Creative Thinking from the Perspective of Embodied Cognition

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Abstract

Creative thinking refers to the cognitive process that generates novel and applicable ideas or products. With the rise of the embodied cognition perspective, research on creative thinking based on this viewpoint has emerged, yet domestic studies in this area remain scarce. To promote the development of this field domestically, this paper reviews research on creative thinking from an embodied cognition perspective through the lenses of bodily action, vision, touch, and taste, and explains the relevant embodied effects from the perspectives of conceptual metaphor theory, Piaget' s genetic epistemology, and evolutionary psychology. Future research should conduct in-depth explorations from the perspectives of bidirectionality of embodied effects, cognitive neural mechanisms, reproducibility, multisensory channels, benevolent and malevolent creativity, and machine learning.

Full Text

Creative Thinking from the Perspective of Embodied Cognition

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Abstract: Creative thinking refers to the cognitive process of generating novel and appropriate ideas or products. With the rise of embodied cognition theory, research on creative thinking from this perspective has proliferated internationally, yet domestic studies in this area remain scarce. To advance the development of this field in China, this paper reviews embodied cognition research on creative thinking through the lenses of bodily movement, vision, touch, and taste, and explains relevant embodied effects from the perspectives of conceptual metaphor theory, Piaget' s genetic epistemology, and evolutionary psychology.

Future research should explore embodied creativity from multiple angles, including bidirectional embodied effects, cognitive neural mechanisms, experimental replicability, multisensory integration, malevolent and benevolent creativity, and machine learning.

Keywords: creative thinking, embodied cognition, metaphor, divergent thinking, convergent thinking

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Creative thinking is the form of thinking that produces novel, unique, and appropriate viewpoints or products under specific circumstances (Yang et al., 2022). It plays a crucial role in numerous societal domains such as science, technology, and invention, and is regarded as a key driver of social development. Creative thinking encompasses both divergent and convergent thinking (Yang et al., 2022). Divergent thinking, the core of creative thinking and sometimes even considered synonymous with it, refers to the cognitive process where individuals explore multiple novel answers by thinking in various directions based on given information. It comprises three dimensions: originality, flexibility, and fluency, and is primarily assessed through tasks such as the Alternative Uses Test (AUT) and the Torrance Tests of Creative Thinking (TTCT) (Duan et al., 2019). Convergent thinking involves synthesizing various pieces of information to arrive at a single correct answer, and is mainly evaluated through tasks like the Remote Association Test (RAT) and insight problem-solving tasks (Duan et al., 2019).

The first generation of cognitive science analogized human mental processes to computer information processing, positing that human cognition and sensorimotor functions are independent. Under its influence, previous creative thinking research focused primarily on the information processing mechanisms underlying innovative ideas or products. For instance, the dual pathway to creativity model (DPCM) suggests that individuals can generate innovative ideas through two pathways: cognitive flexibility, which involves flexible switching between different categories or methods, and cognitive persistence, which entails sustained effortful exploration within a single category (Wu & Koutstaal, 2022). Some researchers propose that the creative thinking process comprises four stages: preparation, incubation, illumination, and verification (Wallas, 1926). Factors such as emotion, motivation, memory, reward, mind wandering, and the nature of interpolated tasks all influence the creative thinking process (Li Ziyi et al., 2022). While these studies have yielded fruitful results, they have largely overlooked the role of bodily sensorimotor experiences in creative thinking.

With the emergence of the second cognitive revolution, researchers have proposed the new perspective of embodied cognition. Embodied cognition theory posits that the body plays a vital role in cognitive processes, serving as both the source of cognition and an influence on cognitive functioning (Ding Fengqin & Sun Yishu, 2020; Malaie et al., 2023). The physical properties of the body determine the manner and steps through which cognitive processes unfold,

while bodily movements and experiences of bodily states provide the content for cognition and affect cognitive functions. Research has demonstrated that visual experiences such as up/down, size, color, and distance; tactile experiences such as hardness/softness and heaviness/lightness; taste experiences such as sourness and sweetness; bodily actions like approaching/withdrawing and closing/opening; and mental simulations such as ascending/descending can all influence cognitive functions including memory, moral cognition, power concepts, and importance judgments (Ding Fengqin & Sun Yishu, 2020; Ding Fengqin & Wang Dongxia, 2019; Wei Hua et al., 2018; Malaie et al., 2023). The development of embodied cognition theory has profoundly impacted psychological research, shifting the focus from disembodied to embodied cognition and providing a novel perspective for the field.

Creative thinking represents one of humanity' s important cognitive functions. Unlike traditional approaches to creative thinking, the embodied cognition perspective emphasizes the role of the body, viewing creative thinking as rooted in bodily experiences. Bodily movements and experiences not only provide raw materials for creative thinking but also exert direct influence on it. Multiple studies have confirmed that actions such as breaking through walls, visual experiences like disordered environments, and tactile experiences such as softness can enhance creative thinking (Kim, 2015; Slepian & Ambady, 2012; Vohs et al., 2013; Wang et al., 2019, 2022). While international research on embodied cognition and creative thinking has yielded substantial results, domestic scholars have conducted only limited studies in this area (Hao et al., 2014; Wang et al., 2019; Xie et al., 2016). Therefore, a comprehensive review of this research domain is essential to advance domestic scholarship. Based on existing literature, this paper reviews progress in embodied cognition research on creative thinking from the perspectives of bodily movement, vision, touch, and taste, discusses theoretical explanations for embodied effects on creative thinking, and proposes directions for future research.

2 Experimental Research on Creative Thinking from the Embodied Cognition Perspective

Bodily movements, visual experiences, tactile experiences, and taste experiences all constitute sensorimotor experiences. Here, we primarily focus on bodily movement and visual perspectives to introduce relevant research progress on how sensorimotor experiences influence creative thinking.

2.1 Bodily Movement

2.1.1 Wall-Breaking Action Walls are architectural structures built from bricks and stones that support roofs or separate interior and exterior spaces. Walls divide houses or courtyards into different areas, thereby restricting people' s range of movement. In both Chinese and Western cultures, walls often symbolize rules, constraints, and confinement. For example, in the phrases "drilling

holes and climbing walls" and "red apricot blossoms extending beyond the wall," the character "wall" represents rules and constraints, while "climbing over the wall" and "extending beyond the wall" signify breaking rules and constraints. Similarly, the English phrase "the Berlin Wall" symbolizes the confinement of freedom, while "tear down this wall" represents breaking constraints to achieve freedom and unity. Consequently, breaking or tearing down walls is metaphorically linked to breaking rules and constraints. Since adherence to convention and rigid rules can constrain creative thinking, innovation requires breaking free from these mental shackles.

