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Authors

Tabatabaeian, Shadab
Marghetis, Tyler

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Seeing the connection: Manipulating access to visual information facilitates creative insight

Shadab Tabatabaeian (stabatabaeian@ucmerced.edu)
Cognitive & Information Sciences, University of California Merced
5200 North Lake Rd., Merced, CA 95343

Tyler Marghetis (tyler.marghetis@gmail.com)
Cognitive & Information Sciences, University of California Merced

Abstract

Creative people move in ways that seem aimless. Artists and mathematicians wander about, sometimes standing next to their easel or blackboard, other times standing across the room. Why do creatives expend energy on aimless movement? We propose that such movements facilitate insight by changing the information that is visually available. We tested this mechanism in two online studies ($N = 337$). Participants attempted to solve an insight puzzle. We manipulated whether participants could only see a diagram representing the puzzle, as though they were standing close to it, or could also see a diagram from an earlier puzzle, as though they had stepped back. Visual access to the second diagram acted as a visual hint, increasing the rate of insight by suggesting an analogous solution. We argue that this mechanism explains the creative benefits of seemingly aimless movement. We discuss implications for understanding creativity as arising from interactions among brain, body, and environment.

Keywords: creativity, embodiment, insight, distributed cognition, epistemic action

Introduction

When creative people work, they move around. Artists are encouraged to use an easel so they can move away and toward the canvas. Mathematicians will wander back and forth, sometimes standing at the blackboard, other times standing across the room, spending much of their time too far from the blackboard to write (Tabatabaeian, Deluna O'bi, Landy, & Marghetis, 2023). Even jigsaw puzzle solvers change their relation to the puzzle by standing up and leaning over the table. And yet these movements are not directly beneficial and can even be antithetical to the task. An artist cannot paint if the canvas is out of reach; a mathematician cannot continue their proof while standing across the room from the blackboard. We thus refer to these movements as "aimless." Why are aimless movements so common during creative activity?

Other forms of movement are known to facilitate creativity (Frith, Miller, & Loprinzi, 2020). For instance, gestures can facilitate problem solving by suggesting new ideas or strategies (Nathan & Walkington, 2017; Goldin-Meadow, Cook, & Mitchell, 2009; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014; Alibali & Nathan, 2012; Alibali, Spencer, Knox, & Kita, 2011; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). When the creative task involves a material artifact, manipulating that artifact can facilitate insight by changing the information structure of the task (Kirsh & Maglio, 1994; Kirsh, 2014; Weller, Villejoubert, & Vallée-Tourangeau, 2011; Vallée-Tourangeau, Ross, Ruffatto Rech, & Vallée-Tourangeau, 2021). Card players, for instance, physically rearrange their cards to more easily notice the best combination (Kirsh, 1995).

These mechanisms cannot explain aimless movement. Unlike gestures, aimless movements are not representational, so the movement itself cannot suggest new ideas. Nor can aimless movements help by transforming some relevant artifact, since aimless movements by definition do not manipulate the environment. Why, then, do creative individuals feel the need to change their physical location?

One deflationary explanation is that these apparently aimless movements have some immediate task-relevant goal, the kinds of actions that Kirsh and Maglio (1994) call "pragmatic." Artists and mathematicians might step away momentarily to grab a paintbrush or piece of chalk. However, creatives move about in the absence of any pragmatic purpose. Mathematicians already holding chalk, for instance, will repeatedly step away from the blackboard, sometimes walking fully across the room (Tabatabaeian et al., 2023). This wastes time and energy — but perhaps boredom or frustration can drive people to wasteful wanderings.

We propose an alternative explanation: Individuals engage in "aimless movement" because it facilitates creative insight by changing the visual information that is available or salient. An artist working on a canvas can better appreciate the holistic composition when standing across the room, and can focus on local details while standing nearby. A mathematician or scientist who has filled a whiteboard with diagrams and equations might not notice connections between spatially separated components — until they step back far enough to see both components at once. In general, changing one's proximity to a visual representation changes the information that is visible. These "aimless movements," therefore, might benefit creative activities that require discovering or appreciating relations among components.

One way to test this proposal would be to manipulate individuals' physical movement as they work on a creative task — perhaps encouraging some to move and forcing others to remain stationary. This approach has its difficulties. Intervening on an individual's natural movement is distracting, thus making it difficult to estimate the downstream benefits of the movement itself on visual information. Despite these challenges, we are pursuing this approach in another line of studies.

