Back to the future: Progressing memory research in eating disorders

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Abstract

Objective: Human behaviors, thoughts, and emotions are guided by memories of the past. Thus, there can be little doubt that memory plays a fundamental role in the behaviors (e.g., binging), thoughts (e.g., body-image concerns), and emotions (e.g., guilt) that characterize eating disorders (EDs). Although a growing body of research has begun to investigate the role of memory in EDs, this literature is limited in numerous ways and has yet to be integrated into an overarching framework.

Methods: In the present article, we provide an operational framework for characterizing different domains of memory, briefly review existing ED memory research within this framework, and highlight crucial gaps in the literature.

Results: We distinguish between three domains of memory—episodic, procedural, and working —which differ based on functional attributes and underlying neural systems. Most recent ED memory research has focused on procedural memory broadly defined (e.g., reinforcement learning), and findings within all three memory domains are highly mixed. Further, few studies have attempted to assess these different domains simultaneously, though most behavior is achieved through coordination and competition between memory systems. We, therefore, offer

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recommendations for how to move ED research forward within each domain of memory and how to study the interactions between memory systems, using illustrative examples from other areas of basic and clinical research.

Discussion: A stronger and more integrated understanding of the mechanisms that connect memory of past experiences to present ED behavior may yield more comprehensive theoretical models of EDs that guide novel treatment approaches.

Public Significance: Memories of previous eating-related experiences may contribute to the onset and maintenance of eating disorders (EDs). However, research on the role of memory in EDs is limited, and distinct domains of ED memory research are rarely connected. We, therefore, offer a framework for organizing, progressing, and integrating ED memory research, to provide a better foundation for improving ED treatment and intervention going forward.

Keywords

anorexia; associative learning; binge-eating; bulimia; eating disorders; episodic memory; learning; memory; procedural memory; working memory

1 | BACK TO THE FUTURE: PROGRESSING MEMORY RESEARCH IN EATING DISORDERS

Eating disorders (EDs), including anorexia nervosa (AN), bulimia nervosa (BN), and binge-eating disorder (BED), are generally characterized by the over or under-consumption of food and disturbances in body image (American Psychiatric Association, 2013; Coffino et al., 2019). EDs are associated with significant psychiatric and medical comorbidity, psychosocial impairment, chronicity, and mortality (Hudson et al., 2007; Smink et al., 2012). As existing interventions for EDs are often unsuccessful in achieving lasting remission (Hagan & Walsh, 2021; Linardon, 2018; Watson & Bulik, 2013), there is an urgent need to clarify the risk and maintenance processes underlying ED onset and maintenance, to improve prevention and treatment approaches. To this end, there has been an explosion of research characterizing the neurocognitive mechanisms that give rise to the cognitive (e.g., attention biases), emotional (e.g., affect regulation difficulties), and behavioral (e.g., decision making) features of EDs. Although it is well-accepted in other fields that each of these features and mechanisms relies heavily on memory processes, research on memory in EDs is relatively limited, and studies evaluating the connections between different facets of memory in EDs are rare. To help bolster research in this area, we outline an operational framework for organizing memory research, briefly summarize existing findings on memory in EDs within this framework, and highlight approaches for addressing important gaps in the literature.

1.1 | Defining memory

Memory refers to a set of mechanisms that allow past experience to guide current behaviors, thoughts, and emotions (Tulving, 1983; Tulving, 1985). For example, memory of the consequences of past behavior motivates us to engage in or avoid those behaviors in the future (Duncan & Shohamy, 2020). Memory is what allows us to maintain a self-image,

to construct an ideal self-image, and to compare the two (Conway, 2005). Memory is why we can consciously recollect moments from our past and re-experience the sensations and emotions of those moments in the present (Tulving, 1985). Memory helps guide our attention to the key features of our environment (Sherman & Turk-Browne, 2022) and is what allows us to problem solve, plan, and imagine the future (Schacter et al., 2012).

Memory researchers typically distinguish between different domains of memory based on their functional attributes and underlying neural systems. However, there is no universally accepted framework for making and categorizing such distinctions (Henke, 2010; Howard & Cohen, 2004; Tulving, 2007). To provide organizational clarity in the current article, we operationally distinguish between three domains of memory—episodic, procedural, and working memory (see Figures 1 and 2)—each of which has demonstrated relevance to eating behavior and may hold promise as potential treatment targets (see Table 1). However, it is important to note that although these are common distinctions, we are using the terms broadly, and they do not encapsulate all facets of memory. Finally, a key theme of this article is that these memory systems are highly interactive in guiding behavior, making it important to better understand not only how each memory system influences EDs separately, but also how they do so in concert (Collins & Frank, 2012; Duncan & Shohamy, 2020; Gershman & Daw, 2017a).

1.1.1 | Episodic memory—Episodic memory refers to the ability to store and retrieve specific experiences from one's past, typically with rich associative and contextual detail (Tulving, 1985). For example, episodic memory underlies the ability to recall a conversation that you had a month ago, re-experience the words, gestures, and emotions of that conversation, and recollect incidental details, like the outfit you were wearing. Importantly, episodic memories are flexible: they can be re-examined from different perspectives, they can be combined and compared, and they can be distorted, forgotten, and recovered over time (Biderman et al., 2020; Schacter, 2021). The flexibility and richness of episodic memory likely reflect that its primary function is to help us adaptively make decisions, problem solve, and plan for the future, rather than simply to re-experience the past (Schacter et al., 2012). For example, brain areas crucial to episodic memory, such as the hippocampus and other areas of the medial temporal lobe, show similar activity during decision making and thinking about the future as during episodic memory retrieval, suggesting that episodic memories are implicitly sampled and modified to guide behavior (Addis et al., 2007; Bakkour et al., 2019; Wang et al., 2015). Episodic memory, therefore, likely plays a central role in adaptive and maladaptive psychological functioning (Beck & Haigh, 2014; Bornstein & Pickard, 2020; Brewin, 2014; Heller & Bagot, 2020).

1.1.2 | Procedural memory (and learning)—Procedural memory refers to the gradual acquisition of skills, habits, and knowledge[1] through repeated experience

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[1]Note that we include semantic memory (general knowledge that can be explicitly stated) as a type of procedural memory, though it is often paired more closely with episodic memory (Howard & Cohen, 2004). We do this because semantic memory reflects a generalized and relatively rigid form of memory, which is typically acquired gradually (Gershman & Daw, 2017a; Henke, 2010). For example, you likely know that coffee is associated with cream (a semantic memory) not because you can recall the first time you saw cream poured into coffee (an episodic memory), but because you have extracted the association from repeated experiences (a procedural memory).

