

# Partial information transmission can be found in music attributes

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Previous studies have proved that partial information transmission can be found between intensity and pitch. In our last study, it was demonstrated that the timbre attribute can be transmitted as partial information between timbre and intensity. We manipulated the two attributes of stimulus, namely, timbre (piano vs. violin) and pitch (high vs. low), to find out whether they also have partial information transmission. We used the two-choice 'go/no-go' paradigm, which included more 'go' trials of timbre. Our result showed that lateralized readiness potentials were elicited in 'no-go' trials, which meant that the timbre attribute had been transmitted to the response preparation stage before the intensity attribute was processed in the stimuli identification stage. This result supports the asynchronous discrete coding model in information processing. Therefore,

we suggest that partial information transmission can be found in music attributes including timbre, intensity, and pitch. *NeuroReport* 25:190–193 © 2014 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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## Introduction

Partial information transmission exists in a large amount of stimuli information. In certain cases, some specific form of information can be transmitted to the next stage before other information has been processed [1].

In cognitive psychology, information processing normally consists of different stages, including sensory processing, stimulus identification, response selection, response preparation, and reaction execution [2].

There are three typical models on information transmission: the discrete stage model, the continuous model, and the asynchronous discrete coding (ADC) model. In the discrete stage model, the later information is processed after the former information finishes, which does not support partial information transmission [3]. In the continuous model, some results of information processing may attain access to the next stage before others do. In addition, their processing stages overlap in time dimensions. This model supports partial information transmission [4]. The ADC model considers that a stimulus consists of various attributes. An attribute can transmit to the next stage immediately after being processed in the present stage, while other information continues to be processed in the same stage. The ADC model is a translational model between the discrete stage model and the continuous one, which also supports partial information transmission [5].

To date, there are few studies on auditory channels as most focus only on the visual ones. In 2012, Gong *et al.* [6,7] found that partial information transmission also exists in the auditory channel through controlling timbre and intensity of tone.

In this study, we focused on pitch, which is a crucial music attribute. We manipulated pitch (high vs. low) and timbre (piano vs. violin) in a tone to study whether they had partial information transmission.

It is difficult to demonstrate the route of transmission through behavior results. However, we chose the lateralized readiness potential (LRP) as an important indicator, which is an electroencephalographic (EEG) component that can reflect lateralization preparation of movement. In the two-choice 'go/no-go' task paradigm, one attribute is transmitted to the next stage before the other attributes. If the partial information transmission phenomenon occurs, it can be perceived by LRP of 'no-go' trials [8].

## Materials and methods

### Participants

Twelve volunteers (two female, 10 male, average age 24 years) participated in this experiment. They were all right-handed with normal hearing, normal vision, and no history of neurological disorders. All of them provided written consent before the experiment was conducted according to the established guidelines of the review boards of the School of Life Science and Technology at University of Electronic Science and Technology of China.

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### Stimuli and apparatus

We used piano tones and violin tones at high and low pitch (1046 and 1025 Hz) generated by SONAR 6 Producer Edition (Cakewalk, Boston, Massachusetts, USA) as stimuli. All stimuli were rechecked by means of the PRAAT speech editing software (Paul Boersma and David Weenink, Amsterdam, the Netherlands). Tones of 375 ms in duration were binaurally presented using Sennheiser headphones (Sennheiser Electronic GmbH & Co. KG, Wennebostel, Germany).

### Design and procedure

We presented the stimulus materials in random order in eight blocks, each of which consisted of 120 trials. In each trial, participants were presented a stimulus tone: a high-pitch or low-pitch piano or violin. The timbre of the tone indicated which hand to use and the pitch of the tone dictated whether or not the response should be performed. The timbre-hand and the pitch 'go/no-go' assignments were counterbalanced across participants. For instance, 25% of the participants were guided to make a left-hand response to a high piano, a right-hand response to a high violin ('go' trials), and no response to a low piano or violin ('no-go' trials). The stimulus response assignments remained constant for each participant throughout the experimental session. Left-hand and right-hand reactions were equally balanced, whereas the likelihood for 'go' and 'no-go' trials was 67 and 33%, respectively.

