Associative Thinking at the Core of Creativity

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Abstract

Creativity has long been thought to involve associative processes in memory: connecting concepts to form ideas, inventions, and artworks. Yet associative thinking has been difficult to study due to limitations in modeling memory structure and retrieval processes. Recent advances in computational models of semantic memory allow researchers to examine how people navigate a semantic space of concepts when forming associations, revealing key search strategies associated with creativity. Here, we synthesize cognitive, computational, and neuroscience research on creativity and associative thinking. The review highlights distinctions between free- and goal-directed association, illustrates the role of associative thinking in the arts, and links associative thinking to brain systems supporting both semantic and episodic memory—offering a new perspective on a longstanding creativity theory.

Keywords: associative thinking; creativity; distributional semantic modeling; semantic memory

Revisiting the Role of Associative Thinking in Creativity

What's the first word that comes to mind when you think of *creativity?* Some people may associate creativity with *art*; others with *imagination, novelty,* or *expression*. This exercise illustrates the phenomenon of association—how one concept links to others in memory, and how people vary in the associations they make [1]. Creative thinking has long been conceptualized as involving an associative process over memory, where concepts are combined to form new and effective ideas [2-6]. Yet, associative thinking has been historically challenging to study, due in part to methodological limitations in modeling memory and the retrieval processes operating on it. Prior studies have relied on simple measures of association, such as counting the total number of associations produced (i.e., the *product* of associative thinking)—obscuring the *process* of associative thinking and limiting our understanding of its role in creativity.

Recent advances in the computational modeling of semantic memory—the vast database of concepts, and the relationships between them [7]—have begun to overcome these limitations, yielding new insights into associative thinking and its contribution to creativity. In particular, **distributional semantic models** (see Glossary) provide powerful tools for quantifying **semantic distance**, allowing researchers to quantitatively measure how far people travel in a semantic space (or network) of concepts when searching memory. Cognitive and neuroimaging studies of associative thinking have yielded additional insights, from disentangling spontaneous/**free association** vs. controlled/**goal-directed association**, to demonstrating the role of associative thinking in the arts and sciences, to linking associative thinking to brain systems implicated in creative thought.

In this review, we integrate cognitive, computational, and neuroscience research on creativity and associative thinking. We operationalize creativity as a cognitive process involving the generation of new and effective ideas [8], while recognizing that creativity is complex, multifaceted, and often domain specific. Here, we focus on the role of associative thinking as a general mechanism driving the early stage of idea generation. We therefore view creative thinking as a form of high-level cognition—a product of "lower-level" cognitive systems, including cognitive control, attention, and memory [9,10].

The review provides empirical support for a longstanding theory on creativity—the associative theory [5]—in light of major advances in computational modeling and cognitive neuroscience. We highlight key memory search characteristics of highly creative individuals based on computational models of memory that can track a person's navigation through semantic space. We approach the contentious question of domain-specificity in the creativity literature by examining how associative thinking—a domain-general cognitive ability—relates to domain-specific creative expertise. We also examine how the brain forms different types of associations (e.g., free- vs. goal-directed association), and whether association processes work differently in the highly creative brain.

Creativity, Free-Associations, and Goal-Directed Associations

According to the associative theory of creativity, what distinguishes more creative people is their capacity for association, i.e., making new connections between seemingly unrelated concepts stored in memory. This theory postulates that creative people can make such novel associations due to their structure of memory: whereas a less creative person has strong connections between common concepts (e.g., table-chair) and weak connections between uncommon concepts (e.g., table-lamp), a higher creative person has connections of similar strength between both common and uncommon concepts, facilitating the bypass of conventional associations to make novel/remote associations [11]. Over the years, the associative theory has received mixed empirical support, largely due to challenges in representing semantic memory structure and the search processes operating over it [see 12 for a comprehensive review and discussion].

Recently, network science—the study of complex systems as networks—has validated and enriched the associative theory [see 13 for review]. By modeling semantic memory as a network of interconnected concepts [14], this work has repeatedly shown that higher creative people exhibit a more "flexible" semantic memory network, with shorter distances and higher connectivity between concepts [15,16]. This flexible semantic memory network structure may facilitate associative processes relevant for creative thinking [17], including free association (i.e., spontaneously connecting concepts) and goal-directed association (i.e., strategically combining concepts; [18]).

Researchers have developed various tasks requiring free- and goal-directed association. Free association tasks prompt people to generate the first, or few words that comes to mind in response to a cue word [19,20]. Free association has been studied for nearly 150 years, largely viewed as a window into the unconscious mind—an idea later expanded upon by psychoanalysts, and followed by cognitive psychologists who developed formal tests of free association [for review see 21]. More recent work [e.g., 1,22] led to the development of free association norms [23,24], allowing researchers to study memory structure and retrieval processes operating on it.

