Memory and creativity: A meta-analytic examination of the relationship between memory systems and creative cognition

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Conflict of Interest

There are no conflicts of interest to be declared.

Data and Code Availability

All data and code are publicly available through the Open Science Framework. Available at https://osf.io/kudvy/?view_only=cd19b0a438a4486b8b5a0dab39339e1d.

Abstract

Increasing evidence suggests that specific memory systems (e.g., semantic vs. episodic) may support specific creative thought processes. However, there are a number of inconsistencies in the literature regarding the strength, direction, and influence of different memory (semantic, episodic, working, and short-term) and creativity (divergent and convergent thinking) types, as well as the influence of external factors (age, stimuli modality) on this purported relationship. In this meta-analysis, we examined 525 correlations from 79 published studies and unpublished datasets, representing data from 12,846 individual participants. We found a small but significant (r = .19) correlation between memory and creative cognition. Among semantic, episodic, working, and short-term memory, semantic memory, all correlations were significant, but semantic memory—particularly verbal fluency, the ability to strategically retrieve information from long-term memory—was found to drive this relationship. Further, working memory capacity was found to be more strongly related to convergent than divergent creative thinking. We also found that within visual creativity, the relationship with visual memory was greater than that of verbal memory, but within verbal creativity, the relationship with verbal memory was greater than that of visual memory. Finally, the memory-creativity correlation was larger for children compared to young adults despite no impact of age on the overall effect size. These results yield three key conclusions: 1) semantic memory supports both verbal and nonverbal creative thinking, 2) working memory supports convergent creative thinking, and 3) the cognitive control of memory is central to performance on creative thinking tasks.

Keywords: semantic memory, working memory, creative cognition, divergent thinking, convergent thinking

Public Significance Statement

We synthesize over 50 years of research on creativity and memory to clarify their relationship. Our findings indicate creativity is positively related to memory, with semantic memory supporting both verbal and visuospatial creativity. People's ability to think creatively is therefore reliably related to their ability to selectively retrieve information from long-term memory. Our findings have implications for education and interventions aimed at fostering creative thinking.

Introduction

General Overview

The act of remembering is an attempt to retrieve concepts or events that have been learned or experienced at some point in the past. In contrast, generating creative ideas and discoveries involves combining learned concepts into new information and perspectives that were not previously apparent (Stein, 1989). How does remembering the past impact creative thinking? While at first glance memory and creativity may appear distinct, creative thought is often conceptualized as a high-level cognitive ability that is supported (or scaffolded) by "lower-level" cognitive processes, including memory, attention, and cognitive control (c.f., Abraham, 2014; Benedek & Fink, 2019; Finke et al., 1992). Understanding the nature of creative thought ultimately requires mapping relevant underlying constructs, including identifying how and when memory may support or constrain creative thought. At the same time, examining the memory-creativity link provides critical insight into consequences and higher-level functions of different memory systems (e.g., the episodic system supports both remembering the past and imagining the future; Schacter & Addis, 2007b).

Yet studying the memory-creativity relationship is a complex endeavor: there are many types of memory (e.g., semantic, episodic, working, short-term) and creativity (e.g., divergent, convergent thinking) that can be elicited and influenced depending on the demands of a given task. Additionally, while classic creativity theories assume a central role of memory in generating creative thoughts (Mednick, 1962), memory is also error-prone, and it can act as a source of interference—particularly when people are reminded of old and unoriginal ideas. Further, the relationship between memory and creativity can also be influenced by individual factors such as age (e.g., Arenberg, 1973; Hess, 2005; Palmiero et al., 2017) or task-specific factors such as stimulus modality (verbal vs. visuospatial response format; Chrysikou et al., 2016; Farah et al., 1989; Freides, 1974; Penney, 1989). Therefore, understanding the relationship between memory and creativity must involve defining the type of memory and creativity under investigation, as well as task parameters and individual differences that can influence the strength and direction of the relationship.

Here, we assess the links between memory and creativity by examining how each memory type uniquely relates to creative performance across a wide range of task contexts. Specifically, our review focuses on the following memory systems: *semantic memory* (a measurement of verbal ability, concepts, and their relations; Collins & Loftus, 1975), *episodic memory* (memory for unique experiences; Tulving & Patterson, 1968), *working memory* (temporary storage and manipulation of information; Baddeley & Hitch, 1974), and *short-term memory* (holding limited information in a temporarily accessible, non-manipulated state; Atkinson & Shiffrin, 1968). Regarding creativity, our review focuses on *divergent thinking* (solving open-ended problems with multiple solutions; Guilford, 1950) and *convergent thinking* (solving problems with only one correct solution; Runco et al., 2010). Together, we leverage meta-analytic tools to identify which memory systems reliably support specific modes of creative thought, thus providing clarity on over 50 years of cognitive research on creativity.

Overview of "Domain-General" Creativity Tasks and Metrics

Although the study of creativity is a broad and diverse field of research, the study of "domain-general" creativity—the ability to come up with ideas and solve problems that do not require domain-specific knowledge or expertise—has converged on a handful of measures to assess divergent and convergent creative thinking. One of the most common measures of divergent thinking is the Alternate Uses Task (AUT; Torrance, 1972), which requires people to think of unusual uses for everyday objects. AUT scores can reflect the number of ideas generated (fluency; Runco et al., 2011), the variety of ideas across categories or themes (flexibility; Guilford, 1968; Runco & Okuda, 1991), and the novelty (statistical infrequency or quality) of an idea (Wallach & Kogan, 1965), among others. Divergent thinking tasks have shown evidence for predictive validity, including moderate to large correlations with real-world creative achievement (Beaty et al., 2018; Jauk et al., 2014). Convergent thinking is often assessed with the Remote Associates Test (RAT; Mednick, 1962), which presents a triplet of apparently unrelated words (e.g., cream, skate, water) and requires people to find a fourth word that conceptually unites them (e.g., ice). Scoring the RAT and other convergent thinking tasks typically involves simply counting the number of problems correctly solved. Convergent thinking tasks can be solved either by analysis or insight. Analysis is the deliberate search of a problem space to find solutions (Ericsson & Simon, 1998; Kounios et al., 1987; Newell & Simon, 1972), whereas with insight, a solution emerges spontaneously into awareness (i.e., the "aha" experience; Metcalfe & Wiebe, 1987; Smith & Kounios, 1996). However, divergent and convergent creative thinking are both susceptible to fixation, or a mental block to problem solving (Smith & Blankenship, 1991.) Despite increasing attempts to map the cognitive mechanisms of divergent and convergent creative thinking, the roles of specific memory systems in specific modes of creative cognition remains inconclusive. Below, we synthesize previous research efforts toward this goal.

Explicit Long-Term Memory and Creative Cognition

Semantic Memory and Divergent Thinking

Semantic memory, or the organization of facts and concepts into networks, is embedded in classic theories of creative cognition. According to the associative theory (Mednick, 1962), creativity involves combining weakly related, remote concepts in semantic memory into novel and useful ideas, a process that is thought to occur through spreading activation (Collins & Loftus, 1975). On this view, as the relative “semantic distance” between two concepts increases, so does the likelihood a conceptual combination will be perceived as creative. The associative theory also suggests that highly creative individuals have a more efficient, “flat” associative hierarchy (numerous and weakly related associations to a given concept) compared to less creative people, who have more “steep” associative hierarchies (few, strong associations to a given concept; Mednick, 1962).

The associative theory has received support from empirical investigations linking individual semantic memory structure to creative task performance, particularly divergent thinking. For example, the semantic networks of highly creative individuals, defined by divergent thinking performance, have higher connectivity (the extent to which two neighbors of a node in a network will be neighbors), shorter path length (average number of steps (edges) between any pair of nodes in a network), and fewer subcommunities (subcategories, or smaller networks, within the overall network) than less creative individuals (Kenett et al., 2014, 2018). That is, denser, highly connected, and less modular networks facilitate more efficient activation spread beyond closely connected (unoriginal) semantic concepts to more remote ones (Kenett et al., 2014, 2018), which in turn leads to the formation of creative ideas (Mednick, 1962; Schilling, 2005). Highly creative individuals have also exhibited a more complex lexical network structure, and they tend to activate a wider range of associations, potentially increasing the number of novel ideas from which to choose (Gruszka & Necka, 2002; Kenett et al., 2018, 2018).

Further support for associative processes in creative thought comes from studies of the serial order effect (Parnes, 1961; Ward, 1969), a phenomenon in which idea production often follows a temporal tendency where ideas become less frequent and more original over time during divergent thinking tasks (Beaty & Silvia, 2012). Initially high idea fluency is attributed to activating the dense semantic neighborhood directly surrounding the stimuli prompt (e.g., a brick, during the AUT) and producing responses similar to the prompt (Gilhooly et al., 2007). Then, as spreading activation unfolds with time, originality increases later in the task, when distant concepts within the semantic networks can be reached (Collins & Loftus, 1975; Mednick, 1962).