(Gershman & Daw, 2017b; Henke, 2010; Howard & Cohen, 2004). It is the set of mechanisms that underlie associative learning, or the ability to form implicit associations between stimuli, contexts, behaviors, and/or outcomes (e.g., reward learning and classical conditioning), and it supports the automaticity of behaviors found to reliably achieve a goal (i.e., habit formation). For example, the incrementally learned associations between contextual stimuli (e.g., the sound of a bell), behaviors (e.g., pressing a lever), and outcomes (e.g., the receipt of food) are stored as procedural memories, which then support automatic response tendencies (e.g., pressing a lever when hearing a bell).

Unlike episodic memory, procedural memory generally does not depend on the hippocampus/medial temporal lobe, and instead is largely reliant upon the striatum, amygdala, and cerebellum (Daw & O'Doherty, 2014; Poldrack & Packard, 2003). Furthermore, whereas episodic memory captures unique details of single instances from the past, procedural memory typically reflects summary information generalized across multiple instances. This summary information describes the value (or utility) of a given action performed in a particular state (e.g., a lever press in the presence of a bell) (O'Doherty et al., 2002; Seymour et al., 2004). Since this information is immediately available (i.e., no computation is required), action evaluation is simple, allowing behavior that was adaptive in the past to be repeated automatically. However, because procedural memories are typically formed through direct and repeated experience, they are often slow to be acquired (Lally et al., 2010), and difficult to change (Orbell & Verplanken, 2010), even if they become inaccurate (e.g., pressing the lever no longer leads to a reward) (Tricomi et al., 2009). Thus, while procedural memory is highly advantageous for completing daily routines, overreliance on this system can be maladaptive when circumstances change. Indeed, excessive use of procedural memory and learning systems in lab-based behavioral tasks appears characteristic of several psychiatric disorders, including substance use and obsessive-compulsive disorders (Gillan & Robbins, 2014; Sjoerds et al., 2013; Voon et al., 2015).

1.1.3 | Working memory—Working memory refers to the ability to hold small amounts of information actively in mind over brief intervals, to mentally manipulate this information, and to use it in service of ongoing tasks (Baddeley, 1986; Miller, 1960). As such, working memory forms a key component of the cognitive architecture supporting a range of behaviors, from the short-term retention of various kinds of information (e.g., visual, verbal, and semantic), to more complex cognitive processes including language comprehension (Collette et al., 2000; Martin et al., 1994), mental arithmetic (Logie et al., 1994), learning and problem solving (Cowan, 2014), and the control and guidance of attention (Desimone & Duncan, 1995). For example, to find a friend in a crowded market, details about the friend's appearance, such as their hair color or what they told you they would be wearing, can be retrieved from long-term memory, maintained in an active state in working memory, and used to guide attention. The ability to temporarily hold information in an active state supports behavioral flexibility by allowing behavior to be guided by internally generated plans and goals, rather than fixed habits and learned stimulus–response associations (D'Esposito & Postle, 2015). Although this is often adaptive, it can sometimes contribute to maladaptive outcomes, such as when an inability to keep particular information out of

working memory contributes to excessive worry (Stout et al., 2015), depression (Baddeley, 2013), or other forms of distress (Brewin et al., 2010).

1.2 | The current state of research on memory in EDs

Although severe, widespread deficits of neuropsychological function are unlikely to characterize EDs, it has long been suggested that specific memory abnormalities may be a factor in their onset and maintenance (Lena et al., 2004). This potential is highlighted by structural and functional alterations in the neurocircuits underlying memory systems in ED populations (Mele et al., 2020; Walton et al., 2022), as well as research suggesting that the manipulation of memory may be a useful tool for ED prevention (Pennesi & Wade, 2018). Indeed, memory plays a central, though often implicit, role in many models of ED onset and maintenance (Schaefer, Forester, Dvorak, et al., 2023). For example, affect regulation models suggest that previous experiences of mood improvement following ED behaviors (e.g., dietary restriction) contribute to continuation of that behavior in the future (Haynos et al., 2017; Heatherton & Baumeister, 1991). Habit models extend this proposed learning process, positing that when contextual cues (e.g., negative affect) become associated with specific response-outcome contingencies (e.g., mood improvement following dietary restriction) in memory, the presence of these cues can trigger the response behavior even when the behavior no longer results in the desired outcome (Steinglass & Walsh, 2016; Walsh, 2013). Expectancy models more explicitly hypothesize that cognitive summaries of past experiences are stored in memory, which are then used to predict the future outcome of a given behavior (e.g., the expected outcomes associated with pursuing thinness or consuming food) (Hohlstein et al., 1998). Finally, models highlighting the role of inhibitory control in ED pathology assume that alterations (i.e., impairments in binge-type EDs and enhancements in restrictive-type EDs) in the ability to actively maintain and utilize joint representations of the current environment, prior experience, and current goals in memory contribute to the onset/persistence of EDs (Brooks et al., 2017; Dawe & Loxton, 2004; Wierenga et al., 2014). However, the precise memory mechanisms that might contribute to these models are often untested. Moreover, relevant findings from ED research are typically not discussed within a broader learning and memory context, which would allow researchers to easily link or differentiate findings across the field. In the following sections, we, therefore, outline existing ED memory research within each memory domain and then highlight the connections between them.

1.2.1 | Episodic memory in EDs—There is a substantial body of research demonstrating a relationship between episodic memory and eating behavior (Higgs & Spetter, 2018; Seitz et al., 2021). Perhaps the most striking evidence comes from patients with the inability to form episodic memories (due to hippocampal damage), who, without memory for having recently eaten, will continue to eat multiple meals within a short period of time (Rozin et al., 1998). Similarly, animal research has shown that the hippocampus and other brain regions underlying episodic memory play an important role in integrating and filtering internal signals of satiety and hunger, suggesting that these brain regions not only help to create and retrieve memories of previous eating episodes but also serve a gate-keeping function with regard to physiological hunger and satiety cues (Parent et al., 2022). Evidence linking episodic memory to eating behavior also comes from experimental

studies in healthy humans. For example, cueing episodic memory retrieval for a recent meal influences subsequent food intake (Collins & Stafford, 2015; Higgs, 2002; Vartanian et al., 2016), as does manipulating the way memory for an eating episode is created or stored (Brunstrom et al., 2012; Higgs & Woodward, 2009; Robinson et al., 2012). Thus, episodic memory appears to play an important role in modulating experiences of hunger and satiety, as well as in eating-related decision making. Despite this, there has been relatively little research examining the relationship between episodic memory and EDs.