Goal-directed association tasks involve generating associations that fit a specific task constraint or requirement. Unlike unconstrained free association, goal-directed association tasks require extracting specific information from memory, such as retrieving synonyms, listing animals, or producing a sequence of unrelated words [25-27]. Factor analytic studies of human cognitive abilities have operationalized goal-directed retrieval as a facet of intelligence, termed "broad retrieval ability" [28,29]. Broad-retrieval ability (i.e., verbal fluency) robustly predicts performance on creative thinking tasks, according to two recent meta-analyses [30,31], and requires executive control to extract information from long-term memory, avoiding repetitions and inappropriate responses along the way.

Contemporary creativity theories have attempted to accommodate both free- and goal-directed association [32-36]. For example, the distance-dependent representation activation model [32] illustrates how spontaneous memory activation interacts with controlled retrieval when people search for new associations: starting from a stimulus word, activation spreads to connected "nodes" (i.e., concepts) in a semantic memory network. This association process can be driven by 1) controlled processes (strategies,

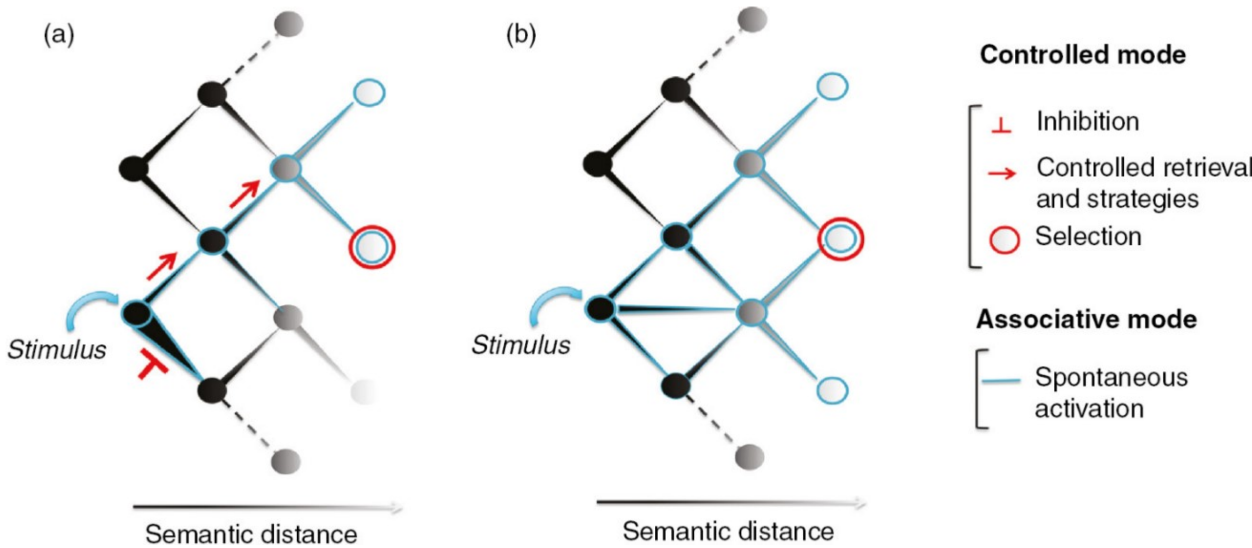

Fig. 1. Schematic representation of spontaneous and controlled processing during idea generation. (a) An individual with higher controlled retrieval abilities; (b) an individual with a more interconnected network. Both make the same connection between a stimulus concept and a distant connection in the network that is selected (red circle), but through different mechanisms (controlled retrieval vs. spontaneous activation). Adapted from [32].

inhibition, selection) and 2) semantic memory network organization (e.g., connectivity between nodes). People with higher executive control processes (**Fig. 1a**), and people with a more interconnected semantic memory network (**Fig. 1b**), can arrive at the same semantically distant node in the network through different cognitive mechanisms. Thus, semantic memory serves as the "scaffolding" of creative thinking [37], upon which association facilitates novel combinations. Importantly, recent work has demonstrated how semantic memory structure and executive processes interact in complex ways, highlighting the role of spontaneous, "free", and executive, "goal-directed" processes in creativity [34,38-41].

Advances in the Computational Assessment of Associative Thinking

Historically, to measure free- and goal-directed associations, researchers counted the total number of associations [42,43] or the uniqueness of associations produced on a task [i.e., clustering and switching; 44]. Although such approaches have advanced our understanding of associative thinking, they focus primarily on the *product* (or output) of association—obscuring the *search processes* involved in associative thinking. Recent computational advances provide rich insights into associative thinking by