Here, we report two studies that take a different tack: Instead of interfering in participants' movements and thus *indi-*

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rectly changing the available visual information, we *directly* manipulated the visual information itself. In both studies, participants solved two puzzles, one after the other. The puzzles were analogous, such that the solution to the first puzzle could be adapted to solve the second (i.e., analogical insight or transfer), although past work has established that naive participants seldom notice the connection (Gick & Holyoak, 1980, 1983). To simulate the changes in visual information that accompany movement, we manipulated the visual information that participants could see. Participants in the 'Close' condition saw a diagrammatic representation while working on each puzzle, but the diagrams were only visible while working on the associated puzzle; this simulates the limited and localized visual information that is available when standing close to a blackboard, easel, or other medium. Participants in the 'Far' condition could still see the diagram from the first puzzle while working on the second; this simulates the greater and more global visual information that is available when standing farther away. If our account is correct, then participants in the 'Far' condition will be more successful in solving the target puzzle.

Study 1

Participants

Participants (N = 103) were recruited from Prolific (www.prolific.co) and compensated \$2 USD. They were at least 18 years old, fluent in English, and located in the US. We excluded participants who did not complete the task ($N = 6$) or who reported afterward that they had previously encountered the puzzles and their solutions ($N = 2$). The final sample consisted of 95 participants ($M_{age} = 34.8$ years, $SD_{age} = 12.60$, 43 men, 46 women, 6 other gender).

Puzzles

Participants solved two puzzles. Each puzzle was accompanied by a diagram visualizing its main components, designed to highlight the structural similarities between the puzzles (Fig. 1, A1-B2). These puzzles and diagrams were adapted from previous research on analogical reasoning and creative problem solving (Duncker, 1945; Gick & Holyoak, 1980, 1983; Grant & Spivey, 2003).

In the *Military* puzzle, a commander is trying to conquer the enemy's headquarters, located in the middle of a lake and thus accessible only via bridge. To succeed, the troops must attack the headquarters simultaneously. However, none of the bridges can handle the weight of all the troops at once; if they all cross on the same bridge, it will collapse. How can the commander conquer the enemy headquarters? The standard solution has three components: (1) divide the troops into smaller groups; (2) distribute the groups across multiple bridges; (3) order all groups to cross the bridges and attack simultaneously.

In the *Radiation* puzzle, a cancer specialist is trying to treat a patient with an inoperable tumor surrounded by healthy tissue. The cancer specialist can destroy the tumor by delivering a full dose of radiation, all at once. However, a full dose would also harm any healthy tissue it passes through. How can the cancer specialist destroy the tumor without harming healthy tissue? The standard solution has three components: (1) divide the full radiation dose into multiple weaker doses; (2) distribute the weaker doses across multiple locations around the healthy tissue; (3) beam the weaker doses from multiple locations simultaneously, so they converge on the tumor as a full dose, but healthy tissue is only hit with a weaker dose.

Note that the two puzzles are analogous: the divide-and-distribute strategy that works for the Military puzzle can be adapted to solve the Radiation puzzle. Despite this connection, among participants who know the solution to the Military puzzle, fewer than a third will spontaneously transfer their knowledge to the Radiation puzzle (Gick & Holyoak, 1980, 1983).

Procedure

After giving informed consent, participants were asked to solve the Military and Radiation puzzles.