Much of the research that has been conducted to date has focused on whether individuals with EDs have general episodic memory deficits (i.e., reduced ability to create, store, and retrieve new information, such as a series of neutral words/images) or biases (e.g., better memory for disorder-relevant stimuli), but results from these studies have been mixed. There is evidence of enhanced memory for disorder-relevant information, such as food or body stimuli (though there are also null or inconsistent findings) (Griffith et al., 2015; Nikendei et al., 2008; Svaldi et al., 2010; Tekcan et al., 2008). Furthermore, one study found that biased episodic memory for negatively valenced information may help explain emotion regulation difficulties in AN (Manuel & Wade, 2013), suggesting that memory biases may underlie key affect regulation deficits in EDs. However, despite intriguing recent findings, tests of general episodic memory deficits have led to highly inconsistent results overall (Eneva et al., 2017; Keeler et al., 2022a; Stedal et al., 2021; Terhoeven et al., 2017; Terhoeven, Faschingbauer, et al., 2023; Weider et al., 2016).

The reason for this inconsistency is likely manifold (e.g., small/heterogenous samples, conflation of memory domains, heterogeneous measures, and stimuli). However, a core issue may be an overreliance on general neuropsychological tests of cognitive function (e.g., from the NIH Toolbox). Although the use of these general memory impairment measures is useful for highlighting potential deficits among ED populations, the intentional broadness and simplicity of these tasks may obscure more nuanced and theoretically meaningful facets of memory. For example, these and other tasks have almost exclusively focused on episodic item memory (i.e., the ability to remember a previously encountered item, such as an object/face/word) rather than on episodic *relational*[2] memory (i.e., the ability to remember the relationships between items or an item and its context, such as the room in which an object was encountered). This distinction between item and relational memory is often crucial in clinically focused memory research (e.g., on schizophrenia, post-traumatic stress disorder, and aging) (Jung & Lee, 2016; Old & Naveh-Benjamin, 2008). For example, a recent study on alcohol use disorder found that individuals who demonstrated more generalized or "gist" level relational memory (see Figure 3a) for the contexts in which alcoholic items were encountered consumed more alcohol over the following month (Goldfarb et al., 2020). In contrast, memory for the alcohol-related items alone was unrelated to drinking behavior. This might reflect that more generalized relational memory (e.g., remembering a beer outside rather than specifically at the beach) could allow a wider variety of contexts to cue memories (and perhaps craving) of alcohol, and in turn, alcohol use. In EDs, more

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[2]Note that this type of memory is often referred "associative" rather than "relational" in episodic memory research. However, in this article, we save the term "associative" for describing "associative learning" in the context of procedural memory, to avoid confusion.

generalized relational memory for food or eating experiences could potentially play a similar role.

Although the studies reviewed above typically assessed memory for arbitrary (but controlled) information (e.g., lists of words/images/movies), another approach is to assess episodic memory for personally meaningful events from the past (e.g., a first date), called autobiographical memory (Williams et al., 2007). Recent research using this approach has consistently found overgeneralized autobiographical memory among individuals with EDs (Bomba & Broggi, 2014; Brockmeyer et al., 2013; Castellon et al., 2020; Dalgleish et al., 2003; Huber et al., 2015; Keeler et al., 2022b; Laberg & Andersson, 2004; Nandrino et al., 2006; Rasmussen, Jørgensen, Connor, Bennedsen, et al., 2017; Ridout et al., 2015; Terhoeven, Nikendei, et al., 2023), an effect that is commonly associated with mood disorders such as depression and post-traumatic stress disorder (Williams et al., 2007). An overgeneralized memory is one that, instead of containing specific episodic details (e.g., "On my last birthday, John and I went for a walk in the park"), is relatively abstract, nonspecific, and often distended in time (e.g., "I usually go for a walk in the mornings"). This lack of specificity may reflect an implicit emotion regulation strategy, allowing individuals to avoid re-experiencing emotions from the past (Williams et al., 2007). However, it is also associated with poorer clinical outcomes among individuals with mood disorders, perhaps because it inhibits the very function of episodic memory—to allow details from the past to guide decision making, problem solving, and planning (Hallford et al., 2020). Indeed, recent studies suggest that overgeneralized memory among individuals with EDs may be associated with a reduced ability to think about the future and problem solve (Keeler et al., 2022a; Rasmussen, Jørgensen, Connor, Godt, & Berntsen, 2017; Ridout et al., 2015), potentially maintaining maladaptive ED behaviors.

1.2.2 | Procedural memory (and learning) in EDs—There is a deep history of research relevant to eating behavior that falls within our broad definition of procedural memory. Indeed, seminal animal research on associative learning typically was (and still is) done using food stimuli, highlighting the power of food for shaping incrementally learned behavior (Anliker & Mayer, 1956; Pavlov, 2010; Pavlov, 1906; Skinner, 1971; Welzl et al., 2001). Recent work also suggests that procedural memory may contribute to a variety of eating behaviors and related experiences in humans, such as the craving and (over)consumption of palatable foods (Boswell & Kober, 2016; Jansen et al., 2016; Pearce et al., 2022). There has thus been consistent and growing interest in characterizing how aspects of procedural memory might contribute to EDs (Steinglass & Walsh, 2006; Steinglass & Walsh, 2016).

One line of research on procedural memory has focused on differences in learning associations between food and stimuli in the environment (i.e., Pavlovian/classical conditioning). For example, several theoretical models have proposed that learned associations between food and aversive stimuli (e.g., nausea) could lead to automatic fear or disgust responses to food, contributing to the onset of restrictive ED symptoms (Anderson et al., 2021; Murray et al., 2018; Strober, 2004). In addition, procedural memory for the associations between food and positive or neutral stimuli (e.g., popcorn and one's living room) could contribute to binge-type ED symptoms by increasing the number or strength

of environmental cues that trigger food craving (Boswell & Kober, 2016; Pearce et al., 2022). Indeed, some evidence suggests that individuals with or at risk for AN may more easily learn to associate a novel stimulus with fear or disgust-inducing stimuli than healthy controls (Lambert & Mcgregor, 2021; Olatunji, 2020) (though see Fyer et al., 2020), and may have more difficulty learning new neutral or positive associations for a given stimulus once a negative association has already been formed (Hildebrandt et al., 2015; Lambert & Mcgregor, 2021). Furthermore, neural responses (i.e., prediction error measured via fMRI) to classically conditioned stimuli may be exaggerated in individuals with AN, while they may be reduced in individuals with BED, BN, and obesity (Deguzman et al., 2017; Frank et al., 2011; Frank et al., 2016; Frank et al., 2021). Thus, although existing findings are mixed and integrating results from distinct paradigms is difficult, there does appear to be evidence for abnormalities in the way that associations between stimuli are formed and updated among individuals with EDs.

