Memory Gaps and Memory Errors

JEFFREY S. NEUSCHATZ, STACY A. WETMORE, and SCOTT D. GRONLUND

Abstract

Memory is a reconstructive process, relying on pre-existing shared knowledge to help us comprehend and interpret what we experience. A reliance on prior knowledge is a vital aid to communication and comprehension, but, as a consequence, results in the modification of some details in an event, the addition of other details, or even the fabrication of entire new events. We review classic research that first demonstrated the phenomenon of reconstructive memory and the capability of prior knowledge to influence what people remember. We next discuss cutting-edge research involving memory gaps and memory errors, including autobiographical memories, distinguishing true from false memories, memory conformity, and potential adaptive reasons for memory errors. Finally, we point to directions for the future research.

INTRODUCTION

A generally accepted theory of memory was introduced by Neisser (1967) and has been reworked and refined over the last half-century (e.g., Loftus, 1979; Loftus & Loftus, 1980; Schacter, 1995). However, the basic tenets of the theory remain similar to those originally described; people are active information processors, encoding and sometimes altering information as it is perceived. In other words, memory is not like a passive recording device (e.g., video camera or DVR). Instead, people encode bits and pieces of information or *details* they experience, and these details are then *integrated* with other sources of information. Thereafter, memories continue to be acted upon and influenced by preexisting knowledge and newly learned information. Memories are fluid entities that change, sometimes dramatically. Every time a person thinks about an event—revisits his or her memory—the memory has the potential to change. Such changes take many forms. For instance, information that is consistent with the person's beliefs about what must have happened can be integrated into the memory to fill in gaps, or information not originally encoded can be subsequently added. These beliefs about what

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may have happened arise as a result of top-down processing. That is, people make inferences from what they know is likely to occur in a situation, and these inferences can become part of the memory. Often time, inferences accurately reflect what occurred; however, at other times inferences can lead to errors. In addition, details that do not seem to fit a coherent story of what happened can be stripped away.

The current state of a memory can be quite different from the memory that an individual originally encoded. For example, Neisser reported remembering listening to a baseball game on the radio when the program was interrupted to announce the attack on Pearl Harbor. He later recounted that this was impossible because baseball is not played in December, when the attack occurred (Neuschatz, Lampinen, Toglia, Payne, & Cisneros, 2007). Thus, memory is constructive (or reconstructive) and often incomplete, compelling a person to fill gaps in memory with what can be inferred from past experiences as well as new information collected from other sources (e.g., suggestions). This entry examines the seminal research that ignited interest in memory gaps and errors, identifies promising lines of investigation, and recognizes key questions that remain to be investigated.

FOUNDATIONAL RESEARCH

The genesis of research on memory errors and gaps can be traced back to Sir Fredric Bartlett (1932), who is generally credited as the founder of the reconstructive memory approach. Bartlett had Cambridge University students read and remember the Native American folktale, "The War of the Ghosts." Bartlett then repeatedly tested participants' memory for the folktale. He found that participants frequently filled in the gaps of their memories with information that was not actually in the folktale. The students generally added information that made the story conform to their own individual experiences and expectations through addition, modification, and elimination. The changes made the stories more consistent with what the Cambridge students had learned to expect despite the inaccuracy introduced by the changes to the actual tale.

Research regarding memory errors was relatively dormant in the ensuing years (but see Deese, 1959; Underwood, 1965). However, in the early 1970s, researchers studying sentence memory also found evidence for constructive memory errors. Bransford and Franks (1971) had participants study short propositions that could be combined to form longer, more complex sentences. These sentences generally conformed to a short story or theme. For example, the thematic sentence, "The girl who lived next door broke the large window on the porch," could be broken down into several propositions: "The girl lived next door; The girl broke the large window; The girl who lived next door broke the large window," and so on. The complex sentence that contained all four propositions was never presented during study. Nevertheless, Bransford and Franks found that participants were not only more likely to say that the complex sentence was presented, but that they were more confident about this than the sentences that were actually studied.

