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Cognitive Neuroscience
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Differences in Brain Activity During Retrieval Of True vs. False Memories

Introduction

One of the most profound aspects of human memory is that it is malleable in nature. This means that one's memories are subject to change over time due to a multitude of factors such as subsequent misinformation, imaginative inflation, context, and biases (Schacter, Guerin, & Jacques, 2011). Researchers suggest that this characteristic of human memory makes individuals susceptible to experiencing false memories, wherein one remembers details of events or even entire events that did not occur (Laney & Loftus, 2013). Following foundational evidence for the existence of false memories, researchers argue that false memories can be experimentally implanted into individuals. This effect is perhaps most famously evidenced in the "Lost In the Mall" experiment, wherein researchers successfully "implanted" the memory of getting lost in a mall as children in several individuals who, in actuality, had never been lost in a mall (Loftus & Pickrell, 1995). Not only does this phenomenon have the potential to impact the emotions of individuals who experience false memories, but it has major implications for consequence in societal, cultural, and political realms. In particular, eyewitness testimony, which serves as the crux for many legal decisions, relies immensely on the accuracy of human memory. Thus, evidence for the unreliability of human memory suggests a major flaw inherent in widespread legal procedure; witness testimonies can be easily swayed by leading questions that distort memories or implant false memories.

Importantly, significant advances have been made in understanding potential underlying neural circuitry involved in false memories. Researchers suggest that the medial temporal lobes (MTL), particularly the hippocampus, parahippocampal cortex, and perirhinal cortex, are critical for memory recollection (Eichenbaum, Yonelinas, & Ranganath, 2007), and that activity of cortico-temporal connectivity correlates with memory retrieval (Polyn, 2005). Furthermore, evidence suggests that neural activity in the MTL differs between true and false memories during encoding (Okado, 2005) and that brain activity differs during the retrieval of studied words versus nonstudied words (Fabiani, Stadler, & Wessels, 2000; Roediger & Mcdermott, 1994). Notably, the literature provides substantial evidence concerning the encoding of false memories, but lacks research on the underlying neural bases of true and false memory retrieval.

In the present study, we examine the differences in both levels and areas of brain activity during recollection of true and false memories in order to attempt to fill this gap in the literature. Previous literature incites the hypothesis that increased activity in the MTL will be associated with the recollection of true memories, while this effect is not observed during recollection of false memories.

Methods

The participants in this study were 40 participants (20 males; 20 females) between the ages of 18 and 36 from the neighboring metropolitan university, and primary exclusion criteria consisted of personal or close familial history of psychiatric disorders. For the experiment, all participants underwent a virtual reality (VR) simulation depicting the visual field as one walks through a city. Participants were asked to complete a navigation task by traveling from point A to point B based on a map of the city (included in the simulation; see **Figure 1**). Participants were asked to complete this task with speed while maintaining as much accuracy (fewest number of wrong turns) as possible. Two days after completing the navigation task, participants answered a series of questions while under fMRI scanning. Each question was in the format of a statement which the participant denoted as “TRUE” or “FALSE”; participants were also asked to rate their level of confidence in each answer on a scale of 1 to 4 (1 = “I am not confident in this answer”; 4 = “I am fully confident in this answer”). Each question was intended to test the participant’s memory of details and events that occurred during the navigation task. Some questions were intended to introduce misinformation to disrupt or alter the memories that the participants had of the initial experience (recall false memories), while other questions were intended to accurately reflect what occurred during the initial experience (recall true memories). A third category of questions served as a control condition, and included statements that did not involve the use of memory or have any relevance to details of the navigation task. Participant responses were considered to constitute a *true* memory if they 1) *correctly* denoted the statement as “TRUE” or “FALSE” and 2) provided a confidence rating of

“4”. Conversely, participant responses were considered to constitute a *false* memory if they 1) *did not* correctly denote the statement as “TRUE” or “FALSE” and 2) provided a confidence rating of “4”. An example of a test question follows: “Identify the following statement as TRUE or FALSE: *I walked by a bagel shop.*” If the simulation did, in fact, show that the participant viewed a bagel shop during the navigation task, participants would indicate a true memory if they responded “TRUE, 4”; participants would indicate a false memory if they responded “FALSE, 4”. An example of a control question follows: “Identify the following statement as “TRUE” or “FALSE”: *Dogs walk on four legs*.” An additional sample of test questions, control questions, and indications of true and false memories can be found in **Table 1**.