Another line of research has focused on how individuals with EDs incrementally learn associations between stimuli (e.g., food), actions (e.g., dietary restriction), and outcomes (e.g., reduced anxiety) to maximize rewards or avoid punishments (i.e., instrumental/operant/reinforcement learning). For example, individuals with EDs may more readily learn to associate ED behaviors with rewarding outcomes, thus strengthening the propensity for engaging in those behaviors in the future (Schaefer, Forester, Burr, et al., 2023; Schaefer & Steinglass, 2021). Additionally, when contingencies between stimuli, actions, and outcomes change over time (e.g., if restriction in the presence of food no longer reduces anxiety or becomes associated with negative outcomes), individuals with EDs may fail to adjust their behavior, reflecting poor "reversal learning." Lab-based assessment of basic deficits/enhancements of this type of procedural memory in EDs has been quite mixed, likely secondary to differences in study design (e.g., focus on initial learning vs. reversal learning) or population characteristics (diagnosis, age, illness stage). However, there does broadly appear to be evidence for altered outcome-guided procedural learning among individuals with EDs (Bernardoni et al., 2017; Celone et al., 2011; Foerde & Steinglass, 2017; Hagan & Forbush, 2021; Hildebrandt et al., 2018; Lao-Kaim et al., 2015; Ritschel et al., 2017; Shott et al., 2012; Wierenga et al., 2022), particularly with regard to reversal learning (Banca et al., 2016; Haynos et al., 2021; Kollei et al., 2018). Relatedly, there is also evidence that individuals with EDs may persist in learned behaviors (e.g., restriction) in response to a specific stimulus (e.g., food), even when the originally reinforcing/punishing outcomes have become irrelevant (e.g., if restriction is now punishing and no longer associated with social reinforcement; i.e., habit) (Davis et al., 2020; Foerde et al., 2021; Gillan et al., 2016; Seidel et al., 2022).

Although there has been more research on procedural than episodic and working memory in EDs, findings in this area are also conflicting, making it difficult to draw clear conclusions. There are likely several reasons for this beyond heterogeneity in populations and paradigms mentioned above. First, most existing research has explored procedural memory without consideration for how state or contextual factors may modulate performance. For instance, outside of EDs, consistent evidence indicates that emotions, stress, or other dynamic cognitive processes influence the encoding and retrieval of procedural memory (Packard et al., 2018; Packard et al., 2021) (as is also true for episodic and working memory)

(Schweizer et al., 2019; Shields et al., 2017; Williams et al., 2022). These changing, state-based processes are particularly relevant given robust links between affective dysregulation and stress reactivity with EDs (Chami et al., 2019; Lavender et al., 2015; Wonderlich & Lavender, 2017). For instance, in a recent study in individuals with elevated depressive symptoms, researchers used a within-subjects design to explore the influence of state-based depressive rumination on reinforcement learning performance, finding that performance was impaired by engagement in rumination (Hitchcock, Forman, et al., 2022). Given the relevance of rumination and other forms of repetitive negative thinking in EDs (Palmieri et al., 2021), this type of manipulation may increase external validity of findings as well as inform more dynamic, context-dependent models of procedural memory in EDs (Hitchcock, Fried, & Frank, 2022). In addition to lack of attention toward state-based effects, the research designs utilized in ED research often do not allow for dissociating crucial subcomponents of procedural memory from each other, or from related neurocognitive functions such as attention, reward sensitivity, and executive function (see Figure 4) (Forester & Kamp, 2023; Gershman & Daw, 2017a; Huys et al., 2013; Ma et al., 2020; McGuire et al., 2014; Wildes et al., 2014). Furthermore, research on procedural memory has predominately focused on reward-based learning, while other forms of procedural memory (e.g., fear/disgust conditioning) have received relatively little attention (Anderson et al., 2021; Murray et al., 2018). Finally, as noted below, procedural memory has largely been studied in isolation by ED researchers, without accounting for the influence of episodic and working memory.

1.2.3 | Working memory in EDs—A growing number of studies suggest a relationship between working memory and food intake among non-ED samples (Dohle et al., 2018; Higgs & Spetter, 2018). For example, behavioral and electrophysiological (i.e., EEG) studies demonstrate that food is preferentially represented in working memory, which can have wide-ranging effects on cognition (Robinson et al., 2012; Rutters et al., 2014). Furthermore, higher (state and trait) working memory capacity has been associated with faster satiation and reduced food intake, which could reflect an enhanced ability to monitor bodily signals related to satiation (Nelson & Redden, 2017; Ward & Mann, 2000).

As with episodic memory, much of the research on working memory in EDs has focused on evaluating general impairments (or enhancements) of working memory (e.g., lower working memory capacity for words, digits, and other neutral stimuli, impaired ability to ignore food-related and neutral distractors when utilizing working memory, impaired working memory updating), and the results to date have been similarly mixed (Brooks, 2016; Voon, 2015). For example, some studies suggest that individuals with restricting-type EDs, such as AN, may have increased working memory capacity compared with individuals with binge-spectrum EDs or controls (Brooks et al., 2012; Dahlén et al., 2022; Israel et al., 2015), though other studies have found reduced capacity in AN or no difference between groups (Fowler et al., 2006; Weider et al., 2016). Research in BED and BN has produced similarly mixed evidence for general working memory dysfunction. For example, although two studies observed overall deficits in working memory among individuals with BED compared with overweight controls (Duchesne et al., 2010; Eneva et al., 2017), another study did not observe this difference (Manasse et al., 2015).

The causes of these discrepancies are likely diverse (e.g., heterogeneity in tasks, stimuli, and sample characteristics). However, one important factor may be an overreliance on working memory tasks that feature neutral (i.e., digits, neutral words, or images) rather than disorder-salient stimuli. The few studies utilizing disorder-relevant stimuli (e.g., food-related words) have revealed enhanced recall and working memory updating for food-related information among individuals with elevated levels of ED pathology (Fenton & Ecker, 2015) and difficulty keeping task-irrelevant food-related information out of working memory among individuals with BED (Svaldi et al., 2014). These findings may be particularly relevant given the large body of basic research showing that attention and cognition are biased by the contents of working memory (Soto et al., 2005). Thus, for example, difficulty in the ability to filter disorder-relevant information out of working memory may help explain well-known attentional and cognitive biases surrounding food or the body among individuals with EDs (Stott et al., 2021; Williamson et al., 1999). Although this idea has largely been untested in EDs, analogous work on anxiety has shown that anxious individuals involuntarily store threat-related cues in working memory, which may account for the persistence of anxious thoughts and actions in the absence of threat-related cues in the immediate environment (Stout et al., 2015) (see Figure 3c).