At around the same time, Loftus and colleagues (Loftus, 1979; Loftus & Greene, 1980; Loftus, Miller, & Burns, 1978) developed the misleading postevent information (MPI) paradigm. In the typical procedure, participants witness some event and are then asked questions that are either true or false about the event. For example, participants might watch a videotape of an office scene in which a Diet Coke can was seen on the desk in the office. Participants then answer a questionnaire about the event. Some participants received only neutral information about the scene (e.g., there was a soda can on the desk), whereas other participants were exposed to misleading information (e.g., the can on the desk was a 7-up). On the ensuing recognition memory test, participants who were misled are more likely to indicate that the original can was a 7-up than those who received neutral information. Loftus and colleagues found that participants not only update their memories with misleading information but also change their memory depending on the information. For instance, participant will remember broken glass from an automobile accident when in fact there was no broken glass, based on being questioned using the word "smashed" (Loftus & Palmer, 1974).

Loftus and colleagues suggested that the memory trace for the original information (e.g., Diet Coke in the previous example) was altered and replaced by the misinformation (e.g., 7-up). They argued that a memory error occurred because there was no way to retrieve the original information once the trace had been altered. McCloskey and Zaragoza (1985) criticized the trace alteration position by contending that the standard procedure used by Loftus produced a bias toward the misinformation. They argued that there were inherent demand characteristics pointing to the misleading information because the misleading information was more recent, and was provided by a source with more knowledge of the event (i.e., the experimenter). Using an alternative test that reduced experimenter bias, McCloskey and Zaragoza (1985; Bekerian and Bowers, 1983) demonstrated that the original memory trace was still accessible. Although an incorrect memory might compete with rather than replace the original memory, the end result is the same, a false report.

In the 1980s, psychologists started examining more naturalistic events and again found evidence for constructive memory errors. Memory for naturalistic events relies on schemas or mental models of what typically happens in a particular situation. These retrieval structures guide encoding and retrieval processes (Neuschatz, Lampinen, Preston, Hawkins, & Toglia, 2002). However, the reliance on schemas can lead to the reporting of information that is typical of a scene even if the information was never presented. In other words, schemas fill in gaps. Brewer and Treyens (1981) demonstrated that participants who were seated in a graduate student's office later falsely recalled and recognized objects (e.g., a stapler) that were consistent with an office schema but were not present. Similarly, Nakamura, Graesser, Zimmerman, and Riha (1985) had students view a lecture by a speaker who performed relevant (e.g., underlining a word on the blackboard) or irrelevant (e.g., sipping coffee) actions. They found that participants falsely remembered relevant actions that were never actually performed by the lecturer.

More recently, the Deese (1959) and Roediger and McDermott (1995, DRM) paradigm has become a popular tool for investigating memory errors. In the DRM paradigm, participants are presented with lists of words (e.g., bed, rest, nap) that are semantically related to a single nonpresented critical lure (e.g., sleep). This procedure results in high rates of false recognition and recall of the critical lure (Payne, Elie, Blackwell, & Neuschatz, 1996; Payne *et al*., 2009; Read, 1996). Participants also report these critical lures with high confidence. We will return to the DRM paradigm below; the ease with which false memories can be created makes it widely used.

This abbreviated history of the study of memory and its errors elucidates some consistent patterns. Memory is not a verbatim copy of what we experience, despite what most lay people believe (Simons & Chabris, 2011). In order to compensate for our imperfect memories, gaps are often filled with information that is plausible, given the context in which the event occurred. A common feature of these memory error phenomena is that they rely on the contribution of top-down knowledge. This might seem disquieting, but a reliance on top-down knowledge is crucial in everyday cognition. For example, it facilitates communication due to shared knowledge. If I invite someone over for dinner, I do not have to tell my guest not to eat in advance. When I go for lunch at a restaurant, I know not to walk into the kitchen to grab what I want. But given how readily, and necessarily, we fill in unstated, but expected, information, it is no surprise that it can be tricky to keep separate what actually happened from what typically happened or what I inferred should have happened. But where has the field gone since these seminal early studies on reconstructive memory? We turn next to emerging areas in reconstructive memory research.