Wang et al. (2019) experimentally examined the metaphorical connection between wall-breaking and rule-breaking for innovation. Using virtual reality technology to create wall-breaking scenarios, their experiments revealed that compared to not breaking walls, breaking walls enhanced the originality, fluency, and flexibility of divergent thinking in the Alternative Uses Test. Both cognitive flexibility and cognitive persistence fully mediated the relationship between wall-breaking and originality. Further research found that compared to the no-wall-breaking condition, wall-breaking reduced activation in the frontopolar region (associated with rule perception), dorsolateral prefrontal region (associated with cognitive control), and right temporoparietal junction (involved in somatosensory information processing). These findings suggest that wall-breaking may promote creative thinking by inhibiting the right temporoparietal junction to enhance embodiment, suppressing the frontopolar region to reduce rule awareness through the metaphorical connection between wall-breaking and rule-breaking, and inhibiting the dorsolateral prefrontal region to reduce cognitive control, ultimately activating cognitive flexibility or persistence.

2.1.2 Opening and Closing Actions When individuals cross their arms over their shoulders and keep their legs together, they adopt a closed posture that rejects external stimuli. Conversely, when arms and legs are extended and opened, the body becomes free and open, receptive to external stimuli. Research has shown that closed postures can induce negative emotions such as anxiety, irritability, and inferiority, whereas open postures can elicit positive emotions like pleasure, relaxation, and confidence (Hao et al., 2017). Since negative emotions can inhibit creative thinking while positive emotions can enhance it (Cheng Rui et al., 2021; Lee et al., 2022), closed and open postures can influence creative thinking through their effects on emotion. Studies have found that compared to closed postures, open postures not only enhance the flexibility, fluency, and originality of divergent thinking in individual creative tasks (Andolfi et al., 2017) but also improve the originality of divergent thinking in group creativity tasks (Zhang Ling, 2022). This may occur because closed postures inhibit creative thinking by inducing negative emotions, while open postures promote creative thinking by eliciting positive emotions.

Furthermore, Hao et al. (2017) investigated the interactive effects of video-induced emotions and bodily postures on divergent thinking. Their experiments

showed that when individuals adopted open postures, originality, fluency, and cognitive flexibility were significantly better under video-induced positive emotion conditions compared to negative emotion conditions. Conversely, when individuals adopted closed postures, originality and cognitive persistence were significantly better under video-induced negative emotion conditions compared to positive emotion conditions. This suggests that the positive emotions elicited by open postures are consistent with video-induced positive emotions, promoting creative thinking through cognitive flexibility, while the negative emotions induced by closed postures align with video-induced negative emotions, enhancing creative thinking through cognitive persistence.

2.1.3 Approach and Avoidance Actions Throughout human social evolution, humans have developed various actions to approach benefits and avoid harm, one of which involves extending or bending the arms. When standing upright and encountering dangerous objects, we typically extend our arms forward with palms facing outward to push objects away. When encountering safe or desirable objects, we reach out, grasp them, and bend our arms to bring them closer. Therefore, when standing upright, arm extension is associated with avoiding objects and signals environmental danger, while arm bending is associated with approaching objects and signals environmental safety (Friedman & Förster, 2000). In dangerous environments, individuals exhibit narrow attention and prefer local processing strategies, which inhibit creative thinking (Friedman & Förster, 2000; Hao et al., 2014). In safe environments, individuals prefer holistic processing and heuristic strategies, which can enhance creative thinking by broadening attention and strengthening connections between more distant concepts in semantic networks (Friedman & Förster, 2000; Hao et al., 2014). Consequently, when standing upright, arm extension inhibits creative thinking while arm bending promotes it.

Research has shown that when seated, individuals in the arm-bending group performed better than those in the arm-extending group on the Embedded Figures Test, Snowy Pictures Test, Gestalt Completion Test, and category inclusion task (Friedman & Förster, 2000), and demonstrated higher fluency and originality in divergent thinking on the Alternative Uses Test (Hao et al., 2014). This suggests that arm bending may promote creative thinking by signaling safety and activating holistic processing, which facilitates abstract concept activation and novel connections between distant concepts in semantic networks, thereby breaking mental sets and enhancing cognitive restructuring and flexibility. In contrast, arm extension may inhibit creative thinking by signaling danger and activating local processing, which suppresses connections between distant concepts.

However, the effects of arm extension and bending differ when lying supine. When lying down and bending upward-extended arms, although objects initially have near-zero distance from the body, they gradually move away as the arms bend and forearms lift, creating an avoidance effect. Conversely, when lying down and extending bent arms, although objects initially lie above the body

due to bent arms and lifted forearms, they gradually descend and contact the body as arms extend parallel to it, creating an approach effect. These different approach/avoidance effects in supine positions influence creative thinking differently. Research found that when lying down, the arm-extending group showed higher fluency and originality in divergent thinking than the arm-bending group (Hao et al., 2014). This may be because arm extension while supine creates approach toward objects, signaling safety and activating holistic processing to enhance novel connections between distant concepts, thereby promoting divergent thinking. In contrast, arm bending while supine creates distance from objects, signaling danger and activating local processing, which inhibits novel connections and impedes divergent thinking.

2.1.4 Hand-Switching Action In English, the word "hand" is often used to represent perspective or aspect, with "the other hand" indicating another perspective, and "on one hand, on the other hand" representing different perspectives. Thus, different hands are metaphorically linked to different angles in language. Old thinking patterns can create mental sets that hinder creative thinking, whereas innovation requires exploring problems from novel perspectives. Consequently, "on one hand, on the other hand" encourages individuals to think from new angles to achieve innovation (Leung et al., 2012). Leung et al. (2012) experimentally examined the metaphorical connection between switching hands and changing perspectives. In the first phase of divergent thinking tasks, both experimental and control groups extended their right hands. In the second phase, the experimental group extended their left hand while the control group continued using their right hand. Results showed no difference between groups in the first phase, but the experimental group demonstrated superior fluency, originality, and flexibility in the second phase. This suggests that maintaining the same hand in the second phase may lead to mental rigidity and difficulty breaking free from initial thinking patterns, whereas switching hands may metaphorically activate awareness of perspective-shifting, promoting novel angles of thought and breaking mental sets to stimulate creative thinking.