1.3 | Moving forward: Integrating memory research in EDs

Although episodic, procedural, and working memory are subserved by (partially) distinct neural systems, it is becoming increasingly clear that these systems do not act in isolation (Collins & Frank, 2012; Duncan & Shohamy, 2020; Gershman & Daw, 2017a). Rather, most adaptive behavior is achieved through coordination and competition between memory systems. Thus, adopting a more integrative approach to studying memory (i.e., assessing the joint influence of different memory systems on behavior) will likely be important for gaining new insight into key facets of EDs. For example, the relationship between trauma and EDs likely depends in part on memory. However, there are several ways through which episodic, procedural, and working memory may connect past trauma to current ED behavior. Thus, a more holistic view of memory may help to understand and intervene in this relationship (Schwabe & Wolf, 2013).

To support a more integrative approach, memory researchers are developing novel paradigms to better assess the interaction between memory systems, and a key feature of many of these methods is a reliance on theory-driven computational modeling. In this context, computational modeling involves evaluating how well mathematical models that provide a formalized, mechanistic explanation of a given neurocognitive process (e.g., models of how individuals learn about cues and outcomes and incorporate this into future behavior) fit observed data. When coupled with strong experimental design, these models offer the opportunity to evaluate differing influences on a given behavioral outcome, and test competing explanations of observed behavior through model comparison. Indeed, computational modeling techniques have already begun to push ED memory research forward, providing a careful examination of the memory-related processes and subprocesses that may contribute to EDs (Bernardoni et al., 2017; Berner et al., 2023; Chan et al., 2014; Deguzman et al., 2017; Reiter et al., 2017; Smith et al., 2020; Wierenga et al., 2022). For example, one recent study using computational modeling found that what appears to

be outcome-guided behavior in AN may actually reflect overreliance on learned stimulus–response associations (Foerde et al., 2021). However, computational modeling work in EDs has been conducted (or at least conceptualized) (Zhou et al., 2023; De Houwer, 2019; Gershman & Daw, 2017a) almost exclusively within the domain of procedural memory. Thus, future ED work would likely benefit from greater integration of episodic and working memory processes into these modeling approaches.

Such an approach has already led to novel insights in other areas of clinical research. For example, by assessing procedural and working memory jointly (see Figure 5a), recent work has found that apparent procedural memory deficits in schizophrenia may be fully explained by deficits in working memory (Collins et al., 2014; Collins et al., 2017). Thus, despite robust evidence for deficits in behavior guided by procedural memory, remediation approaches that target working (as opposed to procedural) memory may be more likely to benefit individuals with schizophrenia (Martin et al., 2020). Similar findings arise when examining the relationships between episodic and procedural memory. For example, recent work has shown that episodic memory can bias decision making, even maladaptively, when choice would otherwise be guided by procedural memory (Bornstein et al., 2017; Madan et al., 2014). Findings like these have led to innovative models of addiction, which account for otherwise inexplicable drug use behavior by incorporating episodic memory processes along-side procedural memory processes (Bornstein & Pickard, 2020). Finally, recent modeling work has shown that the relative influence of procedural and episodic memory on decision making (see Figure 5b) varies as a function of environmental uncertainty and that this balance may be related to (mal)adaptive choice (Nicholas et al., 2022). As EDs are characterized by greater intolerance of uncertainty (Kesby et al., 2017), similar research in this population may prove meaningful.

In addition to potentially clarifying some of the inconsistencies in the current ED memory literature, a more integrative approach may better support the translation of memory findings into clinical applications. For example, overgeneralized autobiographical memory, which is prospectively associated with poor clinical outcomes in other populations (Hallford et al., 2020) appears to be a robust memory deficit in EDs. The question that follows then, is: How do we target autobiographical memory in order to influence ED outcomes (Hitchcock et al., 2017)? Although autobiographical memory is best characterized as episodic, it also strongly depends on both procedural (especially semantic) and working memory, as well as other neurocognitive processes (Addis & Tanguay, 2022; Fan et al., 2023; Hill & Emery, 2013). Thus, an effective answer to the question will likely depend on a better understanding of the joint memory processes that contribute to the deficit (Moscovitch et al., 2023).

2 | CONCLUSION

Memory is fundamental to almost all aspects of human behavior, leaving little doubt of its relevance to both the onset and maintenance of EDs. However, the term "memory" describes a complex collection of mechanisms. These memory mechanisms can be dissociated operationally into three primary domains: episodic, procedural, and working. To date, research on each facet of memory in EDs has typically been done in isolation, often with important methodological gaps, and has yielded mixed findings. We have attempted to

identify key limitations within each area of ED memory research. In addition, we emphasize the highly interactive nature of these memory systems and the importance of studying memory in a more integrative fashion. Such efforts may support the translation of memory research into an increased understanding of how EDs emerge and are maintained over time, to inform critically needed novel treatment and prevention efforts.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed for this manuscript.