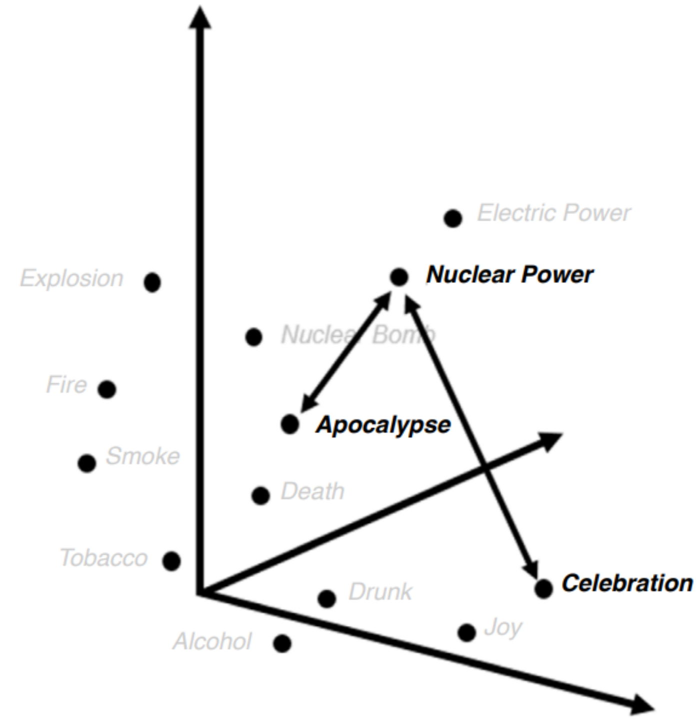

Fig. 2. A semantic space of concepts based on distributional semantic modelling. Concepts that overlap more in their meaning are represented closer in semantic space than concepts that overlap less in meaning, illustrating the notion of semantic distance. Adapted from [51].

quantifying "how far" people travel in memory when freely associating [38,45], generating unrelated words [25], or even writing short stories [46,47].

A key innovation of recent work on associative thinking has been the application of distributional semantic modeling [48-50]. Distributional semantic models quantify *semantic similarity*: the extent to which concepts share semantic meaning (**Fig. 2**). Models such as global vectors (GloVe) and word2vec [51] represent language by learning statistical regularities from massive text corpora (e.g., Wikipedia). Semantic similarity is calculated as the cosine angle between word vectors in a high-dimensional semantic/vector space, reflecting co-occurrence of concepts in natural language.

For example, the word, *apocalypse*, tends to co-occur with *nuclear power* more than with *celebration [52]*; *apocalypse* and *nuclear power* are thus represented closer to each other in semantic space and have a lower semantic distance. Semantic distance is computed as the inverse of semantic similarity. It has strong theoretical links to the associative theory of creativity, as it offers an objective way to quantify novelty of associations [53-55].

Memory Search and Association Processes in Creative Thinking

Since the associative theory of creativity, several studies have examined the role of associative thinking in creativity [10,12,42,56,57]. Much of this work has taken an individual differences approach, relating variation in associative thinking to individual creative performance. In general, higher creative people are more associative in their thinking: they generate a broader, more idiosyncratic set of associative responses compared to less creative people [12,25,38,42,45]. They also tend to perceive semantically distant associations as "closer" together [11]. More recently, researchers have extended these classic findings by identifying key memory search strategies employed by creative individuals. Such recent work is inspired by the classic Search of Associative Memory [58], a cognitive model that computationally examines cognitive search strategies as processes operating within semantic memory [27,44,59-61].

Computational methods are increasingly applied to gain insight into the role of free association dynamics in creative thinking. One study [45] applied distributional semantic modeling to a chain free association task, devising a metric termed **forward flow** (FF). The chain free association task presents participants with a cue word (see **Fig. 3**), then prompts them to say the first word that comes to mind for each successive word they produce [e.g., candle-fire, fire-burn, burn-hot, etc.; 62]. To quantify FF, the semantic distance between the cue word and all subsequently generated words is calculated, capturing how far people travel in semantic space when freely associating. FF was found to correlate with various aspects of creativity, including **divergent thinking** (the ability to produce many different ideas) and real-world creative accomplishment in actors and entrepreneurs [45].

Importantly, FF was predictive of divergent thinking controlling for intelligence—a finding that was subsequently replicated with a larger battery of intelligence tests [38]—indicating that free

