Enhancing Creative Problem-Solving: An Interdisciplinary Approach

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Creative problem-solving is a multifaceted human ability that drives progress and innovation in everyday life. Creative problem-solving has become one of the most pressing and valuable skills; nevertheless, creativity scores have consistently declined over recent decades, leading to a troubling deficit. This paper uses an interdisciplinary approach of psychology and neuroscience to investigate how creative problem-solving skills can be enhanced. The purpose of this paper is to integrate psychological and neuroscientific findings to identify actionable strategies for enhancing creative problem-solving in educational contexts and everyday life. We found very few papers that synthesized psychological and neuroscientific approaches and aimed to address this gap in the literature. Primarily, creative problem-solving can be amplified in two ways: a change in thought processes or a change in the structure and functioning of the brain. We explore the conceptual frameworks of psychology to inform practical interventions for the former, and we evaluate the neural networks of the brain to detail the latter. Central findings are that building up specific cognitive skills, activating the subconscious, and recalibrating the brain through training have potent effects for optimizing ingenuity. Creativity is an emerging field of study, and the paper utilizes recent advancements in brain-imaging studies and ongoing research to suggest initiatives that foster creative problem-solving ability.
Research Question: By combining insights from psychology and neuroscience, what are the optimal individual and systematic methods for enhancing creative problem-solving ability?

Keywords: Creative problem-solving, Psychology, Neuroscience, Theoretical Frameworks, Neural Networks

Introduction

Society as we know it today could not exist without creativity. Creativity is the cutting edge of science that brings about revolutionary ideas, life-saving inventions, and technological breakthroughs. It is the facet of the brain that governs human self-expression, inspiring elaborate artworks and masterpieces of literature. For this paper we will be focusing on creative problem-solving, or the ability to generate actionable creative ideas that address specific issues. We chose to focus on creative problem-solving as a whole, rather than the related process of innovation, because of the latter's narrower focus of developing ideas with tangible value in real-world markets or contexts. There is a very practical and relevant need for all forms of creative problem-solving in the twenty-first century. Tackling urgent problems like global warming, social inequality, refugee crises, and health issues requires an influx of new ideas. Due to rapidly evolving technology and automation, conventionally valued skill sets may be declining in relevance, and the importance of equipping the next generation with creative problem-solving ability cannot be overstated[1,2]. Moreover, creative problem-solving carries many practical benefits and is linked to happiness. Creativity heightens empathy, provides an emotional outlet, alleviates stress, and motivates individuals to pursue their ambitions[3–5].

Unfortunately, contemporary research has revealed that creativity scores have been significantly lower since the 1990s[1,6]. A 2011 study by Kyung Hee Kim analyzed test scores of 272,599 adolescents and adults, and found that the drop occurred across many subtests, particularly among children in early elementary school. For instance, from 1984 to 2008 scores of creative Elaboration among students in kindergarten to third grade dropped by a large effect size (Cohen's $d = 1.23$, $p < .001$) with similarly substantial decreases for students in fourth to sixth grade ($d=1.03$, $p<.001$), high schoolers ($d=1.18$, $p < .001$), and adults ($d = 1.54$, $p<.001$). This alarming trend may be due to the pace of the digital age and has clear negative implications for the future[6]. In light of this, the purpose of this literature review is to integrate findings from psychology and neuroscience to identify actionable methods of how creative problem-solving ability can be enhanced. Our objectives are to (a) reveal the mechanisms that determine creative problem-solving ability, (b) identify methods of enhancing creative problem-solving, and (c) suggest applicable strategies in everyday life, education, and beyond. We begin by demystifying creative problem-solving and breaking it down into distinct cognitive processes. We explore how creative problem-solving transpires on a cognitive level and then dive deeper to examine the three neural networks involved. Throughout the paper, we synthesize these perspectives to provide actionable methods of improving creative problem-solving based on recent research.

Methods

Search Strategy and Databases

Literature on the psychology and neuroscience of creative problem-solving was primarily accessed using the PsycINFO, PubMed, and Google Scholar databases. We prioritized the PsycINFO database because of its strong psychology focus and wealth of high-quality, peer-reviewed content. Additionally, the PubMed database was used to identify studies with a more neuroscientific basis, and Google Scholar was consulted due to its comprehensive nature covering both psychology and neuroscience. We conducted a systematic search using relevant keywords including ”psychological frameworks,” ”creative process,” ”neural mechanisms,” and “brain networks.” For each search term we filtered the order of the results page based on (a) relevance, (b) number of citations, and (c) recency. Once we had identified the foundational concepts, we used more specific search terms to investigate niche topics such as memory’s role in creative problem-solving.

Inclusion and Exclusion Criteria

We referred to seminal works but mainly utilized papers from the last ten years to maximize relevance. Additionally, whenever it was practical we included newer articles from within the past two years to ensure the information reflected ongoing findings. We considered a journal’s impact factor and the number of times a paper was cited as one way to assess a paper’s relevance. However, we also accounted for the fact that newly published or niche articles with few citations could also be valuable. We included meta-analyses, systematic reviews, and original studies based on their pertinence to the central theme of psychological concepts and neural mechanisms behind creative problem-solving. We primarily included quantitative studies that relied on cognitive assessments of creativity or neuroimaging for statistical analysis. Additionally, specific studies that illustrated more niche concepts were included, as well as studies that provided context for topics discussed, such as well-being and cognitive efficiency, even if the sole focus was not creativity. During the initial round, the abstracts and methodology of papers were carefully read through, and papers without robust methodology supporting their conclusions were excluded. Articles that did not have a strong psychological or neuroscientific basis or were too theoretical for this real-world applicable context were also excluded from the review.

Furthermore, specific characteristics related to the participants in the studies were considered. We examined variables such as age range, cognitive health, and IQ, where available. To make the strategies of enhancing creative problem-solving relevant to our audience, we included papers that studied adolescents and adults, and that reported average or above-average IQ and typical cognitive health (lack of mental disorders). Age range may influence creative problem-solving ability, with children showing more cognitive flexibility but adults possessing superior reasoning and depth of knowledge[6,7]. However, it is reasonable to assume that strategies that enhance creative problem-solving for one age group are likely to carry some relevance to other ages as well, and throughout the paper age range is reported alongside findings. Few studies reported socioeconomic status. These factors were taken into account to ensure a well-rounded understanding of how different variables influence creative problem-solving ability.

Discussion

1. Psychological Frameworks

1a. Basic Cognitive Processes

The first step to enhancing creative problem-solving ability is to demystify creativity and its related frameworks. Creativity, or the production of new, original, and viable ideas, is a complex cognitive process rooted in the synthesis of prior knowledge[8,9]. The power of creativity lies in the ability to adapt existing ideas and emerge with groundbreaking ways of thinking[10]. During creative problem-solving, the brain connects a wide range of prior knowledge to the problem at hand, finding unique ways to combine concepts. From this synthesis of material, a novel idea is formed[8]. Creative problem-solving can be broken down and defined in terms of four dimensions—originality, flexibility, fluency, and elaboration—that were first identified by Psychologist J.P. Guilford[11]. By understanding the interplay of these four dimensions we can target specific skills in each domain to enhance overall creative problem-solving ability.

