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RESEARCH REPORT

Give Your Ideas Some Legs: The Positive Effect of Walking on Creative Thinking

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Four experiments demonstrate that walking boosts creative ideation in real time and shortly after. In Experiment 1, while seated and then when walking on a treadmill, adults completed Guilford's alternate uses (GAU) test of creative divergent thinking and the compound remote associates (CRA) test of convergent thinking. Walking increased 81% of participants' creativity on the GAU, but only increased 23% of participants' scores for the CRA. In Experiment 2, participants completed the GAU when seated and then walking, when walking and then seated, or when seated twice. Again, walking led to higher GAU scores. Moreover, when seated after walking, participants exhibited a residual creative boost. Experiment 3 generalized the prior effects to outdoor walking. Experiment 4 tested the effect of walking on creative analogy generation. Participants sat inside, walked on a treadmill inside, walked outside, or were rolled outside in a wheelchair. Walking outside produced the most novel and highest quality analogies. The effects of outdoor stimulation and walking were separable. Walking opens up the free flow of ideas, and it is a simple and robust solution to the goals of increasing creativity and increasing physical activity.

Keywords: creativity, embodied cognition, exercise

People have noted that walking seems to have a special relation to creativity. The philosopher Friedrich Nietzsche (1889) wrote, "All truly great thoughts are conceived by walking" (Aphorism 34). The current research puts such observations on solid footing. Four studies demonstrate that walking increases creative ideation. The effect is not simply due to the increased perceptual stimulation of moving through an environment, but rather it is due to walking. Whether one is outdoors or on a treadmill, walking improves the generation of novel yet appropriate ideas, and the effect even extends to when people sit down to do their creative work shortly after.

The Mind–Body Connection

Prior research has documented several ways that physical activity can influence cognition. These include studies that have shown global protective effects of exercise against cognitive decline (e.g., Kramer, Erickson, & Colcombe, 2006), the "embodied" dependency of semantic concepts on physical activity (e.g., Klatzky, Pellegrino, McCloskey, & Doherty, 1989), and the competition of physical and mental activity for shared attentional resources (e.g., Li, Lindenberger, Freund, & Baltes, 2001). As we show later, these literatures do not explain the creativity effect demonstrated here. More relevant is research that examines how physical activity selectively enhances specific cognitive processes.

Studies on selective cognitive effects of physical activity have largely focused on aerobic activity (running), rather than mild activity (walking) or anaerobic activity (sprinting). For example, aerobic activity appears to increase the speed of concurrent cognition (Brisswalter, Collardeau, & Rene, 2002; Fontana, Mazzardo, Mokgothu, Furtado, & Gallaher, 2009; Tomoporowski, 2003). Researchers have also investigated short-term residual effects of aerobic exercise (e.g., Kubesch et al., 2003). In their meta-analysis, Lambourne and Tomporowski (2010) found a small improvement in memory performance following acute exercise. Within this literature, there is also a hint that exercise could have positive effects on creativity.

Gondola (1986, 1987) found gains in participants' ideational fluency after aerobic running or dancing, and Netz, Tomer, Axelrad, Argov, and Inbar (2007) found similar results for aerobic walking, regardless of participants' fitness history. Steinberg et al. (1997) measured people's flexibility in generating unusual uses for common objects after they had participated in aerobic exercise or slow rhythmic stretching. Both activities led to greater flexibility compared with watching a 20-min video on rock formations. Unfor-

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tunately, the authors of this study did not determine whether physical activity facilitates ideation or a geology video suppresses it.

These creativity effects occurred after sustained periods of exercise, often aerobic. Asking people to take a 30-min run to improve their subsequent seated creativity would be an unhappy prescription for many people. Thus, the current research examined the more practical strategy of taking a short walk. In the General Discussion, we consider possible mechanisms by which the creativity effect takes hold.

Creativity Training

Early research investigated the traits of creative people (Barron, 1955; Feist, 1998). More recently, research has emphasized increasing creativity (Amabile, 1996, Scott, Leritz, & Mumford, 2004). Creativity has a number of positive benefits (Plucker, Beghetto, & Dow, 2004), so there are reasons to increase it. Creativity is implicated in workplace success (Tierney, Farmer, & Graen, 1999; Torrance, 1972, 1981), healthy psychological functioning (Davis, 1989; Kin & Pope, 1999; McCracken, 1991; Russ, 1998; Terr, 1992), and the maintenance of loving relationships (Livingston, 1999). Of course, creativity is also valued for its potential contributions to society.