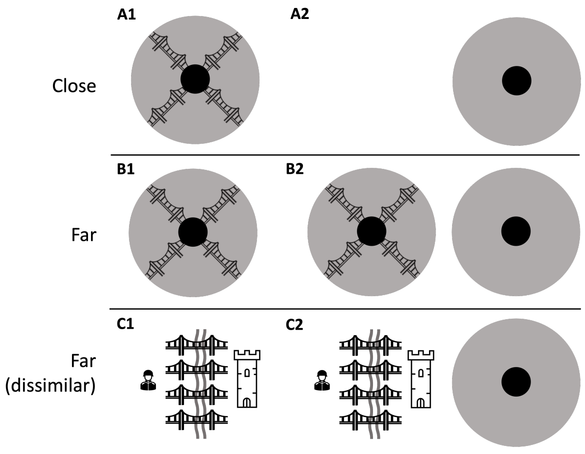

Figure 1: Design of Studies 1 and 2. (A) In the Close condition, participants attempted to solve the Military puzzle while viewing the diagram in A1 (black circle = enemy headquarters; gray circle = the lake; bridge icons = the bridges around the lake). They then attempted to solve the Radiation puzzle while viewing only the diagram in A2 (black circle = tumor; gray circle = healthy tissue). (B) In the Far condition, participants began by attempting the Military puzzle while viewing the same diagram as in the Close condition, as shown in B1. When attempting the Radiation puzzle, however, they could see both the Military and the Radiation diagrams simultaneously, side-by-side, as shown in B2. (C) Study 2 introduced the Far (dissimilar) condition, which was identical to the Far condition except the Military diagram was changed so it was no longer visually analogous to the Radiation diagram (soldier icon = commander's troops; wavy gray lines = lake; bridge icons = bridges around the lake; tower = enemy's headquarters).

All participants began with the Military puzzle, which was described in writing, accompanied by its illustrative diagram (Fig. 1, A1 and B1). Participants had up to 5 minutes to propose a solution. If they found a solution, participants were asked to describe it in writing. All participants were then shown the standard solution, told to read it carefully, and asked whether it matched their own solution if they had proposed one (Yes, Somewhat, or No).

Participants then proceeded to the Radiation puzzle. In a between-subjects design, participants were randomly assigned to either the Close or Far condition. The Close condition was designed to recreate the visual experience of standing close to a whiteboard, with only limited information available within the field of vision. The text of the Radiation puzzle was accompanied only by its illustrative diagram (Fig. 1, A2). The Far condition was designed to recreate the visual experience of standing back from a whiteboard, with visual access to the entire whiteboard, including previous work. The text of the Radiation puzzle was accompanied by its illustrative diagram, but the diagram for the Military puzzle was still visible (Fig. 1, B2). As with the Military puzzle, participants had up to 5 minutes to propose a solution, were presented with the standard solution afterward, and those who proposed a solution were asked whether it matched the standard one.

Participants then answered debriefing questions about their experience with the puzzles, including whether they had previously encountered the puzzles and recalled their solutions (used to exclude participants), and whether the Military diagram helped them find a solution to the Radiation puzzle (i.e., if they noticed any connections between the diagrams). The study ended with standard demographic questions (age, gender, ethnicity, employment, and education).

Analysis

Two independent raters confirmed participants' judgments of their own solutions. Raters were unaware of participant condition. For both puzzles, the raters coded the solutions for the presence or absence of three features: division into smaller groups, distribution across multiple directions, and simultaneous arrival at the target. Agreement between these independent ratings and participants' self-evaluations confirmed that self-evaluations were objective (Military problem: Cohen's $\kappa = .89$, Pearson's correlation $r = .77$; Radiation puzzle: $\kappa = .83, r = .84$).

All analyses used Bayesian regressions with uninformative priors, conducted using the *brms* package in R.

Results

Before the manipulation, for the Military puzzle, participants in the Close and Far conditions were indistinguishable (self-reported match with the standard solution, from 0 to 1: Close: $M = 0.86 \pm 0.04\, SEM$; Far: $M = 0.85 \pm 0.05\, SEM$).

For the Radiation puzzle, however, 'stepping back' to see both diagrams facilitated creative insight. Participants in the Far condition were 30 seconds faster to propose a solution to the Radiation puzzle, compared to those in the Close condition ($M = 72.14$ vs. 102.88 sec., $b = -30.53$, Bayesian 95 % Credible Interval $[-54.1, -6.6]$; Fig. 2). Moreover, they proposed more insightful solutions. We modeled solution quality with a Bayesian ordinal generalized linear model of the match between participant's solutions and the standard solution (Yes=1, Somewhat=0.5, No=0) ($M_{far} = 0.48$ vs. $M_{close} = 0.23$; $b = 1.21$, 95% CI $[0.39, 2.06]$; Fig. 3). Moreover, as predicted, this effect was mediated by whether participants noticed the connection between the Military and Radiation diagrams (Fig. 4).

These results were confirmed by analyses of the independent raters' scores, not reported here for want of space.