CUTTING-EDGE RESEARCH

The last 15 years has seen an explosion of research on the constructive nature of memory as it relates to autobiographical memory errors and false memories. The dramatic growth has been fueled, in part, by media accounts of repressed/recovered memories in high-profile court cases (e.g., George Franklin and Paul Ingram; Franklin v. Duncan, 1995; State of Washington v. Ingram, 1988) and DNA exonerations involving (primarily) faulty eyewitness identifications (e.g., Junkin & Bloodsworth, 2004; Thompson-Cannino, Cotton, & Torneo, 2009). The interest in memory errors also has spurred study of these false memories in neuroscience. Researchers have started using neuroimaging techniques to understand underlying structures and processing, as well as the role sleep plays in reinforcing true versus false memories. In addition, researchers have begun examining whether neuroimaging techniques can be used to distinguish true from false memories.

Autobiographical Memory Errors and False Memories

Many researchers have explored a powerful laboratory paradigm known as the *familial informant false narrative procedure*, or, more colloquially, the "lost in the mall" technique to study false memories (Lindsay, Hagen, Read, Wade, & Garry, 2004; Loftus, 1993; Loftus & Davis, 2006; Loftus & Pickrell, 1995). In this paradigm, participants are asked to recall several events from their childhood. The experimenter concocts one false event from true details the participant provided and creates an event like, being lost in the mall at age 5. After the initial interview, participants attempt to recall more details about the true and false events (perhaps through writing in a journal), which is then followed by repeated interviews. On the final interview, participants are asked to recall all the events. As many as 30% of the participants "remember" specific details about the false event and report them as actually occurring (Hyman, Husband, & Billings, 1995; Lindsay *et al.*, 2004; Loftus & Pickrell, 1995; Pezdek & Hodge, 1999). These estimates vary with the plausibility of the events. It is harder to implant memories for implausible events such as having a rectal enema (Pezdek, Finger, & Hodge, 1997) than more plausible scenarios such as spilling a punch bowl (Hyman & Pentland, 1996). However, it is not impossible (Sharman & Scoboria, 2009).

Sleep

False memories and memory errors, whether plausible or implausible, also can be affected by sleep (Diekelmann, Buchel, Born, & Rasch, 2011; Dieklemann, Landolt, Lahl, Born, & Wagner, 2008; Payne, 2011). Sleep is known best for its contribution to consolidation—a process that transforms newly encoded memories into a more stable representation to be integrated into pre-existing long-term memories. But there is currently some debate as to what phase of sleep is best for consolidation [e.g., rapid-eye movement (REM) or slow-wave sleep], and how exactly these phases of sleep affect memory. To investigate the effects of slow-wave sleep on memory and memory errors, Payne *et al*. (2009) had participants complete a DRM task (discussed earlier). Participants were either tested after a night's sleep or a day of wakefulness. They found that the recall of studied words was significantly higher for those who slept, and, more interestingly, those who had slept also falsely recalled more of the critical lures (nonstudied semantically related words). Therefore, slow-wave sleep may make individuals more prone to false memories because of the reorganization of memory that occurs during consolidation. This is consistent with the more-is-less pattern discussed by Toglia, Neuschatz, and Goodwin (1999). That is, the recall of more of the studied items is accompanied by more memory errors. However, this pattern is not always apparent. Diekelmann *et al*. (2011) found that the reactivation of memory through odor presentation during slow-wave sleep stabilized memories and protected against memory errors. Future research must determine the extent to which slow-wave sleep promotes the stabilization of memories versus enhancing the creation of false memories.