2.1.5 Fluid Movement Actions Fluid movement actions refer to free, flexible, and smooth bodily movements, such as free walking or drawing smooth, flowing lines. In contrast, non-fluid movements are constrained or jerky, such as walking along a fixed path or drawing zigzag, angular lines.

During creative tasks, creative thinking enables individuals to flexibly switch between categories and continuously generate diverse, novel ideas. Scholars have proposed that creative thinking flows freely and smoothly like a liquid. Based on this similarity, fluid divergent thinking may be metaphorically related to fluid movements (Slepian & Ambady, 2012). Slepian and Ambady (2012) confirmed this metaphorical relationship experimentally. Their results showed that compared to drawing zigzag, angular lines, drawing smooth, fluid lines enhanced cognitive flexibility in category inclusion tasks, fluency and originality in divergent thinking on the Alternative Uses Test, and convergent thinking on

the Remote Association Test. This suggests that when drawing smooth, fluid lines, the flowing movement may metaphorically activate free, flexible creative thinking, whereas drawing zigzag, angular lines may cause thinking to become similarly constrained and stuck. However, this study did not explore the underlying cognitive mechanisms.

When walking freely, individuals can move as they please without constraints while freely looking around with broad vision. In contrast, walking along a restricted path—such as moving back and forth along a straight line or around a rectangular path—creates a sense of constraint and requires constant attention to the path to avoid stepping out of bounds, resulting in narrowed attention. Research using the Navon test to manipulate attentional scope found that broadened attention promotes divergent thinking while narrowed attention inhibits it (Murali & Händel, 2022). Therefore, free walking versus restricted-path walking can differentially affect divergent thinking. Studies comparing free-walking groups with restricted-path groups found that free-walking groups showed superior flexibility, fluency, and originality in divergent thinking (Leung et al., 2012; Murali & Händel, 2022). In online games where participants imagined themselves as avatars, those controlling avatars that walked freely demonstrated greater originality in divergent thinking tasks than those with restricted-path avatars (Leung et al., 2012). This may be because free walking in both real and virtual worlds broadens attentional scope, facilitating novel connections between distant, unrelated objects, breaking old thinking patterns, and activating creative thinking. Conversely, restricted-path walking in both contexts causes excessive focus on staying within the path, narrowing attentional scope and focusing on old associations, thereby creating mental sets that inhibit creative thinking.

2.1.6 Convergent Actions Convergent actions involve gathering dispersed items together, such as collecting scattered books, coins, or fruits with one' s hands. Similar to convergent actions, convergent thinking processes integrate multiple pieces of dispersed information to arrive at a single correct answer. In English, the phrase "put two and two together" is commonly used to encourage convergent thinking (Leung et al., 2012), suggesting a metaphorical relationship between convergent actions and convergent thinking. Leung et al. (2012) confirmed this relationship experimentally by cutting multiple circular paper coasters into left and right halves, creating two piles. The experimental group used both hands to simultaneously move both piles to the center of the table, converging them into one pile, while the control group moved only one pile. Subsequent performance on convergent and divergent thinking tasks revealed that the experimental group outperformed the control group on convergent thinking tasks, with no difference on divergent thinking tasks. This suggests that the "two into one" convergent action may prime convergent thinking, facilitating the integration of multiple ideas to reach a single correct answer and improving convergent thinking performance. However, since divergent thinking involves exploring multiple novel answers unrelated to convergence, convergent actions

promote convergent thinking without affecting divergent thinking.

2.2 Visual Experience

2.2.1 Distance Distance refers to the visual experience of spatial separation. In both Chinese and Western languages, people often use physical distance to describe relationship closeness, as in "close/intimate" and "distant," or "distant relation." In daily life, we embrace, shake hands, and walk arm-in-arm with relatives and friends, maintaining close physical proximity, while we avoid enemies. Thus, interpersonal spatial distance becomes internalized as an indicator of relationship closeness or distance (Shin et al., 2019). Close interpersonal relationships facilitate group cooperation and collective creativity (Wang et al., 2022). Therefore, spatial distance among team members can influence group creativity. Wang et al. (2022) used the Alternative Uses Test as a group creative task to examine how different spatial distances among team members affect group creativity. Results showed that compared to large spatial distances, close spatial distances among team members led to more cooperative teamwork and superior group creativity in terms of fluency and originality. Further analysis revealed higher inter-brain synchronization in the frontopolar region (associated with verbal fluency), angular gyrus (associated with perspective-taking), and dorsolateral prefrontal cortex (associated with interpersonal cooperation) under close-distance conditions. This suggests that close proximity among team members may induce feelings of close relationships, activating synchronized angular gyrus activity that facilitates perceiving or imagining other members' perspectives, synchronized frontopolar activity that promotes smooth communication, and synchronized dorsolateral prefrontal cortex activity that enhances teamwork, ultimately strengthening group creativity.

2.2.2 Direct and Averted Gaze During interpersonal communication, direct and averted gaze convey different meanings. When we feel contempt, hostility, or resentment toward others, we often avoid looking at them directly and instead view them with sidelong glances, finding each word they speak excruciating. When we respect, sincerely appreciate, or admire others, we typically look directly at them and listen attentively. Thus, averted gaze during communication is often perceived as contempt or hostility, signaling problematic relationships, while direct gaze is seen as sincerity and respect, indicating close relationships. Contempt and hostility versus sincerity and respect differentially affect group cooperation (Eriksson et al., 2021). Therefore, direct or averted gaze influences group creativity through its impact on teamwork. Wang et al. (2022) investigated how team members' direct versus averted gaze affects group creativity. Results showed that compared to 60-degree averted gaze, direct gaze among team members led to more cooperative teamwork and higher originality in group creativity. Further analysis revealed higher inter-brain synchronization in the angular gyrus and dorsolateral prefrontal cortex under direct gaze conditions. This suggests that direct gaze among team members conveys sincerity and respect, activating synchronized activity in these brain regions

that facilitates perspective-taking and promotes teamwork, ultimately enhancing group creativity.

