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The effect of late posterior negativity in retrieving the color of Chinese characters

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HIGHLIGHTS

- Associative color source retrieval elicited a reliable LPN in Chinese characters.
- The organizational color source retrieval task also observed a robust LPN effect.
- The spatial distribution of LPN is wider in retrieving the organizational source.
- The distribution of LPN is insensitive to both the stimulus and the source.

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ABSTRACT

Previous event-related potentials (ERPs) research has suggested that the retrieval tasks for many sources of items were operated in the frontal regions, but Cycowicz et al. [2–4,6] recorded the late posterior negativity (LPN), a component over the posterior cortex, in retrieving the associative color sources of pictures. To examine whether the LPN could also be observed in retrieving both the associative and the organizational color sources of verbal stimuli, two experiments were designed by using Chinese nouns as stimuli. Both experiments revealed significant LPN that was related to the tasks of color source retrieval. These findings demonstrate that the association between LPN and search for and/or retrieval/evaluation of the colors of objects is fairly strong, and this association is insensitive to both the attributes of stimulus materials and those of the color sources.

1. Introduction

Previous research investigating the mechanisms of episodic memory has provided evidence for two aspects of this cognitive process: one is to identify the stimulus as familiar, which is referred to as the recognition task and has also been called item memory; and the other is to retrieve details of the encoding context within which an event has been embedded, and is referred to as source memory [11,18]. On the basis of the dual-process model, the item memory is mainly associated with familiarity, a relatively automatic process; and the source memory is mainly associated with recollection, a process requiring effortful and conscious deliberation [7]. The differentiation between these two types of memory is reinforced by ERP studies, implicating that compared with the simple old/new item judgment tasks, the source memory, i.e., the retrieval of the voice gender, the list membership and the object location, requires the engagement of prefrontal and/or frontal cortices, and such scalp activations are irrespective of whether the stimuli are words or pictures [13,15–17,19–21]. These studies consistently showed that the items whose sources were correctly attributed elicited more positive waveforms than those of the correctly rejected lures over these anterior scalp regions.

Conversely, Cycowicz et al. recorded a different ERP component while focusing on the retrieval of the colors that previously outlined the pictures [2–4,6]. In one of their studies, the exclusion paradigm developed by Jacoby [7] was adopted: object pictures were randomly presented in two different colors during the encoding phase, and the item memory and source memory tests were conducted subsequently. The item memory task required the subjects to differentiate the old from the novel pictures. For the source memory task, subjects were required to press one button if they thought a picture was associated with a certain color (either red or green) during the study phase, which was hereafter labeled as target; and press a second button for pictures previously displayed in the alternate color and for novel pictures, hereafter designated as nontarget-old and nontarget-new, respectively. This investigation

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observed a late old/new effect maximal over parieto-occipital scalp during the color source retrieval phase, showing that the amplitudes elicited by the target were more negative than those of the nontarget-new [4]. Such distribution, however, was absent when the simple old/new judgment was made.

This parieto-occipital scalp distributed negative old/new effect is hereafter labeled as late posterior negativity, LPN [9], in the source memory, such negative deflection is obtained by subtracting the ERPs of the items whose source is correctly retrieved from those of the correctly discriminated totally new items. Follow-up research from Cycowicz et al. further demonstrated that the association between the LPN component and retrieving the color source was not regulated by both the experimental paradigm and color swap from study to test phases [2,3,6]. Therefore, Cycowicz et al. claimed that LPN might reflect the search for and/or retrieval/evaluation of the source-specifying information, i.e., color, in the cortical regions that initially processed the stimuli.

Nevertheless, two potential problems could arise with respect to the studies of Cycowicz et al.'s [2–4,6]. First, to our knowledge, their results have not yet been observed in verbal stimuli. Hence, it is unclear whether the LPN is specific to the nature of the color source or to the binding between color and pictures. Second, the colors that they manipulated were served as the associative source that could be bound to items relatively automatically. This makes it impossible to know whether the observed LPN is merely related to the retrieval of the associative color source or could also be driven by the retrieving of other colors that cannot be automatically integrated with items, i.e., organizational source (see Moscovitch [12], for the distinction between associative and organizational sources).