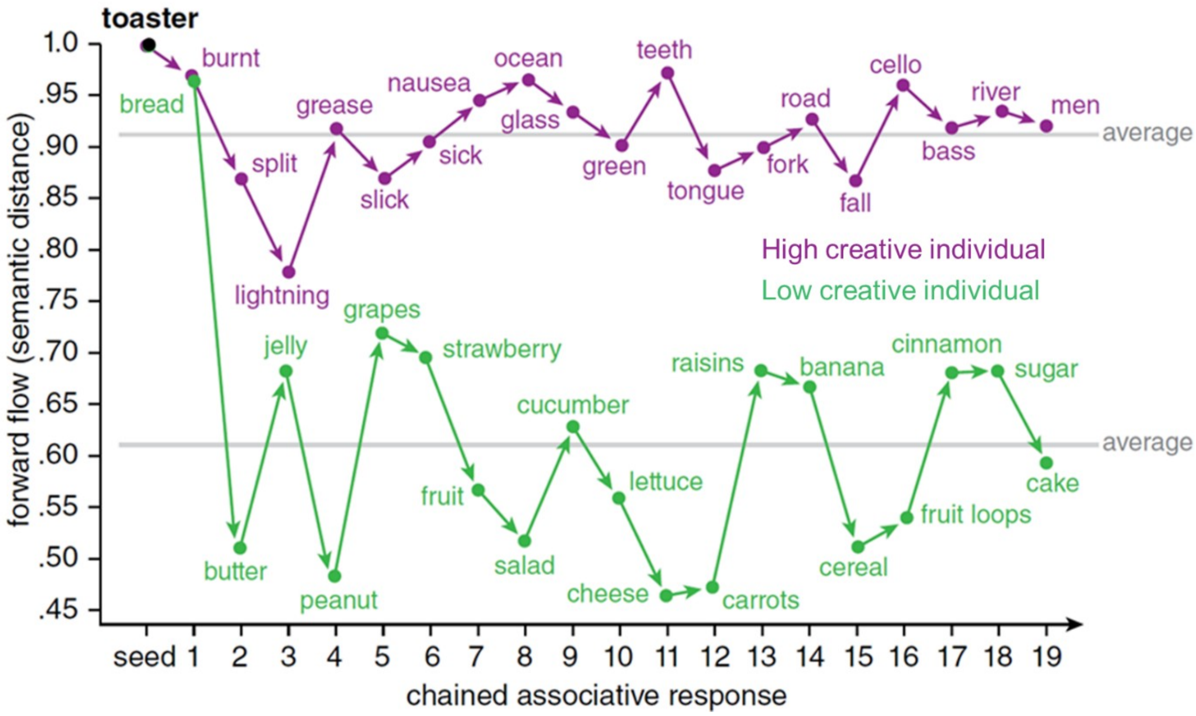

Fig. 3. Free associations on the forward flow task from high and low creative participants. Starting from the same cue word (toaster), the higher creative participant travels farther away in semantic space, as quantified by semantic distance. Adapted from [45].

association is psychometrically distinct from intelligence. This observation is notable, since free association tasks may seem to tap aspects of intelligence, such as verbal fluency (i.e., efficiently retrieving words from memory) and crystallized intelligence (i.e., knowing the meaning of many words). These findings also provide support for "dual process" theories of creativity that emphasize unique contributions of spontaneous and controlled cognitive abilities [4,32,33,35,63].

In addition to FF, other associative metrics were recently applied [64] to capture retrieval dynamics predictive of creative thinking: *clustering* (the number of categories visited), *switching* (alternating between semantic categories), *complexity* (the range of combinations of different semantic categories), *global semantic distance* (i.e., FF), and *local semantic distance* (distance from previous responses). These metrics were used to model how creative thinking relates to navigating between conceptual categories [64]. **Fig. 4** shows an example of the "retrieval trajectory" of example high and low creative participants in this study. As can be seen, starting from the same seed word (white node), higher

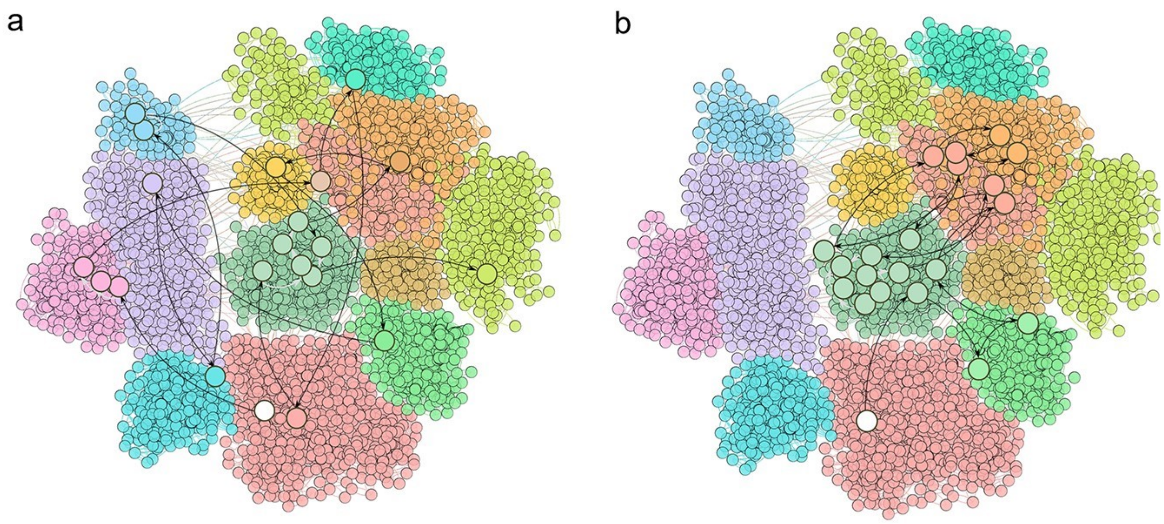

Fig. 4. Retrieval trajectories modeled from free association data from higher (a) and lower (b) creative participants. Clustering analysis identified different conceptual categories of words (colors) based on the semantic distance between all responses produced by all participants. Each category had a cluster center that was used to measure the distance between categories. Starting from the same cue word (white node in the network), the higher creative participant travels further in the network, switches between more subcategories (colored nodes), and made larger "leaps" between their associations. Adapted from [64].

creative participants "traveled" further in the network (FF), switched between more subcategories (switching), and made larger "leaps" between their associations (local semantic distance).