2.2.3 Brightness and Darkness Brightness and darkness are visual experiences resulting from the intensity of light emitted or reflected by objects. In Western languages, mental dilemmas are likened to dark nights, while insights are compared to bright lamps illuminating these dilemmas. Thus, insight may be metaphorically linked to bright light. Research has confirmed this metaphorical relationship experimentally. When participants solved problems, researchers turned on fluorescent or incandescent lights. Compared to dim fluorescent lighting, bright incandescent lighting accelerated judgment speed for insight-related words and improved performance on spatial, verbal, and mathematical insight problems, without affecting non-insight problems (Slepian et al., 2010). This suggests that the metaphorical mapping between insight and bright light may activate insight concepts or processes, enhancing creative motivation and facilitating insight problem-solving, but not affecting non-insight problems. However, excessively bright lighting can cause tension, and dim environments may actually yield better insight problem-solving and divergent thinking originality than bright environments (Wang et al., 2021). Beyond positive metaphors, light bulbs can also negatively impact insight through negative metaphors. While insight is metaphorically linked to bright lamps in darkness, mental exhaustion and creative depletion are associated with burned-out bulbs. Marin et al. (2014) examined the effect of this negative metaphor by presenting images of burned-out, dim bulbs. Results showed that compared to viewing bright bulb images, viewing burned-out bulb images reduced creative motivation, decreased thinking time for difficult insight problems, and worsened insight problem performance. This suggests that burned-out bulb images may induce feelings of mental exhaustion through negative metaphor, reduce creative motivation, cause premature abandonment of difficult problems, and ultimately impair insight problem-solving performance.

2.2.4 Color Color is ubiquitous in daily life and is often imbued with different meanings that influence cognition and behavior. Red is frequently associated with prohibition, danger, and avoidance—for example, red traffic lights mean stop, and red signs warn of danger and avoidance. Research has shown that red can induce avoidance motivation (Mehta & Zhu, 2009). In contrast, the blue sea is often associated with openness and inclusiveness, making blue capable of inducing approach motivation (Mehta & Zhu, 2009). Approach motivation can enhance creative thinking, while avoidance motivation can inhibit it (Hao et al., 2020). Therefore, blue and red can differentially affect creative thinking by inducing different motivational states. Studies have found that compared to red backgrounds, blue backgrounds induce approach motivation and enhance originality in divergent thinking on the Alternative Uses Test and convergent thinking on the Remote Association Test, with approach motivation serving as a mediator (Mehta & Zhu, 2009; Xia et al., 2016). This may be because blue

backgrounds induce approach motivation, under which individuals tend to adopt risk-taking strategies with more exploratory and flexible thinking, ultimately promoting creative thinking. Conversely, red backgrounds induce avoidance motivation, under which individuals adopt conservative strategies with narrowed attention and reduced cognitive flexibility, thereby inhibiting creative thinking (Xia et al., 2016).

2.2.5 Spatial Physical Order Spatial physical order, universally present in human society, refers to the arrangement of objects in space according to certain patterns or regularities. Spatial order, such as orderly versus disorderly environments, is often associated with social culture and moral norms, thereby influencing psychology and behavior. In society, good living and working habits involve keeping homes and offices clean with items neatly arranged. Therefore, orderly environments are often associated with habits and rules, while disorderly environments are linked to breaking conventions and rules—that is, order is metaphorically related to habits and rules. Vohs et al. (2013) found that compared to orderly office environments with neatly arranged books, disorderly office environments enhanced divergent thinking on the Alternative Uses Test and increased preference for novel juice products. Kim and Zhong (2017) used LEGO blocks to examine creative thinking differences under varying order conditions. In the orderly condition, LEGO blocks were neatly sorted by color and shape in separate boxes, while in the disorderly condition, blocks of different colors and shapes were mixed together. Both groups were tasked with building aliens using the blocks. Results showed that the disorderly group demonstrated higher originality in their alien constructions than the orderly group, with both cognitive flexibility and persistence serving as mediators. This indicates that both disorderly environments and disorderly experimental materials can enhance creative thinking. This may be because disorderly LEGO blocks and office environments metaphorically activate awareness of breaking habitual and rule constraints, promoting the recombination of distant, unrelated concepts in semantic networks, breaking mental sets and functional fixedness, and ultimately enhancing creative thinking through increased cognitive flexibility or persistence.

2.2.6 Inside and Outside Spatial inside/outside experiences are common in daily life. When inside iron boxes or houses, vision is blocked and bodily movement is restricted. When outside, vision is broad and body and mind are free. In English, "box" often expresses constraints on thinking, while "think outside the box" encourages breaking free from mental constraints and innovating (Leung et al., 2012). Therefore, mental constraint or freedom may be metaphorically related to spatial inside/outside positions. Since creative thinking requires freedom from constraints and exploratory thinking, spatial positions may differentially affect creative thinking. Leung et al. (2012) found that compared to thinking inside a box or without a box, thinking outside a box enhanced convergent thinking on the Remote Association Test. Marin et al. (2014) pre-

sented participants with an image of a brain located outside a box to induce an outside-the-box thinking feeling. Results showed that the outside-the-box brain image enhanced convergent thinking on the Remote Association Test. This suggests that whether actually sitting outside a box or viewing an outside-the-box brain image, the metaphorical induction of mental freedom facilitates breaking free from mental sets and exploring novel answers along different directions, ultimately promoting creative thinking. In contrast, sitting inside a box or viewing inside-the-box images induces feelings of constraint that inhibit perspective-shifting and suppress creative thinking.

2.3 Tactile Experience

Tactile experience is the earliest and most fundamental human sense, arising when skin tactile receptors receive mechanical stimulation. Hardness/softness represents one aspect of touch. In daily life, soft objects are often flexible and variable—for example, dancers' soft limbs can rotate freely and transform into multiple shapes. Hard objects often have single shapes; for instance, hard stones are difficult to deform. Therefore, people associate "softness" with "flexibility and variability" and "hardness" with "singularity."