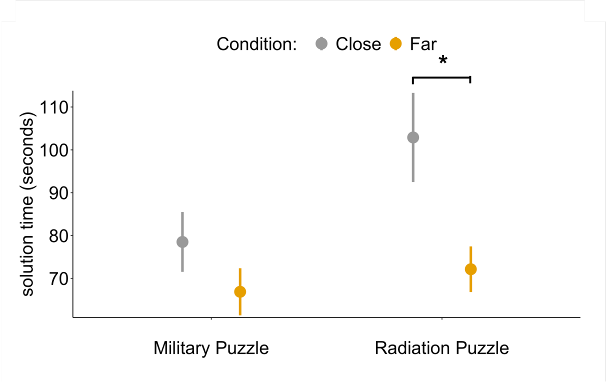

Figure 2: In Study 1, participants with visual access to both puzzle diagrams (Far condition) were faster to propose a solution to the Radiation puzzle. (Means ± SEM; * indicates Bayesian 95% Credible Intervals exclude zero).

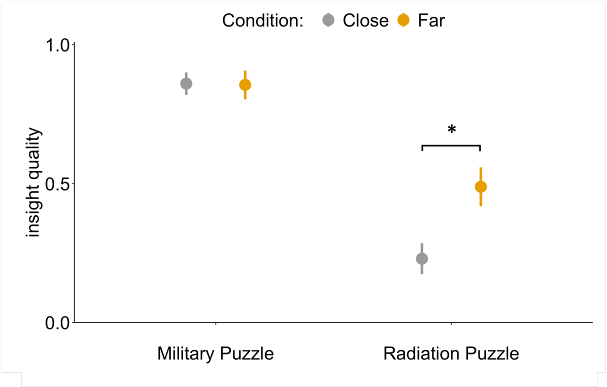

Figure 3: In Study 1, participants with visual access to both puzzle diagrams (Far condition) produced more insightful solutions to the Radiation puzzle. (Means ± SEM; * = Bayesian 95% Credible Intervals exclude zero).

Discussion

We manipulated participants' access to visual information in a way that simulated motion away and toward a blackboard. Visual access to an earlier but relevant diagram increased the

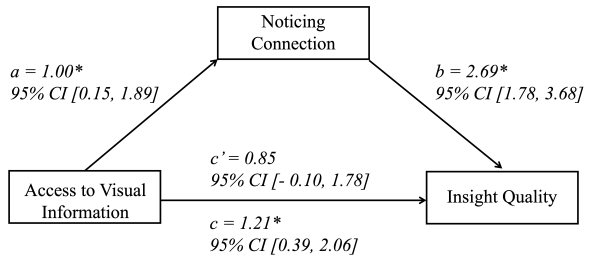

Figure 4: In Study 1, the benefit of visual information for insight was mediated by noticing the connection between diagrams. The indirect effect excluded zero: $ab = 2.06$, 95% *CI* $[0.42, 5.30]$. (* = 95% Credible Intervals exclude zero)

speed and quality of participants' insights. This effect was mediated by whether they noticed the connection between the diagrams. That is, having access to relevant visual information facilitated the discovery of novel connections, which in turn facilitated creative insight.

Study 2

Study 2 replicated and extended Study 1. The design and analysis were preregistered (https://osf.io/nj9t6).

The design was identical to Study 1 except for the inclusion of one additional condition. Recall that the diagrams in Study 1 were designed to highlight the structural similarities between the two puzzles. This raises the question of whether simultaneous access to earlier work is only helpful if the relevance is visually evident. The new condition of Study 2, therefore, manipulated the diagrammatic representation of the Military puzzle so it no longer resembled the Radiation diagram (Fig. 1, C1 and C2). This condition therefore simulated the scenario wherein one steps back to view earlier work, but it is not immediately evident that the visual representations are related.

Participants

According to a generative simulation, 97% power to replicate the primary finding of Study 1 would require 80 participants in each condition. We thus recruited 80 participants per condition through Prolific (www.prolific.co), which produced a final sample $N = 234$ ($M_{age} = 36$, $SD_{age} = 13$, 108 men, 113 women, 13 other gender).

Procedure

Study 2 was identical to Study 1 except for the inclusion of an additional condition, Far-but-Dissimilar. Participants randomly assigned to the Far-but-Dissimilar condition received a Military diagram that was designed to differ maximally from the Radiation diagram. During the Radiation puzzle, they viewed both this new Military diagram and the Radiation diagram, presented simultaneously like in the Far condition.