Alongside such passive activation spread, contemporary theories of semantic memory also emphasize the importance of top-down, strategic, and controlled processes to guide memory retrieval (Rosen & Engle, 1997; Unsworth & Engle, 2009). Indeed, there is now considerable evidence linking creative cognition to aspects of controlled semantic retrieval, with several studies reporting positive effects of verbal fluency (a measure of sematic retrieval ability) on divergent thinking ability (Benedek et al., 2012; Forthmann et al., 2019; Gilhooly et al., 2007; Silvia et al., 2013). For example, category fluency tasks require people to produce as many unique words as possible within a semantic category (e.g., animals), and phonological fluency tasks require people to produce as many unique words starting with a given letter (e.g., F, A, and S); the tasks are scored by summing the unique/correct words (Shao et al., 2014). Given the close resemblance in task requirements for verbal fluency and divergent thinking tasks—both involve open-ended retrieval from memory—classic models of intelligence have viewed divergent thinking as a lower-level factor of broad retrieval ability (McGrew, 2009). A critical distinction, however, is that divergent thinking tasks often consider the quality of response, whereas canonical verbal fluency tasks only consider the number of responses. Together, top-down retrieval strategies are thought to facilitate divergent creative thinking, in addition to the aforementioned passive process of spreading activation.

While access to semantic memory can facilitate divergent thinking, prior knowledge can also constrain creative thought. Indeed, the semantic system is organized to facilitate efficient and appropriate linguistic functions, many of which do not call for creativity. Within the spreading activation framework (Collins & Loftus, 1975), one must overcome strongly activated semantic interference to generate a creative response, as reflected in the beginning stages of the serial order effect (Beaty & Silvia, 2012; Christensen et al., 1957). One type of interference associated with semantic retrieval is functional fixedness, whereby stereotypical object information impedes generating novel ideas during creative problem solving (Duncker, 1945), including on open-ended tasks (Glucksberg & Weisberg, 1966) such as the AUT (Chrysikou et al., 2016). Further, increased knowledge can lead to the fan effect (Anderson, 1974), whereby increasing knowledge about concepts leads to increased interference from related information (Beaty et al., 2019). Although the fan effect is known as an episodic phenomenon, a semantic analog—increasing associative elements linked to a given cue—has been shown to impact the quality and quantity of responses on the AUT: low-association AUT cues yield higher originality but less fluency than high-association AUT, potentially due to less interference from closely-related concepts in semantic memory (Beaty et al., 2019). Thus, semantic memory has shown both costs and benefits to divergent creative thinking.

Semantic Memory and Convergent Thinking

The semantic system has also been implicated in convergent thinking. The RAT was constructed in such a way that only one solution is possible and that the first solution is commonly incorrect, thus requiring one to overcome the incorrect solution and identify the correct, "remote" association (Akbari Chermahini & Hommel, 2012). Spreading activation (Collins & Loftus, 1975) accounts of the RAT (Smith et al., 2013) suggest the cue words activate close associates in semantic space, and the activation spreads until people ultimately converge on a solution. If the solution to a RAT problem readily comes to mind, then the cues are considered to be "closer" together in the underlying network. According to this research (Smith et al., 2013), the RAT can be solved using two semantic search strategies. First, participants will select a set of possible answers constrained by just one word from the triplet at a time. Second, they'll adopt a local search strategy and make new guesses based in part on their previous guesses (Smith et al., 2013). This semantic search approach also applies to other cognitive tasks such as generating hypotheses (Thomas et al., 2008) and analogies (Forbus et al., 1995). If this search process is biased in any way, such as forcing participants to respond quickly, then high-frequency words are produced even if they are not correct (Gupta et al., 2012). Successful convergent creative thinking is therefore thought to require bypassing high-frequency responses that passively activate in semantic space via spreading activation.

In contrast to passive activation, another line of research suggests individuals take a more controlled, top-down memory search approach when problem-solving known as information foraging. Foraging theory was first applied to non-human animals searching for food (Stephens & Krebs, 1986), and it has since been adopted to explain information foraging in cognitive systems (Hills et al., 2012; Pirolli, 2007). Foraging has specifically been used to describe semantic memory search behaviors when solving creative problems, such as the RAT. Specifically, the three RAT cues may activate adjacent semantic neighborhoods and eventually intersect. Information within this intersection is activated more strongly than the individual neighborhoods, but not to the point where individual cue-specific items would get excluded. An optimal memory forage would involve focusing one's search on the intersection of the cues 'semantic neighborhood to maximize the difference in activation between targets and distractors (Davelaar, 2015). In contrast, when completing a verbal fluency task (e.g., listing animals), search behavior typically involves staying within a "patch," or neighborhood cluster, until it is exhausted (Hills et al., 2012). Searching the intersection of a RAT triplet is particularly advantageous when the target is weak and cue patches contain strong interference (Davelaar, 2015). Thus, compared to passive activation spread and controlled retrieval, memory foraging may allow one to intentionally bypass distractors, allowing more efficient retrieval of the target solution.

On the other hand, more spontaneous, insight-based problem-solving is thought to be the result of using shortcuts (or creating links) between semantic concepts when searching semantic memory (Schilling, 2005). One study (Samsonovich & Kuznetsova, 2018) attempted to map memory search processes when solving classic insight problems (DeYoung et al., 2008) and found people take a less linear approach through semantic concepts, particularly at the very end of the task—just prior to the insight experience—compared to moving linearly towards a single solution (Samsonovich & Kuznetsova, 2018). These findings suggest the anticipated end of an insight problem is enough to alter a semantic search path. Notably, performance on classic insight problems has shown questionable validity evidence—including near-zero correlations reported between insight problem solving and creative achievement (Beaty et al., 2014)—so the generalization of such findings to real-world creativity is currently unclear.

Similar to the relationship between semantic memory and divergent thinking, semantic memory can also lead to mental fixation and impede problem solving (Duncker & Lee, 1945; Maier, 1931). For example, simply exposing participants to inappropriate or misleading semantic associates can impair performance on the RAT, leading to fixation (Smith & Blankenship, 1991). People also tend to naturally fixate on salient but incorrect solutions (e.g., high-frequency words), a phenomenon that can be redirected with clues and other types of priming (Vul & Pashler, 2007). Therefore, bypassing inappropriate ideas to formulate new and creative ones appears to be relevant to problem solving (Storm et al., 2011). Convergent thinking is also susceptible to negative transfer, which is when prior learning causes poorer subsequent performance. For example, when the test words of RAT problems (e.g., cottage, Swiss, cake) are paired with conceptually related words (e.g., hut, chocolate, icing) that are unrelated to solutions (e.g., cheese), performance on the RAT decreases due to fixating on what had recently been learned (Beda & Smith, 2018). Bypassing or forgetting fixation-inducing semantic associates thus seems to be important for solving creative problems in this task (Storm et al., 2011). Yet the literature is still mixed on the broader role of semantic memory in convergent creative thinking, particularly regarding whether individual differences in semantic memory abilities (e.g., verbal fluency) reliably predict performance on convergent thinking tasks, such as the RAT.

Episodic Memory and Divergent Thinking

Although a majority of research on memory and creativity has focused on the semantic system, recently, researchers have begun to explore the potential role of episodic memory in the creative process. Episodic memory retrieval is considered to be a *constructive process*, wherein past events are reconstructed by piecing together individual-stored memories of people, contexts, and actions. The constructive episodic simulation hypothesis (Schacter & Addis, 2007a, 2007b) suggests episodic memory provides a source of details for the retrieval of past events. The hypothesis also contends that the constructive nature of the episodic memory system allows for the recombination of such details into a simulation of a novel event, like when one imagines future experiences that have not yet occurred (Schacter & Addis, 2007a). There is considerable evidence demonstrating an overlap between memory retrieval and imagination, including neuroimaging studies showing a substantial overlap in the brain regions engaged during tasks involving episodic retrieval and future simulation (Addis et al., 2009; Schacter et al., 2012; Szpunar & Schacter, 2018). Regarding creativity, more recent evidence has demonstrated individuals sometimes draw on episodic memories when performing divergent thinking tasks (e.g., Addis et al., 2016; Benedek, Jauk, Fink, et al., 2014; Duff et al., 2013; Ellamil et al., 2012), suggesting that the constructive nature of the episodic system may extend to creative tasks that similarly require flexibly combining information.

Divergent thinking may also benefit from direct recall of solution-relevant past experiences (Sheldon et al., 2011; Vandermorris et al., 2013). For example, participants who completed a think aloud version of the AUT occasionally drew on their personal past experiences when generating object uses, though this type of retrieval primarily occurred at the beginning of the task (Gilhooly et al., 2007). Drawing on previous experiences can also be beneficial for real-world creative problems, such as when experienced engineers educate novice engineers by sharing hints and previously used examples (Smith et al., 1993). Neuroimaging work has found that brain regions typically associated with episodic memory, including the hippocampus, show increased activity when performing divergent thinking tasks such as the AUT (Benedek, Jauk, Fink, et al., 2014) and when generating ideas on a drawing task (Ellamil et al., 2012). Researchers have also causally tested this relationship using inhibitory transcranial magnetic stimulation (TMS; Thakral et al., 2020). Specifically, inhibitory TMS to the hippocampus (via the angular gyrus)—core regions of the episodic system—led participants to produce fewer ideas on the AUT and fewer episodic details when imagining future events.