Kim (2015) validated this metaphorical relationship by examining how squeezing hard versus soft balls affects creative thinking. Results showed that compared to squeezing hard balls, squeezing soft balls enhanced originality and fluency in divergent thinking on the Torrance Tests of Creative Thinking. Xie et al. (2016) also found that seat hardness affected creative thinking, with participants on soft seats performing better on Chinese riddle insight problems than those on hard seats. This may be because the shape-changing soft ball or cushion metaphorically activates concepts of flexibility and variability, promoting free dimensional switching and flexible thinking during creative tasks, thereby breaking mental sets and exploring multiple novel answers. In contrast, the singular-shaped hard ball or seat may metaphorically activate concepts of singularity, causing thinking to consider only limited perspectives. Additionally, Kim (2015) found that compared to squeezing soft balls, squeezing hard balls enhanced convergent thinking on the Remote Association Test. This may be because the singular-shaped hard ball activates concepts of singularity that align with convergent thinking' s requirement to synthesize information into a single answer, thereby promoting convergent thinking through similarity. The variable-shaped soft ball, however, activates concepts of variability that are dissimilar to the single-answer focus of convergent thinking, thus not enhancing it.

Warmth/coldness is the sensation produced when skin receptors receive thermal stimulation. In both Chinese and Western languages, temperature is often used to describe interpersonal relationships, as in "warm/enthusiastic" and "cold/indifferent." Research has revealed a metaphorical relationship between physical temperature and relational distance, where warmth or coldness can respectively close or distance relationships (Ding Fengqin & Wang Dongxia, 2019).

Since tasks like category inclusion and the Torrance Tests require establishing connections between unrelated items, warmth or coldness may affect creative thinking by influencing perceived relationships between things. Research found that participants holding warm water cups demonstrated better cognitive flexibility on category inclusion tasks and superior divergent thinking on the Torrance Tests compared to those holding cold water cups (IJzerman et al., 2014). This may be because warm cups metaphorically activate concepts of close relationships, helping individuals abandon old notions that unrelated things cannot be combined, facilitating novel perspective-taking to discover connections between unrelated items and construct new combinations, ultimately promoting creative thinking.

2.4 Taste

Throughout human evolutionary development, using taste to preliminarily judge food properties has been crucial for survival. Wars and disasters often cause famines, making food storage necessary. When tasting stored food, sourness signals potential spoilage. Therefore, consuming sour foods involves risk, and research has found that drinking sour water can promote risk-taking behavior (Vi & Obrist, 2018), while individuals inclined toward risk-taking strategies are more likely to innovate (Xu, Xia, & Pang, 2022). Thus, sourness can enhance creative thinking (Wang et al., 2021). Beyond sourness, sweetness is also vital for human survival. Human energy primarily comes from carbohydrates, which often taste sweet. Sweetness indicates energy-rich food, signifies life safety, and induces positive emotions (Zhou & Tse, 2022). Safe environments can activate holistic processing to promote creative thinking (Hao et al., 2014), and positive emotions can also enhance creative thinking (Lee et al., 2022). Therefore, sweetness can also promote creative thinking (Wang et al., 2021; Xu, Mehta, & Hoegg, 2022).

In both Chinese and Western cultures, alcohol—primarily characterized by its spicy taste—is metaphorically linked to breaking free from worldly constraints and achieving mental freedom. Since innovation requires freedom from worldly rules and exploratory thinking, many ancient poets experienced flashes of inspiration and produced masterpieces after drinking. Research has found that compared to placebo, moderate alcohol consumption can reduce top-down cognitive control and enhance convergent thinking on the Remote Association Test (Benedek et al., 2017). This suggests that alcohol may moderately reduce cognitive control through metaphorical associations or physiological reactions, freeing individuals from rule constraints and enhancing mental freedom, thereby stimulating creative convergent thinking.

3 Theoretical Explanations

Current theoretical explanations for how sensorimotor experiences influence creative thinking primarily include conceptual metaphor theory, Piaget' s genetic epistemology, and evolutionary psychology.

3.1 Conceptual Metaphor Theory

Within the embodied cognition framework, Lakoff and Johnson (1999) proposed Conceptual Metaphor Theory (CMT). Metaphors emerge when familiar, concrete experiences share similar organizational structures with unfamiliar, abstract concepts, mapping from a familiar source domain to an unfamiliar target domain. CMT posits that metaphors help individuals construct unfamiliar, abstract concepts using familiar, concrete experiences (Ding Fengqin & Sun Yishu, 2020). Bodily movements and sensory experiences constitute familiar, concrete experiences. Through metaphorical mapping mechanisms, individuals can understand abstract concepts through bodily movements and sensory experiences (Ding Fengqin & Sun Yishu, 2020). For instance, individuals can represent abstract social distance through physical temperature, understand abstract moral purity through physical cleanliness, and construct abstract power concepts through physical size (Ding Fengqin & Wang Dongxia, 2019). For abstract creative thinking, people can similarly use metaphorical mapping to understand and represent it through familiar bodily actions and sensory experiences. For example, walls, being inside boxes, and orderly environments often convey feelings of rules or constraints. Breaking walls, sitting outside boxes, and disorderly environments can break these rules or constraints, creating physical and mental freedom. Therefore, walls, being inside boxes, and orderly environments are metaphorically mapped to rules and constraints, while breaking walls, sitting outside boxes, and disorderly environments are metaphorically mapped to breaking rules and constraints. Since innovation requires breaking rule constraints, creative thinking is enhanced under wall-breaking, outside-box, and disorderly conditions compared to control conditions (Leung et al., 2012; Murali & Händel, 2022; Vohs et al., 2013; Wang et al., 2019). As previously discussed, hand-switching is metaphorically related to perspective-shifting, and softness is metaphorically related to flexible thinking. Both perspective-shifting and flexible thinking help break mental sets for innovation. Therefore, compared to not switching hands and squeezing hard balls, hand-switching and squeezing soft balls can enhance creative thinking (Kim, 2015; Leung et al., 2012).