Building on these dimensions, divergent and convergent thinking are the major psychological processes that work in conjunction to enable the production and revision of creative solutions[11,12]. Divergent thinking is the rapid brainstorming of ideas without critique or analysis, and during creative problem-solving, generates an array of solutions that range from the feasible to the far-fetched. For instance, a team tasked with designing advertisements may suggest celebrity endorsements, along with unconventional ideas like using drones or delivering real-time samples. Convergent thinking, on the other hand, is a more analytical approach that involves narrowing down options until an effective solution is reached[11,12]. During this stage, the advertisement ideas would be evaluated based on costs, practicality, and impact. To solve problems, divergent thinking is vital in producing a list of expansive possibilities, but only through convergent thinking can the ideas be refined for real-world effectiveness[9,12].

The distinct measures of divergent and convergent thinking are the backbone of creative problem-solving and allow researchers to quantify creative problem-solving ability and assess the effectiveness of various enhancement techniques. The Remote Associates Test (RAT) is commonly used to measure convergent thinking, which is crucial to identifying viable solutions during the creative problem-solving process. The Remote Associates Test requires participants to come up with their own word that logically connects to a list of three words presented[3]. For instance, if given the words "opera," "hand," and "dish," the correct answer linking these ideas would be "soap." The Torrance Tests of Creative Thinking (TTCT), on the other hand, measure divergent thinking and involve tasks such as inferring cause-and-effect in scenarios and filling in incomplete drawings[13]. The TTCT are a valuable indicator of a person's ability to brainstorm out-of-the-box solutions to a problem. A study by Jonathon Plucker tracked the career accomplishments of over 200 elementary school children and revealed through statistical modeling that the TTCT are over three times superior at indicating creative potential than IQ scores from childhood[14]. This proposed model of childhood TTCT scores accounted for nearly 50% of the spread of future creative achievement ($p < .01$), with a Tucker-Lewis Index of 0.91, indicating a good model fit. It should be noted, however, that the participants possessed above-average intelligence (mean = 121, SD=16), which may limit the generalizability of these findings to the larger population. A similar test that also measures divergent thinking is the Alternative Uses Test, in which participants are asked to brainstorm unconventional ways that an object could be used[15]. Many real-world problem-solving scenarios involve creative tasks of this nature—the astronauts of the disastrous Apollo 13 mission, whilst stranded in space, had to think of unique ways to combine cardstock, duct tape, a plastic bag, and a spacesuit hose to create a makeshift carbon-dioxide filter[16]. These psychological tests encompass and define the fundamental processes of creative problem-solving and are invaluable in tracking improvements in creative problem-solving ability.

1b. Training Cognitive Skills

Like many cognitive skills, the four dimensions of creative problem-solving (Originality, Flexibility, Fluency, and Elaboration) and convergent and divergent thinking can be fine-tuned through deliberate practice[17,18]. Regarding the four dimensions of creative problem-solving, adopting personality and mindset traits that increase each one of these subscales is critical to increasing creative problem-solving as a whole[18]. In everyday life, Originality can be fostered through seeking out diverse life experiences —traveling, meeting new people, participating in new clubs or activities—and is tied to personal conviction, open-mindedness, and nonconformity[10,15,18,19]. Creative problem-solving involves combining interdisciplinary knowledge in unique ways, and being inquisitive about diverse topics, through activities like reading, gives the brain a wider breadth of possibilities from which to derive solutions[20,21]. Regarding the dimension of Flexibility, a 2024 study by Mishra & Singh conducted a cross-sectional survey of 635 young adults (mean age = 19.2 years, SD = 1.49), and found that greater cognitive flexibility and emotional intelligence led to heightened entrepreneurship[18,22]. As such, Flexibility relies on being able to employ multiple perspectives and navigate both challenging intellectual and social situations. The dimension of Fluency in divergent thinking[23] can be built up through brainstorming exercises, such as jotting down a question at the top of a page, setting a timer, and scribbling down as many solutions to the problem as possible[18]. Additionally, using mind maps to visualize the expansive branching of ideas can aid with the prolific production of creative solutions through divergent thinking[18,24]. For instance, a problem such as 'Eliminate Food Waste' would occupy the center of the mind map, and diverse ideas like 'start public campaigns,' 'rethink expiration dates,' and 'reduce overproduction' would spiral from the center. Fluency in convergent thinking, which is needed to identify a viable solution, can be practiced by creating prototypes and outlining the pros and cons of ideas. For each proposed solution to eliminating food waste, practice quickly visualizing a plan and how to adapt to various time and budget constraints. Actually, carrying out creative solutions, Elaboration, is highly dependent on self-efficacy, adaptability, and perseverance[17,19]. Creative problem-solving is highly tied to intrinsic motivation, which can be enhanced by setting clear goals and relating the problems at hand with a larger purpose[17,20,25]. Children may possess greater cognitive flexibility and divergent thinking skills, allowing them to benefit from open-ended brainstorming exercises and developing new personality traits[26]. Meanwhile, it may be difficult for adults to adopt new personality and mindset traits, and structured exercises and training programs may be more effective at altering ingrained patterns of thought.

Relying on these personality traits and cognitive processes, several programs have aimed to amplify creative problem-solving ability among adults by teaching and ingraining these skills. A 2023 meta-analysis by Haase et al. found that, among adults, training courses spanning multiple weeks had a moderately strong effect size on enhancing creative problem-solving ability ($g=0.66$, 95% CI [0.53, 0.79], $p<.0001$)[18]. A 2023 study by Gu et al. was, to our knowledge, the first study to employ an online training program to see how creative problem-solving skills could be developed[27]. They recruited 136 college students (mean age = 20.7, SD = 2.83) to complete daily 10–15-minute exercises such as coming up with inventions and solving word association problems. Over the span of five weeks, the group that completed this online creativity course displayed markedly improved divergent thinking, producing a significantly greater number of creative ideas on the final administration of the Alternative Uses Test compared to the pretest ($p<.001$, $\eta p^2 = 0.10$), and producing significantly more varied ideas ($p < .001$), with a moderately large effect size ($\eta p^2 = 0.083$). Thus, daily apps and online programs, which require less commitment than in-person classes, may be a practical way to increase creative problem-solving skills in many domains including Flexibility, Fluency, and Originality.