DISTINGUISHING TRUE FROM FALSE MEMORIES

Researchers have begun to investigate the neurological basis of true and false memories using neuroimaging techniques such as fMRI (functional magnetic resonance imaging) and event-related potentials (EEGs). This is an exciting avenue of research because it could potentially be used to help resolve legal cases (Schacter & Loftus, 2013). The hope would be that, although we cannot be certain about whether to trust what a defendant reports about an event, an examination of his or her brain might reveal the underlying truth. Participant's brains have been scanned as they complete the recognition portion of the DRM paradigm. Neuroimaging studies have shown that many of the same brain regions are active when true and false memories are retrieved. However, there are some differences in activations. Specifically, brain areas associated with sensory and perceptual information during encoding and retrieval tend to be more active when true as opposed to false memories are retrieved (Schacter & Loftus, 2013; Schooler, Gerhard, & Loftus, 1986; Slotnick & Schacter, 2004).

Although provocative, there are many issues to overcome before we know if these brain-based methods can provide an unfettered window into the truth of a memory (Schacter, Chamberlain, Gaesser, & Gerlach, 2012). Will neuroscience serve as a panacea for ferreting true from false memories, liars from truth tellers in the courtroom? Schacter and Loftus (2013) are skeptical that this will happen anytime soon and suggest that the best use of neuroimaging in the courtroom, currently, is to educate jurors and bolster general claims regarding the reconstructive nature of memory.

Memory Conformity

Another emerging area of research involves the effect of cowitness suggestion, where witnesses discuss an event before reporting it. This can alter one's memory for the original event to conform to what was discussed instead of what a witness actually saw. Wright, Memon, Skagerberg, and Gabbert (2009) referred to this phenomenon as memory conformity. One approach to studying memory conformity is to have a confederate leak information, both accurate and inaccurate, after a witnessed event. Memory conformity occurs because individuals often report the inaccurate information that the confederate reports.

Wright *et al*. (2009) offered three explanations for memory conformity. Normative influence occurs when the participants do not want to disagree with the confederate so they accept the information over what they may remember. In this case, the cost of disagreeing with the confederate is greater than the price of being accurate. Informational influence occurs when participants accept the confederate's memory of the event as more accurate than their own. Lastly, the memory distortion explanation suggests that people remember the information but forget its source. As a consequence, the participants believe that they saw particular events when in fact they only heard about it from the cowitness. Future research must determine the circumstances and the extent to which each of these explanations play a role in producing memory conformity.

Adaptive Errors

>Most lay people view memory errors as hindrances or incidents to bemoan; however, researchers have come to view them as adaptive features of our memory system (Schacter & Wagner, 1999). Schacter, Guerin, and St. Jacques (2011) propose that memory errors and distortions are a by-product of memory's adaptive functioning. The authors use imagination inflation to illustrate the adaptive nature of memory errors. Imagination inflation is when the veracity of false memories increase as a result of participants imagining that an event may be true. For example, in one experiment, participants imagined themselves or an experimenter performing an action. Neuroimaging studies utilizing fMRI have shown that the brain areas associated with visual imagery were active for items that were imagined

and falsely remembered (Gonsalves & Paller, 2002). Research has shown that remembering past events and imaging future events use many of the same brain systems (Schacter & Addis, 2009). This overlap in neural subsystems could explain how memory and imagining get confused. Nevertheless, Schacter *et al*. went on to argue that such a system is adaptive, because it allows stored information to be used flexibly to simulate a variety of future outcomes. If our memory for the past was perfect, such that there were no gaps to fill, we would be unable to flexibly simulate the future. The adaptive nature of memory errors and the relationship between memory for the past and imaging the future is an emerging and exciting line of inquiry.