Switching and clustering are classically studied in the context of verbal fluency, i.e., goal-directed retrieval of specific information from long-term memory [27,59,65]. For example, on an animal verbal fluency task, switching reflects alternating between different subcategories of animals (e.g., "birds, snakes, fish"), whereas clustering reflects grouping related animals together [e.g., small animals; "mouse, rabbit, hamster"; 66]. Memory search and retrieval have been conceptualized as an internal "foraging" process—akin to external foraging for food and resources in nature—whereby people explore the landscape of concepts in memory (exploration) and exploit specific categories (exploitation), based on task constraints [27,59,67,68].

A recent study [44] examined switching and clustering in free association, devising a task using polysemous words—i.e., words with multiple meanings (e.g., *bark*; *dog-bark*, *tree-bark*)—which enabled clear distinctions for switching and clustering (e.g., clustering is naming dog-related words and not tree). In this study, switching correlated with convergent thinking (e.g., generating a word that conceptually relates to three cue words), whereas clustering correlated with divergent thinking (e.g., generating original uses for objects). Moreover, switching related to both executive functions and semantic memory network structure, whereas clustering related to the ability to retrieve many items from a semantic category (i.e., fluency). These findings indicate that switching during free association reflects an interplay between controlled processes and semantic memory network structure (i.e., "exploration" of semantic space), and clustering reflects controlled processes relevant for exhaustive memory search (i.e., "exploitation" of a semantic category).

This relation between switching and semantic memory network structure provides additional evidence that associative thinking reflects a search process operating on a semantic memory network structure. A recent study [18] triangulated the relations between associative thinking, semantic memory structure, and creative thinking, finding that associative thinking mediated the relationship between semantic memory network efficiency and creativity. In other words, higher creative people could search through semantic space more fluently, and make more distant semantic associations, because they possessed a more richly connected semantic memory network. Importantly, this study [18] assessed both free and goal-directed association, reflecting the involvement of both spontaneous and controlled search processes. One of the goal-directed associative thinking abilities studied in this work was dissociation—the ability to generate semantically unrelated words [26,42].

Dissociation was examined in another recent study [25] using the Divergent Association Task (DAT). In the DAT, participants generate unrelated words, and the semantic distance between all word pairs is computed (**Fig. 5**). The authors [25] found that DAT performance reliably predicted creativity: people who produced the most unrelated words scored higher on divergent thinking tests. Thus, in

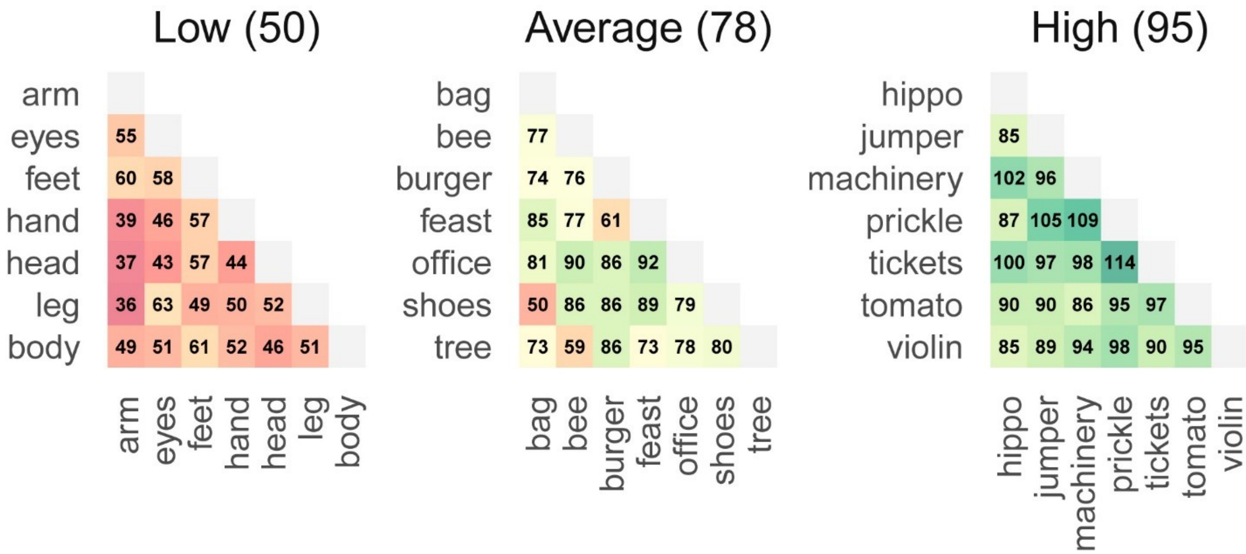

Fig. 5. Divergent Association Task scores for participants scoring low, average, and high on the task. Numbers represent the semantic distance between word produced by participants. Adapted from [25].

addition to free association, creative thinking may also benefit from the goal-directed ability to make large leaps in semantic space, deliberately expanding the search space while bypassing related associations.