Courses that take a different approach and simply educate people about the cognitive and neurological basis of creative problem-solving can also lead to real improvement[18,28]. For instance, Denmark researchers Onarheim and Friis-Olivarius developed an Applied NeuroCreativity (ANC) program to assess how creativity could be taught among adults in their mid-twenties (mean age = 26 years). Using the Alternative Uses Test, the study found that instructing participants about the underlying neuroscience of creativity and skills like divergent and convergent thinking led adults' creative problem-solving capacities to increase by 28.5%, on average, over the span of eight weeks[28]. Those in the Applied NeuroCreativity program showed significantly greater improvement in creative problem-solving ($p = 0.0212$, $\eta 2 = 0.5$) than those in a control group after taking varying baseline skill levels into account. Despite these promising results, training programs are not universally effective and require a substantial investment of time and commitment that may be feasible for adolescents but difficult for many adults' busy lives. Moreover, the long-term effects of such interventions across diverse populations warrant more investigation[18]. We suggest that while children may have greater cognitive flexibility toward the new ways of thinking that these programs teach, adults are more self-disciplined and able to comprehend the cognitive processes involved in these trainings[26].

1c. The Creative Process & The Subconscious

As demonstrated by these training programs, creative problem-solving skills are often built up over time, and the temporal dimension of creativity as a whole should not be overlooked. While creative solutions often seem to arise spontaneously, the Creative Process provides a temporal framework for dissecting the underlying processes at play. Understanding how these four steps produce solutions enables us to exercise greater control over when and how these ideas arise. The Creative Process hypothesizes that problem-solving is achieved through Preparation, Incubation, Illumination, and Verification stages in which the subconscious mind plays a vital role[29,30]. The ancient Greek mathematician Archimedes famously illustrated these steps when the King asked him to solve the seemingly impossible problem, for his time period, of assessing the purity of a golden crown[31]. During Preparation, the brain analyzes the context of the issue and gathers relevant information; in this case, Archimedes had to examine the crown's physical properties like weight and recall his previous scientific knowledge. Next, Archimedes stopped dwelling on the problem and took a bath, initiating the Incubation phase in which the unanswered question ruminates in the subconscious, which has superior processing abilities[25,30]. To illustrate, each second the subconscious mind can process an incredible 11 million bits of information, while the conscious mind can only register about 40 bits[32]. Once the subconscious uncovers an exciting solution, the turning point of Illumination occurs and the brain suddenly becomes aware of the idea, with rewarding chemicals being released in the process[15,30,33]. While bathing, Archimedes suddenly realized that he could measure the volume of the crown through water displacement, to determine if the density was that of real gold. Archimedes supposedly shouted "Eureka" to celebrate his discovery; indeed, creative-problem solving epiphanies—or "Eureka" moments—often occur at seemingly random times such as while in the shower or in the middle of the night[30,33]. The last phase of the creative process, Verification, involves the evaluation and implementation of the solution[3,29]. To finish off the creative process, Archimedes submerged the crown in water to calculate its density and determined that the crown was not, indeed, pure gold. Importantly, creative problem-solving insights are the product of a psychological process and not as spontaneous, and therefore not as unfathomable, as they may initially seem.

Since the incubation phase plays the dominant role in discovering these creative problem-solving insights, initiatives to increase creative problem-solving should focus not only on the conscious but also on the subconscious mind[21,30,34]. Activities that relax the conscious mind and function as incubation phases precipitate the emergence of new creative solutions[21,30,34]. One such technique that exploits the Creative Process is the "Macgyver Method," in which individuals write down a question or problem on a piece of paper and then engage in a low-energy activity. After a few hours, the Macgyver Method entails revisiting the piece of paper and putting the pencil to the page, based on the premise that the incubation phase has formed ideas that will soon materialize[25]. To enhance creative problem-solving, try to incorporate powerful incubation periods like quality sleep, meditation, and exercise into daily routines[18,30]. Meditation boosts working memory, enhances concentration, and reduces anxiety of criticism, which are all valuable parameters of creative problem-solving[23,35,36]. During open-monitoring meditation, allowing thoughts to drift freely through the mind enables divergent thinking and receptiveness towards seeing the problem from other perspectives[25,35]. Indeed, a 2023 meta-analysis by Haase et al. found that meditation was one of the most highly effective creative problem-solving enhancement strategies for adults ($g=0.66$, 95% CI [0.38, 0.94], $p<.0001$)[18]. Additionally, time spent exercising—especially outdoors—is a valuable incubation period that engages the subconscious to bring on fresh solutions and inspiration[15,37]. Throughout everyday life, implementing relaxing habits like reading or gardening that are away from the distractions of high-stimulus environments allows the subconscious to optimally function and enhance creative problem-solving ability[30].

1d. Emotional Regulation

Expanding on this idea of relaxation and reflection fostering inspiration, emotional regulation is a viable strategy for enhancing creative problem-solving ability[19,38]. Emotions shape our outlook on problems and release neurotransmitters that powerfully affect cognition and behavior[25]. Positive emotions, such as happiness, promote openness to new ideas and facilitate optimal problem-solving by enhancing memory, concentration, and motivation through neurochemicals like dopamine, oxytocin, and serotonin[4,25,38]. On the other hand, irritable moods narrow thinking and hinder creativity; thus, the ability to regulate these negative emotions and maintain optimism is crucial for enhancing creative problem-solving[4,39]. A study by Karuna Subramaniam found that people are more imaginative after viewing comedic video clips, suggesting that a positive attitude equates to less inhibition towards voicing risky or unique ideas[19,39]. Additionally, Kudrowitz (2010) found that trained comedians outperformed corporate project designers on creative tasks, outputting up to 20% more ideas. The study demonstrated that humor and liveliness are associated with creative problem-solving, and suggested that improvisation classes and games, which develop these attitudes, can teach ingenuity, leading to observed improvements of about 37%[40].

Despite mental illness sometimes being associated with a state of creativity (as popularized through artists like Vincent Van Gogh), mental and physical well-being is imperative[3,5,19]. Creativity and well-being may interact through a mutually reinforcing relationship—that is, creative individuals are happier and being happy can increase ingenuity[5,19]. Indeed, Conner et al. (2016) analyzed 658 young adults (mean age = 19.8, SD = 1.7) and found that individuals who spent more time on creative hobbies reported better states of mind through diary reports, with a moderately positive correlation between Positive Affect and Creativity of $r= 0.347$ ($p<.001$)[4]. Taking a break from the problem at hand and participating in enjoyable activities such as reading, drawing, or spending time with family is vital to recharging creative problem-solving and avoiding burnout[30]. Exercise is one of the best ways to foster inspiration because it releases dopamine and alleviates stress[25,37]. Likewise, sleep is highly beneficial for regulating emotions and also provides an incubation period.

