Behavioural Brain Research 290 (2015) 143–151

Contents lists available at ScienceDirect

Behavioural Brain Research

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

Research report

The sensory timecourses associated with conscious visual item memory and source memory

Preston P. Thakral[a,*], Scott D. Slotnick[b]

[a] Center for Vital Longevity and School of Behavioral and Brain Sciences, University of Texas at Dallas, Dallas, TX 75235, United States
[b] Department of Psychology, Boston College, United States

HIGHLIGHTS

- The timecourse of conscious and nonconscious visual sensory memory effects.
- Visual sensory source memory and item memory effects are temporally distinct.
- The rapid onset of visual sensory item memory effects.

ARTICLE INFO

Article history:
Received 15 December 2014
Received in revised form 25 March 2015
Accepted 27 April 2015
Available online 5 May 2015

Keywords:
Explicit memory
Implicit memory
ERPs
fMRI
Occipital
Temporal

ABSTRACT

Previous event-related potential (ERP) findings have suggested that during visual item and source memory, nonconscious and conscious sensory (occipital–temporal) activity onsets may be restricted to early (0–800 ms) and late (800–1600 ms) temporal epochs, respectively. In an ERP experiment, we tested this hypothesis by separately assessing whether the onset of conscious sensory activity was restricted to the late epoch during source (location) memory and item (shape) memory. We found that conscious sensory activity had a late (>800 ms) onset during source memory and an early (<200 ms) onset during item memory. In a follow-up fMRI experiment, conscious sensory activity was localized to BA17, BA18, and BA19. Of primary importance, the distinct source memory and item memory ERP onsets contradict the hypothesis that there is a fixed temporal boundary separating nonconscious and conscious processing during all forms of visual conscious retrieval.

1. Introduction

Memory can be based on explicit (conscious) processing or implicit (nonconscious) processing. Conscious retrieval and nonconscious retrieval are typically investigated using direct or indirect tasks, respectively. During direct tasks, such as old-new recognition, participants respond based on conscious memorial experience. By comparison, during indirect tasks, participants respond based on a non-memorial feature, such as item pleasantness, but behavioral or neural memory effects can still be measured. For instance, repetition priming is reflected by a change in the magnitude of neural activity for repeated versus novel items. Despite the widespread assumptions that direct memory tasks tap into conscious processing and indirect tasks tap into nonconscious processing, it has long been known that both types of tasks can reflect nonconscious and conscious processing (i.e., performance on memory tasks is not process-pure; [1–3]). However, previous studies have successfully isolated conscious and nonconscious memorial processing using a single direct memory task by using the appropriate comparisons [4–11, for a review, see 12]. For instance, it is common to compare memory judgments associated with high retrieval content (e.g., retrieval success, remembering, or true recognition) with memory judgments associated with low retrieval content (e.g., retrieval attempt, knowing, and false recognition) to isolate conscious memory processes. In contrast, memory judgments with no conscious retrieval (e.g., inaccurate memory judgments) have been used to isolate nonconscious memory.

Previous event-related potential (ERP) results have suggested that nonconscious memory activity in visual sensory regions occurs relatively early in time, within 800 ms after stimulus onset [7,13–15, see also, 16], while conscious memory activity in visual sensory regions occurs relatively late in time, within 800 to 1600 ms after stimulus onset [7]. For example, visual object priming effects, which can be assumed to reflect nonconscious memory processing, have been shown to occur before 800 ms [15]. In contrast,

* Corresponding author. Tel.: +1 972 883 3737; fax: +1 972 883 3250.
E-mail address: preston6667@gmail.com (P.P. Thakral).

http://dx.doi.org/10.1016/j.bbr.2015.04.045
0166-4328/

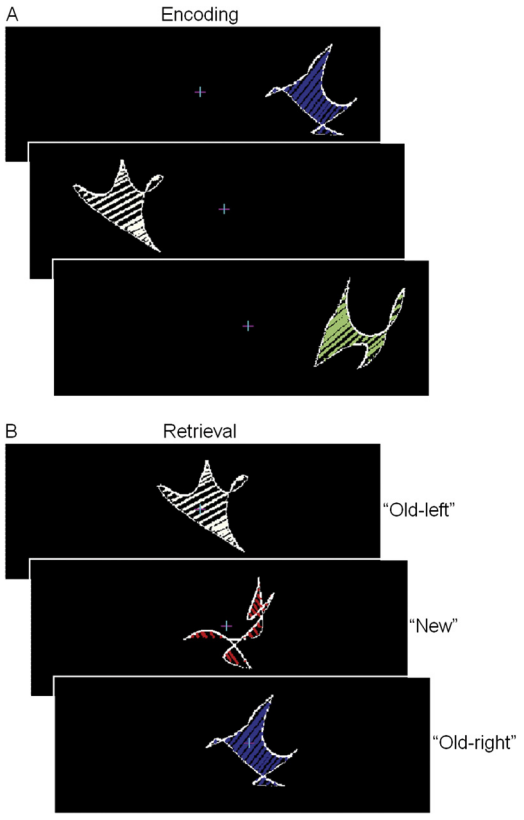

Fig. 1. Stimuli and task. (A) At encoding, abstract shapes were presented to the left and right of fixation. (B) At retrieval, old and new shapes were presented at fixation and participants classified each shape as old and previously on the left, "old-left", old and previously on the right, "old-right", or "new" (correct responses are shown to the right).

