexicon and real-world objects or events. Such meaning principally depends on arbitrary but not analog relationships (Davies, 1994; Van Petten and Rheinfelder, 1995). By contrast, music communicates meaning through different extra-musical sign qualities (for a review, see Koelsch, 2012), depending on either an analog or arbitrary relationship. Although Meyer (1956) extensively addressed musical meaning, the neural processing of musical meaning continues to receive increasing attention among researchers (e.g., Daltrozzo and Schön, 2009a, 2009b; Goerlich et al., 2012; Koelsch, 2011; Koelsch et al., 2004; Painter and Koelsch, 2011; Schön et al., 2010; Steinbeis and Koelsch, 2008, 2011).

With the paradigm of cross-modal priming, researchers have found that music can prime representations of concepts (e.g., Daltrozzo and Schön, 2009a, 2009b; Koelsch et al., 2004; Painter and Koelsch, 2011; Schön et al., 2010). In previous studies, N400, an event-related brain potential (ERP) elicited by semantic mismatches (Kutas and Federmeier, 2011; Kutas and Hillyard, 1980), has been observed for mismatches in emotional conceptual associations between music and words (Goerlich et al., 2012; Steinbeis and Koelsch, 2008, 2011) and between music and faces (Kamiyama et al., 2013).

Although music is known to convey emotional concepts, few studies have presented the conceptual priming effect of music that was purely based on non-emotional connections. Iconic musical meaning has been proposed to potentially emerge from music resembling qualities of objects or qualities of abstract concepts (Fritz et al., 2013; Koelsch, 2011, 2012); for example, an ascending diatonic scale may be associated with a staircase. To explore whether music conveys iconic musical meaning, a recent study (Zhou et al., 2014) investigated conceptual priming effects based on iconic sign quality. In that study, the authors found that semantic congruency in spatial concepts (openness/closeness) between musical excerpts and pictures was able to modulate the N400, indicating that music can convey spatial concepts.

Music is a form of art that unfolds over time. Similar to space, movement is a fundamental aspect of iconic musical meaning (Clarke, 2001; Davies, 1994). People usually experience musical motions metaphorically in terms of their experience of motion in the physical world (Larson, 2002, 2004; Sloboda, 1998). Strong evidence exists of music perception and production recruiting motor regions of the brain (e.g., Bangert et al., 2006; Chen et al., 2008a, 2008b; Grahn and Rowe, 2009; James et al., 2012; Zatorre et al., 2007), and of the ability of certain musical features (e.g., rhythm and tempo) to modulate the images of motion pictured by listeners (Eitan and

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http://dx.doi.org/10.1016/j.neuropsychologia.2015.07.029
0028-3932/

Granot, 2006) and their behavioral responses to such images (Hedger et al., 2013). However, little is understood about the neural processing of movement representations in music at the conceptual level. Therefore, whether music is capable of conveying the concept of movement remains to be fully understood.

The current study aimed to investigate the aforementioned problem by testing the conceptual priming effects of music in picture processing. Similar to semantic priming paradigm, musical excerpts and pictures were used as primes and targets, respectively. The pictures depicted objects that were either in motion or at rest, and musical excerpts were semantically congruent or incongruent to the corresponding pictures. According to general theoretical accounts of priming, such as spreading activation (Collins and Loftus, 1975), a prime pre-activates the representations of conceptually related targets at the conceptual level by spreading the activation through the conceptual network and then proceeding to the facilitative encoding of targets that are congruent to the prime. However, the conceptual priming effects obtained in meaningful categorization task is suspected to also possibly reflect the conflict at the response stage of processes. Specifically, a prime may trigger a response tendency, and an observed priming effect may result from the facilitated responses to the congruent targets, the inhibitory responses to incongruent targets, or both. In this case, matching between the prime and target at the conceptual level may be confounded at the response level (e.g., Goerlich et al., 2012; Wentura, 1999, 2000). To distinguish automatic conceptual activation from response competition, conceptual priming effects were tested in both implicit recognition task and categorization task; to achieve this goal, participants were asked to memorize the stimuli for a subsequent recognition in addition to the object decision. Multiple regression analyses for the stimuli used in this study and Zhou et al. (2014) were carried out to reveal the acoustic and musical features underpinning the processing of iconic extra-musical concepts. In both tasks, target pictures incongruent to the preceding musical context were expected to induce a larger N400 than the congruent pictures. Furthermore, some acoustic and musical features with the ability to predict musical expression may be found.