1e. Implications for Education and Workplaces

Along with promoting positive emotional regulation, surrounding environments should implement social norms that facilitate creative problem-solving ability, specifically in classroom settings. Children's school and home environments are highly influential in fostering creative problem-solving tendencies and initiatives that target the norms of these spaces can encourage creative expression from a young age[20,41]. Environments that promote curiosity, risk-taking, and unconventional thinking—such as by normalizing failure and providing unconditional support—are pivotal in providing safe spaces for creative exploration[20,41,42]. Teachers play a pivotal role in such environments, and teachers should receive resources and training that enable them to effectively teach creativity to students[7]. While countries such as Britain and China have promoted programs that actively teach creative problem-solving, American schools seem reluctant or unable to adopt such measures[1]. In the classroom, curriculum should carve out time for students to pursue projects that investigate personal interests (such as Mars rovers) or propose solutions for real-world issues (like ocean acidification)[17,20]. Prompting students to constructively reflect on work and entertain other perspectives, such as in literature or healthy debate, also guides creative problem-solving[17]. Nevertheless, at its root creative problem-solving must be intrinsically driven by the student, and these programs to enhance creative problem-solving should prompt students' curiosities but avoid emphasizing external rewards[20,41]. A 2024 meta-analysis by Zhang et al. was the first to assess aggregated literature on how after-school programs affect creativity. They found that extracurricular programs, particularly those that allow students to practice creativity in the arts and STEM, can improve creativity even in timeframes less than a week. The researchers suggested that schools should try to emulate the greater autonomy in learning and self-expression that after school programs provide and recommended that initiatives begin at younger grades, where they are most influential[7]. Specifically, the influence of after-school programming on creativity had the largest effect size among preschoolers (Hedges' $g = 1.033$), followed by primary school students ($g=0.726$) and students in secondary school ($g=0.578$).

This trend of children growing older being linked to creative problem-solving declining—that many researchers, like Zhang et al., have found—may be due to social norms that value logic and realism over imaginative thought[6,7,25]. Due to changing social norms as people age, creativity scores typically slump around fourth grade or middle school, an issue which schools should remedy by taking initiatives to encourage imagination throughout the upper grade levels[6,7]. In both classrooms and workplaces, establishing and posting shared guidelines for flexibility, risk-taking, and collaboration can bolster creative problem-solving, while a bureaucratic culture may discourage people from voicing unconventional solutions[17,42,43]. For instance, a 2022 study by Zhou et al. found that employees given more choices produced more creative ideas of higher quality[43]. Essentially, educational and corporate policies to increase creative problem-solving should promote an environment conducive to trying new things, offer opportunities to pursue interests, and promote a healthy exchange of ideas and collaboration. Connecting back to previous ideas, these environments should also instill innovative personality traits, teach problem-solving techniques and exercises, allow for breaks that activate the subconscious mind, and promote positive emotional regulation. Some limitations are that these policies must balance practical constraints like budget, time, and employee productivity quotas while still promoting creative problem-solving ability.

Additionally, there is a lack of long-term studies that track how these educational and workplace initiatives to increase creative problem-solving play out. Across non-western cultures with different social norms, more research needs to be done to identify the best classroom and workplace strategies.

2. Neuroscientific Mechanisms

2a. The Three Neural Networks

While psychological frameworks provide a lens into the cognitive processes of creative problem-solving, neuroscience offers insight into the brain's underlying mechanisms that enable these processes. The field of neuroscience allows us to take psychology's broad concepts of how creative problem-solving surfaces and dive deeper to precisely examine what transpires in the brain. Comparatively, the neuroscience of creative problem-solving is a much more recent field and has only emerged in the last two decades with the advent of advanced brain-imaging techniques[44]. Much of creative problem-solving ability is dependent on the wiring and functioning of the brain. Neuroplasticity enables the brain to reshape itself via training; thus, creative problem-solving can be increased by strengthening the brain regions involved in creative thought[45,46]. Despite popular belief that the right hemisphere of the brain is more imaginative and artistic, creativity is not solely located in the right hemisphere, nor is logic solely reliant on the left half. Instead, creative problem-solving involves the collaboration of multiple networks and brain structures[3]. Particularly important to creative problem-solving are the Default Mode, Executive Control, and Salience Networks[47]. A careful examination of these three networks is instrumental to understanding the neural correlates of creative problem-solving and strategies to engage these neural functionalities. Each brain network consists of various structures, scattered throughout the brain, that work in conjunction to achieve a certain purpose.

The primary network of creative problem-solving is the Default Mode Network (DMN) which produces random and imaginative solutions[44,47,48]. The Default Mode Network controls mind-wandering and daydreaming and operates whenever the brain is not completely engaged with a task. This network allows the brain to contemplate future outcomes and introspectively reflect on the past—skills that are vital to problem-solving[44,48]. The Default Mode Network consists of many structures such as the posterior cingulate cortex, medial prefrontal cortex, precuneus, and angular gyrus[41,44,48]. Meanwhile, the Executive Control Network (ECN) directs the brain's center of focus toward the problem at hand and processes new stimuli and information about the issue. The anterior cingulate cortex (which manages perception-reaction discrepancies) and the posterior parietal cortex (responsible for sensory awareness) play a crucial role in this network[49,50]. Additionally, the prefrontal cortex and dorsolateral prefrontal cortex allow the Executive Control Network to facilitate working memory and decision-making[50].

Understanding these two brain networks and how they simultaneously activate to facilitate creative problem-solving is critical to enhancing this ability[47]. The Default Mode and Executive Control Network are generally viewed as opposite in function—one decentralizes attention, one highly focuses—with only one of the two engaging at any given time[15,47]. However, generating creative solutions requires these two networks to work in tandem with the aid of a third network, the Salience Network. The Salience Network observes the workings of the Default Mode Network and informs the Executive Control Network of any salient, or promising, creative solutions[47,51]. The Salience Network includes the anterior cingulate cortex and anterior insula, which process external stimuli[51]. During creative problem-solving, the mind is wandering and the Default Mode Network is generating random ideas[51]. To illustrate, a software developer trying to name a new retail app may produce a random stream of ideas in their Default Mode Network: checkout, shopping bags, garments, seams. At any point during this mind-wandering state, a word like 'seams' may catch the attention of the Salience Network, which activates whenever a creative solution is conceived and prompts the Executive Control Network to take notice of the idea. The Executive Control Network, would, in turn, consciously craft the app name 'Seamless Shopping.' In other words, the Salience Network allows the brain to alternatively activate the Default Mode and Executive Control Networks to subconsciously produce and consciously evaluate new solutions[47,51].

2b. Integration of Neural Networks with Psychology

This neuroscience behind creative problem-solving directly parallels the psychological-level cognitive approaches and the creative process. The functioning of the Default Mode Network can be likened to the random and expansive brainstorming that occurs during divergent thinking, while the Executive Control Network mirrors the analytical, careful reasoning of convergent thinking[25,52]. Creative problem-solving involves the interplay of divergent thinking and convergent thinking to produce and analyze solutions; at a neuroscientific level creative problem-solving requires the production of ideas by the Default Mode Network and the conscious evaluation by the Executive Control Network[52]. Additionally, the Default Mode, Executive Control, and Salience networks work together to enable the sequence of the creative process through Preparation, Incubation, Illumination, and Verification stages. After the Executive Control Network intently focuses on the problem during Preparation, the neuroscience of the Default Mode Network can be compared to the Incubation phase of the creative process, as they both rely on mind-wandering and daydreaming[44,47,48]. Once the Default Mode Network contemplates ideas during Incubation, the Salience Network identifies a promising idea, triggering the Illumination phase of the creative process. After Illumination occurs, the Salience Network passes along the idea to the Executive Control Network which allows the critical evaluation of the Verification phase to be carried out.