To assess the extent to which episodic memory contributes to divergent creative thinking, researchers have used an experimental procedure known as episodic-specificity induction (ESI). ESI trains participants in recollecting specific details of recent experiences (e.g., recalling the details of events from a video), which activates constructive retrieval mechanisms and thus can be used to test the involvement of the episodic system on a subsequent behavioral task. Across several studies, ESI has been found to boost the number of categories of appropriate uses, as well as episodic details (but not semantic details) in both young and older adults (Madore et al., 2014, 2015; Madore & Schacter, 2014), despite the observation that age-related differences in remembering the past extend to imagining the future (Schacter et al., 2013). At the individual level, performance on the AUT was shown to positively correlate with the amount of episodic details when younger and older adults imagine future personal scenarios (Addis et al., 2016). Further, an fMRI study of divergent thinking found that the ESI engages the hippocampus (Madore et al., 2019). Notably, however, the behavioral effects of ESI appear to be limited to increasing the number (i.e., fluency) of ideas on divergent tasks, and not their creative quality, indicating that episodic memory may make people more generative but not necessarily more original (Madore et al., 2016). Together, ESI studies lend further support to the constructive episodic hypothesis and the involvement of episodic memory in divergent thinking (van Genugten et al., 2021).

While the above research supports the role of episodic memory in divergent creative thinking, access to past experiences can also negatively impact creative output as well. For example, past experiences can bias people toward schemas that are not conducive to creativity. In the aforementioned study of engineers (Smith et al., 1993), biasing retrieval through conformity was found to render expert engineers unable to think beyond hints and examples to generate novel designs (Linsey et al., 2010). In another study (Smith et al., 1993), participants were asked to create new toys and new animals to inhabit a foreign planet. Participants who were shown pictorial examples prior to creation tended to conform to these examples, despite explicitly being asked to avoid using components of the examples. Such effects hold even if the examples contain design flaws, and participants will replicate such flaws even when explicitly instructed not to (Chrysikou & Weisberg, 2005). Thus, prior experience can be both a cost and benefit to divergent thinking.

Episodic Memory and Convergent Thinking

Episodic memory may also influence convergent thinking skills such as problem-solving (Roediger et al., 2007). For example, insights are typically incorporated into long-term memory, facilitating more efficient problem-solving in the future (Holland & Gallagher, 2006; Ludmer et al., 2011). One line of research suggests that solving RAT problems with insight necessitates a fundamental, unconscious changes to the initial problem representation (Ohlsson, 1992; Ohlsson, 2011). A separate line of research examines how episodic false memories, or erroneously remembering an experience that did not actually happen, interact with higher cognitive abilities such as problem-solving. In the Deese/Roediger-McDermott (DRM) paradigm, for example, participants are given word lists (e.g., bed, rest, awake) whose members are all associates of an unpresented critical lure (e.g., sleep). Despite having never been presented during the study phase, participants often falsely remember the critical lure as being presented in the list (Deese, 1959; Roediger & McDermott, 1995). Of relevance to creativity, researchers primed RAT performance with a preceding DRM list whose critical lure was also the solution to one of the RAT problems (Howe et al., 2010). They found that when the critical lure was falsely recalled in the DRM, RAT problems were solved more often and faster than when problems were not primed. Critically, there were no differences between primed and unprimed RAT problem solution rates and reaction times when the critical lure was not falsely recalled. These results demonstrate that episodic false memory can influence performance on creative problem-solving tasks.

On the other hand, previous experiences can negatively influence how one solves a single-solution problem. For example, in the classic “water jug problem” (the Einstellung effect; Luchins, 1942), participants were required to take jugs filled with water and find a sequence of pouring that would produce a prespecified amount of water in each jug. After the researchers performed a demonstration, participants would continuously attempt to use the solution they saw demonstrated, even when it was not practical. Such experience-induced inflexibility can become an even greater problem when someone is an expert in a topic: coming up with new ideas may be challenging simply because one knows how things should be done (De Bono, 1968). Further, even if one generates a solution via insight, memory for the solution decays (Ormerod et al., 2002). Thus, moving beyond previous experiences stored in memory appears to be important for creatively solving single-solution problems.

Explicit Short-Term Memory and Creative Cognition

Working Memory and Divergent Thinking

A longstanding question in the creativity literature concerns the role of attention control via working memory in creative thought. Does creative thinking require focused attention, or rather a relaxation of attention control? The controlled-attention theory of working memory (Engle, 2002) suggests working memory capacity contributes to higher order cognition, such as language comprehension (King & Just, 1991) and reasoning (Kyllonen, 1996). On this view, attentional control is critical to facilitating more efficient maintenance of task-relevant information in working memory (Drabant et al., 2006), efficient switching between tasks (Baddeley et al., 2001), and sustaining general attention (Unsworth & Engle, 2009)—abilities strongly related to fluid intelligence, or the ability to solve novel problems (Unsworth et al., 2014). Although working memory plays a critical role in such cognitive abilities, the contribution of working memory to divergent thinking is less clear.

The controlled attention theory has been adopted by some creativity researchers. According to this theory, attention control facilitates divergent thinking by directing search processes away from strong, common associates (Beaty et al., 2014; Benedek et al., 2014; Jauk et al., 2013). In other words, controlled attentional processes may intervene in an otherwise spontaneous process of spreading activation within semantic memory networks by suppressing unoriginal mnemonic information (Frith et al., 2021). Additional findings suggest working memory capacity supports divergent thinking through cognitive persistence, or sustained task-relevant processing that is robust to proactive interference (De Dreu et al., 2012). In addition, because creativity appears to involve pulling concepts from long term-memory into working memory, which are then manipulated to find a solution, working memory may allow for the discrimination of task-relevant and -irrelevant information (De Dreu et al., 2012; Unsworth & Engle, 2009). Together, working memory has been hypothesized to benefit divergent thinking through attentional control mechanisms that manage and direct complex search processes.

A number of individual differences studies have investigated links between working memory, executive functions, and divergent thinking (e.g., Beck et al., 2016; Lee & Therriault, 2013; Menashe et al., 2020; Vartanian et al., 2013). In one study on divergent thinking, researchers (Benedek, Jauk, Sommer, et al., 2014) examined three executive functions utilized within working memory: shifting, updating, and inhibition. They found shifting (switching between different tasks and mental sets) did not relate to divergent thinking, but updating (monitoring and revising working memory content) and inhibition (suppressing dominant but irrelevant response tendencies) showed significant and positive associations with divergent thinking originality. The researchers concluded working memory (as assessed by updating tasks) uniquely contributes to divergent thinking (Benedek, Jauk, Sommer, et al., 2014). On the other hand, several studies found no specific relationship between working memory capacity and divergent thinking tasks (Furley & Memmert, 2015; Smeekens & Kane, 2016). Still others maintain top-down control actually harms divergent thinking because it restricts mind wandering, which can sometimes facilitate creativity, particularly during incubation periods (Gable et al., 2019; Leszczynski et al., 2017). These conflicting findings motivate a meta-analytic investigation into the relationship between working memory capacity and divergent thinking.

Working Memory and Convergent Thinking

Because working memory involves the storing and processing of information online (Baddeley, 1986), and given its strong association with novel problem solving (i.e., fluid intelligence; Shelton et al., 2010), one might assume working memory is relevant for creative problem-solving (Ericsson & Simon, 1998). Notably, although early reports examining working memory's benefit to convergent thinking were mixed (see Wiley & Jarosz, 2012 for a review), recent studies point to a stronger relationship between the two constructs (Chein & Weisberg, 2014; Chuderski & Jastrzębski, 2018; Lee et al., 2014). The executive-attention framework suggests maintaining information in working memory is critical to success across higher-order cognitive domains by sustaining attentional focus in the face of distraction (Kane & Engle, 2002). In the context of convergent problem-solving, working memory is hypothesized to help focus attention, narrow search through a problem space, and inhibit distractions. This ability may be particularly useful, since such problems typically yield initial failed attempts at finding a solution, requiring subsequent iterative attempts to more remote solutions. For example, when reaching an impasse in solving, one might make incremental modifications by back-tracking and systematically searching semantic space. This search process, enabled in part by working memory, ultimately results in solutions that are generally weakly related to their initial representations and hence more creative (Kaplan & Simon, 1990).

The Present Study

Decades of research has sought to characterize the relationship between memory and creativity. And yet, the field remains marked by inconsistent findings, with no clear view on which memory systems reliably support creative cognition. For the field to progress, a systematic analysis of the literature is necessary. Despite longstanding interest in the topic of memory and creativity, to our knowledge, only two book chapters have provided qualitative overviews (Nęcka, 1999; Stein, 1989). Critically, no attempt has been made to quantitatively summarize the memory-creativity relationship. Here, we conduct a systematic meta-analysis to synthesize and quantify the overall association between memory and creative cognition. Across 50 years of research, we aim to clarify the strength and direction of the memory-creativity relationship. We also examine whether any relationship is affected by memory system (episodic, semantic, short-term, working) and creativity type (convergent, divergent); we also examine whether other study-specific factors affect the strength of the relationship, such as stimulus modality of response (visual (e.g., drawing, selecting shapes), verbal (e.g., writing words, selecting multiple choice)) and participant age.

In our view, the psychology of creativity has matured to a point where a quantitative review of memory and creativity is warranted and necessary. There is now a critical mass of data available to reliably assess the memory-creativity relationship, and clarifying this association is critical to resolving persistent controversies in the field. Therefore, in this meta-analysis, we sought to answer the following questions:

1. What is the general relationship between memory and creative cognition (across all types of memory and creativity)?
2. If a general relationship between memory and creative cognition exists, is the summary effect size between constructs influenced by the type of memory (e.g., semantic) or creativity (e.g., divergent thinking)?
3. If a general relationship between memory and creative cognition exists, is the summary effect size influenced by study-specific factors, like age or stimulus modality (verbal versus visual)?

