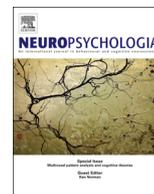




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The cortical basis of true memory and false memory for motion



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ABSTRACT

Behavioral evidence indicates that false memory, like true memory, can be rich in sensory detail. By contrast, there is fMRI evidence that true memory for visual information produces greater activity in earlier visual regions than false memory, which suggests true memory is associated with greater sensory detail. However, false memory in previous fMRI paradigms may have lacked sufficient sensory detail to recruit earlier visual processing regions. To investigate this possibility in the present fMRI study, we employed a paradigm that produced feature-specific false memory with a high degree of visual detail. During the encoding phase, moving or stationary abstract shapes were presented to the left or right of fixation. During the retrieval phase, shapes from encoding were presented at fixation and participants classified each item as previously “moving” or “stationary” within each visual field. Consistent with previous fMRI findings, true memory but not false memory for motion activated motion processing region MT+, while both true memory and false memory activated later cortical processing regions. In addition, false memory but not true memory for motion activated language processing regions. The present findings indicate that true memory activates earlier visual regions to a greater degree than false memory, even under conditions of detailed retrieval. Thus, the dissociation between previous behavioral findings and fMRI findings do not appear to be task dependent. Future work will be needed to assess whether the same pattern of true memory and false memory activity is observed for different sensory modalities.

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1. Introduction

False memory can be rich in sensory detail under certain task conditions (Lampinen, Neuschatz, & Payne, 1998; Payne, Neuschatz, Lampinen, & Lynn, 1997; Porter, Yuille, & Lehman, 1999; Roediger & McDermott, 1995). For instance, Roediger and McDermott (1995) implemented a behavioral paradigm adapted from Deese (1959) in which participants heard lists of words (e.g., table, sit, legs, etc.) that were each related to a single critical nonpresented word (e.g., chair). The critical words were falsely recalled with high confidence, and “remember” judgment rates were not significantly different for true recognition of studied words and false recognition of critical nonpresented words.

By contrast, there is fMRI evidence that suggests true memories are associated with a greater degree of sensory detail as compared to false memories, as true memories have been associated with greater sensory cortical activity than false memories. In an fMRI study of memory for abstract shapes (Slotnick & Schacter, 2004), true memory activated earlier visual processing regions (BA 17, BA 18) to a greater degree than false memory, while both true

memory and false memory activated later visual processing regions (BA 19, BA 37) to a similar degree. In a more recent fMRI study (Stark, Okado, & Loftus, 2010), participants were presented with visual vignettes and, the following day, heard conflicting auditory misinformation (participants were under the impression that the auditory information was truthful). During the retrieval phase, participants were asked whether sentences accurately or inaccurately described previously presented vignettes. Consistent with previous findings (Slotnick & Schacter, 2004; see also, Garoff-Eaton, Slotnick, & Schacter, 2006), true memory produced greater activity in earlier visual processing regions (BA 17, BA 18) than false memory, while false memory for auditory misinformation produced activity in auditory/language processing regions (BA 22, BA 42). These fMRI results suggest true memory and false memory are distinct in that true memory produced greater activity than false memory in earlier visual processing regions, while true memory and false memory activated later processing regions to a similar degree.

The aim of the present study was to address the apparent discontinuity between previous behavioral results that suggest true memory and false memory can be associated with similar levels of subjective sensory detail and the fMRI results that suggest true memory is associated with a greater degree of sensory detail than false memory. Specifically, previous fMRI paradigms may

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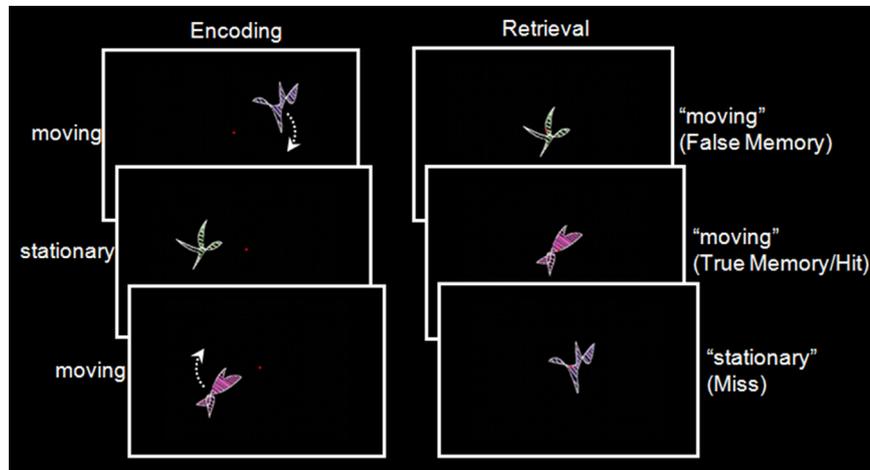


Fig. 1. Stimulus paradigm and relevant event types. During encoding, moving and stationary shapes were presented to the left or right of fixation. During retrieval, shapes from encoding were presented at fixation and participants classified items as previously “moving” or “stationary” within the “left” or “right” visual field.

have produced false memory for modality-specific (e.g., visual) information without sufficient sensory detail to activate earlier visual processing regions (see Slotnick, 2004). To investigate this possibility, in the present fMRI study we employed a paradigm to produce false memory for feature-specific (motion) information with a higher degree of visual detail than in previous fMRI studies (although these false memories may not be as detailed as true memories, which is addressed below). During the encoding phase, participants were presented with moving or stationary abstract shapes to the left or right of fixation (Fig. 1, left). During the retrieval phase, shapes from encoding were presented at fixation and participants classified each item as previously “moving” or “stationary” within the “left” or “right” visual field (Fig. 1, right). True memory corresponded to a “moving” response to a previously moving item, whereas false memory corresponded to a “moving” response to a previously stationary item.