The participants were asked to sit in a dim, quiet, and electrically shielded room, and were at a distance of ~1.1 m from the computer screen. Every trial began with a cross at the middle of the screen. Participants were asked to look at the cross throughout the trial. About 500 ms before every imperative stimulus, the cross would flash as a reminder of the upcoming critical tone, which then lasted for 375 ms. Participants were instructed to respond as quickly and accurately as possible in the 'go' trials by pressing a sequence of three keys (C, Z, and X keys on a standard keyboard for left-hand responses; the comma, slash, and period keys for right-hand responses) with the index, ring, and middle fingers. For 'no-go' trials, participants were asked to avoid any response.

Before the experiment, participants were first given a practice session, in which accuracy feedback was given immediately after each response or after a period of 2 s with no response. The feedback lasted for 1500 ms showing correct responses, errors, or very slow responses. There was no feedback in real tests. Stimulus presentation and recording of behavioral and electrophysiological responses were controlled by two compatible microcomputers (Lenovo, Beijing, China).

### Electroencephalographic recording and data analysis

#### Electroencephalography

EEG data were measured with an electrode cap of 64 Ag-AgCl electrodes connected according to the extended

10–20 system and digitized with a sampling rate of 500 Hz. The impedance for all electrodes was kept below 5 k $\Omega$  and all the data were bandpass-filtered (0.01–100 Hz) online (Brain Products GmbH, Starnberg, Germany). All channels were recorded with FCz as the reference. AFz served as ground electrode during recording. Participants were asked to stay still and prevent their eyes from blinking.

We conducted the offline EEG analysis with the computer software Brain Vision Analyzer version 2.0.1 (Brain Products GmbH). EEG data were bandpass-filtered (0.01–30 Hz) and corrected for horizontal and vertical ocular artifacts. Trials with eye artifacts were discarded. Finally, recordings were re-referenced to 'infinity' reference provided by the reference electrode standardization technique free-software offline (<http://www.neuro.uestc.edu.cn/rest/>) [9–12].

To calculate perceptual accuracy, one level of each stimulus dimension was arbitrarily defined as signal and the other as noise [13].

#### Lateralized readiness potential

LRP was calculated with difference between the electrodes contralateral and ipsilateral to the responding hand over the primary motor cortices, which are C3–C4 and C4–C3. They represented the right-hand and left-hand responses, respectively. The difference curves for the left-hand and right-hand responses were averaged separately to eliminate all activity that is symmetrically distributed over the primary motor cortices. The difference curves across left-hand and right-hand responses were averaged to eliminate all nonmotor asymmetries. To evaluate possible electrooculogram effect on the LRP, an identical computation to that for deriving the LRP was performed for the horizontal electrooculogram [14]. For controlling the peripheral activation for the LRP, a camera was used to monitor any tiny finger movement.

## Results

### Behavioral results

The percentage of different stimuli in each type of response is shown in Table 1. Timbre and pitch perceptual sensitivity for each participant and grand average are shown in Table 2.

**Table 1 Behavioral results**

Responses	Stimulus			
	Left go	Left no-go	Right go	Right no-go
Left go	82.7	11.6	3.1	2.9
Right go	8.1	7.2	80.2	6.8
No-go	9.2	81.2	16.7	90.3

The values show percentage of different stimuli in each type of responses.

**Table 2** Timbre and pitch perceptual sensitivity for each participant and grand average

Perceptual sensitivity	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Timbre	3.21	3.25	2.92	2.81	3.15	2.95	2.15	2.47	3.64	3.12	3.22	3.26	3.01
Pitch	3.10	2.56	2.48	2.51	2.75	2.64	1.76	2.13	3.12	2.86	2.95	2.14	2.58

### Event-related potential result

The LRP waveform (C3–C4) is shown in Fig. 1. The axes show voltage and time. The onset and initial growth of the waveforms were roughly similar regardless of whether the trial was a 'go' or 'no-go' trial. After a short time, the LRPs on 'no-go' trials deviated from this growth pattern and returned to the baseline.