For transparency, we will first define and operationalize all variables to be used in subsequent analyses. *Semantic memory* will refer to a person's capacity to remember facts, meanings, and general knowledge about the world, including comprehension of characteristic item properties and the semantic labels used to describe them (Barsalou, 2003; Menon et al., 2002; Patterson et al., 2007; Quillan, 1966; Smith, 1978; Squire & Zola, 1998; Tulving, 1972). Specifically, semantic memory concerns representing and retrieving, or mentally operating on, stored information about the world that is abstracted from episodic experiences and is describable (e.g., not present to the senses; Barsalou, 2003; Menon et al., 2002; Patterson et al., 2007; Smith, 1978; Tulving, 1972). Common semantic memory tasks (Saumier & Chertkow, 2002) emphasize retrieving as many items as possible related to a specific cue (e.g., fluency tasks) and are typically scored by the total number of valid, unique responses provided.

Episodic memory will refer to the ability to remember personally experienced events (Baddeley, 2001; Craik, 2002; Ezzyat & Davachi, 2011; Hassabis & Maguire, 2007; Squire & Zola, 1998; Tulving, 1972, 1983, 1993, 2002). Specifically, episodic memory receives and stores spatial and temporal information (and spatial-temporal relationships) among events experienced between event boundaries for later retrieval (Hassabis & Maguire, 2007; Squire & Zola, 1998; Tulving, 1972, 1983, 1993, 2002). Episodic memories can be *recalled*, which is when the memory of stimulus items is evaluated without the presence of the to-be-remembered information available (e.g., "Tell me all the words you remember"), or *recognized*, when memory evaluation of stimulus items occurs in the presence of the to-be-remembered items (e.g., "Did you see this word previously?"; Tulving & Thomson, 1973). Common episodic memory tasks involve encoding stimuli (e.g., word lists, picture presentations) and a later recognition or recall phase. While these tasks can be scored on several types of metrics, we will focus on veridical memory "hits", which represents how much information during encoding was accurately remembered during retrieval.

Working memory will refer to the ability to maintain and manipulate a limited amount of information held in a highly accessible mental state (Cowan, 2008). Although not completely distinct from short-term memory, it is thought to uniquely function as an interface between perception, long-term memory, and action (Aben et al., 2012; Andrade, 2001; Baddeley, 2003; Baddeley & Hitch, 1974; Conway et al., 2007; Miyake & Shah, 1999). Recalling information from working memory requires engaging in an activity interleaved between the presentation of to-be-remembered information and recall (Unsworth & Engle, 2007). Working memory tasks involves the simultaneous demands of short, uninterrupted sequences of information for immediate recall (e.g., assessed via backwards digit span, complex span, n-back tasks) and are scored on the correct recognition or recall of one set of information.

Short-term memory will refer to the ability to temporarily hold and recall a limited amount of information in a highly accessible mental state, including sensory events, movements, and information from long-term memory (R. C. Atkinson & Shiffrin, 1971; Cowan, 1988, 2008; Kail & Hall, 2001). Short-term memory tasks often involve the presentation of short, uninterrupted sequences of information for immediate recall or recognition (e.g., serial recall tasks such as forwards digit span) and are commonly scored on the number or length of correctly recalled or recognized consecutively presented sequences of information.

Divergent creative thinking will refer to the ability to solve open-ended problems with multiple solutions (Guilford, 1950). This ability is often tested with ill-defined problems, where multiple solutions are often requested (Mumford & Gustafson, 1988) and are traditionally scored on the number of ideas generated (fluency; Runco et al., 2011), the variety of ideas across categories or themes (flexibility; Guilford, 1968; Runco & Okuda, 1991), and the originality (statistical infrequency or quality) of an idea (Wallach & Kogan, 1965), though labels may differ by researcher. Common divergent thinking tasks (e.g., Alternate/Unusual Uses Task, Torrance Test of Creative Thinking) are scored by fluency, originality, flexibility, cleverness, or uniqueness, variably operationalized by different researchers of the original studies presented here.

Convergent creative thinking is the ability to solve problems with only one correct solution (Runco et al., 2010). Convergent thinking tasks can be solved either by analysis or insight. Analysis is the deliberate search of a problem space to find solutions (Ericsson & Simon, 1998; Kounios et al., 1987; Newell & Simon, 1972), whereas with insight, a solution emerges spontaneously into awareness (i.e., the "aha" experience; Metcalfe & Wiebe, 1987; Smith & Kounios, 1996). Common convergent creative thinking tasks (e.g., Remote Associates Test, classic insight problems) are measured by summing the number of problems correctly solved.

Method

Power Analysis

To determine the feasibility of this meta-analysis, we conducted an a priori power analysis using the R package *metapower* version 0.2.0 (Griffin, 2020). Based on the current state of the literature, we expected that 40 studies would meet inclusion criteria with an average study size of 100 and moderate-large heterogeneity among effect sizes. Overall, we expected that the correlation between measures of creative cognition and memory would be small (i.e., $r = .25$). Under these expectations, power to detect a statistically significant summary effect size was 100%. For two-group moderator analysis (divergent vs. convergent thinking), power to detect group differences was 90.2%. Since power for subgroups is generally low for meta-analyses, we had no stopping rules and intended to include as many studies as possible to generate a representative dataset of the relevant literature (see Cuijpers et al., 2021; Griffin, 2021).

Literature Search

With the aim of adhering to transparent and rigorous psychological practices (Johnson, 2021), we identified, screened, and determined eligibility of empirical studies in accordance with all Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; (Page et al., 2021) guidelines, including the content checklist (see Supplemental File 1) and study search flow diagram. On April 21, 2020, we conducted searches using the online databases PsycINFO, PubMed, Web of Science, and Scopus (Bramer, 2017). Each search contained the following terms and Boolean operators: ((memory OR recollection OR familiarity OR recognition OR recall OR retrieval OR "verbal fluency") AND (creativity OR creative OR "divergent thinking" OR "convergent thinking" OR "idea generation" OR originality)). We collected peer-reviewed published/in-press research articles, preprints (e.g., unreviewed work posted to PsyArxiv, bioRxiv, etc.), and dissertations/theses. Additionally, we solicited relevant unpublished datasets using topic-relevant listservs and Twitter to reduce selective reporting bias. From these hits, we first removed duplicates, then applied our inclusion criteria in a sequential three-step screening procedure: title only screening, title and abstract screening, and full-text review. Finally, we conducted a manual reference screen by extracting the references of all articles meeting inclusion criteria from the database search and applied the same three step screening procedure. The entire study identification, screening, and eligibility process is shown in Figure 1. The review and protocol for this study were unregistered and were considered exempt by the XXX Institutional Review Board.

Study Selection

Inclusion and Exclusion Criteria

For inclusion, articles must have (1) administered at least one direct, observable measure of memory and one direct, observable measure of creativity; (2) administered memory and creativity tasks that reflect semantic memory, episodic memory, working memory, short-term memory, divergent creative thinking, and/or convergent creative thinking; (3) reported the correlation coefficient between memory and creativity performance (or information to calculate the correlation coefficient); (4) been published in English, and (5) included a neurotypical sample.

Articles were excluded if (1) memory or creativity tasks were measured via self-report or interviews from which a memory could not be verified in the lab (e.g., autobiographical memories for events purported to have been experienced outside of the lab); (2) performance could not be verified by a researcher, as is the case for tasks reflecting autobiographical memory, dream recall, prospective memory, etc.; and (3) the creativity task was domain-specific (e.g., musical).

Database Search

The searches from PsycINFO, PubMed, Web of Science, and Scopus were concatenated, and all duplicates were removed. All titles and abstracts were then screened for inclusion. This step was completed such that records were excluded only if there were clear examples of exclusion, such as the full-text record was not available, or it was non-empirical. After this, full-text articles were screened for the aforementioned primary inclusion and exclusion components. We used a double-screening approach where the first author and a research assistant completed all screening steps independently of each other. Inclusion disagreements were resolved by the second author.

Data Extraction

For each included study, we extracted values for the sample size and correlation coefficients between measures of creativity and veridical memory. Specifically, we extracted data computed from raw scores (e.g., summative totals) on semantic memory and convergent thinking tasks; recall or recognition for episodic, short-term, or working memory tasks; and fluency, originality, flexibility, cleverness, or uniqueness for divergent thinking tasks—all operationalized by the researchers of the original study.

When access to the raw data were provided (5 unpublished datasets), we calculated the correlation coefficient manually. Since meta-analysis of correlation coefficients are performed on Fisher's *r*-to-*z* transformation scores, we used the *metafor* package (Viechtbauer, 2010) to convert all study-specific correlation coefficients to Fisher's *z* scores with the respective variances. Many studies included more than one effect size that met inclusion criteria. To maximize and include as much data as possible, we accounted for this multilevel structure by coding each study and unique effect size.

Moderator Variables. To evaluate the influence of age-related variation among effect sizes, we extracted participant information on age (in years) for each study. Specifically, we extracted the average sample age relevant to each effect size. Additionally, to assess the influence of methodological variation among effect sizes, we extracted information related to the *type* of memory (semantic memory, episodic memory, short-term memory, working memory) and creativity (divergent thinking, convergent thinking), as well as the *paradigm modality* used to measure memory and creativity (i.e., verbal, visual).