Researchers have also begun to pinpoint the specific neural correlates of these psychological processes. A 2020 study by Zhang et. al suggested that the process of insight, or Eureka moments, is associated with activity in the left dorsolateral prefrontal cortex and the left inferior frontal gyrus along with the superior temporal gyrus (part of the temporal lobe and memory)[52]. They also identified some specific brain structures that facilitated divergent and convergent thinking. The left inferior frontal gyrus, which has been associated with greater creative Flexibility scores on the TTCT and is involved with speech and cognitive control, is active during divergent thinking activities like the Remote Associates Test. Meanwhile, the left dorsolateral prefrontal cortex, part of the Executive Control Network and responsible for executive functioning, is more associated with convergent thinking[52]. Incubation periods and positive moods facilitate creativity on a psychological level; indeed, lower levels of the neurotransmitter norepinephrine, indicating relaxation, are linked to greater communication between brain regions and greater creative problem-solving[53]. Additionally, higher levels of the neurotransmitters dopamine and oxytocin in the brain, which contribute to positive emotional regulation, are associated with greater creativity[26]. This release of feel-good neurotransmitters is intertwined with the onset of feelings of happiness—in many cases, the psychological and neuroscientific mechanisms of creative problem-solving directly interact and reinforce one another.

2c. Brain Function & Structure as a Predictor of Creative Problem-Solving Ability

Using the three mapped-out neural networks of creativity, brain-imaging technologies have enabled researchers to assess how neural structures contribute to different levels of creative problem-solving, with the aim of finding solutions to boost this neural capacity. Fink et al. (2009) used EEG and fMRI scans to examine the neural activity of 47 adult participants (mean age = 24.09 years, SD = 2.95) while performing various creative tasks including Alternative Uses and Name Invention. They found that greater creativity was linked to alpha brain wave synchronization centered in areas like the prefrontal cortex, signaling a conscious state of activity but not high alert[41,54]. As such, creative problem-solving may involve the ability to take a step back and grasp the broader context without becoming caught up on details[25]. Learning how to concurrently maintain both the strong focus of the Executive Control Network and the drifting spontaneity of the Default Mode Network is a skill of highly creative individuals[25,46,53]. This relates back to how increasing the dimension of cognitive Flexibility, or being able to employ multiple perspectives, is key to enhancing creative problem-solving. Interestingly, Fink et al. found that the type of creative task participants performed had a significant impact on alpha brain wave activity ($p < 0.01$, $\eta 2 = 0.50$), and significantly impacted the area of the alpha wave synchronization ($p < 0.01$, $\eta 2 = 0.32$), with upper levels of the brain having more activity during Alternative Uses and Object Characteristics Tasks, and less activity during Word Ends and Name Invention tasks. Relating back to psychological processes, divergent thinking tasks are associated with an increase in alpha wave synchronization, while convergent thinking tasks are associated with a decrease[52]. Since the location of brain activity differs depending on the nature of the creative task, enhancing creative problem-solving ability should involve practicing diverse tasks—and both divergent and convergent thinking—to fully engage neural regions.

A similar study by Beaty et al. (2018) suggested that underlying brain structure may be closely tied to creative aptitude. Using fMRI scans of 163 adult participants (mean age = 22.50 years, SD = 5.79), they discovered that individuals with greater integration between the Default Mode, Executive Control, and Salience Networks displayed greater creative problem-solving, as measured through the Alternate Uses Test and an object characteristics task[51]. Predicting creative problem-solving ability depending on the connectivity of these neural networks was demonstrated to be a valid model specifically among those with high creative ability. They found a significant correlation of high connectivity and high creative ability through internal validation ($r = 0.30$, $p = 0.000129$) and three external validation tests ($r = 0.35$, $p = 0.03$; $r = 0.28$, $p = 0.03$; $r = 0.13$, $p = 0.008$). Based on this association, we suggest that creative problem-solving ability can be enhanced through strengthening the circuitry between these three neural networks[51,53].

2d. Deliberate Practice and Experience

To achieve this robust circuitry between neural networks, practicing cognitive processes that exercise creative problem-solving is of utmost importance and can physically reshape the brain. Regularly engaging the neural pathways of creative thought can strengthen the Default Mode, Executive Control, and Salience Networks and allow the brain to alternate between these networks and produce ideas more efficiently[46]. Across creative domains, individuals who are more experienced and artistically skilled demonstrate different patterns of neural activity during creative problem-solving tasks[2,53,55]. For instance, Rosen et al. (2020) studied jazz musicians from early to middle adulthood (mean age = 27.9 years, SD = 9.38, min = 18, max = 55), and found that inexperienced jazz musicians displayed more neural firing in the right hemisphere while playing improvised pieces, whereas in seasoned musicians the activity was more localized in the left[55]. Brain wave frequency was also associated with improvisation quality; low-quality improvisations exhibited significant beta and gamma wave activity ($P_{FWE} < 0.001$) near right temporo-parietal electrodes, while high-quality pieces displayed stronger beta ($P_{FWE} = 0.005$), alpha ($P_{FWE} < 0.001$), and theta ($FWE = 0.002$) activity at right frontal electrodes. Unsurprisingly, experience influenced these neural patterns, with a musician's number of prior live performances significantly predicting higher quality improvisation ratings ($p = 0.002$). These results indicate that becoming more skilled in a craft leads the brain to work differently and experience creative problem-solving on an entirely different neurological level. Therefore, it is important to gain experience and practice creative problem-solving to strengthen and tune the neural pathways of creativity[2]. Psychologically, creative practice also serves another important purpose: it increases familiarity and understanding with a topic, which translates to a superior ability to identify creative problem-solving solutions during divergent and convergent thinking[2,21]. Immersing oneself in the intricacies of the subject matter through activities like reading provides the brain with more raw material to form connections with, and neuroscientifically, this added experience allows the brain to function differently. Possessing more experience and skill in diverse subjects connects back to increasing the cognitive domains of Fluency, Flexibility, and Elaboration, and ensuring better creative problem-solving quality.