The only other change from Study 1 was a modification of one of the debriefing questions: When we asked whether the Military diagram had helped participants solve the Radiation puzzle, we allowed three possible answers (very helpful, somewhat helpful, not helpful) instead of the yes/no options from Study 1.

As in Study 1, independent raters confirmed the objectivity of participants self-evaluation of whether their solution matched the standard solution (Cohen's $\kappa = .81$, Pearson's correlation $r = .86$).

Result

The effect of access to visual information on solution time did not replicate ($M_{close} = 98.24 \pm 7.63\, SEM$; $M_{far} = 99.26 \pm 8.21\, SEM$; $M_{far-but-dissimilar} = 87.06 \pm 7.07\, SEM$). A Bayesian linear model of solution time found that neither of the Far conditions were significantly faster than the Close condition (Far: $b = 1.00$, Bayesian 95% Credible Interval $[-19.77, 21.37]$; Far-but-Dissimilar: $b = -10.79$, 95% *CI* $[-30.43, 9.67]$).

The effect of access to visual information on the insights themselves, however, was once again significant. Participants in the Far conditions generated better solutions than those in the Close condition (Far: $M = 0.40 \pm 0.05\, SEM$; Far-but-Dissimilar: $M = 0.30 \pm 0.05\, SEM$; Close: $M = 0.19 \pm 0.04\, SEM$)(Fig. 5). According to Bayesian ordinal model of solution quality, insights improved when participants had simultaneous access to a Military diagram that was visually similar to the current Radiation diagram ($b = 1.00$, 95% *CI* $[0.32, 1.69]$). Solutions in the Far-but-Dissimilar condition were numerically better than those in the Close condition, though the credible interval for this effect included zero ($b = 0.58$, 95% *CI* $[-0.10, 1.29]$).

Moreover, the effect of access to visual information on insight quality was once again mediated by whether participants detected the connection between the Military and Radiation diagrams (Fig. 6).

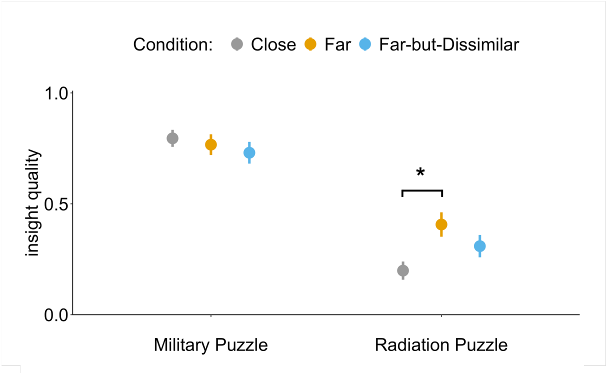

Figure 5: In Study 2, participants with visual access to a relevant diagram (Far condition) generated more insightful solutions. (Means ± SEM; * = Bayesian 95% Credible Intervals exclude zero).

To better estimate the effect of manipulating access to visual information, we conducted Bayesian analyses of the

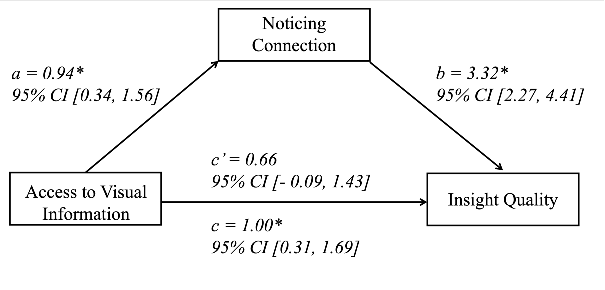

Figure 6: In Study 2, the benefit of visual information for insight was mediated by noticing connections between puzzle diagrams. The indirect effect excluded zero: $ab = 3.04$, 95% *CI* $[0.99, 5.52]$. (* = 95% Credible Intervals exclude zero)

pooled data from both studies. We used a Bayesian ordinal regression to model insight quality, with predictors for condition (Far and Far-but-Dissimilar, compared to Close baseline), whether participants noticed the connection between diagrams, and study number. Proposed solutions were better in both Far conditions, even when the diagrams were visually dissimilar ($b = 0.99$, 95% *CI* $[0.23, 1.70]$) (Fig. 7). The effect of visual information on insight was mediated by whether participants noticed the connection between visual elements (Fig. 8). Rebaselining the model on the Far condition with similar diagrams, moreover, confirmed that the two Far conditions did not differ ($b = .05$, 95% *CI* $[-0.60, 0.70]$).