Attempts to improve individual creativity often involve training people in the steps of creativity including shifting perspective (Kozbelt, Beghetto, & Runco, 2010), trying something counterintuitive (Amabile, 1983), or, in the most direct fashion possible, simply trying to "be more creative" (Christensen, Guilford, & Wilson, 1957). While effective, these depend on diligence and the direct, perhaps effortful, manipulation of one's creative processes. Rather than trying to improve people's command of the creative process, we simply had people walk at a natural pace. If successful, it is an easily adopted (and healthy) approach for enhancing creative output.

Across nearly every discipline, there are discussions of what counts as creativity. We adopt an operational definition of creativity as the production of appropriate novelty. Creative ideas are not only relatively novel; they are also appropriate to the context or topic (e.g., lighter fluid is a novel ingredient for soup, but inappropriate).

The achievement of creativity, whether grand or in small everyday moments, includes many facets and processes. In nearly all cases, a key component is the initial generation of novel and appropriate ideas, which may be subsequently refined. The current research employed two widely accepted creativity tasks that focus on the ideational component of creativity, Guilford's alternate uses test (Guilford, 1960) and Barron's symbolic equivalence test (Barron, 1963).

Experiment 1

In the first study, people completed a divergent creativity task—first when sitting and then when walking on a treadmill. To determine whether walking had a selective effect on creative ideation, as opposed to cognition in general, we also asked the participants to complete a convergent thinking task when sitting and walking.

To evaluate divergent creative output, participants completed Guilford's alternate uses test (GAU). Given 4 min, people generated alternate uses for common objects such as a button or tire. GAU depends on cognitive flexibility (Benedek, Konen, & Neubauer, 2012), so that people can avoid locking into a single category of uses. For example, in the following study, one person heard "button" and generated "as a doorknob for a dollhouse, an eye for a doll, a tiny strainer, to drop behind you to keep your path." The GAU has exhibited various forms of validity (Gibson, Folley & Park, 2009; Harrington, Block, & Block, 1983; Stimson, 1968), and it has been used to assess the success of creativity training (Renner & Renner, 1971).

Guilford (1967) argued that divergent thinking is distinct from convergent thinking. The compound remote-association test (CRA), created by Bowden and Jung-Beeman (2003) and based on the remote-association test by Mednick, Mednick, and Mednick (1964), is a widely adopted measure of convergent thinking. People need to produce a single word that combines with each of three words. Given the words "cottage—Swiss—cake," the answer is "cheese." The CRA has been used for many purposes but mostly for investigating insight (Kounios & Beeman, 2009), and the variables that might affect insight (e.g., social stress; Alexander, Hillier, Smith, Tivarus, & Beversdorf, 2007).

The distinction between the free-flowing divergent thinking of GAU and the tight constraint satisfaction of CRA creates good companion measures. Combined, they can be used to determine whether walking has global effects on cognition or whether it is selective to one type of thinking over another. Moreover, creativity writ large depends on both appropriate novelty and insight, so there is practical value in knowing which aspects of creativity walking influences.

Method

Participants. Undergraduate psychology students ($N = 48$) were drawn equally from a community college and a private university. All students received course credit.

Design and procedure. A within-subject research design compared the effects of movement (sitting vs. walking) on cognitive task (GAU vs. CRA). Participants completed the procedure individually in a small room with a chair and desk facing a blank wall and a treadmill facing a blank wall. Participants spoke their responses, which were audio recorded.

Participants first completed the seated condition. After receiving task instructions, they heard three words and had 4 min to generate as many alternate uses as possible. If they stopped early, they were encouraged to continue. They then repeated the process with three new words.

Next, they completed the CRA task. They received 16 triads, with 15 s per triad. The CRA task always followed the GAU task, because pilot work indicated that the CRA could be demoralizing, which interfered with performance on an immediately following GAU task.

Participants then moved to the treadmill. They found a comfortable, self-selected walking pace. They completed a new GAU and CRA. The GAU and CRA used two forms, counterbalanced across participants.

Coding. GAU responses passed through a series of increasingly restrictive coding filters. The first pass coded *ideation*—the total number of generated uses. The second pass coded *appropriate* uses per GAU's criteria: specific, different from the given common use, feasible, and nonrepetitive. Given the prompt "tire," a nonspecific response is "to use the parts," a common use is "as a wheel on a car," and an infeasible use is "as a pinkie ring." If a person stated the same use across the experiment, only the first use counted. A primary coder scored all responses, and a secondary coder scored a 20% subset exhibiting agreement of $r = .73$. The final filter coded *novelty*, operationalized as unique within the sample of participants. If two or more people gave the same use for a specific object, the response did not count as novel for either. This final filter determined *appropriate novelty*, which is our operationalization of creativity.

For the CRA, participants could receive a maximum score of 16 for each form. Participants received a point for each answer that matched those provided with the CRA test.