To elucidate these problems, two experiments using the exclusion paradigm, as Cycowicz et al. [2–4,6] did, were designed. The first experiment (Experiment 1) used Chinese concrete nouns as stimuli and color served as the associative source. The major purpose of this experiment was to discriminate the influence of the color source from that of the stimuli on LPN. If words worked like pictures and the attribute of stimulus materials was not a critical factor that determined the presence of LPN, it was expected that, similar to the findings reported by Cycowicz et al., Experiment 1 would observe reliable LPN in the task of color source retrieval. The manipulation of the second experiment (Experiment 2) was similar to that of Experiment 1, except that color was served as an organizational source but not the associative source (see Section 2.3 for details). If the presence of the LPN effect would not be regulated by the conditions of whether the colors could be automatically bound to items or not, Experiment 2 would also find a negative-going old/new effect in retrieving the color source.

2. Methods

2.1. Subjects

Thirty-three right-handed adults (15 males, age averaged 23.7 ± 4.9 years) were recruited for the present study with 16 (7 males) for Experiment 1 and 17 (8 males) for Experiment 2. Their eyesight or corrected eyesight was above 20/40 and with no color blindness. All subjects were native Chinese speakers, and reported no major neurological and psychiatric problems.

2.2. Stimuli

Both the present two experiments used the same stimuli. They were 400 low-frequency Chinese two-word concrete nouns, and were carefully constructed into 8 blocks of 50 each to ensure that these blocks were equated on frequency, stroke, spelling and pronunciation of words [10]. An additional 82 nouns with the same criterion, not analyzed later, were used for practice or served as fillers. Each block had one study task and two tests (item memory and source memory). In each block, there were 30 nouns for the study task (with 2 fillers at the beginning and 2 others at the end of the block to avoid the primacy and recency effects), one half of the nouns were associated with red and the other half were associated with green. The nouns for the item memory test were 10 old (5 previously associated with red and 5 with green) and 10 new, while the remaining 20 old nouns with 10 additional novel nouns were for the source memory test.

2.3. Procedure

In Experiment 1, half of the nouns were presented in red and the other half were in green during the study stage, and subjects were instructed to memorize each noun and its associated color for subsequent tests. During the item memory stage, all nouns were presented in white, and the task was to discriminate the old from the new nouns. The nouns for source memory were also displayed in white, and the task was to distinguish the target from the nontarget-old and the nontarget-new nouns: targets were the ones previously associated either with red or green based upon the task definition, and nontargets were those previously associated with alternate color and the novel nouns. In Experiment 2, all nouns were presented in white and with one half surrounded by a red rectangular frame and the other half surrounded by a green rectangular frame during the study stage, while the other manipulations (i.e., stimuli, block arrangement, and task assignments) were equivalent to Experiment 1. The schematic procedure for both experiments is illustrated in Fig. 1.

In both experiments, all nouns were presented in the center of a black background at a viewing distance of 60 cm, each noun subtended with a visual angle of $6.82^\circ \times 3.40^\circ$, and the angle of the colored rectangular frame was $8.5^\circ \times 4.8^\circ$ in Experiment 2. All nouns were displayed in the Font of SimSun and none of them were represented across blocks. Each noun was presented for 500 ms followed by an inter-stimulus interval of 1300 ± 200 ms during the study stage and 1800 ± 200 ms during the test phases, a white fixation cross of $0.19^\circ \times 0.19^\circ$ was shown in each interval. The trial presentation within each block was pseudo-randomized for all subjects, and the sequences of the tests and the assignment of the response fingers were counterbalanced among blocks.

2.4. Electrophysiological data recording

The electroencephalogram was recorded continuously with SynAmp amplifers from 32 Ag/AgCl electrodes extended from the 10/20 system [8]. The vertical EOG was recorded from electrodes placed on the supra- and infra-orbital ridges of the left eye, and the horizontal EOG was recorded from electrodes placed at the external canthi of both eyes. The right mastoid served as the reference electrode online, and scalp recordings were algebraically re-referenced offline to the average of both mastoids. All signals were amplified with a gain of 500 and were digitized at a sampling rate of 500 Hz per channel, and were filtered with a band-pass of 0.05–40 Hz. The impedance was kept below 5 kΩ.

2.5. EEG data analyses

Trials were epoched offline with 100 ms pre- and 1500 ms post-stimulus periods, and the baseline for ERP measures was the mean voltage of the 100 ms pre-stimulus interval. The waveforms were averaged for the correctly judged old and new nouns for item memory, and correctly discriminated target, nontarget-old and nontarget-new separately for source memory. Eye artifact correction was accomplished using a semi-automatic procedure before