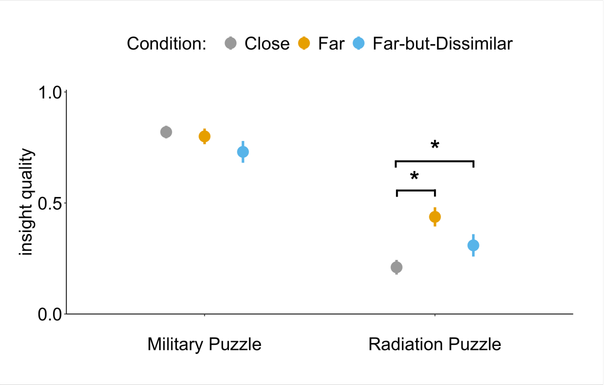

Figure 7: Pooling across studies, visual access to both diagrams (Far conditions) improved creative insight regardless of the similarity between diagrams. (Means ± SEM; * = Bayesian 95% Credible Intervals exclude zero)

Discussion

In two experiments, we investigated a possible mechanism that can explain the ubiquity of apparently "aimless" wandering during creative activity: changes in access to visual information. When you stand back from a blackboard, easel, or statue, you can see more, including earlier work. When standing close, you mostly see what you are working on. To test this mechanism, we manipulated whether participants had visual access only to a diagram representing the current problem, as though they were standing close to it, or could also see a diagram from an earlier problem, as though they had stepped back. In both studies, participants were more insightful when they could see the earlier diagram, particularly when the earlier diagram was visually similar to the current diagram. Merely having visual access to the diagram encouraged the discovery of previously unnoticed connections. Visual access to the earlier diagram thus acted as a visual hint, improving insight by suggesting a connection that was otherwise available but difficult to discover. The strategic manipulation of visual information, therefore, can enhance creativity.

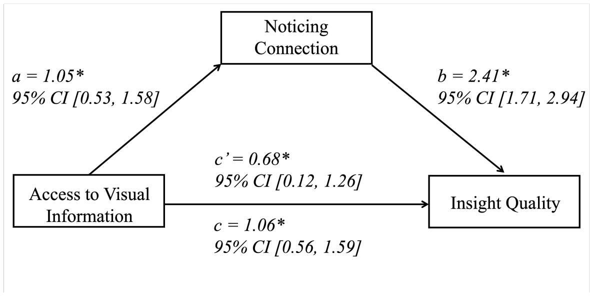

Figure 8: Pooling across studies, the benefit of visual information for insight was mediated by noticing the connection between diagrams. The indirect effect excluded zero: $ab = 2.0$, 95% *CI*: $[1.2, 3.9]$. (* = 95% Credible Intervals exclude zero)

Aimless wandering as self-hinting

This mechanism offers an explanation of why individuals working creatively with material artifacts — whether sculptures, paintings, or mathematical equations— constantly move around, changing their physical distance from the artifacts. Stepping back allows them to take in more visual elements, juxtaposing elements that were previously seen in isolation, potentially noticing novel connections. Mathematicians, for example, may step away from the blackboard to see all the components of the problem, juxtaposing earlier inscriptions with more recent work, thus making it easier to discover previously unnoticed relationships between elements (Tabatabaeian, Deluna, Landy, & Marghetis, 2022).

Seemingly aimless movements can thus act as an engine for self-generating hints. A hint can improve creative problem solving because it "triggers a reassessment" or "a rethinking" of different components of a problem and their relations (Kirsh, 2014). Hints add diversity to the creative process, reducing bias for prior knowledge (i.e., functional fixedness) and facilitating a more flexible exploration of the solution space. Physically moving around can play the same role.

Wanderings can thus be *epistemic actions* — actions performed to gather information or facilitate cognition. Epistemic actions are contrasted with *pragmatic* actions that physically bring an individual closer to a goal (Kirsh & Maglio, 1994). When a mathematician grabs the chalk, walks to the board, and begins to write, they are engaged in pragmatic action; when they step back to see all inscriptions at once their action is epistemic. Thus, by moving about, creative individuals leverage the environment to provide themselves with useful hints.