Statistical Analysis

We used the *metafor* package version 2.40 for the statistical software R to analyze all data (R Core Team, 2020; Viechtbauer, 2010). To estimate a summary effect size for the correlation between memory and creative cognition, we fit a three-level model to partition the sampling variance of the observed effect sizes, between-study variability, and within-study variability. Unlike traditional univariate meta-analysis, this modeling approach allows for the inclusion of multiple effect sizes per study, while accounting for the interdependency among effect sizes within studies (Assink & Wibbelink, 2016; Cheung, 2014, 2019). To determine if there was significant between-study heterogeneity among effect sizes, we evaluated Cochran's Q and calculated the percentage of variation across studies that is not due to sampling variability (i.e., I^2), with values of 75%, 50%, and 25% reflecting large, moderate, and small degrees of heterogeneity (Higgins & Thompson, 2002). In the presence of moderate-large heterogeneity, we evaluated potential sources of heterogeneity through moderator analyses and sensitivity to small-study effects (e.g., publication bias).

Moderator Analyses

We extended the three-level model to evaluate the influence of sample- and methodological-related study characteristics, including sample age, type of memory, type of creativity, and paradigm modality. Since some studies did not report information for all moderator variables, we evaluated the influence of each moderator separately to maximize statistical power (Assink & Wibbelink, 2016; Cheung, 2014; Viechtbauer, 2010). Lastly, we only included a moderator category if there was a substantive cluster ($k > 5$).

Sensitivity to Small-Study Effects

To evaluate the sensitivity of meta-analyses to small-study effects, visual inspection of funnel plot asymmetry and the Egger's regression test are standard methods for evaluating the potential presence of publication bias (Egger et al., 1997). However, visual inspection is subjective and the Egger's regression test is not appropriate for multilevel data (Nakagawa & Santos, 2012). Therefore, to evaluate sensitivity of our meta-analytic estimates to small-study effects, we objectively evaluated funnel plot asymmetry by regressing our summary effect size estimate onto the study-specific standard errors. This method is conceptually identical to the Egger's regression test, but preserves the multilevel form (Nakagawa & Santos, 2012; see also Griffin et al., 2021). In the presence of statistically significant funnel plot asymmetry, we planned to conduct sensitivity analysis by excluding effect sizes that contributed to funnel plot asymmetry. Finally, to evaluate the potential risk of bias due to unpublished results, we evaluated the summary effect size with and without published data.

Results

Study Selection

The full study identification, screening, and selection process are displayed in Figure 1. In total, we included 525 effect sizes from 79 unique empirical articles and unpublished datasets (indicated by the studies listed in Table 1 (presented at the end of the document) and marked with an asterisk (*) in the Reference section) representing data from 12,846 individual participants. On average, each study included 6.65 effect sizes (*SD* = 9.45). Overall, the average study sample age was 22.09 (*SD* = 11.05). Table 1 reports the included studies 'sample sizes, study characteristics, participant demographics, memory type, creativity type, and paradigm modality.

Summary Effect Size

Overall, the effect size between creativity and memory was statistically significant and small in magnitude ($r = .19$, $se = .02$, 95% CI [.15, .22], $p < .0001$; see Figure 2). Consistent with our choice of a random-effects model, we also observed considerable heterogeneity among effect sizes ($Q = 1897.64$, $I^2 = 79.41\%$, $p < .0001$). Specifically, our three-level model revealed that 20.59% of the total variance was attributed to sampling variability, 19.96% was attributed to variation among effect sizes of the same study, and 59.44% was attributed to between-study variability. We evaluated potential sources of this heterogeneity with moderator analysis.

Moderator Analyses

Memory Type

While all memory types (semantic, episodic, short-term, and working memory) were related to creative cognition, the magnitude varied by type. Specifically, the summary effect size was strongly moderated by memory type (Q = 33.56, p < .0001). The largest correlation was found between creative cognition and semantic memory (r = .25), followed by working memory (r = .17), episodic memory (r = .16), and short-term memory (r = .15). Statistically, the correlation between memory and creative cognition was significantly larger for semantic memory compared to all other memory types, including working memory (b = -.08, se = .01, 95% CI[-.11, -.05], p < .0001), episodic memory (b = -.09, se = .03, 95% CI[-.15, -.03], p = .002), and short-term memory (b = -.10, se = .03, 95% CI[-.16, -.04], p = .003; see Figure 3 and Table 2). The correlation between semantic memory and creative cognition was not different across memory paradigm modality (verbal vs. visual; b = .34, se = .20, 95% CI[-.04, .72], p = .09). Additionally, we found that the summary effect size was moderated by episodic retrieval demands (i.e., recognition, recall, cued recall; Q = 8.91, p = .01). Specifically, the summary effect size was larger for cued recall compared to recognition (b = .10, se = .03, 95% CI[-.03, -.17], p = .003).

Creativity Type

Similarly, the summary effect size was moderated by creativity type (Q = 16.74, p < .0001). Specifically, the correlation between creative cognition and memory was different for convergent (r = .23) compared to divergent (r = .17) creativity tasks (b = -.06, se = .02, 95% CI[-.09, -.03], p < .0001). Since divergent thinking tasks evaluate numerous dimensions of creativity (e.g., fluency, originality, flexibility, cleverness, uniqueness), we also tested for moderation among these dimensions. We did not find evidence of significant variation across effect size metrics (Q = 3.96, p = .78).

Memory Type as a Function of Creativity Type

We also evaluated whether the summary effect size between creative cognition and memory was conditional on whether the creativity task was measuring either convergent or divergent thinking. We found that working memory was more strongly correlated with convergent thinking (r = 0.23) than divergent thinking (r = 0.15; p < .001), though we did not find a significant Creativity Type x Memory Type interaction (Q = 5.52, p = .14).

Age

Overall, the summary effect size was not moderated by average sample age (Q = 0.67, p = .41). Specifically, the average sample age was not significantly related to the strength of correlation between creative cognition and memory performance (b =.001, se = .001, 95% CI [-.002, .005], p = .41)

Paradigm Modality

The summary effect size was not moderated by paradigm modality of the memory task ($Q = 3.15$, $p = .08$). Overall, the summary effect size was similar for visual compared to verbal memory tasks ($b = -.03$, $se = .02$, 95% CI [-.06, -.003], $p = .08$). Similarly, the summary effect size was not different for visual and verbal creativity tasks ($b = -.002$, $se = .02$, 95% CI [-.04, .03], $p = .86$). These findings were qualified by a two-way interaction ($Q = 13.15$, $p = .0003$). Specifically, within visual creativity, the relationship with visual memory was greater than that of verbal memory, but within verbal creativity, the relationship with verbal memory was greater than that of visual memory. See Figure 3 for a visualization of these results.

Sensitivity to Small-Study Effects

We evaluated the influence of small-study effects on the overall summary estimate using a modified Egger's regression that preserves the multilevel structure of the data to quantify funnel plot asymmetry (Nakagawa & Santos, 2012). Overall, we found no evidence of significant plot asymmetry ($b = -.11$, $se = .37$, 95% CI [-.84, .61], $p = .76$; see Figure 4), suggesting that the results presented here were not impacted by small-study effects, including publication bias. In addition, there were 56 effect sizes that were from unpublished studies or datasets. We found that without these effect sizes, the overall summary effect was virtually identical ($r = .19$, $se = .02$, 95% CI [.16, .22], $p < .0001$).

Discussion

The present meta-analysis sought to quantitatively summarize the relationship between memory and creative cognition. To our knowledge, this is the first quantitative attempt to summarize over 50 years of research in the literature. Overall, we found a small positive correlation between memory and creative cognition. Importantly, this association varied as a function of the type of memory and creative thinking under investigation. Semantic memory ($r = .25$) shared the largest overall relationship with general creative cognition ~~than~~compared to all other memory types ($ps < .001$), convergent thinking ($r = .23$) shared a stronger relationship with general memory than divergent thinking ($r = .17$, $p < .001$), and working memory was more strongly correlated with convergent than divergent thinking ($p < .001$). Moreover, within visual creativity, the relationship with visual memory was greater than that of verbal memory, but within verbal creativity, the relationship with verbal memory was greater than that of visual memory. Our findings thus provide insight into the role of memory in creative thinking, addressing a longstanding question in the psychology of creativity regarding the relative importance of specific memory systems for creative cognition.

The general relationship between memory and creative cognition

Despite decades of research describing the relationship between memory and creativity, a consensus on the strength and direction of this relationship has never been reached. We synthesized 525 effect sizes from 79 unique empirical studies to quantitatively summarize the overall association (correlation) between memory and creative cognition. We found that better memory—averaged across semantic, episodic, working, and short-term memory—is related to higher creativity (collapsed across divergent and convergent thinking tasks). This suggests memory systems reliably support creative cognition. In addition, the magnitude of the effect size ($r = .19$) suggests memory and creativity have modest similarities, with substantial variance in creative ability left unexplained by memory ability alone. Additionally, follow up analyses showed that the modesty of the correlation can be attributed to the variance of memory and creativity type.

Impact of memory and creativity type on the relationship between memory and creative cognition

Semantic memory showed the largest correlation with creative cognition compared to all other memory types (episodic, working, and short-term). This finding provides some support for the classic associative theory (Mednick, 1962), which first suggested creativity involves connecting weakly related, remote concepts. However, given that semantic memory was primarily assessed with tasks involving goal-directed retrieval (e.g., verbal fluency), our findings are perhaps more consistent with a growing literature emphasizing the roles of strategic semantic retrieval ability in creative cognition (Avitia & Kaufman, 2014; Forthmann et al., 2019; Silvia et al., 2013). Importantly, the meta-analytic effect of semantic memory on creative performance was not moderated by creativity modality (verbal vs. visuospatial) and it was consistent across creativity type (divergent and convergent), indicating that semantic memory's role in creative cognition is broad and not limited to verbal tasks only. Thus, the ability to retrieve items from long-term memory reliably predicts creative performance across a diverse range of tasks. This result suggests that semantic memory is a cognitive system fundamentally supporting people's ability to think creatively.