Of importance, MT+ is the primary region involved in motion perception and memory for motion (Slotnick & Thakral, 2011), and thus can be assumed to mediate earlier visual processing in the present investigation. The pattern of true memory activity and false memory activity in MT+ and later cortical processing regions will be used to evaluate two hypotheses. If true memory and false memory for motion activate MT+ to a similar degree, this would support the hypothesis that false memories in previous fMRI studies did not have sufficient detail to activate earlier visual regions (i.e., the effects are task dependent). However, if true memory for motion still produces a greater magnitude of activity in MT+ than false memory for motion (with both true memory and false memory for motion producing activity in more anterior cortical regions), this would suggest false memory does not depend on earlier sensory cortical regions (i.e., there is a dissociation between behavioral and neural effects).

2. Materials and methods

2.1. Participants

Twelve students at Boston College participated in the study (9 females, age range 19–28 years). Participants were right-handed, native English speakers, and had normal or corrected-to-normal vision. Participants were compensated \$10 for the behavioral training session and \$25/hour (approximately \$100) for fMRI. The Boston College Institutional Review Board approved the behavioral protocol and the Massachusetts General Hospital Institutional Review Board approved the fMRI protocol. Informed and written consent was obtained before each session began.

2.2. Stimuli and paradigm

Participants completed a behavioral training session, which included a one-quarter length run and two full-length runs, and six runs during fMRI. They were instructed to always maintain fixation and to remember whether each shape was moving or stationary and its spatial location (i.e., the left or right visual field). During the encoding phase of each run, 24 abstract shapes spanning 4° of visual angle were presented in the left or right visual field along an arc spanning $\pm 45^\circ$ of polar angle from the horizontal meridian with the nearest edge 2° of visual angle from fixation. The shapes were designed to minimize verbal encoding strategies (for details on shape construction, see Slotnick & Schacter, 2004). Each shape was presented for 2.5 s with an inter-trial-interval of 3.0 s. Shape sets were repeated three times during encoding with each shape set randomized and presented sequentially. An equal number of shapes were stationary, at one of six equally spaced locations along the stimulation arc within each hemifield, or moving, smoothly traversing the entire stimulation arc in each hemifield with either upward or downward motion. In each run, all spatial locations and movement directions were presented equally often. Immediately before the retrieval phase, an instruction screen was presented for 8 s that reminded participants to maintain fixation and displayed the previously learned response mappings. During the retrieval phase of each run, the 24 shapes from encoding were presented in random order at fixation for 3.5 s with an inter-trial-interval of 7–10 s. Participants pressed response buttons with the fingers of their left hand to classify each shape as “previously in motion in the right visual field”, “previously in motion in the left visual field”, “previously stationary in the right visual field”, or “previously stationary in the left visual field”. Participants also made a subsequent “remember”–“know” response to characterize their subjective experience, but these responses were collapsed in the fMRI analysis to maximize power. During both encoding and retrieval, no more than three shapes of a given type were presented sequentially. Shapes were never repeated across runs. Sets of shapes (moving-right, moving-left, stationary-right, and stationary-left) were counterbalanced across participants using a Latin Square design.

2.3. Data acquisition and analysis

A Siemens 3 T Trio Scanner (Erlangen, Germany) with a standard head coil was used to acquire data. To acquire functional images, an echo planar imaging sequence was used (TR=2000 ms, TE=20 ms, flip angle=90°, field-of-view=256 × 256 mm², acquisition matrix=64 × 64, slices=33, slice thickness=4 mm, 4 mm isotropic resolution). To acquire anatomic images, a magnetized prepared rapid gradient echo sequence was used (TR=30 ms, TE=3.3 ms, flip angle=40°, field-of-view=256 × 256 mm², acquisition matrix=256 × 256, slices=128, slice thickness=1.33 mm, 1.33 × 1 × 1 mm resolution). Analysis was conducted using Brain Voyager QX (Brain Innovation B.V., Maastricht, The Netherlands). Pre-processing included slice-time correction, motion correction, and temporal filtering by removal of linear trends and components at or below 2 cycles per run length (using a general linear model to remove low frequency Fourier basis sets). To maximize spatial resolution, spatial smoothing was not conducted. Functional and anatomic images were transformed into Talairach space.

A random-effect general linear model was conducted. To produce each hemodynamic response model, a canonical hemodynamic response function was convolved with the protocol of each event for each participant (i.e., a square wave defined by each event onset and the subsequent behavioral response). It was

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