In addition to reshaping the functioning of the brain through immersive experience and creative practice, creative problem-solving can be enhanced by targeting general cognitive skills like reasoning and recall. Creativity and intelligence are highly related (among young adults $r = 0.63$, $p < .001$) and are both characterized by efficient working memory and problem-solving[23,36,56,57]. For instance, a 2022 study by Cancer et al. found that creative problem-solving among both young adults and elderly people is moderately predicted by verbal working memory 95% CI [0.005,0.03][56]. The prefrontal cortex governs planning, goal orientation, and decision-making, and is vital to intelligence and creative problem-solving[57]. Due to neuroplasticity, the more often reasoning and problem-solving skills are practiced, the stronger and more efficient those neural pathways become. Optimizing the workings of the prefrontal cortex through engaging with stimulating problems and maintaining well-being is conducive to increasing overall creative problem-solving ability[3,45,57]. Thus, creative training programs and classroom initiatives should hone these reasoning and memory skills of the prefrontal cortex, instead of just focusing on creativity-related techniques. During divergent thinking and brainstorming, creative problem-solving heavily relies on the temporal lobe, specifically the hippocampus, which retrieves past experiences and enables the synthesis of prior ideas[3,36,50]. A case study by Duff and colleagues (2014) showed that patients with impaired hippocampi scored significantly worse on the Torrance Tests of Creative Thinking compared to healthy individuals, scoring 43.95% lower on verbal ($p = 0.002$) and 26.72% lower on figural scales ($p = 0.004$). The poor hippocampus function of participants resulted in a shortcoming of divergent thinking, and an inability to rapidly brainstorm solutions[58]. The volume of the hippocampus proportionally relates to memory capacity and can be increased through exercise and sleep, which facilitates the growth of new neurons in the brain, referred to as neurogenesis[59,60]. As such, exercise and sleep are highly-effective ways to enhance creative problem-solving, as they work through multiple approaches by providing an incubation period, improving emotional states, and boosting memory by facilitating the growth of neurons in the hippocampus[37,60].

Expanding on the idea of improving cognitive skills and neurogenesis, the efficiency of creative problem-solving can be enhanced by bolstering the white matter pathways that link various regions in the brain. Individuals with greater connectivity of white matter can more efficiently associate and synthesize random ideas, leading to greater creative problem-solving[3,46,53]. Schlegel et al. (2015) demonstrated that among college students, highly creative artists possessed different formations of white matter in their frontal cortices when compared to less creative peers. In just eleven weeks, students who took an art class experienced changes in their bilateral prefrontal white matter, exhibiting a significant decline in Fractional Anisotropy, an indicator of white matter organization ($t = -2.41$, $p = 0.016$) compared to the control group[61]. Indeed, one explanation for why children are typically more creative than adults is because they possess so many more disorganized neurons that later get pruned away to streamline adult brains[25]. Reading, exercise, meditation, and learning new skills are all effective approaches to increasing white matter connectivity and problem-solving efficiency[45,62]. Thus, from a psychological standpoint, activities that teach something new and bolster well-being are vital in developing new expertise, providing a relaxing incubation period, and allowing the brain to regulate emotions and think more expansively. Importantly, these training courses and activities are also key to facilitating greater white matter volume and formation, for more efficient synthesis during creative problem-solving.

2e. Benefits of Sleep

Furthermore, sleep is one of the most beneficial measures in boosting creative problem-solving from both a psychological and neuroscientific perspective, as it optimizes cognition, primes the subconscious mind, and regulates mood. When solving problems, though, sleep serves another large purpose: allowing the brain to fire in random ways and imagine brilliant possibilities. Particularly important to creative problem-solving are two phases of sleep, the moment of falling asleep, known as hypnagogia or N1, and dreaming, which takes place during REM sleep[63,64]. During N1, the Default Mode and Executive Control Networks become active and ideas arise as the brain shifts between states of consciousness[15,63]. Rapid Eye Movement (REM) Sleep, on the other hand, involves intense neuronal firing across various regions of the brain, similar to the activity level of conscious awareness. During REM sleep the brain vividly lives out possibilities and experiments with new ideas[64]. Novel information from the day is incorporated into previous knowledge, allowing the brain to solidify memories and shuffle random thoughts into creative solutions[63,64]. Sleep is a pivotal incubation phase that allows the mind to shuffle through ideas, and the importance of quality sleep for creative problem-solving cannot be overstated. Indeed, sleep deprivation has been found to lower creative problem-solving Fluency and stymie divergent thinking[26].

Recent Findings

Recent research on enhancing creative problem-solving ability has emphasized the creative flow state, a mental state of heightened cognitive performance and intense creativity that the brain can occasionally shift into. A study by Rosen et al. (2024) was one of the first to assess how creativity manifests differently in the brain during flow states. They recruited jazz guitarists to test out two theoretical frameworks for flow (a) that flow is the result of intense activity in the Executive Control and Default Mode Networks and (b) that considerable experience allows the Executive Control Network to relax and enable the brain to perform effortlessly. Using EEG to track brain activity, they found that while the moderately positive relationship between high experience and higher flow was not statistically significant ($b = 0.354$, $p = 0.089$), higher experience strongly predicted higher judge ratings of performance ($b = 1.458$, $SE = 0.407$, $t = 3.584$, $p < 0.001$), and greater judge ratings in turn were a fairly strong predictor for flow ($b = 0.175$, $SE = 0.048$, $t = 3.659$, $p < 0.001$). These findings support the second theory, suggesting that, while confounding factors are at play, mastery and quality are important prerequisites for flow[2,65]. Thus, gaining expertise through creative practice may be highly effective for inducing the unparalleled level of creative problem-solving characteristic of flow[2]. In addition, this finding reveals that once mastery has been achieved, peak creative problem-solving is induced through relaxing control and letting the mind do the rest.

Other research has investigated what biological patterns distinguish extremely creative individuals from typically creative people, who are often the sole subjects of study. A 2024 study by Anderson et al. used two sample groups of adults (average age in early 40s), one composed of accomplished scientists (mean IQ = 116.4) and artists (mean IQ = 113.8) and one of a typical population (with similar intelligence, mean IQ =115), to compare brain activity on the Alternative Uses and Remote Associates Tests. The study revealed that extraordinarily creative individuals had higher random activation of distant brain regions compared to the control group and less logical firing patterns. Highly creative scientists exhibited lower levels of small-world connectivity during rest states ($p<.05$), indicating less efficient global brain organization. However, clustering coefficients and local connectivity were higher for extraordinarily creative individuals ($p<.05$) during rest states, and local and global connectivity had a moderately strong negative correlation ($r \approx -0.7$, $p<.05$)[66]. The research reveals that creativity to some level is about efficient neural circuitry, but once this has been attained, outstanding creative problem-solving may break the rules and work in spontaneous ways. Nevertheless, the study was only able to enroll 42 extraordinarily creative individuals, making it difficult to discern how the groups meaningfully differed. As with flow states, recent scientific discoveries emphasize progress and taking creative problem-solving to the next level.