3.2 Piaget' s Genetic Epistemology

Piaget' s genetic epistemology posits that schemas store large amounts of action-internalized thinking, and through assimilation and accommodation processes, individuals progress from disequilibrium toward higher states of equilibrium (Piaget, 1983). Therefore, Piaget' s theory supports the embodied cognition view that cognition originates from and is influenced by the body. The internalization of sensorimotor experiences also affects creative thinking. For example, interpersonal spatial distance is linked to relationship closeness. When relatives, friends, or couples reunite after long separations, they often embrace, shake hands, and walk arm-in-arm, making zero-distance bodily contact. When opponents or enemies see each other from afar, they often avoid one another. Thus, interpersonal spatial distance becomes internalized as relationship distance, with far distances

internalized as distant relationships and close distances as close relationships. When team members are physically close or far apart, they may unconsciously activate concepts of close or distant relationships, thereby facilitating or inhibiting subsequent teamwork and group creativity (Wang et al., 2022). Similarly, averted gaze during communication is internalized as contempt and hostility, signaling relationship distance, while direct gaze is internalized as sincerity and respect, signaling relationship closeness. Therefore, compared to mutual direct gaze, team members' mutual averted gaze may induce contempt and hostility, reducing teamwork and group creativity levels (Wang et al., 2022).

3.3 Evolutionary Psychology

Higher-level human cognition is often built upon bodily sensorimotor experiences formed through natural selection, serving adaptive functions for human survival. For example, during infancy, accidental puncture or cutting by sharp objects causes bleeding and intense pain, triggering immediate avoidance behaviors. After repeated similar experiences, infants associate the color red with danger and avoidance. Red can induce avoidance motivation (Mehta & Zhu, 2009; Xia et al., 2016), which protects individuals from danger and has evolutionary significance. Avoidance motivation can also inhibit creative thinking (Hao et al., 2020). Therefore, red can inhibit creative thinking through avoidance motivation (Mehta & Zhu, 2009; Xia et al., 2016). For infants, when upright walking encounters dangerous people or animals, they extend their arms to push away threats, but when encountering safe, desirable food or toys, they grasp them and bend their arms to bring them close. Over time, infants associate arm extension with danger signals and arm bending with safety signals, enabling them to approach benefits and avoid harm—a function with clear evolutionary significance. When standing upright, arm extension or bending automatically signals danger or safety, respectively inhibiting or promoting creative thinking by activating local or holistic processing (Friedman & Förster, 2000; Hao et al., 2014). Additionally, throughout human evolutionary development, food taste reflects food quality and energy information crucial for survival. As previously discussed, sourness signals food spoilage risk and may promote creative thinking by activating risk-taking behavior (Vi & Obrist, 2018; Wang et al., 2021; Xu, Xia, & Pang, 2022). Sweetness signals energy-rich food, indicating life safety, and may promote creative thinking by inducing positive emotions or activating holistic processing (Wang et al., 2021; Xu, Mehta, & Hoegg, 2022).

4 Summary and Outlook

The embodied cognition perspective has shifted creative thinking research from disembodied to embodied approaches, providing a novel viewpoint that has greatly advanced the field through recent empirical and theoretical work. Embodied creativity research has explored how the body influences creative thinking through bodily movement, vision, touch, and taste. As discussed, red—associated with prohibition and danger—inhibits creative thinking through avoidance

motivation, while blue—associated with openness and inclusion—promotes creative thinking through approach motivation (Mehta & Zhu, 2009; Xia et al., 2016). When standing upright, arm extension signaling danger inhibits creative thinking by activating local processing, while arm bending signaling safety promotes creative thinking by activating holistic processing (Friedman & Förster, 2000; Hao et al., 2014). Hand-switching may promote innovation by metaphorically facilitating perspective-shifting to break old thinking patterns (Leung et al., 2012). Alcohol may stimulate creative convergent thinking by metaphorically breaking worldly constraints or physiologically reducing top-down cognitive control (Benedek et al., 2017). Closed or open postures can inhibit or promote creative thinking by inducing negative or positive emotions, respectively (Andolfi et al., 2017; Hao et al., 2017). Thus, bodily sensorimotor experiences influence creative thinking through mediating factors such as motivation, cognition, and emotion, as illustrated in the integrated model shown in Figure 1 [Figure 1: see original paper].

Although embodied cognition research on creative thinking has accumulated valuable findings, the field remains in its early stages with several limitations. Future research should explore the following directions:

First, strengthen research on the bidirectionality of embodied effects. While numerous studies have examined how sensorimotor experiences influence creative thinking, few have investigated how creative thinking affects sensorimotor experiences, leaving the bidirectionality of embodied effects unexplored. Research has demonstrated bidirectionality in various embodied effects. For example, embodied moral cognition studies show bidirectional mapping between black/white colors and morality (Ding Fengqin & Wang Dongxia, 2019): black backgrounds lead participants to judge characters in moral dilemmas as more immoral, while dark environments lead participants to perceive greater injustice from others. Conversely, recalling immoral events causes participants to perceive environments as darker. Bidirectional mappings also exist between temperature and moral judgment, cleanliness and moral judgment, and power and size (Ding Fengqin & Sun Yishu, 2020; Ding Fengqin & Wang Dongxia, 2019). Therefore, given the possibility of bidirectional embodied effects, future research should examine not only how sensorimotor experiences influence creative thinking but also how creative thinking affects sensorimotor experiences.

Second, strengthen research on the cognitive and neural mechanisms of creative thinking from the embodied cognition perspective. While many studies have demonstrated that sensorimotor experiences can influence creative thinking, most have not explored the underlying cognitive or neural mechanisms. Investigating the psychological factors through which sensorimotor experiences affect creative thinking is crucial for understanding internal cognitive mechanisms and developing interventions. Exploring neural mechanisms can illuminate how the brain processes information from an embodied perspective. Functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) can reflect embodied effects on creative thinking through brain region activation and tem-

poral dynamics. However, bodily movement variables may generate noise that affects data collection and analysis. This challenge can be addressed through images and mental simulation, as demonstrated by Marin et al. (2014), who used images to represent the outside-the-box variable and found that presenting such images enhanced creative thinking. Additionally, functional near-infrared spectroscopy (fNIRS) can reduce noise from bodily movements. Wang et al. (2019) used fNIRS to examine the neural mechanisms of wall-breaking effects on creative thinking, revealing important roles for the frontopolar cortex, dorsolateral prefrontal cortex, and right temporoparietal junction.

Third, strengthen the replicability of embodied cognition research on creative thinking. Although multiple studies have found that sensorimotor experiences can influence creative thinking, most lack replication evidence, and some face replicability issues. For example, Slepian and Ambady (2012) found that drawing smooth, fluid lines enhanced both fluency and originality in divergent thinking compared to drawing zigzag, angular lines. However, Imaizumi et al.' s (2020) replication found that drawing smooth, fluid lines enhanced fluency but not originality. Therefore, future studies should include replication experiments or provide multiple experimental validations of embodied effects to enhance replicability and scientific rigor.