The goal of this procedure was to simulate a true-to-life experience but with controlled and testable factors. Additionally, this procedure aimed to provide a more accurate representation of how false memories may develop and occur in reality (e.g., eyewitness testimony) compared to those used in previous literature. The component of participant confidence rating was included in this procedure to serve as a measure of the strength of each participant’s “memory” of the respective detail or event. Thus, responses that were not accompanied by a confidence rating of at least a “3” were recorded but not critical for analysis of the memories. This helped assure that the analyzed responses were more accurate measures of what participants actually retrieved from memory of the initial event.

Critically, participants underwent fMRI scanning during the test question phase of the procedure in order to observe areas and levels of brain activity during retrieval of true and false memories. The primary regions of interest were the medial temporal lobes, where MTL average activity levels during participant responses to control questions served as the baseline to which experimental responses (brain activity levels during recollection of true and false memories) were compared.

Figure 1. Sample virtual reality field of vision (left) and sample virtual reality map showing point A and point B.

Sample Statement	Simulation Detail	True Memory Response	False Memory Response	Baseline Response
“The woman I spoke to was named Rebecca”	TRUE	TRUE, 4	FALSE, 4	--
“The woman I spoke to was named Taylor”	FALSE	FALSE, 4	TRUE, 4	--
“The person I passed was pushing a stroller”	TRUE	TRUE, 4	FALSE, 4	--
“The person I passed was walking a dog”	FALSE	FALSE, 4	TRUE, 4	--
“A rose is a type of flower”	--	--	--	TRUE
“Zebras have spots”	--	--	--	FALSE

Table 1. Examples of test statements and responses constituting true memories, false memories, and baseline responses.

Results

In order to measure the degree to which brain areas, particularly the MTL, were active during recollection of true versus false memories, fMRI scanning was conducted to observe the Blood Oxygen Level-Dependent (BOLD) response in the brains of participants during their responses to each test question during the second phase of the experiment. These results demonstrated significantly greater activity bilaterally in the MTL in participants during retrieval of true memories (confident answers that accurately depicted true event details) compared to the level of MTL activity both during control responses and during the retrieval of false memories (confident responses that did not accurately depict true event details). Interestingly, MTL activity during retrieval of false memories was generally greater than during control responses, but this difference was not significant.

In addition, fMRI data displayed average BOLD response in cortico-temporal circuitry that was significantly higher when participants recalled true memories than both false memories and control responses.

As previously noted, average brain activity patterns during participant responses of confidence ratings below “3” did not show any statistically significant differences with respect to control responses.

Discussion

Together, these results support the present hypotheses that the recollection of true memories is correlated with increased activity in the MTL. In addition, this suggests that there is increased activity in cortico-temporal circuitry during this same recollection period, but no significant effect is observed during the recollection of false memories. This may serve as foundational evidence for identification of false memories at the time of retrieval. This evidence is striking; while true memories and false memories are typically considered "behaviorally and subjectively indistinguishable" (Fabiani, Stadler, & Wessels, 2000), there is now evidence for a neural basis to differentiate between true memories and false memories at the stage of retrieval. These findings complement the already robust literature on the neural underpinnings of false memories by adding neural data of false memory retrieval with previous findings regarding false memory encoding (Okado, 2005). Additionally, the findings of the present study contribute a more realistic model of false memories than previous literature by using virtual reality simulation and therefore creating experiences and memories that subjects recall with respect to the self, rather than using individual words as the bases for recollection (Fabiani, Stadler, & Wessels, 2000). Thus, this study suggests a promising future in the role of identifying false memories in other fields, such as law. While these data are preliminary, this study may serve as a starting point to improve the integrity and pursuit of the truth in legal environments, especially with respect to eyewitness testimonies. These improvements could manifest in new practices or they could be woven into pre-existing, common practices.

In the present study, one strength is that a control condition was included to serve as a baseline for BOLD activity to which experimental conditions could be compared. One weakness of this study is that the test questions do not focus on emotionally salient details and events, which may or may not influence the strength of the memories.

Overall, the evidence found in this study suggests that neural activity differs in both scope and strength during the retrieval of true and false memories.

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