Additionally, evolving technology has led to new ways of modeling creative problem-solving. In 2022, Khalil & Moustafa pioneered the first computational model of creativity designed off of the neural networks of the brain[50]. As the field of Artificial Intelligence has swelled in recent years, more literature has investigated how humans and AI use similar and different processes for creative problem-solving. A paper by Esling & Devis (2020) suggested that AI is conditioned to think in conventional patterns and may struggle to organically connect unrelated topics in the same way human brains can[67]. Indeed, a study by Doshi & Hoser (2024) revealed that generative AI can effectively increase the creativity of short stories. They found that AI excels in one dimension of creative problem-solving, producing useful ideas, but not in the dimension of producing truly novel, idiosyncratic work. For instance, when judges assessed stories for the quality of Usefulness, writers with one generative AI source scored 3.7% higher than writers without ($b = 0.185$, $p = 0.039$), with more generative AI sources leading to higher gains; writers using five generative AIs scored 9.0% higher than writers with no AI at all ($b = 0.453$, $p < 0.001$). Importantly, AI enhanced the creativity and quality of typical writers but did not meaningfully boost creativity for highly creative writers[68]. While a limitation of this finding is that AI is still a very recent development, this suggests that AI can be useful in enhancing creative problem-solving up to a certain point and excels in Flexibility, Fluency, and Elaboration, but lacks in the subscale of Originality. Other research has taken AI in a completely different direction and used machine learning to build effective, instantly AI-graded creativity tests that enable schools to administer widespread assessments of creative problem-solving skills[69]. Thus, AI may be used as a teaching tool to help efficiently benchmark and target creative problem-solving ability. The future of creative problem-solving research will almost certainly gravitate towards AI and emphasize how the co-creative process combining the human mind and AI can enhance problem-solving efficiency[67].

Conclusion

Ultimately, creative problem-solving is among the most intricate of brain processes. Creative problem-solving involves convergent and divergent thinking approaches, multiple cognitive dimensions, and the conscious and the subconscious mind. Moreover, the Default Mode, Executive Control, and Salience Networks as well as the prefrontal cortex, temporal lobe, and white matter all play vital roles. Creative problem-solving ability can be increased by refining the skills of originality, flexibility, fluency, and elaboration through lifestyle and mindset shifts, as well as by practicing convergent and divergent thinking techniques through tasks like mind maps or online exercises. While inspiration may feel spontaneous, ideas tend to follow the four phases of the Creative Process and incubation periods are critical to finding solutions. Creative problem-solving can be enhanced through activities that engage the subconscious and regulate emotional states—exercise, meditation, fresh air, and quality sleep. Additionally, external environments and social norms that promote unconventional thought enable creative problem-solving to thrive. From a neuroscientific perspective, creative solutions are produced by the Default Mode, Executive Control, and Salience Networks. Importantly, creative training can strengthen these networks, and improving reasoning and memory skills can also boost creative problem-solving. Additionally, remaining intellectually curious and physically active supports the connectivity of white matter in the brain. Exercise, meditation, sleep, and problem-solving practice emerge among the most beneficial activities that both psychologically and neuroscientifically increase creative problem-solving ability. In essence, creative problem-solving can be enhanced through activities that relax or open the mind and allow the brain to generate ideas at optimal capacity.

While individual methods of improving creative problem-solving can have tremendous personal impacts, wide-scale programs that empower the next generation should be the top priority. Systematic approaches should be used to combat declining creative problem-solving ability. Across the world, schools should emphasize problem-solving-oriented curriculum and incorporate student-driven, open-ended projects. Schools and workplaces should reward risk-taking and encourage new ways of approaching issues over intellectual conformity and sticking to the comfort zone. To this end, policies that give students and employees more flexibility and establish norms of collaboration can increase creative problem-solving ability. These institutions should also implement policies that teach problem-solving exercises, such as by having presentations on the neuroscience behind psychology or administering divergent thinking problems in classrooms. Lastly, particularly in workplaces where long hours are common, providing breaks during the day is crucial to activating the Incubation Period of the subconscious, and a pleasant, healthy working environment enables positive emotions that allow the brain to think more expansively. As the world becomes increasingly fast-paced, society must remember to slow down and value daydreaming, abstract expression, and critical and reflective thought. When finding new solutions to today's pressing issues, it is essential to not become overwhelmed by negativity and lost in the minutiae and drudgery. Rather, brilliant solutions generally arise from taking carefree breaks, prioritizing well-being, and remaining flexible to new thinking strategies. When seen as incredible bursts of insight or dissected to the connections occurring at the neuronal level, creative problem-solving is an attestation to the astounding human brain. As Albert Einstein once said, "Creativity is intelligence having fun." With creative problem-solving, the future is bright and the possibilities are truly endless.

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References

1 P. Bronson and A. Merryman, *The Creativity Crisis*, `http://itunes.apple.com/us/podcast/newsweek-on-air/id73329823`.

2 W. Yang, A. Green, Q. Chen, Y. Kenett, J. Sun, D. Wei and J. Qiu, *Creative problem solving in knowledge-rich contexts*.

3 D. Cavdarbasha and J. Kurczek, *Connecting the Dots: Your Brain and Creativity*, `https://doi.org/10.3389/frym.2017.00019`.

4 T. Conner, C. DeYoung and P. Silvia, *Everyday creative activity as a path to flourishing*.

5 C.-Y. Tan, C.-Q. Chuah, S.-T. Lee and C.-S. Tan, *Being Creative Makes You Happier: The Positive Effect of Creativity on Subjective Well-Being*.

6 K. Kim, *The Creativity Crisis: The Decrease in Creative Thinking Scores on the Torrance Tests of Creative Thinking*.

7 Y. Zhang, Q. Xu and T. Zhang, *The impact of after-school programs on K-12 students' creativity: a meta-analysis*.

8 S. Mednick, *The Associative Basis of the Creative Process*.

9 M. Runco and G. Jaeger, *The Standard Definition of Creativity*.

10 F. Barron, *The disposition toward originality*.

11 J. Guilford, *Creative abilities in the arts*.

12 B. Wigert, V. Murugavel and R. Reiter-Palmon, *The utility of divergent and convergent thinking in the problem construction processes during creative problem-solving*.

13 E. Torrance, *Torrance Tests of Creative Thinking*.

14 J. Plucker, *Is the Proof in the Pudding? Reanalyses of Torrance's (1958 to Present) Longitudinal Data*.

15 K. Weir, *The science behind creativity*.

16 L. Gottschlich, *Conserving the Creativity that Saved the Apollo 13 Astronauts*.

17 J. Horng, J. Hong, L. ChanLin, S. Chang and H. Chu, *Creative teachers and creative teaching strategies*.

18 J. Haase, P. Hanel and N. Gronau, *Creativity enhancement methods for adults: A meta-analysis*, `https://doi.org/10.1037/aca0000557`, and the Arts.

19 S. Liu, Y. Tang, M. Peng and G. Lewandowski, *The effect of self-expansion on creativity: Examining the role of novelty experiences*, https://doi.org/10.1037/aca0000682, and the Arts.

20 D. Fasko, *Education and creativity*.

21 S. Hélie and R. Sun, *Incubation, insight, and creative problem solving: A unified theory and a connectionist model*.

22 A. Mishra and P. Singh, *Effect of emotional intelligence and cognitive flexibility on entrepreneurial intention: mediating role of entrepreneurial self-efficacy*.

23 S. Dygert and A. Jarosz, *Individual differences in creative cognition*.

24 C. Malycha and G. Maier, *Enhancing creativity on different complexity levels by eliciting mental models*.

25 S. Kotler, *The Art of Impossible: A Peak Performance Primer*.

26 M. Baas, B. Nijstad and C. Dreu, *Editorial: The cognitive, emotional and neural correlates of creativity*.

27 X. Gu, S. Ritter and A. Dijksterhuis, *Online Creativity Training: Examining the Effectiveness of a Comprehensive Training Approach*.