Analyses also revealed that working memory was more strongly related to convergent than divergent thinking. While the effect size was modest, this finding is in line with previous work raising questions about whether convergent creative thinking tasks (such as the RAT) are measures of creativity or intelligence (Lee & Therriault, 2013). Recently, several latent variable studies have reported large correlations between RAT performance and working memory capacity, as well as other cognitive abilities such as fluid and crystallized intelligence (Chein & Weisberg, 2014; Lee & Therriault, 2013). Importantly, however, our meta-analysis could not disentangle the roles of insight vs. analytical problem solving, which have been shown to differentially relate to working memory (i.e., stronger working memory associations for analytical over insight; Fleck, 2008). Nevertheless, to the extent that the RAT and other convergent thinking tasks index creative thought, our meta-analytic finding emphasizes the importance of cognitive control processes that allow people to maintain and manipulate multiple items from memory in an active state to solve complex creative problems (Benedek et al., 2014). Future work may wish to examine other memory variables commonly examined alongside the RAT, such as false memories (e.g., Howe et al., 2010).

Notably, compared to convergent thinking, the contribution of working memory to divergent thinking was smaller, despite this being the most well-powered comparison in the analysis, with 179 effect sizes reported in the literature. On the one hand, relatively weaker relationship between working memory and divergent thinking may raise questions about the executive nature of divergent creativity; on the other hand, the finding may call for increased specificity in the field. Perhaps some executive functions relate to divergent thinking more strongly than others (c.f., Benedek et al., 2014). In other words, although working memory is a broad construct that tends to correlate with other higher cognitive abilities that relate to divergent thinking (e.g., fluid intelligence), the specific ability to update items in working memory—as indexed by complex span tasks—appears to be less relevant to divergent creativity compared to convergent thinking.

We also found that episodic memory was associated with divergent thinking to a weaker degree than that of semantic memory. Although a growing number of studies have found a contribution of the episodic system to divergent thinking, via an experimental manipulation that boosts episodic memory known as the episodic specificity induction (Madore et al., 2014), our meta-analytic results do not support a strong relationship between episodic memory ability and divergent thinking. One possibility is that episodic memory can support divergent thinking in a state-dependent manner. That is, experimentally activating the episodic system may temporarily boost some aspects of divergent thinking, but trait-level episodic memory ability may not impact people's ability to think divergently. Further meta-analytic work is needed, however, before such conclusions can be made.

Impacts of paradigm modality and age on the relationship between memory and creative cognition

Our results showed that the summary effect size was similar for visual compared to verbal memory tasks and for visual and verbal creativity tasks. However, a difference was found between memory modalities for verbal compared to visual creativity tasks with respect to direction. Specifically, within visual creativity, the relationship with visual memory was greater than that of verbal memory, but within verbal creativity, the relationship with verbal memory was greater than that of visual memory. This indicates that whether the task involves verbal or visual stimuli impacts relationships between memory and creative thinking. Although our analysis did not detect a visual/verbal difference for creativity tasks, our finding for verbal memory highlights a consideration for future research on memory and creativity. Specifically, prior work demonstrates functional fixedness may be differentially induced depending on stimulus modality, such as whether people are presented pictures or words in a divergent thinking task (Chrysikou et al., 2016). The Matched Filter Hypothesis contends task demands influence the level of cognitive control required to complete the task (Chrysikou, 2019). In this context, stimulus modality can bias retrieval strategy during divergent thinking, either towards top-down (visual, e.g., pictures) or bottom-up (verbal, e.g., words), which has implications for both the type of memory engaged and the level of cognitive control required. We encourage future researchers to carefully consider stimulus modality and other task parameters when designing cognitive experiments on creativity to avoid unintentional confounds in their data.

Finally, the summary effect size between memory and creativity was not moderated by age. Most memory types (Schneider & Pressley, 2013) and performance on convergent thinking abilities (Kleibeuker et al., 2013) continue to develop well into young adulthood. However, divergent thinking does not follow a linear developmental pattern. For example, fluency and flexibility are already well-developed by adolescence, and in one study, adolescents excelled on a visuospatial divergent thinking task compared to other older individuals (age range: 10-30; Kleibeuker et al., 2013). There are also reports of slumps and jumps in creative abilities as a function of age/school grade (Claxton et al., 2005; Saggar et al., 2019; Said-Metwaly et al., 2021;

Torrance, 1962). An alternate speculative interpretation of our finding could be that children rely more on memory because their executive functions are less developed than younger adults aged 18-30 (Schneider & Pressley, 2013). After young adulthood, one model suggests a general decline in creative potential as a function of old age (e.g., over age 60) due to changing underlying cognitive processes (Simonton, 1984). Indeed, with the exception of semantic memory (Bäckman & Nilsson, 1996), there is a general decline in cognitive abilities, particularly in the memory domain, around the time one transitions from middle age to older age (Josefsson et al., 2012; Olaya et al., 2017). Empirical work on creativity and aging has primarily focused on divergent thinking, producing mixed results. Some findings suggest creativity is maintained into older adulthood (Addis et al., 2016; Foos & Boone, 2008; Palmiero et al., 2014), perhaps related to preserved crystallized intelligence (Palmiero et al., 2014). Others findings suggest aging is marked with a reduction of fluency and originality (Alpaugh & Birren, 1977), with this deficit first present in middle adulthood (Reese et al., 2001). Coupling this prior research with the findings from our meta-analysis, individuals may differentially rely on memory for creative thinking across the lifespan, and this inconsistency may be too subtle to detect with binned age categories, as was done in the current study.

Creative cognition and the cognitive control of memory

Taken together, the current findings emphasize the central importance of cognitive control to creative cognition. Specifically, we found semantic memory—assessed primarily by verbal fluency tasks, which require controlled semantic retrieval—consistently predicted performance on both divergent and convergent creative thinking tasks. After semantic memory, we found working memory to be the second strongest predictor of convergent thinking, pointing to the role of controlled attention (Kane & Engle, 2002). Here, we explore the implications of these meta-analytic results in the context of the ongoing debate on the role of cognitive control in creative thought.

Longstanding theories in the creativity literature emphasized the role of unconscious processes in creative cognition (see Abraham, 2018; Campbell, 1960; Martindale, 2007; Mednick, 1962; Mendelsohn, 1976; Wallas, 1926), particularly with respect to insight problem solving. On this view, cognitive control plays a minimal role—and in some cases, even a detrimental role—in solving creative problems. In a similar vein, the Blind Variation and Selective Retention (BVSR) theory of creativity (Campbell, 1960; Simonton, 2011) posits that creative idea generation is largely spontaneous and unpredictable (i.e., blind). Likewise, several theories propose that cognitive disinhibition (or defocused attention) supports creative performance by "releasing" attentional control (Martindale, 2007; Mendelsohn, 1974), allowing diffuse semantic activation and extraneous sensory information to be entertained when thinking creatively (Zabelina et al., 2016).

On the other hand, more recently, researchers have begun to theorize about how cognitive control may support creative cognition, particularly in light of evidence linking the two cognitive abilities (Silvia, 2015). For example, studies linking divergent thinking to facets of intelligence, such as verbal fluency (or broad retrieval ability, Gr), have informed the view that divergent thinking in part relies on controlled retrieval from long-term memory (Avitia & Kaufman, 2014; Forthmann et al., 2019; Silvia et al., 2013). Common verbal fluency tasks require participants to retrieve specific exemplars from memory, such as category fluency tasks (e.g., foods, animals, etc.) and phonemic fluency (e.g., words that start with the letters F, A, or S). Verbal fluency is considered a canonical task of cognitive control: performance reliable engages prefrontal brain regions, particularly the inferior frontal gyrus (Costafreda et al., 2006; Hirshorn & Thompson-Schill, 2006; Phelps et al., 1997; Schlösser et al., 1998). Verbal fluency is thought to require selective and goal-directed memory retrieval mechanisms, such as generating and maintaining search cues (Unsworth et al., 2011).

In the context of divergent thinking, and given evidence linking verbal fluency to divergent thinking, researchers have theorized that similar selective retrieval mechanisms contribute to divergent thinking performance. Although the goals of verbal fluency and divergent thinking tasks differ in terms of *what* is to-be-retrieved from memory, i.e., typical vs. atypical exemplars, *how* information is retrieved from long-term memory may be at least partly similar with respect to controlled retrieval mechanisms (e.g., maintaining a retrieval cue in mind while strategically searching memory for candidate responses). Despite commonalties, however, selection demands may be even higher for divergent thinking, particularly when many salient and unoriginal items become activated during search. Of course, elaborative processing, beyond simply retrieving information from memory, is required to formulate creative ideas, which may require more or less controlled aspects of cognition. The current meta-analysis could not provide such mechanistic insight into specific cognitive subprocesses of divergent thinking (e.g., generating vs. evaluating ideas), but we see this as a fruitful direction for future research, with an eye toward dissociating contributions of controlled vs. spontaneous semantic retrieval, or the relative roles of semantic search *processes* vs. the semantic network *structure* (Kenett & Hills, 2022).