Associative Thinking in Domain-Specific Creative Performance

So far, the review has focused on the role of associative thinking in "domain-general" creativity, i.e., creative thinking in the general population. To what extent does associative thinking contribute to domain-specific creative expertise in the arts and sciences? Prior work found differences in the uncommonness of associations produced by creative experts [69], consistent with the associative theory. More recently, researchers have begun to provide more granular insights into the memory search processes of creative experts, informing a longstanding debate in the creativity literature: the extent to which creativity is domain-general or domain-specific [70].

Recently, we [71] analyzed the associative responses generated by award-winning visual artists, research scientists, and intelligence-matched comparison group of less creative people, under three associative conditions: one free association and two goal-directed association (producing common and uncommon associations) conditions. Overall, artists produced significantly more semantically distant associations—but this effect was driven by the free association condition. Interestingly, although the association task was verbal, the artists were trained in the visual domain, so their free association performance could not be simply explained by advanced verbal abilities (the groups were also matched on intelligence). Other recent studies have shown that artists tend to generate more semantically distant word associations, particularly performing artists [e.g., actors; 45,72].

Associative thinking also appears to contribute to the creative quality of literary works. In one recent study [40], the ability to generate distant word associations predicted the creative quality of short stories. Similarly, we [47] found that associative thinking predicts creativity in short stories: people who generated more distant goal-directed associations wrote more original short stories.

Additional insights come from computational analysis of large-scale text corpora, such as books and movie scripts. One study [73] applied FF to analyze the Gutenberg Library English Corpus [74], finding the following rank order of FF: 1) poems 2) plays 3) essays 4) stories, 5) children books, and 6) novels [73]. Analysis of specific authors in the corpus found that poets (e.g., Wordsworth, Shakespeare) had the highest FF, whereas essayists and novelists (e.g., Defoe, Newton) had the lowest FF. Other work [75] studied the semantic progression of narratives, e.g., how much a story "moves quickly" or "covers lots of ground", linking such movements to how well a narrative is liked (e.g., movies, TV shows) or cited (academic papers). Movies and TV shows that were more fast-paced and covered less ground were liked more, and academic papers that were slower-paced and covered more ground were cited more.

In sum, evidence indicates that associative thinking—particularly the ability to efficiently navigate semantic space and connect concepts—contributes to domain-specific performance, adding to the ongoing debate on the role of domain-general abilities in creative expertise [70] and suggesting that general cognitive systems (e.g., semantic memory) may impact idea generation in the arts. On the other hand, computational analysis of large text corpora points to domain-specific differences: some domains may constrain associative processes based on cultural and field-specific preferences and practices.

Mapping Associative Thinking in the Brain

In addition to cognitive and computational research, brain imaging investigations have begun to reveal some of the neurocognitive mechanisms of associative thinking, offering another means to study the process of association. Much of this work has used functional MRI to link patterns of brain activity to associative thinking and creativity. This emerging literature can be categorized into 1) studies examining brain region activity during associative thinking, and 2) studies examining functional brain network connectivity (i.e., interactions among multiple brain regions) related to individual differences in associative thinking.

A key discovery from this work is that associative thinking recruits both semantic and episodic memory regions, implicating cognitive processes beyond the semantic system. Associations within familiar contexts may recruit episodic memory, as people draw on their past experiences, while distant associations may require semantic memory to connect unfamiliar contexts. Moreover, associative thinking ability involves functional connectivity between brain networks previously associated with creativity, pointing to a shared neurocognitive system supporting association and creative thinking.

Brain Regions Activated during Associative Thinking

A common finding in the neuroscience literature is that associative thinking engages the default mode network [DMN; 76]. The DMN consists of medial prefrontal cortex, posterior cingulate cortex, and lateral temporal and parietal regions; these regions collectively activate during tasks involving memory, imagination, and self-referential thinking [77,78]. DMN also robustly activates during 'passive' resting states, when people are not engaged in a task (i.e., mind wandering), as well as during tasks involving both episodic and semantic memory retrieval [77].