28 B. Onarheim and M. Friis-Olivarius, *Applying the neuroscience of creativity to creativity training*.

29 G. Wallas, *The Art of Thought*.

30 Z. Irving, C. McGrath, L. Flynn, A. Glasser and C. Mills, *The shower effect: Mind wandering facilitates creative incubation during moderately engaging activities*.

31 J. Chipman, *Eureka! 7 easy steps to a more creative mind*.

32 T. Wilson, *Strangers to Ourselves: Discovering the Adaptive Unconscious*.

33 M. Prenevost, I. Nilsen, E. Bølstad, F. Pons, P. Harris and R. Reber, *Young children's understanding and experience of insight*.

34 Y. Gao and H. Zhang, *Unconscious processing modulates creative problem solving: Evidence from an electrophysiological study*.

35 D. Henriksen, C. Richardson and K. Shack, *Mindfulness and creativity: Implications for thinking and learning*.

36 C. Gómez-Ariza, *Memory inhibition as a critical factor preventing creative problem solving*.

37 T. Kimura, T. Mizumoto, Y. Torii, M. Ohno, T. Higashino and Y. Yagi, *Comparison of the effects of indoor and outdoor exercise on creativity: an analysis of EEG alpha power*.

38 A. Isen, K. Daubman and G. Nowicki, *Positive affect facilitates creative problem solving*.

39 E. Humphrey, *Laughter Leads to Insight*.

40 B. Kudrowitz, *Haha and aha!: Creativity, idea generation, improvisational humor, and product design*.

41 S. Mullen Raymond, *Neural Foundations of Creativity: A Systematic Review*.

42 R. Sawyer, *Teaching creativity in art and design studio classes: A systematic literature review*.

43 J. Zhou, G. Oldham, A. Chuang and R. Hsu, *Enhancing employee creativity: Effects of choice, rewards and personality*.

44 J. Carroll, *Imagination, the Brain's Default Mode Network, and Imaginative Verbal Artifacts*.

45 Y.-Y. Tang, Q. Lu, M. Fan, Y. Yang and M. Posner, *Mechanisms of white matter changes induced by meditation*.

46 J. Li, N. Orlov, Z. Wang, B. Jiao, Y. Wang, H. Xu, H. Yang, Y. Huang, Y. Sun, P. Zhang, R. Yu, M. Liu and D. Zhang, *Flexible reconfiguration of functional brain networks as a potential neural mechanism of creativity*.

47 R. Beaty, M. Benedek, P. Silvia and D. Schacter, *Creative Cognition and Brain Network Dynamics*.

48 R. Beaty, M. Benedek, R. Wilkins, E. Jauk, A. Fink, P. Silvia, D. Hodges, K. Koschutnig and A. Neubauer, *Creativity and the default network: A functional connectivity analysis of the creative brain at rest*.

49 K. Shen, T. Welton, M. Lyon, A. McCorkindale, G. Sutherland, S. Burnham, J. Fripp, R. Martins and S. Grieve, *Structural core of the executive control network: A high angular resolution diffusion MRI study*.

50 R. Khalil and A. Moustafa, *A neurocomputational model of creative processes*.

51 R. Beaty, Y. Kenett, A. Christensen, M. Rosenberg, M. Benedek, Q. Chen, A. Fink, J. Qiu, T. Kwapil, M. Kane and P. Silvia, *Robust prediction of individual creative ability from brain functional connectivity*.

52 W. Zhang, Z. Sjoerds and B. Hommel, *Metacontrol of human creativity: The neurocognitive mechanisms of convergent and divergent thinking*.

53 K. Heilman, *Possible Brain Mechanisms of Creativity*.

54 A. Fink, R. Grabner, M. Benedek, G. Reishofer, V. Hauswirth, M. Fally, C. Neuper, F. Ebner and A. Neubauer, *The creative brain: Investigation of brain activity during creative problem solving by means of EEG and FMRI*.

55 D. Rosen, Y. Oh, B. Erickson, F. Zhang, Y. Kim and J. Kounios, *Dual-process contributions to creativity in jazz improvisations: An SPM-EEG study*.

56 A. Cancer, P. Iannello, C. Salvi and A. Antonietti, *Executive functioning and divergent thinking predict creative problem-solving in young adults and elderlies*.

57 E. Frith, D. Elbich, A. Christensen, M. Rosenberg, Q. Chen, M. Kane, P. Silvia, P. Seli and R. Beaty, *Intelligence and creativity share a common cognitive and neural basis*.

58 M. Duff, J. Kurczek, R. Rubin, N. Cohen and D. Tranel, *Hippocampal amnesia disrupts creative thinking*.

59 K. Erickson, M. Voss, R. Prakash, C. Basak, A. Szabo, L. Chaddock, J. Kim, S. Heo, H. Alves, S. White, T. Wojcicki, E. Mailey, V. Vieira, S. Martin, B. Pence, J. Woods, E. McAuley and A. Kramer, *Exercise training increases size of hippocampus and improves memory*.

60 P. Lucassen, P. Meerlo, A. Naylor, A. Dam, A. Dayer, E. Fuchs, C. Oomen and B. Czéh, *Regulation of adult neurogenesis by stress, sleep disruption, exercise and inflammation: Implications for depression and antidepressant action*.

61 A. Schlegel, P. Alexander, S. Fogelson, X. Li, Z. Lu, P. Kohler, E. Riley, P. Tse and M. Meng, *The artist emerges: Visual art learning alters neural structure and function*.

62 S. Reynolds, *What Creates Superior Brain Connectivity, According to Study*.

63 C. Lacaux, T. Andrillon, C. Bastoul, Y. Idir, A. Fonteix-Galet, I. Arnulf and D. Oudiette, *Sleep onset is a creative sweet spot*.

64 P. Lewis, G. Knoblich and G. Poe, *How Memory Replay in Sleep Boosts Creative Problem-Solving*.

65 D. Rosen, Y. Oh, C. Chesebrough, F. Zhang and J. Kounios, *Creative flow as optimized processing: Evidence from brain oscillations during jazz improvisations by expert and non-expert musicians*.

66 A. Anderson, K. Japardi, K. Knudsen, S. Bookheimer, D. Ghahremani and R. Bilder, *Big-C creativity in artists and scientists is associated with more random global but less random local fMRI functional connectivity*.

67 P. Esling and N. Devis, *Creativity in the era of artificial intelligence*, https://arxiv.org/abs/2008.05959v1.

68 A. Doshi and O. Hauser, *Generative AI enhances individual creativity but reduces the collective diversity of novel content*.

69 D. Cropley, C. Theurer, A. Mathijssen and R. Marrone, *Fit-For-Purpose Creativity Assessment: Automatic Scoring of the Test of Creative Thinking – Drawing Production (TCT-DP*.