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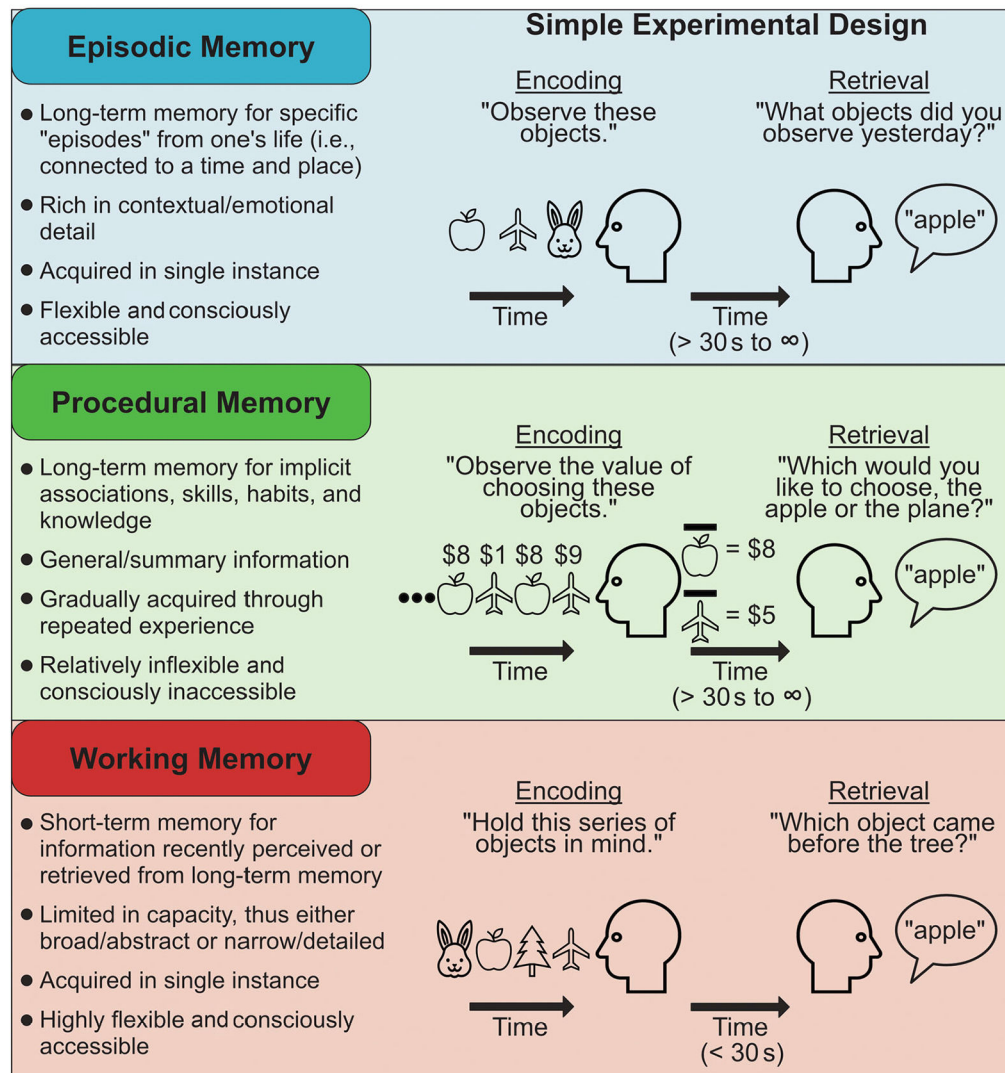
FIGURE 1.
Contrasting three broad domains of memory. Key features (left) and typical methods for testing (right) three domains of memory. This operational framework for distinguishing memory domains is based on differences in functional attributes and underlying neural systems (Henke, 2010; Howard & Cohen, 2004; Tulving, 2007), but its definitions here are broad for the sake of organizational clarity. Note that memory encoding refers to the representation