Fourth, strengthen research on multisensory integrated experiences of sensorimotor experiences on creative thinking. Current studies primarily examine single sensory channel experiences, with few investigating multisensory integration. Compared to single channels, multisensory integrated experiences may have stronger effects on creative thinking. Moreover, real-life sensorimotor experiences derive from multiple sensory channels rather than single ones. Therefore, research on multisensory integrated experiences is more meaningful and valuable for enhancing creative thinking training. For example, an individual on a blue playground, slightly intoxicated, with arms outstretched, walking freely, might demonstrate better performance on creative tasks.

Fifth, strengthen research on malevolent and benevolent creativity from the embodied cognition perspective. Current embodied creativity research primarily uses tasks like the Alternative Uses Test and Remote Association Test to examine effects on general creativity. However, creativity also has "dark" and "bright" sides—malevolent and benevolent creativity (Gao et al., 2023). Malevolent creativity refers to creativity that intentionally harms individuals, organizations, or society. Its destructive and unpredictable nature poses significant challenges for effective prevention and response. Benevolent creativity refers to creativity based on good intentions that helps individuals, organizations, or society. Embodied cognition research on malevolent and benevolent creativity is currently scarce yet highly significant. Revealing embodied influencing factors and applying them to intervention research could positively impact moral education in families, schools, and society, with major practical implications for social stability.

Sixth, apply machine learning to embodied cognition research on creative think-

ing. In recent years, machine learning has been widely used in psychological research on cognition and emotion, as well as in diagnosing psychiatric conditions like autism, depression, and schizophrenia, due to its powerful data processing and mining capabilities (Dong Jianyu et al., 2020; Zhang Wenpei et al., 2019; Stevens & Zabelina, 2020). Machine learning can construct models by learning patterns in training data and apply these models to classification and prediction in test sets. Algorithms include decision trees, random forests, and support vector machines. Among these, multivariate pattern analysis (MVPA) based on support vector machines has been widely applied in psychological research (Xie Hui et al., 2023; Zhao Chunyu & Guo Chunyan, 2023; Huang et al., 2021). Future research could use machine learning algorithms for neural decoding of signals from fMRI, EEG, and fNIRS in embodied creativity studies to explore differences in neural representations of creative thinking under different sensorimotor experiences.

In summary, embodied cognition has become a new perspective in creative thinking research, but many questions remain to be addressed. Future research should explore embodied creativity from the angles of bidirectional effects, cognitive neural mechanisms, replicability, multisensory integration, malevolent and benevolent creativity, and machine learning. Embodied cognition research on creative thinking has significant applied value. Future work on stimulating and cultivating creative thinking should incorporate the embodied cognition perspective and integrate influencing factors such as bodily movements and sensory experiences to cultivate more innovative talents for the nation and society.

Cheng, R., Lu, K., & Hao, N. (2021). The effect of anger on malevolent creativity and regulatory strategies. *Acta Psychologica Sinica*, 53(8), 847–860.

Ding, F., & Sun, Y. (2020). Characteristics, influencing factors, and future prospects of moral concept purity metaphor from an embodied perspective. *Psychological Science*, 43(6).

Ding, F., & Wang, D. (2019). Embodied metaphor of moral concepts and its influencing factors: Evidence from meta-analysis. *Advances in Psychological Science*, 27(9).

Dong, J., Wei, W., Wu, K., Nina, Wang, C., Fu, Y., & Peng, X. (2020). Application of machine learning in the field of depression. *Advances in Psychological Science*, 28(2), 266–274.

Li, Z., Zhang, Z., Zhang, Y., & Luo, J. (2022). The incubation effect in creative thinking. *Advances in Psychological Science*, 30(2), 291–307.

Wei, H., Duan, H., & Zhou, Z. (2018). Consumer behavior from the perspective of embodied cognition. *Advances in Psychological Science*, 26(7), 1294–1306.

Xie, H., Lin, X., Hu, W., & Hu, X. (2023). Emotion regulation promotes forgetting of negative social feedback: Evidence from behavior and EEG. *Acta Psychologica Sinica*, 55(6), 905–921.

Zhang, L. (2022). The effect of open postures and fluid movements on group creative activities and brain-to-brain neural interaction mechanisms (Master' s thesis). East China Normal University, Shanghai.

Zhang, W., Shen, Q., Song, J., & Zhou, R. (2019). Diagnosis of test anxiety based on event-related potentials (ERPs) and machine learning. *Acta Psychologica Sinica*, 51(10), 1116–1127.

Zhao, C., & Guo, C. (2023). The relationship between associative encoding and item encoding in compound characters and compound words. *Acta Psychologica Sinica*, 55(4), 513–528.

Andolfi, V. R., Di Nuzzo, C., & Antonietti, A. (2017). Opening the mind through the body: The effects of posture on creative processes. *Thinking Skills and Creativity*, 24, 20–28.

Benedek, M., Panzierer, L., Jauk, E., & Neubauer, A. C. (2017). Creativity on tap? Effects of alcohol intoxication on creative cognition. *Consciousness and Cognition*, 56, 128–134.

Duan, H., Wang, X., Wang, Z., Xue, W., Kan, Y., Hu, W., & Zhang, F. (2019). Acute stress shapes creative cognition in trait anxiety. *Frontiers in Psychology*, 10, 1517.

Eriksson, K., Simpson, B., & Vartanova, I. (2021). The power of tolerance vs. unselfishness as a cultural determinant of cooperation. *Frontiers in Psychology*, 12, 678237.

Friedman, R. S., & Förster, J. (2000). The effects of approach and avoidance motor actions on the elements of creative insight. *Journal of Personality and Social Psychology*, 79(4), 477–492.

Gao, Z., Lu, K., & Hao, N. (2023). Transcranial direct current stimulation (tDCS) targeting the postcentral gyrus reduces malevolent creative ideation. *Social Cognitive and Affective Neuroscience*, 18(1), 1–12.

Hao, N., Qiao, X., Cheng, R., Lu, K., Tang, M., & Runco, M. A. (2020). Approach motivational orientation enhances malevolent creativity. *Acta Psychologica*, 203, 102985.