Regarding convergent thinking, cognitive control may likewise support performance on tasks such as the RAT, particularly when participants solve problems analytically (compared to insightfully). Given large correlations between performance on classic convergent thinking tasks like the RAT and cognitive ability—including large latent correlations between convergent creative thinking tasks and WMC (Chuderski & Jastrzębski, 2018)—researchers have recently raised the question of whether convergent creativity tasks actually measure creativity or rather working memory/intelligence (Chein & Weisberg, 2014; Lee et al., 2014). The present meta-analysis indeed supports the role of working memory in solving convergent thinking tasks. However, it is important to mention that our analysis could not dissociate insightful vs. analytical problem solving, which may contribute to the WMC-convergent thinking relation (Kounios & Beeman, 2014; Salvi et al., 2016). Nevertheless, our findings clearly implicate cognitive control (via WMC) to overall performance on classic tests of convergent creative thinking, suggesting that the ability to actively maintain and manipulate information in working memory is a reliable path toward successful creative problem solving.

The current meta-analysis is partly consistent with the recently proposed minimal theory of creative ability (MTCA; Stevenson et al., 2021). According to MTCA, individual creative performance can be largely explained by two factors: intelligence (domain-general cognitive ability) and expertise (domain-specific knowledge). Our meta-analysis provides support for the first factor of MTCA, with respect to general cognitive ability (e.g., verbal fluency, working memory), and it is aligned with another recent meta-analysis by Gerwig et al. (2021), who reported a meta-analytic correlation between general intelligence and divergent thinking. Importantly, the current work points more directly at the cognitive control of memory; that is, although general cognitive control abilities (e.g., fluid intelligence) have previously been shown to support creative cognition, our findings provide specificity on the role of cognitive control by demonstrating meta-analytic relations between creative performance and cognitive abilities that require the control of memory (via working memory and verbal fluency).

Limitations

Some limitations of this meta-analytic review merit attention. First, while the current review attempted to cover a wide breadth of research, the number of studies for each memory and creativity type included for analysis was unequal, which could impact Type I error rates. Second, Pearson correlation coefficients cannot capture potential non-linear effects that may exist between variables. Third, regarding convergent thinking, we could not examine analytical vs. insight problem solving separately, and prior work highlights key cognitive differences between these two modes of solving convergent thinking problems (Kounios & Beeman, 2009, 2014), with specific implications for semantic and working memory. Fourth, the current review focused exclusively on explicit behaviors that were observed in a laboratory setting (i.e., psychometric creativity tests), and not domain-specific creative performance. Future reviews could also focus on implicit, primed, or subjective facets of creativity and memory. Also with respect to memory, there was not a large enough quantity of papers to pull in memory metrics other than hit rate. This influences the interpretation of the present study, as the results may only generalize to accurate episodic memory (as opposed to other memory metrics that can account for false alarm and miss rates, such as discriminability). Finally, the meta-analysis did not account for the potential contribution of general cognitive ability (i.e., general intelligence), which may partly explain associations between memory abilities (e.g., working memory) and creative cognition.

Conclusion

By aggregating over 50 years of research on memory and creativity, we provide the first quantitative and conclusive meta-analytic evidence that memory supports creative cognition. Collapsing across types of memory and creativity, we found a small but significant ($r = .19$) general relationship between these two constructs. A closer examination of memory type revealed this association to be driven largely by semantic memory, assessed primarily by performance on verbal fluency tasks. Further, despite previously mixed evidence, we showed working memory capacity is more strongly related to convergent than to divergent creative thinking. Regarding paradigm modality, we found that within visual creativity, the relationship with visual memory was greater than that of verbal memory, but within verbal creativity, the relationship with verbal memory was greater than that of visual memory. Finally, there was no impact of age on the general effect size. These findings provide clarity regarding the nature of the relationship between memory and creative cognition—pointing to the cognitive control of memory as central to creative task performance—and they help to address longstanding controversies around how, and to what extent, specific cognitive systems support specific modes of creative thought.

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Note: * = contains data included in analysis.

Figures

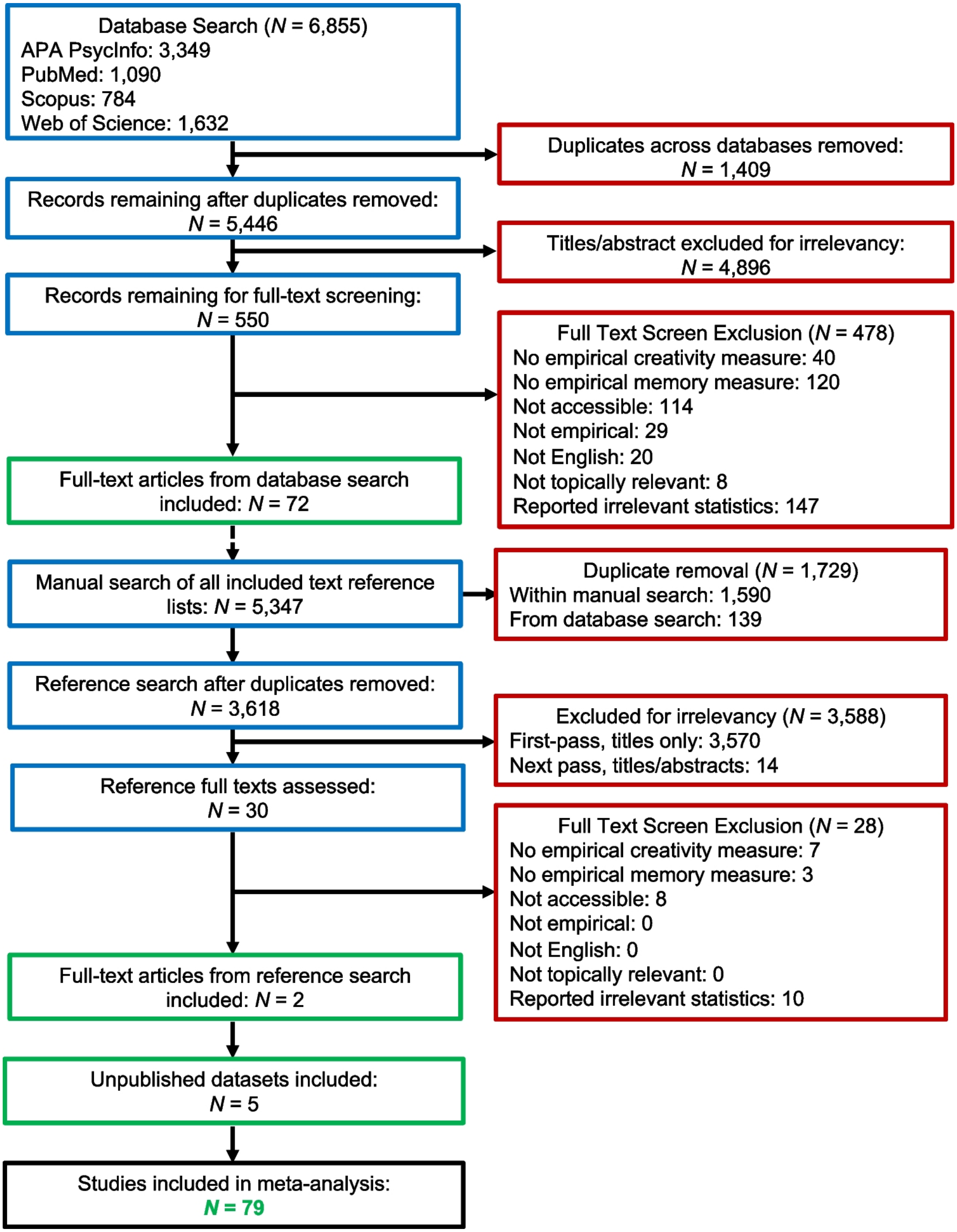

Figure 1. PRISMA flow diagram illustrating study identification, screening, and selection

processes. Blue boxes = records interrogated for inclusion; Red boxes = excluded records; Green boxes = included in meta-analysis.