Results

Figure 1 indicates that walking improved performance on GAU but mildly hurt performance on CRA. Among the 48 participants, 81% improved their creative output when walking, and only 23% improved on the CRA when walking. To test the effects, we collapsed across the alternate forms of the GAU and CRA. (For both measures, the alternate forms exhibited no appreciable differences, $ps > .5$.) A within-subject analysis of variance crossed the cognitive task (GAU vs. CRA) with movement (sitting vs. walking). There is a main effect of cognitive task, $F(1, 47) = 19.50$, $p < .001$; a main effect of movement, $F(1, 47) = 19.69$, $p < .001$; and importantly, an interaction of cognitive task by movement, $F(1, 47) = 60.31$, $p < .001$. When taking the measures in isolation, walking significantly decreased the number of correct responses for CRA, $t(47) = -2.23$, $p = .03$, $d = 0.38$, whereas walking significantly increased the number of creative ideas for GAU, $t(47) = 7.03$, $p < .001$, $d = 0.70$.

If we ignore the criteria of appropriateness and nonrepetition, a notable finding is that participants produced roughly 50% more total ideas (good and bad uses) when walking ($M = 33.1$, $SD = 10.22$) than sitting ($M = 22.2$, $SD = 12.20$); $t(47) = 10.46$, $p < .001$. Walking made people more loquacious. Walking however did not increase creativity simply because people talked more. For each participant, we divided the number of creative ideas (appropriate novel) by the total ideation to compute density scores. When walking, people had a creative use for 3.0 out of every 10 generated uses ($SD = 1.1$) compared with 2.5 out of every 10 uses ($SD = 1.2$) when sitting, $t(47) = 2.51$, $p = .016$. Thus, when walking, people were more talkative, and more of their talk included creative ideas.

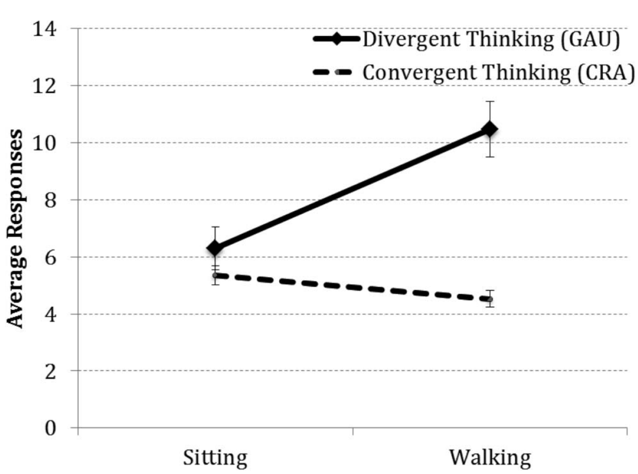

Figure 1. Effects of walking and sitting on divergent and convergent thinking. Divergent thinking score is the number of appropriate novel alternate uses on Guilford's alternate uses (GAU) test. Convergent thinking score is the number of correct responses on the compound remote-association (CRA) test. Error bars are standard errors of the mean.

Discussion

Walking had a large effect on creativity. Most of the participants benefited from walking compared with sitting, and the average increase in creative output was around 60%. When walking, people also generated more uses, good and bad. Simply talking more, however, was not the sole mechanism for the increased creativity. When walking, people generated more uses, and more of those uses were novel and appropriate.

People did mildly worse on the CRA when walking than when sitting. The selective positive and negative effects of walking indicate that the creativity outcome is not due to the global facilitation of exercise as found in prior work. Physical (aerobic) activity has been generally associated with broad protective outcomes (Colcombe & Kramer, 2003; Cotman, Berchtold, & Christie, 2007; Erickson et al., 2011; Hillman, Erickson, & Kramer, 2008; Kramer et al., 2006; Lautenschlager et al., 2008). Gow et al. (2012), for example, showed that physical exercise, rather than intellectual leisure activities, may be the best way to prevent age-related decline in brain functioning. While the long-term effects of aerobic activity may be general, the concurrent effects of mild physical activity were selective to divergent thinking.

A methodological concern for the current study was that walking always came after sitting, so it was possible that people simply improved at alternate uses with practice rather than because of walking. If true, then people should demonstrate marked improvement on the second administration of the GAU, whether they are walking or not. The next study tested this possibility.

Experiment 2

Experiment 2 replicated the sit-then-walk condition from the previous study (sit–tread). In a second condition, we asked people to sit for both sessions to determine whether there are practice effects (sit–sit). In a third condition, people walked first and then sat (tread–sit) to permit a comparison of people who sat or walked for the first session.

The tread–sit condition had the second purpose of allowing us to evaluate the contribution of embodied cognition (e.g., Barsalou, 1999; Schwartz & Black, 1999). Embodied cognition occurs when movements influence thought contents. For instance, moving one's hand forward facilitates thoughts about moving forward but interferes with thoughts about moving backward (De Vega, Robertson, Glenberg, Kaschak, & Rinck, 2004). Applying this to creativity, walking might improve divergent thinking because walking triggers thoughts of moving from one idea to another. In the tread–sit condition, if people exhibited residual creativity effects when seated, an embodied explanation becomes less plausible.