of information so that it has the potential to influence thought and behavior in the future (i.e., memory creation). Memory retrieval refers to the processes that allow previously encoded information to influence thoughts or behavior in the present. In the procedural memory panel, the apple/airplane with a bar over it represents the average (i.e., generalized) value of the item.
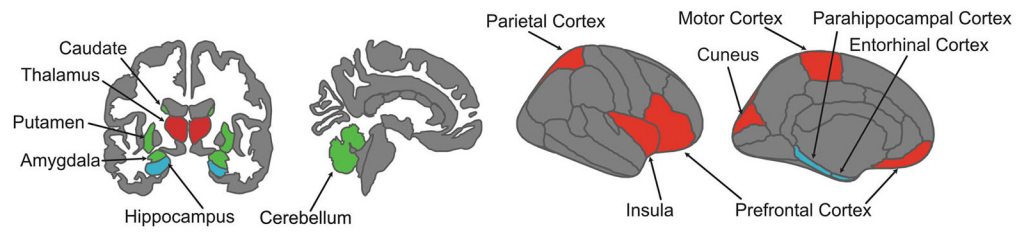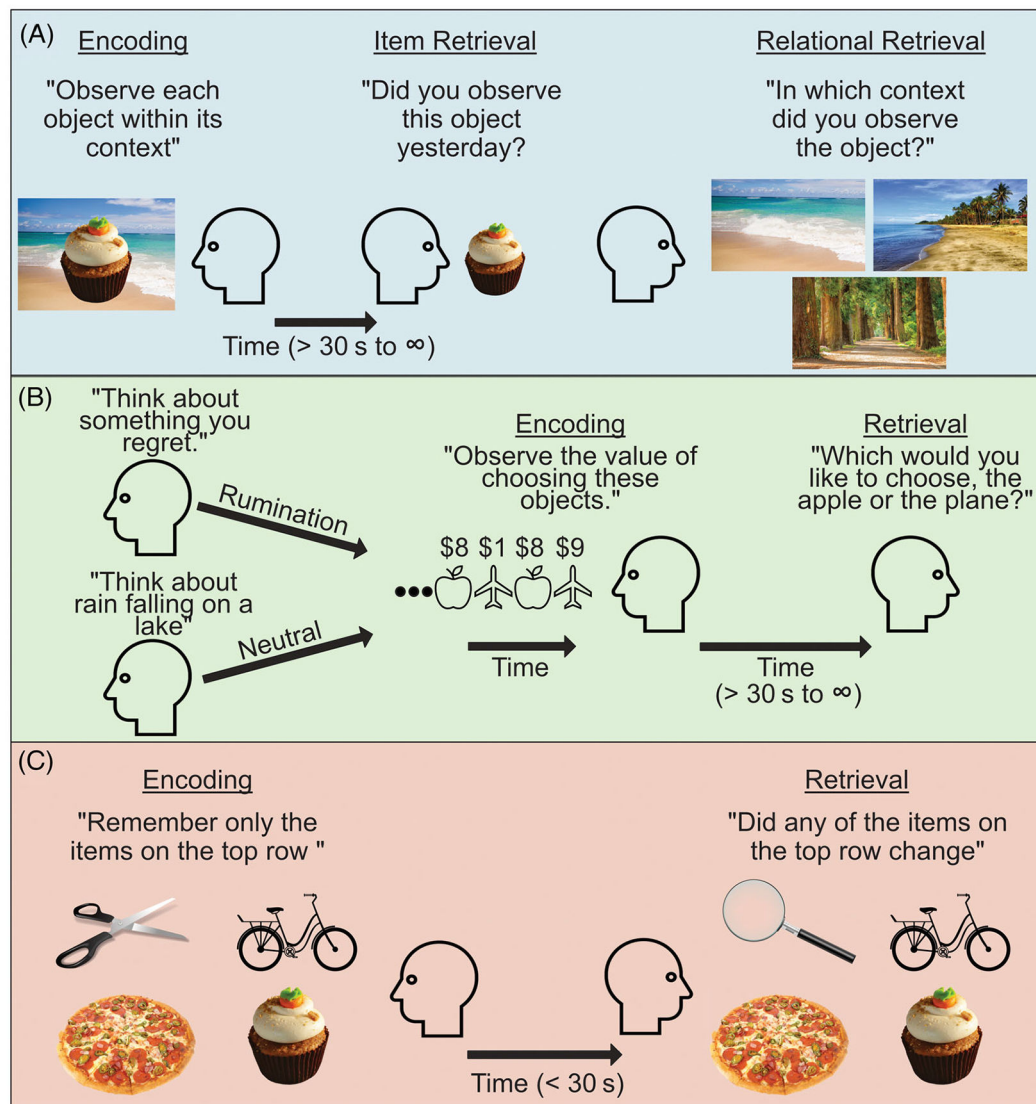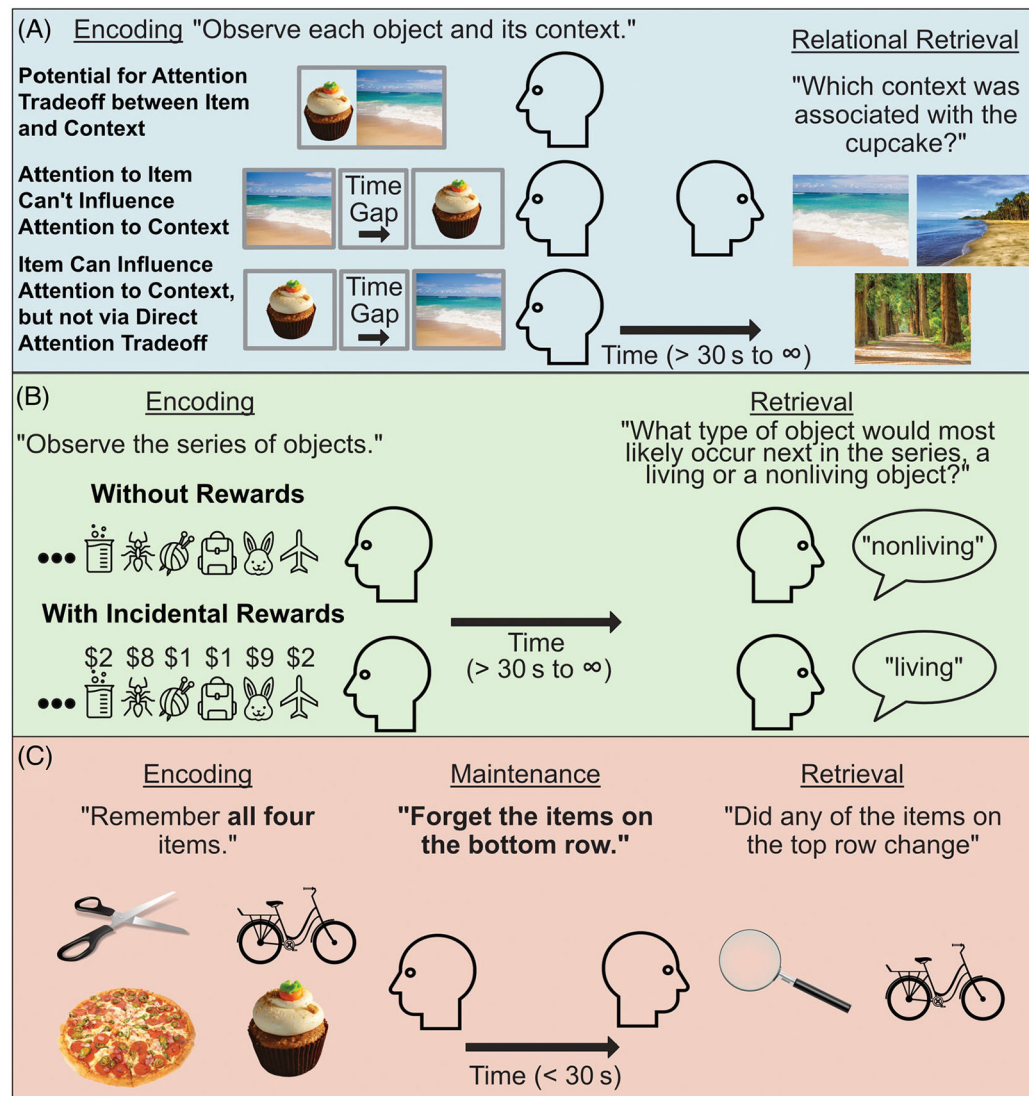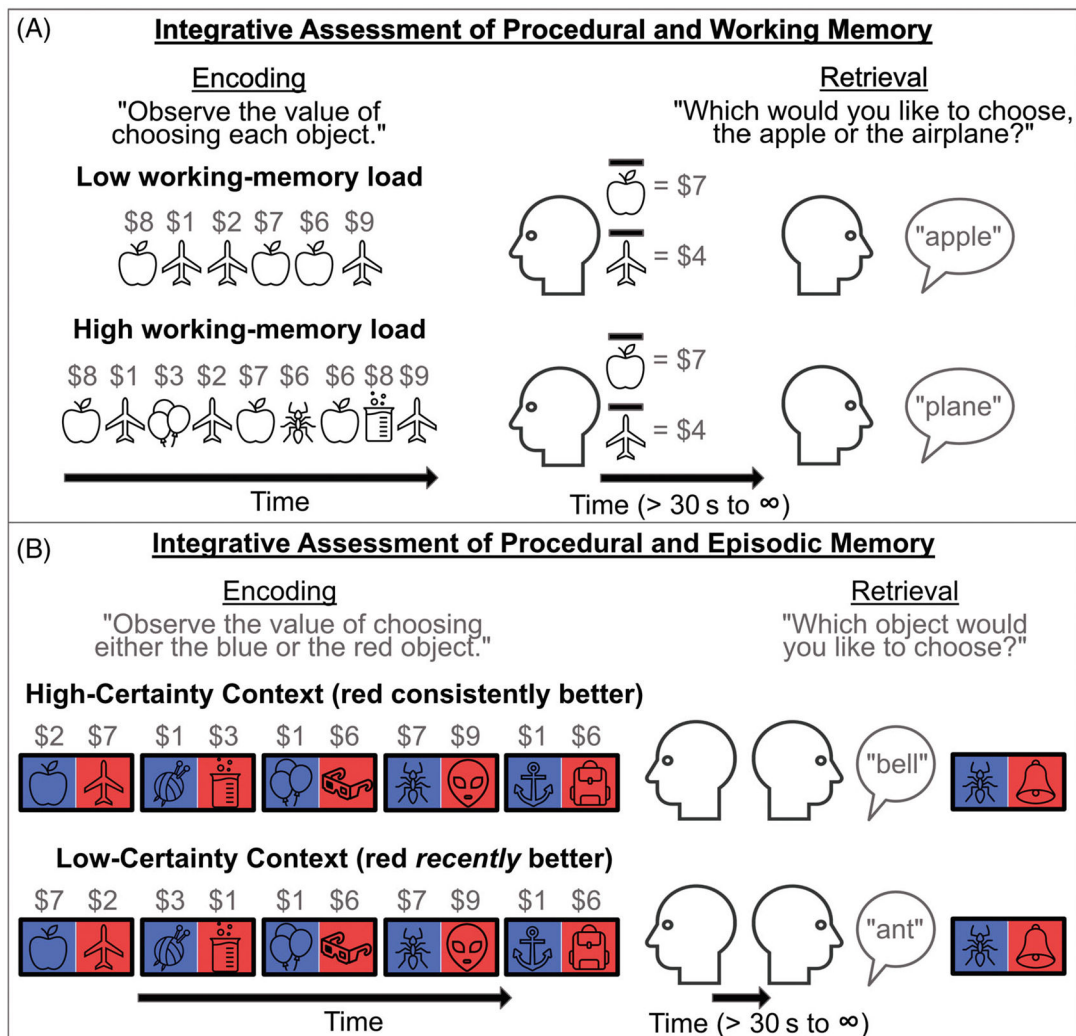
FIGURE 2.