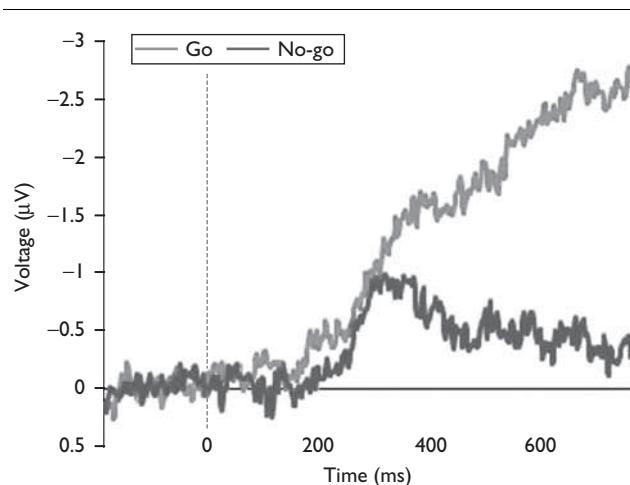
To prove that LRPs were induced by 'no-go' trials, we compared the mean amplitude in the fixed time window with the mean baseline for 200 ms. The LRP waveforms were evaluated in terms of the mean amplitude during the interval from 250 to 500 ms poststimulus [1]. The difference in the mean amplitude between 'go' trial LRPs and 'no-go' trial LRPs in a fixed window (250–500 ms) reached significance [ $t(11) = -2.95$ ,  $P$  (two-tailed) < 0.01]. To calculate the presence of LRPs (250–500 ms) in 'no-go' trials,  $t$ -tests were performed against the mean amplitude during the baseline interval [ $t(11) = -3.16$ ,  $P$  (two-tailed) < 0.01], and similarly in 'go' trials [ $t(11) = -5.18$ ,  $P$  (two-tailed) < 0.001]. Results showed significant difference between them, which was strong evidence to show that participants had response preparation. The difference between 'go' and 'no-go' trials suggested that the response preparation was not based on the whole information such as the two attributes, but on the partial information such as timbre of the stimulus [6,7].

### Discussion

Results showed that participants' mean perceptual sensitivity for timbre was 3.01 and for pitch was 2.58, which suggests that participants could detect timbre more easily than pitch. That is to say, timbre information can be transmitted to the next stage before pitch information is totally processed.

Timbre has been described as a multidimensional perceptual attribute of complex sounds. Timbre dimensions acoustically correspond to attack time, spectral centroid, and spectrum-fine structure [15]. Therefore, both timbre and pitch are related to spectrum and are interactive with each other.

As timbre and pitch are interactive, partial information transmission still occurs between them. We suggest that the interaction between the two attributes may happen at an early stage before 200 ms. Caclin *et al.* [15] found that the interaction of timbre dimensions happened at both early perceptual and late stimulus identification stages of processing. According to this result, partial information transmission may occur after the stimulus identification stage. Further study could focus on the

**Fig. 1**

Lateralized readiness potential on 'go' and 'no-go' trials. Lateralization of the motor readiness potential was obtained on 'no-go' trials, and the lateralization was similar in onset latency to 'go' trials. Each curve represents an average of roughly 7400 responses for 'go' trials or 3700 responses for 'no-go' trials.

exact time and stage when information is transmitted. This work is mainly based on the temporal information provided by behaviors and event-related potentials, whether the spatial information [16,17] or the spatial-temporal processes [18] can be introduced to further explore the details.

Our result supports the ADC model in information processing. Partial information transmission can be found in music attributes including timbre, intensity, and pitch.

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### Conflicts of interest

There are no conflicts of interest.

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