A recent study examined the neural correlates of chained free association [76]. Here, free association was compared to tasks requiring goal-directed retrieval (e.g., phonemic and semantic fluency, as well as free recall from episodic memory). Chained free association more strongly engaged DMN

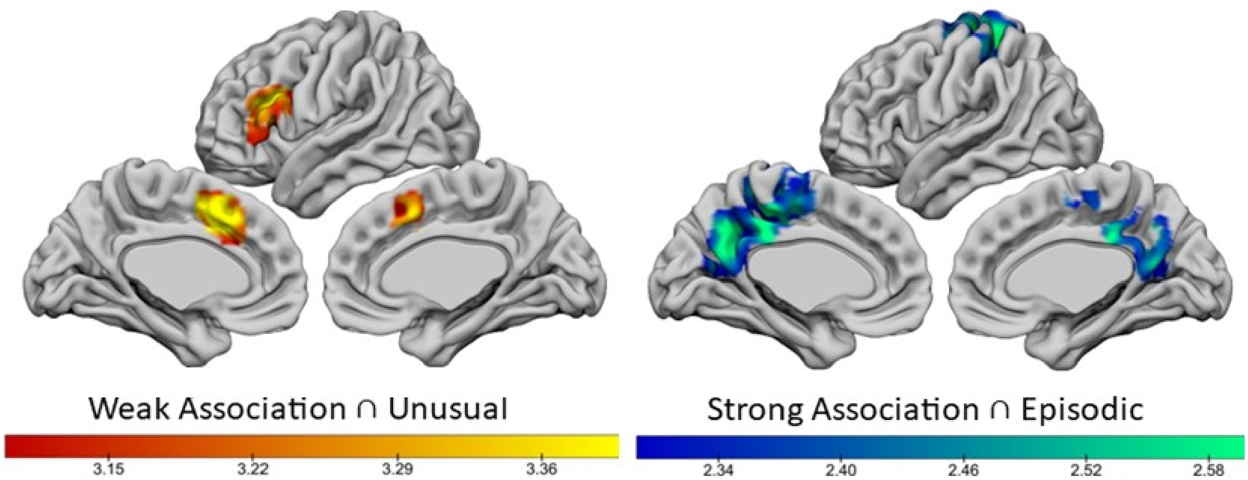

Fig. 6. Brain activity related to bi-association for strong and weak cue words. Left panel: Conjunction analysis (common brain activity) for weak associations and unusual responses (within semantic control regions, including the left IFG). Right panel: Conjunction of strong associations and episodic retrieval (within DMN regions, including the posterior cingulate). Adapted from [82].

regions, as well as some frontal regions, including the left inferior frontal gyrus—a region previously associated with semantic retrieval and verbal creativity [79,80]. DMN activity during free association correlated with behavioral measures of divergent thinking, suggesting that DMN may play a role in freely associating when thinking creatively.

Other work has sought to identify neural correlates of goal-directed association, including two studies using the bi-association task [81,82]. In this task, participants are shown two words (e.g., *large - silent*) and asked to think of a third word that relates to both words (e.g., *whale*); in both studies, bi-association ability correlated positively with divergent thinking performance, supporting the validity of bi-association. One study [81] included two additional goal-directed association conditions: common association (generating a word highly related to a cue word) and original association (generating a word remotely related to the cue). Interestingly, compared to the other association conditions, bi-association more strongly recruited bilateral hippocampus and lingual gyri—regions associated with episodic memory retrieval and mental imagery, respectively—as well as bilateral angular gyri of the DMN.

Similarly, another bi-association study [82] reported activation of the left angular gyrus and bilateral lingual gyri (**Fig. 6**). However, their study manipulated the semantic distance between the bi-association cue words, with two conditions: 1) semantically similar (e.g., *confetti - helium*) and 2) semantically distant (e.g., *melon - bookcase*) concepts. Participants indicated how much each response they produced came from their general knowledge (semantic memory) or a specific personal experience (episodic memory). Behaviorally, semantically similar word pairs were more likely to elicit an episodic retrieval strategy, as well as more homogenous associative responses in the sample; in contrast, semantically distant word pairs tended to engage a semantic strategy and more heterogeneous associative responses. A similar pattern emerged at the neural level (**Fig. 6**): the semantically related condition showed stronger involvement of the DMN, including the left angular gyrus, whereas the semantically distant condition showed stronger engagement of semantic control network regions, including the left IFG.

Taken together, the DMN and semantic control network appear to support distinct memory processes during associative thinking. DMN may support episodic memory when forming associations within familiar contexts [82; e.g., confetti – helium; remembering a birthday party with balloons]—whereas semantic control regions (e.g., IFG) may contribute more to forming distant associations in less familiar contexts, when people cannot draw on relevant past experiences.

Individual Differences in Associative Thinking and Brain Network Connectivity

Studies of brain network connectivity have begun to investigate how associative thinking relates to the interaction of multiple brain regions, i.e., functional connectivity. Previous brain network studies of creative thinking implicated three large-scale networks: the DMN, the Executive Control Network (ECN), and the Salience Network (SN) [83-87]. However, questions have remained about the specific cognitive mechanisms underlying their interactions (e.g., memory retrieval, inhibition).