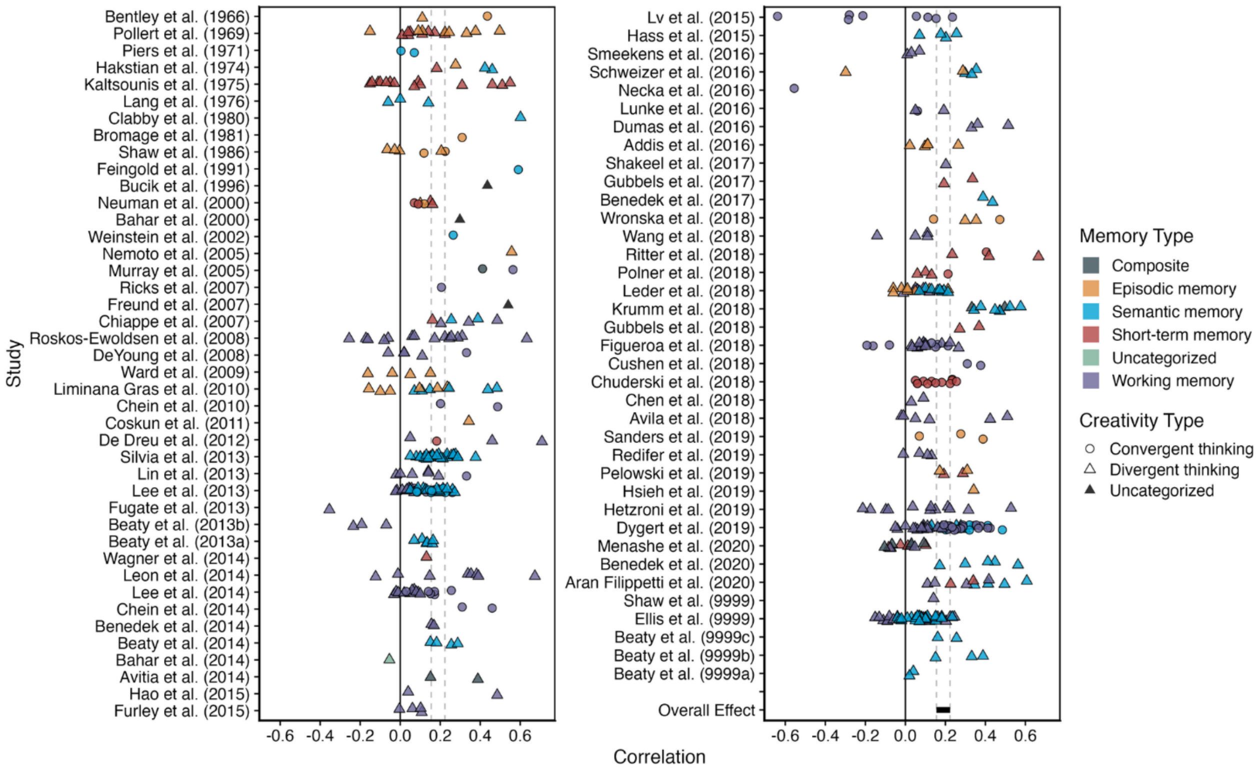

Figure 2. Meta-analytic forest plot containing all effect sizes nested within studies (organized by publication year). Effect sizes vary by memory type (color) and creativity type (shape). The dashed grey lines reflect the 95% CI for the overall summary effect for all studies.

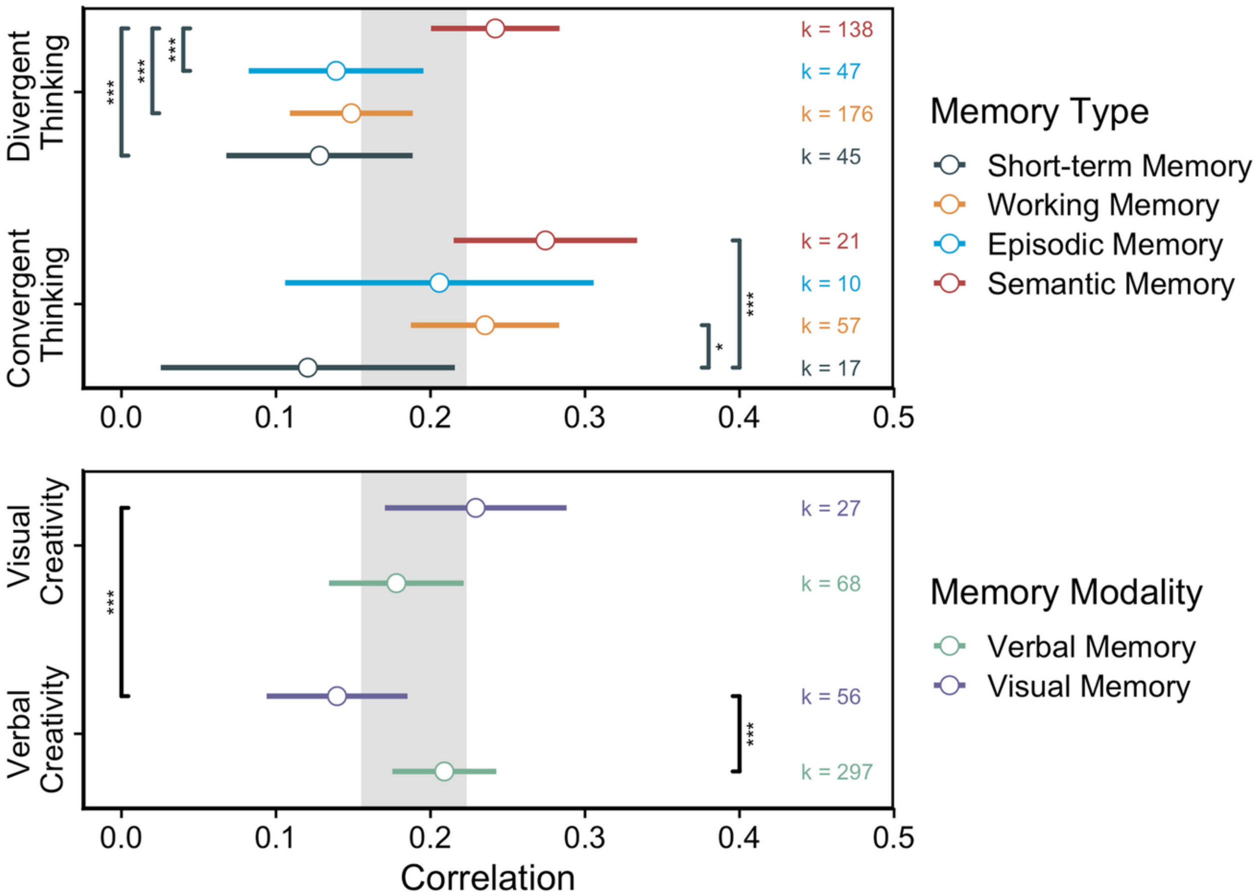

Figure 3. The top panel displays the summary effect sizes for each Memory Type (Short-term Memory, Working Memory, Episodic Memory, Semantic Memory) as function of Creativity Type (Divergent Thinking, Convergent Thinking). The bottom panel displays the summary effect sizes for Verbal and Visual memory as a function of Creativity Modality (Visual, Verbal). Points reflect point estimates and error bars reflect 95% confidence intervals. *k* = number of effect sizes contributing to summary effect size estimates. Gray vertical bands in each panel represents a summary effect size confidence interval at 95%. * = *p* < .05; *** = *p* < .001.

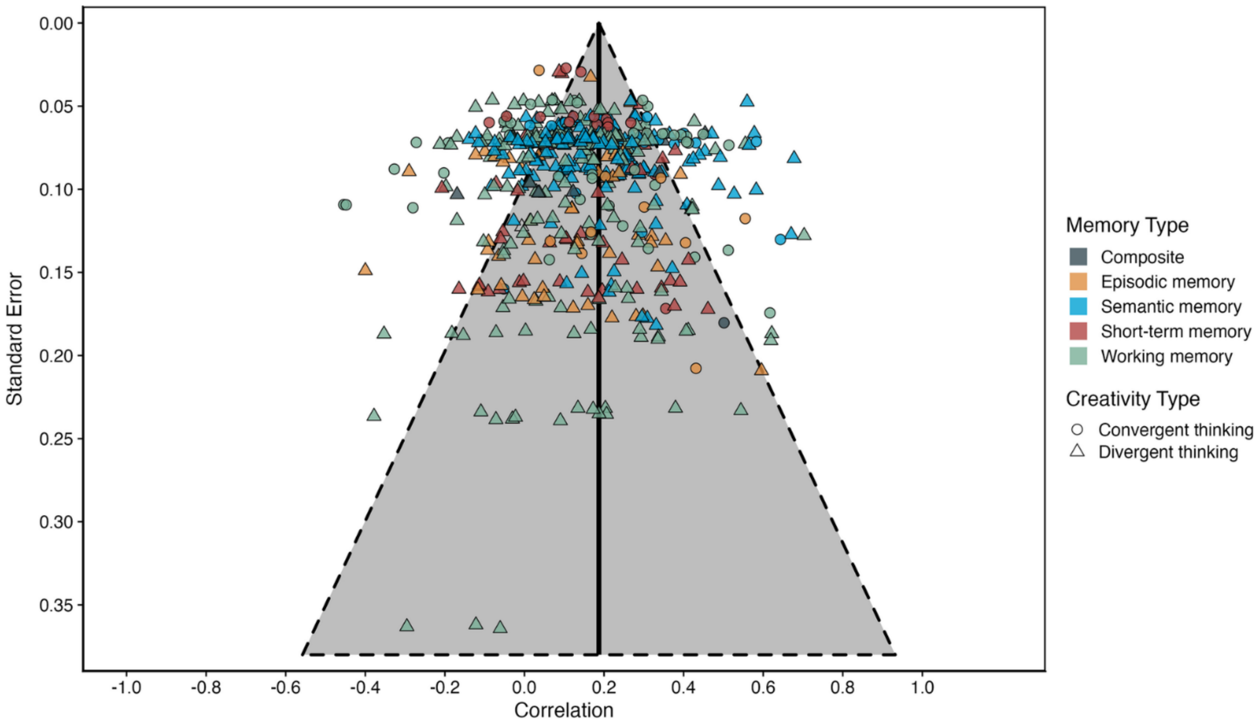

Figure 4. Funnel plot displaying the summary effect size estimates as a function of precision (i.e., standard error). The funnel plot is centered on the overall summary effect size for all effect sizes (k = 525) indicated by the vertical black line (r = .19). Effect sizes vary by memory type (color) and creativity type (shape).