conscious sensory activity for accurate retrieval has been shown to occur after 800 ms [7]. It should be noted that the latter conscious memory effects that were associated with visual sensory reactivation in occipital–temporal regions are spatially distinct from the conscious memory effects that have been associated with the processes of familiarity and recollection in frontal regions (within 300–500 ms) and parietal regions (within 500–800 ms), respectively (for a review, see [17]).

Of particular relevance to the present investigation, Slotnick and Schacter [7] used ERPs to measure the time at which conscious and nonconscious activity occurred in visual sensory occipital–temporal regions-of-interest (ROIs) during a direct memory task. In that study, as in the present study, abstract shapes were presented to the left or right of fixation during encoding (Fig. 1A). During retrieval, previously presented (old) shapes and new shapes were shown at fixation and, for each shape, participants made a combined item memory and source memory judgment (old and previously on the left, "old-left", old and previously on the right, "old-right", or "new"; Fig. 1B).

Conscious memory activity was isolated by taking the difference in activity between accurate item memory and source memory (old item memory-hits and source memory-hits, referred to as old-hit-hits) and completely forgotten items (inaccurate item memory and source memory, old-miss-misses), given that these events track memorial experience ("old" versus "new") with item type (old items) held constant [6,18]. Nonconscious memory activity was isolated by taking the difference in activity between inaccurate item memory and source memory and correctly rejected new items (old-miss-misses – new-correct rejections), given that these events differ as a function of item type (old versus new) with memorial experience (reflected by "new" responses) held constant [4–6,10, see also, 19]. Slotnick and Schacter [7] reported that the onset of nonconscious memory activity occurred in the early (0–800 ms) epoch, while the onset of conscious memory activity occurred in the late (800–1600 ms) epoch.

As the previous study collapsed across both conscious (i.e., accurate) item and source memory (old-hit-hits > old-miss-misses), it is possible that the previously described temporal dissociation in visual sensory regions exists during all forms of conscious retrieval (i.e., item memory and source memory), which predicts that there is a fixed temporal boundary (at 800 ms) between the onset of nonconscious processing and the onset of conscious processing. Alternatively, such a temporal dissociation may only exist during certain types of conscious retrieval, which predicts the onsets of nonconscious and conscious processing will not be restricted to particular epochs. In the first experiment of the present study, we used ERPs to distinguish between these hypotheses by separately measuring the onset of conscious sensory activity during source memory and item memory, two forms of conscious retrieval. Conscious source memory was isolated by taking the difference in activity between old-hit-hits and old-hit-misses. Conscious item memory was isolated by taking the difference in activity between old-hit-misses and old-miss-misses. As source memory and item memory performance can be assumed to be based on both conscious processing and nonconscious processing, we also isolated and subtracted out nonconscious processing for each type of memory. A follow-up fMRI experiment that employed the same paradigm was also conducted. To anticipate the present ERP results, the onset of conscious processing differed during source memory and item memory, which indicates there is no fixed temporal boundary separating nonconscious and conscious processing during all forms of conscious retrieval in visual sensory regions.

2. Experiment 1

2.1. Materials and methods

2.1.1. ERP participants

Twelve right-handed participants (5 females, aged 18.9–21.8) with normal or corrected-to-normal vision completed the experiment. The protocol was approved by the Boston College Institutional Review Board, and informed consent was obtained from each participant. Although the current experiments utilize datasets analyzed by Slotnick [21] and Slotnick and Schacter [6,7], the results presented in the current manuscript have not been reported previously.

2.1.2. ERP stimuli and task

In each of 6 runs at encoding, 32 abstract shapes filled with colored oriented lines [6] were each presented for 2.5 s followed by a 0.5 s fixation period (Fig. 1A). Each shape spanned 5.5° of visual angle with the nearest edge 3° of visual angle to the left or right of fixation. Participants were instructed to maintain fixation and encode each shape and its spatial location. During retrieval, the 32 old shapes from encoding and 16 new shapes were randomized and presented at fixation for 4 s followed by a 2 s fixation period (Fig. 1B). The time delay between encoding and retrieval was 10 s, which included an 8 s instruction screen followed by a 2 s fixation screen. Participants classified each shape as old and previously on the left, "old-left", old and previously on the right, "old-right", or "new". Item types (old-left, old-right, and new) were counterbalanced using a Latin square design. Participants responded via a button box in their left hand. During encoding and retrieval, no more than 3 shapes of a given type were repeated.