Associative thinking may constitute one mechanism of DMN, ECN, and SN interaction. Two recent studies provide some evidence along these lines [44,64], reporting correlations between associative thinking, creativity, and functional connectivity among DMN, ECN, and SN. One study [44] found that switching categories during free association was predicted by functional connectivity among the three networks. Similarly, other work [64] found that clustering and switching during free association was related to a functional connectivity “state” (i.e., a recurring correlational pattern among the networks at rest) comprised of DMN, ECN, and SN, and that free association ability mediated the relationship between this brain state and verbal creative thinking.

These findings point to a central role of associative thinking in the brain dynamics of creativity. Broadly speaking, DMN is theorized to support the generation of candidate ideas (via associative thinking and other memory-related processes), with SN involved in the identification of promising ideas, and ECN contributing to idea evaluation, selection, and modification [88,89]. Thus, the neurocognitive architecture of associative thinking may go beyond the DMN to include brain systems involved in cognitive control and monitoring—indicating the involvement of both controlled and spontaneous associative processes, even in seemingly “unconstrained”, free associative processes [44,64].

Concluding Remarks and Future Directions

Creativity is a high-level cognitive process, involving multiple systems (e.g., memory and cognitive control) and stages [e.g., idea generation and evaluation; 32,90,91]. Our review highlights the central role of associative thinking as a cognitive mechanism in the early stage of idea generation, implicating different memory systems (semantic and episodic) and retrieval processes operating within these systems [free association and goal-directed association; 90]. Higher creative individuals are better able to navigate semantic memory: they travel further when associating [38,45], switch between more semantic subcategories [64], and make larger "leaps" between associations [25]. Associative thinking also contributes to specific creative domains—artists show enhanced free association [71]—highlighting how domain-general cognitive abilities relate to domain-specific creative expertise. Network science studies suggest that associative thinking reflects a search process operating on a semantic memory network structure [18]. Yet neuroscience research also implicates episodic memory in associative thinking, particularly when connecting familiar concepts from past experience [81,82].

Although the notion that associative thinking is critical for creativity is not new [4-6,42], the application of computational methods and neuroscientific research over the past decade have significantly enhanced our understanding of how the associative thought process contributes to creativity, by driving the generation and combination of novel and effective ideas, and uniquely allow us to examine how it unfolds over time. Our review also identifies the central role of goal-directed association in creative thinking, constituting a significant advance in understanding the role of associative cognition in creativity that calls for an update to the classic associative theory.

Looking ahead, research on associative thinking should examine how free- and goal-directed association contribute to real-world creative behavior [e.g., 46,92,93], and how associative thinking interacts with other cognitive systems that support creativity [e.g., attention and cognitive control; 9]. A recent model, Memory in Creative Ideation [90], situates association alongside other memory processes relevant for creativity (e.g., idea evaluation), with association contributing to the early process of memory search and construction. Specifically, this new framework builds upon the generation-evaluation model of creativity [91] by incorporating four sub-stages: search, construction, novelty evaluation, and effectiveness evaluation [90]. Our review emphasizes the role of associative thinking in the first two generative stages of this new framework. Yet, studying how association interacts with downstream phases of the creative process is an important goal. For example, more work is needed to examine how associative thinking interacts with evaluative processes critical for creativity [94,95].

Future work should move beyond individual differences to study how associative thinking can be enhanced through learning [98]: targeting the structure of semantic memory (e.g., via concept learning techniques that promote connectivity between concepts during learning) or the associative processes operating on it (e.g., via memory retrieval strategies that encourage semantically distant connections). Furthermore, advances in the investigation of associative processes in creativity can be achieved through the application of computational models that converge different types of memory systems (e.g., semantic and episodic memory) as “layers” in a multidimensional cognitive network [99,100].

Turning back to the associative theory of creativity, we are now equipped with tools to rigorously examine this theory. Researchers can ask increasingly granular and mechanistic questions about the process of associative thinking, and how it contributes to creativity, using computational and neuroscience tools to study how people navigate a constellation of concepts when searching through memory. Although creativity is complex, requiring many of our cognitive capacities, associative thinking is a critical vehicle for navigating memory, one that allows us to “move away” from prototypicality toward more remote, creative ideas.

Glossary

Divergent thinking: the ability to generate many different ideas in response to open-ended prompts (e.g., unusual object uses).

Distributional semantic modeling: a natural language processing modelling approach used to analyze and represent the meaning of words in a given context by studying their distribution patterns in large corpora of text.

Forward flow: a method for quantifying the forward motion of naturalistic thought, reflecting how far one moves away from an initial idea or concept, calculated via semantic distance.

Free association: a thought process in which a person freely associates ideas, words, or memories without deliberate censorship or cognitive control.

Goal-directed association: a thought process in which a person associates ideas, words, or memories with a specific goal or purpose in mind.

Semantic distance: a measure of the inverse of similarity (or relatedness) between two words or concepts, often used in natural language processing and computational linguistics.

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