Neuroanatomy of memory domains. A given brain region may contribute to multiple memory systems. However, episodic, procedural, and working memory depend on somewhat anatomically distinct networks (Rottschy et al., 2012; Sherman et al., 2023). Working memory is reliant upon inferior, superior, and medial frontal regions, parietal and insular cortices, and the thalamus (regions in red). Procedural memory function is supported by the dorsal striatum (regions in green), whilst episodic memory relies upon medial temporal lobe structures, including the hippocampus, parahippocampal gyrus, and entorhinal cortex (regions in blue). Given the fairly distinct anatomical systems supporting different types of memory, neuroimaging approaches (e.g., fMRI, MEG, and EEG), may be useful in elucidating the particular memory alterations that exist in EDs, as well as indicating targets of interventions to address these alterations.

FIGURE 3.

Examples for progressing research on each domain of memory separately. (a) Episodic item memory (for the cupcake) may be successful, while relational memory for the context the item was encountered in can be specific (beach on left), general (beach on right), or failed (forest) (Goldfarb et al., 2020). (b) Procedural memory can be influenced by cognitive or affective states. For example, a ruminative state can impair procedural memory and thus potentially impair adaptive behavior (Hitchcock, Fried, & Frank, 2022). (c) Working memory is useful not only when it maintains information important to current goals (items in top row), but also when it successfully filters out information that is irrelevant to current goals (food items on bottom row) (Stout et al., 2015).

FIGURE 4.
Examples of dissociating memory subprocesses. (a) Multiple processes during encoding, storage, and/or retrieval could influence episodic relational memory. One simple mechanism could be imbalanced attention (i.e., to disorder-relevant cues) during encoding. This could be tested by varying the timing and order in which related information is encoded (Forester & Kamp, 2023). (b) Alterations in reward-based procedural memory could reflect differences in, for example, reward sensitivity or the ability to incrementally abstract statistical information (e.g., the relative probabilities of living and non-living objects). In this task, individuals especially sensitive to reward may be inappropriately biased by incidental associations with reward, while learning normally in a context without rewards (McGuire et al., 2014). (c) Working memory problems could occur, for example, due to impaired storage of task-relevant information or a failure to control access to working memory during either encoding or retrieval (see Figure 3c). But, it could also be due to an inability to remove no-longer-relevant information from working memory during storage (Lewis-Peacock et al., 2018).

FIGURE 5.

Examples of integrative assessments of memory across memory domains. (a) Simplified task design to study the joint influence of procedural and working memory on decision making. The high working-memory load condition includes a greater number of unique stimuli, and more time in between repetitions, which taxes working memory. Based on procedural memory alone, however, the choice should be the same, because the average reward value for the apple/airplane is the same in both conditions. Differences in choice may therefore reflect the influence of working memory (Collins et al., 2014). (b) Simplified task design to study the joint influence of procedural and episodic memory on decision making. At the time of retrieval, procedural and episodic memory may have different preferences: procedural memory should favor the novel red object because red has recently been more rewarding (incremental generalization), while episodic memory might favor the ant because the ant was previously associated with a high reward (single instance detail). When certainty is low (due to volatility in whether red or blue is more rewarding), behavior may be guided more by episodic memory, even if this is maladaptive (Nicholas et al., 2022).

TABLE 1

Hypothetical case examples highlighting likely relationships between memory and eating disorders.

Case 1 clinical notes	Case 2 clinical notes	Case 3 clinical notes
Amanda is a 22-year-old female with anorexia nervosa. Amanda continues to recall an idealized view of the onset of her eating disorder (e.g., "when I first started restricting, I felt really great, lost a bunch of weight, and people commented on how good I looked.") which drives continued attempts to restrict, despite awareness that the behavior is harming her. Additionally, when her therapist prompts her to imagine herself in the future, she struggles to imagine a life either with or without her eating disorder. Therefore, she struggles to access salient, future-focused motivation to change her behavior.	Patrick is a 29-year-old male presenting for treatment of binge-eating disorder. Patrick describes that, 8 years ago, he began binge eating because it helped him relax and experience some pleasure when he was feeling sad or lonely. However, he says that now, binge eating rarely provides him any relief, and usually makes him feel even worse. Despite this, he feels a strong and automatic need to eat whenever he is feeling sad, and this usually turns into a binge-eating episode.	Yvonne is an 18-year-old female with bulimia nervosa. Yvonne explains that when a thought about food gets into her mind, it is difficult to get it out, even when there is no food around. She notes that, as a result, it is often difficult to think about anything else. For example, she describes that her long-term goals seem to fade from her mind, and she has trouble engaging fully with her environment (e.g., when spending time with friends).
Memory in Case 1	**Memory in Case 2**	**Memory in Case 3**
Memory allows recollecting the past and imagining the future. See especially the sections "Episodic Memory" and "Episodic Memory in EDs."	Memory allows behaviors to become relatively automatic, driven by internal or external cues. See especially the sections "Procedural Memory" and "Procedural Memory in EDs."	Memory allows actively maintaining and utilizing information in mind to guide attention and behavior. See especially the sections "Working Memory" and "Working Memory in EDs."