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The influence of explicit conceptual knowledge on perception of physical motions: An ERP study

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HIGHLIGHTS

- We classify subjects into two groups based on their explicit conceptual knowledge.
- We manipulate the physical plausibility of the target oddball event.
- Correct-concept group indicates larger P3 to incorrect oddball event.
- Wrong-concept group indicates larger P3 to correct oddball event.
- Explicit conceptual knowledge modulates the perception with a P3 indication.

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ABSTRACT

Event-related potential is used to study the influence of explicit conceptual knowledge on the perception of physical motions. Participants holding correct or wrong physics concept performed an oddball task with a pair of stimuli. For half of the blocks, the motion consistent with the physical law was the oddball stimulus and the motion inconsistent with the physical law was the standard stimulus and vice versa. The participants holding correct conceptual knowledge showed the larger parietal P3 to the incorrect target stimulus. By contrast, the participants holding wrong conceptual knowledge showed the larger parietal P3 to the correct target stimulus. The results suggest that explicit conceptual knowledge could affect the perception of physical motions. People tend to bias their perception toward the existing explicit knowledge. This study could be helpful for understanding the contribution of education to human perception.

1. Introduction

Abundant studies have shown that prior knowledge contributes to the perception of incoming stimulus [4,6,9–13,17,24–27]. The study of prior knowledge on perception could be helpful for understanding our particular way to perceive the world. Therefore, it has been paid many attentions in these years.

Nowadays, neuroimaging techniques provide an efficient way to examine the brain activities during the processing of information associated with prior knowledge [18,19,21,28]. Event-related potential (ERP) technique is one of the most frequently used methods to explore the underlying brain mechanism with a high temporal resolution. Using ERP technique, researchers examined the neurocognitive consequence of the correct or incorrect spatial prediction induced by spatial cues [7]. Gómez et al. found the increased P3a and P3b responses for the invalidly cued target [2,8]. Mangun et al. obtained the enhancement of the early P1 and the subsequent N1 by the validly cued stimuli [15]. Recently, Roser et al. investigated the effect of experience with object interactions on the perception of collision using ERP technique [22]. They found that the P3 component elicited by the oddball event was enhanced by physical implausibility. They suggested that scientific knowledge derived from prior experience can influence the maintenance of the mental model of the incoming stimulus. Their study mainly focused on the knowledge implicitly acquired through experiences.

However, many of our concepts are explicit knowledge learned through formal education. Especially, some explicit knowledge often contradicts our implicit knowledge. A famous example is the motion of a freely falling body as shown by Galileo in his experiments. Naturally, questions are raised: Does the explicit knowledge have the same impact on the processing of information as the implicit knowledge? How does the explicit knowledge affect the perception when it is in conflict with daily experiences?

The main purpose of this study is to investigate the effect of the explicit conceptual knowledge on the perception of relevant stimulus by ERP. In our experiment, participants holding correct

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or wrong physics knowledge performed an oddball task using a pair of physical motions as stimuli: for half of the blocks, physically incorrect and correct motions were the target and standard stimuli, respectively, and vice versa for the other half of the blocks. We hypothesized that the explicitly knowledge had the similar impact on the information processing as the implicit knowledge, and this impact can be indicated by P3 component. Furthermore, participants with different conceptual knowledge would display an opposite P3 enhancement effect, which could be a potential indication of concept understanding.

2. Methods

2.1. Participants

Twenty-three students (12 females, 11 males; mean age 22.3 years, SD = 1.6 years) took part in the experiment. All participants had normal or corrected-to-normal vision. All participants had no history of neurological disease and were free of medication for more than one week before the experiment. Each participant signed the informed consents before the experiment, which was in accordance with the ethical principles of the Declaration of Helsinki.

2.2. Stimuli

Stimuli were the animations demonstrating the curvilinear motion of a ball. A white fixation cross subtending 0.4° visual angle was firstly presented at the center of the screen for a randomized interval of 400–550 ms. Then an L-shaped glass channel was presented, as shown in Fig. 1. A small ball fell into the channel with high speed. After 1590 ms, the ball reached the exit and shot out of the channel.

This kind of motion does not often appear in daily life. People tend to predict that the ball would keep a curved path after leaving the channel. The wrong prediction was coming from daily experience with moving objects in specific situations [14,16]. Actually, the ball will shoot out along a straight path according to Newtonian mechanics. The correct and incorrect motions of the ball were both presented to the participants. The motions of the ball inside of the channel were identical for both stimuli. The stimuli were removed from the screen 1053 ms after the ball shoot out the channel. Stimuli were programmed and presented using Presentation software (Version 14.6 Neurobehavioral System Inc.).