2. Methods

2.1. Participants

A total of 20 healthy university students (mean age=22 years, *SD*=2 years; 8 males) served as paid volunteers. They were right-handed native speakers of Chinese, with normal hearing, normal or corrected-to-normal vision, and no past history of psychiatric or neuronal diseases. None of them had received any extracurricular training in music. All participants signed a written consent form before the experiment was conducted. Three participants were excluded: two due to excessive α-wave activity and one because of excessive drift artifacts. Therefore, data from 17 participants (mean age=22 years, *SD*=1.8 years; 7 males) were used in the final statistical analysis.

2.2. Stimuli

2.2.1. Stimuli construction

A total of 400 musical excerpts, all instrumental music without lyrics, were selected from commercially available CDs. All excerpts were Western tonal music composed during classical or romantic musical periods from around 1750–1900. The musical excepts were selected based on two criteria: the first criterion consisted of self-reports from the composers (e.g., the second movement "*Play of the Waves*" in Debussy's "*La mer*" was intended to express the motion of water), and the second criterion was the result of musicological analysis (e.g., Wagner's "*Siegfried Idyll*" sounds *peaceful*, and *peaceful* is semantically related to *stillness*). The excerpts were recorded from the beginning of the musical phrases using Adobe Audition CS6 software (Adobe Systems Incorporated, San Jose, CA, USA) with 44 kHz, 16-bit resolution, and the duration was 3 s. The loudness of all excerpts was normalized to 68 dB.

Three hundred and twenty images were selected as pictorial stimuli. All of them were real-world scene images (1024 × 768 pixels), including animate (e.g., bird, horse, dog) and inanimate (e.g., flag, train, car) objects without any visible words (see Hedger et al., 2013 for similar manipulations). Each image depicted an object either in motion or at rest. Both"'in motion" and"'at rest" images were static, i.e., no real motion appeared during stimulus presentations.

2.2.2. Stimuli pre-tests

To evaluate the expression of musical stimuli, a group of non-musicians (n=12, mean age=21 years, *SD*=2 years), who did not participate in the subsequent ERP experiment, were asked to rate each excerpt using a 9-point scale, ranging from −4 (obviously at rest) to +4 (obviously in motion), with 0 corresponding to the neutral expression of movement. They were also asked to decide whether the objects depicted by each picture were in motion or at rest by pressing one of two buttons.

To avoid the possible influence of emotional congruency, another group of subjects (n=10, mean age=22 years, *SD*=2 years) was recruited to evaluate the emotional valence (negative/positive) of all excerpts and pictures using a 9-point scale, ranging from −4 (very negative) to +4 (very positive), with 0 corresponding to the neutral emotion.

Table 1 shows the behavioral measurements for the final set of experimental stimuli. In terms of the rating data, 144 excerpts were selected as final prime stimuli for the subsequent experiment. These excerpts were selected from two extreme regions of the continuous distribution of "in motion"/"at rest" values and divided into two groups (72 excerpts per group). Only the excerpts with mean expressive rating value of higher than 1 or lower than −1 were included as experimental material. The mean rating consistency across subjects for selected excerpts in the "in motion" group was 94.44% (*SD*=8.03%), which meant that 94.44% of the subjects indicated a positive value to the excerpts. The mean rating consistency in the "at rest" group was 83.56% (*SD*=10.46%), which meant that 83.56% of the subjects indicated a negative value to the excerpts. An independent samples *t*-test was conducted for the two groups of excerpts. The result showed that the two groups were significantly different from each other in terms of expressions ($t_{(142)}$=65.7, p<.001), but were well-matched in emotional valence ($t_{(142)}$=0.33, p=.74).

According to the rating results, 144 pictures with high consistency (100% for each picture) in the "in motion"/"at rest" judgment were selected as final target stimuli in the subsequent experiment. Among these 72 pictures were in the "in motion"

Table 1
Summary of behavioral measurements of the experimental stimuli.

	Motion group (*SD*)	Rest group (*SD*)	*t*
Music stimuli			
Expression	3.04 (0.43)	−2.37 (0.55)	65.70***
Emotional valence	0.07 (0.83)	0.03 (0.50)	0.33
Picture stimuli			
Expression	1.00 (0.00)	0.00 (0.00)	
Emotional valence	1.43 (0.27)	1.32 (0.91)	0.58

Note: Means, standard deviations (SD) of the stimuli that were selected for the EEG experiment. The expression of pictures was rated by value of 1 or 0, and the other tests were rated by 9-point scales ranging from −4 to 4.

*** P < .001