KEY ISSUES FOR FUTURE RESEARCH

Merging Behavioral and Neuroscientific Approaches

Neuroscience-based approaches have begun to transform psychology. But these techniques are still new to many researchers and require specialized (and expensive) equipment and knowledge. Future research on memory gaps and memory errors will continue to discover interesting new phenomena, and useful new paradigms for the study of these phenomena. But the capability now exists to understand these phenomena to a degree, and in a manner, that was impossible 15 years ago. We need to continue to integrate our best behavioral work with these remarkable new neuroscience technologies.

Interplay of Data and Theory

Another key for future research involves the continuing interplay of data and theory. New phenomena without an explanation are simply curiosities; patterns of brain activations are baffling without guidance from theory regarding the regions on which to focus. Wixted and Mickes (2013) argued that the path for understanding must work both ways. Specifically, they noted that theory must inform how we interpret fMRI, and fMRI must inform how we evaluate cognitive theories. In addition, there are several theoretical frameworks that already have played important roles in understanding memory gaps and errors including source monitoring (Johnson, Hashtroudi, & Lindsay, 1993), activation monitoring (Mather, Henkle, & Johnson, 1997; Roediger, Balota, & Watson, 2001), and fuzzy trace theory (Brainerd & Reyna, 2005). Formal models also must play a role. Kimball, Smith, and Kahana (2007) developed a computational model of DRM recognition errors. Arndt and Hirshman (1998) showed that an exemplar model (MINERVA 2, Hintzman, 1986) could reproduce several false recognition phenomena (but see John & Jones, 2010). Clark (2003) developed a formal model for eyewitness identification decisions (see also Goodsell, Gronlund, & Carlson, 2010). Applied researchers in particular will benefit from greater guidance by theory (Clark, 2008).

There are important questions to be answered about how memory works, and the potential consequences when memory goes awry can be devastating. Therefore, we call on researchers, those with more of an orientation toward laboratory research, as well as those more interested in real-world applications, to work together to address key issues (see also Lane & Meissner, 2008).

Understanding how our memory functions can benefit a variety of endeavors (e.g., best practices in education). Understanding memory also benefits society. For example, the criminal justice system will continue to benefit from the use of memory experts in battling faulty eyewitness identifications (innocenceproject.org). Although we have come a long way since Bartlett's (1932) original demonstration of the reconstructive nature of memory, there is much left to do.

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JEFFREY S. NEUSCHATZ SHORT BIOGRAPHY

Jeffrey S. Neuschatz received his BS at Roger Williams University in 1992 and his PhD at Binghamton University in 1999, and is a Professor and Chair of the Psychology Department at the University of Alabama in Huntsville. Dr. Neuschatz is the coauthor of more than 30 scholarly works. His work has appeared in leading academic journals including *Law and Human Behavior* and *Journal of Experimental Psychology: Learning, Memory, and Cognition*. He is the recipient of the University of Alabama-Huntsville Foundation Award for Creative Achievement.

STACY A. WETMORE SHORT BIOGRAPHY

Stacy A. Wetmore is a doctoral candidate in Cognitive Psychology at the University of Oklahoma. She previously obtained a BA in Psychology and MA in Experimental Psychology from the University of Alabama in Huntsville where she received the Psychology Department Outstanding Thesis Award. Her primary area of research interest concerns issues in eyewitness memory and, more specifically, on identification procedures to enhance discriminability and improve memory.

SCOTT D. GRONLUND SHORT BIOGRAPHY

Scott D. Gronlund is a Professor of Psychology and the Roger and Sherry Teigen Presidential Professor at the University of Oklahoma. Scott earned his undergraduate degree in Psychology from UC Irvine and his PhD from Indiana University. Before arriving at the University of Oklahoma, he completed a postdoctoral fellowship at Northwestern University. Scott prepared an *Amicus Brief* for the US Supreme Court for petitioner Kevin Keith. He has served on the Editorial Board of the *Journal of Experimental Psychology: Applied* and is a Fellow of the Association of Psychological Science (APS) and the Psychonomics Society.

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