2.3. Procedure

Before the EEG recording, participants took a simple test to identify their conceptual knowledge. In this test, each participant was asked which motion of the ball is correct in his or her mind. Without any feedback to their answers, the EEG session started.

Participants sat about 75 cm before the screen. Stimuli, subtending a visual angle of 3.8° × 4.8°, were presented in a two-stimulus oddball paradigm with a balanced design. The experiment was run in 16 blocks of 30 trials. For half of the blocks (incorrect-oddball condition), the target oddball event was the incorrect motion, and the standard event was the correct motion. For the other half of the blocks (correct-oddball condition), these arrangements were reversed so that the oddball was the correct motion but the standard was the incorrect motion. For each block, the probabilities of the oddball and standard events were 0.15 and 0.85, respectively. The target conditions were randomized across blocks.

Participants were required to pay attention to the track of the ball, and silently count the number of the target stimuli for each block. After the EEG recording session, the participants were asked again about the correct motion in their mind to examine whether they kept their initial beliefs during the whole experiment. Participants giving the opposite answers in the tests before and after recording will be excluded from further analysis.

2.4. EEG recording and analysis

EEG activity was recorded from 64 tin electrodes mounted on an elastic cap (NeuroScan Inc., Herndon, VA, USA) with the reference on the left mastoid. The electro-oculogram (EOG) was recorded from two electrodes on the canthi and two electrodes located above and below the right eye. All electrode impedances were maintained below 10 kΩ. The signals of EEG and EOG were amplified with a band pass of 0.05–70 Hz, and continuously sampled at 1000 Hz for offline analysis.

After preliminary analysis of the recorded data, we excluded the data recorded from three participants from further analysis. Among them, two participants reported that they realized that their initial conceptual knowledge were wrong and changed their beliefs during the EEG recording. The EGG data of another subject contains too many ocular artifacts to obtain enough trails for averaging. The remaining twenty participants were classified into two groups according to their conceptual knowledge. The correct-concept group involved twelve participants, who held the correct concept of the motion. The wrong-concept group involved the other eight participants, who held the wrong concept.

Since the discrimination of the presentation and perception occurred after the ball shot out of the channel, separate EEG epochs corresponding to this duration were extracted off-line (with 200 ms pre-stimulus baseline). Epochs were re-referenced to the linked mastoid electrodes. Ocular artifacts were corrected with an eye-movement correction algorithm [23]. Those trials in which EEG voltages exceeded a threshold of $\pm 90\,\mu$V were excluded from further analysis. The EEG data were low-pass filtered with a cut-off frequency 30 Hz. For the oddball and standard stimuli, about 30 trials and 180 trials were used for averaging, respectively.

3. Results

Grand average ERP waveforms are shown in Fig. 2 (a). The P3 component can be visually observed. Its peak appears at around 575 ms after the ball shot out of the channel for both oddball and standard events.

We also analyzed the scalp topographic maps of the difference wave (oddball minus standard) at different latencies. Fig. 2 (b) illustrates the typical topographic maps in latency range of 480–550 ms (the first row) and 550–620 ms (the second row), respectively. The maximum amplitudes of difference waves always appear over the central/parietal areas, but not over the frontal/central areas even in early latency. This result suggested that only the P3b (parietal P3) was evoked in the experiment. It is also observed that the P3 amplitude depended on the conceptual knowledge of the participants. For the correct-concept group, the P3 amplitude of the incorrect oddball is relatively larger than that of the correct oddball. By contrast, for the wrong-concept group, the P3 component of the correct oddball is relatively large. To examine the statistical significance, analysis of variance (ANOVA) was conducted on the mean amplitudes of P3 during 500–650 ms [Gray window in Fig. 2 (a)]. In our statistical analysis, group (correct vs. wrong concept group) was the between-subject factor. Stimulus probability (standard vs. oddball), stimulus plausibility (correct vs. incorrect motion) and electrodes site (Cz and Pz) were the within-subject factors.

Statistical results yielded a significant main effect of stimulus probability [$F(1,18) = 82.17$, $P < 0.001$], with P3 response being more positive for oddball events relative to the standard events.