Hao, N., Xue, H., Yuan, H., Wang, Q., & Runco, M. A. (2017). Enhancing creativity: Proper body posture meets proper emotion. *Acta Psychologica*, 173, 32–40.

Hao, N., Yuan, H., Hu, Y., & Grabner, R. H. (2014). Interaction effect of body position and arm posture on creative thinking. *Learning and Individual Differences*, 32, 261–265.

Huang, Q., Li, D., Zhou, C., Xu, Q., Li, P., & Warren, C. M. (2021). Multivariate pattern analysis of electroencephalography data reveals information predictive of charitable giving. *NeuroImage*, 242, 118475.

IJzerman, H., Leung, A. K. Y., & Ong, L. S. (2014). Perceptual symbols of creativity: Coldness elicits referential, warmth elicits relational creativity. *Acta Psychologica*, 148, 136–147.

Imaizumi, S., Tagami, U., & Yang, Y. (2020). Fluid movements enhance creative fluency: A replication of Slepian and Ambady (2012). *Plos One*, 15(7), e0236825.

Kim, J. (2015). Physical activity benefits creativity: Squeezing a ball for enhancing creativity. *Creativity Research Journal*, 27(4), 328–333.

Kim, Y. J., & Zhong, C. B. (2017). Ideas rise from chaos: Information structure and creativity. *Organizational Behavior and Human Decision Processes*, 138, 15–27.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind & its challenge to Western thought*. Chicago: University of Chicago Press.

Lee, S., Kenworthy, J. B., & Paulus, P. B. (2022). Effects of positive affect and humor on divergent thinking. *Journal of Creativity*, 32(3), 100037.

Leung, A. K. Y., Kim, S., Polman, E., Ong, L. S., Qiu, L., Goncalo, J. A., & Sanchez-Burks, J. (2012). Embodied metaphors and creative "acts" . *Psychological Science*, 23(5), 502–509.

Malaie, S., Karimi, H., Jahanitabesh, A., Bargh, J. A., & Spivey, M. J. (2023). Concepts in Space: Enhancing Lexical Search With a Spatial Diversity Prime. *Cognitive Science*, 47(8), e13327.

Marin, A., Reimann, M., & Castaño, R. (2014). Metaphors and creativity: Direct, moderating, and mediating effects. *Journal of Consumer Psychology*, 24(2), 290–297.

Mehta, R., & Zhu, R. (2009). Blue or red? Exploring the effect of color on cognitive performances. *Science*, 323(5918), 1226–1229.

Murali, S., & Händel, B. (2022). Motor restrictions impair divergent thinking during walking and during sitting. *Psychological Research*, 86(7), 2144–2157.

Piaget, J. (1983). "Piaget' s theory," in *Handbook of Child Psychology* (Vol. 1), ed P. H. Mussen (New York: Wiley), 103–128.

Shin, J. E., Suh, E. M., Li, N. P., Eo, K., Chong, S. C., & Tsai, M. H. (2019). Darling, get closer to me: Spatial proximity amplifies interpersonal liking. *Personality and Social Psychology Bulletin*, 45(2), 300–309.

Slepian, M. L., & Ambady, N. (2012). Fluid movement and creativity. *Journal of Experimental Psychology: General*, 141(4), 625–629.

Slepian, M. L., Weisbuch, M., Rutchick, A. M., Newman, L. S., & Ambady, N. (2010). Shedding light on insight: Priming bright ideas. *Journal of Experimental Social Psychology*, 46(4), 696–700.

Stevens Jr, C. E., & Zabelina, D. L. (2020). Classifying creativity: Applying machine learning techniques to divergent thinking EEG data. *NeuroImage*, 219, 116990.

Vi, C. T., & Obrist, M. (2018). Sour promotes risk-taking: An investigation into the effect of taste on risk-taking behaviour in humans. *Scientific Reports*, 8(1), 7987.

Vohs, K. D., Redden, J. P., & Rahinel, R. (2013). Physical order produces healthy choices, generosity, and conventionality, whereas disorder produces creativity. *Psychological Science*, 24(9), 1860–1867.

Wallas, G. (1926). *The Art of Thought*. New York, NY: Harcourt Brace.

Wang, Q. J., Barbosa Escobar, F., Mathiesen, S. L., & Alves Da Mota, P. (2021). Can Eating Make Us More Creative? A Multisensory Perspective. *Foods*, 10(2), 469.

Wang, X., He, Y., Lu, K., Deng, C., Qiao, X., & Hao, N. (2019). How does the embodied metaphor affect creative thinking? *NeuroImage*, 202, 116114.

Wang, X., Lu, K., He, Y., Gao, Z., & Hao, N. (2022). Close spatial distance and direct gaze bring better communication outcomes and more intertwined neural networks. *NeuroImage*, 261, 119515.

Wu, Y., & Koutstaal, W. (2022). Creative flexibility and creative persistence: Evaluating the effects of instructed vs autonomous choices to shift vs. dwell on divergent and convergent thinking. *Consciousness and Cognition*, 105, 103417.

Xia, T., Song, L., Wang, T. T., Tan, L., & Mo, L. (2016). Exploring the effect of red and blue on cognitive task performances. *Frontiers in Psychology*, 7, 784.

Xie, J., Lu, Z., Wang, R., & Cai, Z. G. (2016). Remember hard but think softly: Metaphorical effects of hardness/softness on cognitive functions. *Frontiers in Psychology*, 7, 1343.

Xu, L., Mehta, R., & Hoegg, J. (2022). Sweet ideas: How the sensory experience of sweetness impacts creativity. *Organizational Behavior and Human Decision Processes*, 172, 104169.

Xu, X., Xia, M., & Pang, W. (2022). Do all roads lead to Rome? Authenticity, openness to experience, and risk-taking relate to general and malevolent creativity differently. *Current Psychology*, 1–8.

Yang, W., Green, A. E., Chen, Q., Kenett, Y. N., Sun, J., Wei, D., & Qiu, J. (2022). Creative problem solving in knowledge-rich contexts. *Trends in Cognitive Sciences*, 26(10), 849–859.

Zhou, Y., & Tse, C. S. (2022). Sweet taste brings happiness, but happiness does not taste sweet: The unidirectionality of taste-emotion metaphoric association. *Journal of Cognitive Psychology*, 34(3), 339–361.

Note: Figure translations are in progress. See original paper for figures.