The significance of our findings becomes more obvious when considered within the context of previous research on mechanisms of creative cognition. One major mechanism consists of finding connections between combinations of ideas and concepts that were deemed irrelevant (Mednick, 1962; Simonton, 2021; Poincaré, 1913; Hummel & Holyoak, 2002; Gick & Holyoak, 1980; Holyoak & Thagard, 1996; Pólya, 1990). In Koestler's words (1964), the process of *creation* is one that "uncovers, selects, re-shuffles, combines, synthesizes already existing facts, ideas, faculties, skills" (p. 323). The ultimate aim of aimless wandering may be to uncover, select, reshuffle, and combine.

The creative body

These results contribute to a larger literature on the body's role in creative insight (Frith et al., 2020; Sargent, LePage, Kenett, & Matheson, 2023). One line of work has investigated the role of gaze and attention. Successful problem-solvers tend to more often shift their attention between relevant components (Knoblich, Ohlsson, & Raney, 2001), and drawing attention to important elements of a visual representation of a problem can boost creative performance (Grant & Spivey, 2003; Thomas & Lleras, 2007, 2009; Litchfield & Ball, 2011). For instance, one study asked participants to perform an insight problem-solving task while occasionally using a number tracking task to guide their eye movements in either a pattern related to the solution or an unrelated pattern. While participants were unaware of the connection between the tracking task and the insight problem, those who moved their eyes in a related pattern were more successful in solving the problem. Directing participants' visual attention in a pattern that embodies the solution can thus help participants discover the solution (Grant & Spivey, 2003; Thomas & Lleras, 2007, 2009; Litchfield & Ball, 2011). Our results reveal that gaze need not be actively guided; merely manipulating the availability of relevant visual information can suffice to improve insight.

The body can also contribute to creativity in virtue of its ability to represent ideas and transform the environment. A reasoner's representational gestures, for instance, can predict performance in creative tasks, from general problem solving to the generation of mathematical proofs (Nathan & Walkington, 2017; Goldin-Meadow et al., 2009; Novack et al., 2014; Alibali & Nathan, 2012; Alibali et al., 2011; Goldin-Meadow et al., 2001). Physically interacting with the environment can improve creative performance, especially when rearranging physical components can reveal helpful connections (Kirsh & Maglio, 1994; Kirsh, 2014; Weller et al., 2011; Glucksberg, 1964; Vallée-Tourangeau et al., 2021). Changing one's physical location differs in that it is not itself representational and it leaves the rest of the world unchanged. Nevertheless, if our proposal is correct, even non-representational non-interactive movements like seemingly 'aimless' wandering can benefit creativity by self-regulating attention.

The picture that emerges is one in which creativity reflects the entanglement of brain, body, and environment (Clark, 2008; Hutchins, 2010; Menary, 2007; Marghetis, Samson, & Landy, 2019). Here we have argued that sometimes the body can help merely by changing the relative configuration of this distributed system – making some things easier to see, others more difficult.

Limitations and future directions

The intervention used here was intended to simulate the real-world experience of individuals manipulating visual input by changing their physical location. While this approach allows us to control the visual information available to participants — the mechanism that we hypothesised to be facilitating insight — it also brackets the actual physical movements of a body. In ongoing follow-up work, we are conducting in-person experiments which directly manipulate participants' physical distance to puzzle components. That line of work will complement the current studies by connecting our hypothesized mechanism to actual movement.

We have focused on one possible mechanism through which changes in physical distance could influence creativity — namely, by facilitating discovery of connections that had not been noticed before. Other mechanisms might be at work, too. Movement may be a tactic for maintaining interest and motivation. Movement can help enter a creative state of mind (Leung et al., 2012), perhaps because freedom in movement can transfer to freedom in thought. Movement may be used to actively *ignore* distracting elements. Or movement may work like gesture to ground ideas in the body — such as when the mathematician Terrence Tao rolled around on the floor to gain insight into a vexing mathematical problem (Cook, 2015). Future research should examine these and other possible effects of not-so-aimless wandering.

Conclusion

Many individuals engaged in creative thought exhibit a distinct pattern of movement: constantly changing their physical distance from the material artefacts with which they are working. Here, we proposed that such movements could be conducive to creative performance by changing the visual information to which they have access. We provided empirical evidence that manipulating access to visual information can prompt the discovery of novel connections and thus facilitate insight. When creativity emerges from interactions among brain, body, and environment, aimless wandering may not be aimless after all.

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