Method

Participants. Forty-eight community college psychology students were randomly assigned to three conditions. All students received course credit.

Design and procedure. In the sit–sit condition, people sat for both forms of the GAU. In sit–tread, people sat and then walked on the treadmill. In tread–sit, participants walked on the treadmill and then sat. The procedures were the same as before with two exceptions: (a) there was no CRA, and (b) there was no encouragement to continue generating until time expired. In these experiments, the experimenter could not be blind to condition. We removed the encouragement to avoid possible subtle differences across treatments.

Results

Figure 2 summarizes the main results. In the sit–tread condition, walking again produced more creative ideas than sitting. In the sit–sit condition, practice did not improve GAU performance. In the tread–sit condition, people showed a marked advantage in seated creative production compared with those who had not first walked.

The following analyses consider appropriate novel responses. (The pattern of results for total ideation, total appropriate responses, and density of novel responses were similar to the results of Experiment 1.) We begin with a between-subject comparison of sitting and walking. A one-way analysis of variance (ANOVA) used only the Time 1 data. There was a significant effect of condition, $F(2, 45) = 20.07$, $p < .001$. Planned comparisons showed that the two sitting conditions did not differ, $p = .842$, and combined they generated fewer creative ideas than those walking on the treadmill, $p < .001$. Thus, the effect of walking held up in a between-subjects design.

A separate ANOVA found a significant effect among the three conditions at Time 2, $F(2, 45) = 7.86$, $p = .001$. The first planned comparison demonstrated that sitting after walking (tread–**sit**) led to significantly more creative uses than sitting after sitting (sit–**sit**), $p = .001$. The second comparison showed that sitting after walking (tread–**sit**) was as good as walking after sitting (sit–**tread**), $p = .975$. This indicates short-term residual benefits of walking on creativity.

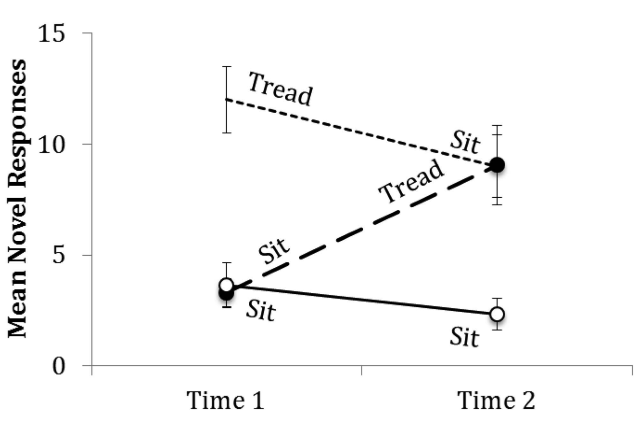

Figure 2. Mean number of novel appropriate responses by time and condition. Error bars are standard errors of the mean.

To simplify within-subject analyses, we take each condition separately. Similar to participants in Experiment 1, 88% of the participants in the sit–tread condition increased their number of novel ideas when walking, $t(15) = 4.08$, $p = .001$. In the sit–sit condition, participants decreased production from Time 1 to Time 2, $t(15) = -2.44$, $p = .028$. Practice, at least in the short run, does not improve GAU performance. In the tread–sit condition, participants decreased their production of novel ideas, $t(15) = 2.70$, $p = .016$. People did worse when subsequently seated compared with when they were walking, but the residual benefit of walking was apparent when these participants were compared with those who sat at both times.

Discussion

Walking again increased people's creative production on the GAU. Practice cannot explain the effects. On their first try, people who walked did better than those who sat, and those who only sat did not improve across trials. Walking also exhibited a residual effect on creativity. After people walked, their subsequent seated creativity was much higher than those who had not walked.

This latter finding has practical and theoretical significance. Practically, taking a walk immediately before a brainstorming session should help improve one's performance. Theoretically, the effect of walking does not appear to result from a semantic association between action and thought. People do not need to move their legs at the same time as they generate alternate uses.

An issue with this experiment is that people who switched from sitting to walking and vice versa changed their performance context. The sit–sit participants, in contrast, sat at the same wall-facing table, which may have suppressed performance at Time 2. In the next study, we addressed this problem by having the sit–sit participants switch rooms between sessions.

Experiment 3

A treadmill desk is not a popular option for most people. Walking through an environment—for example, a mall, a building, or outdoors—is more likely. To examine the practical reach of the current findings, people walked outside in this study.

The outdoors can offer cognitive and emotional renewal. Attention restoration theory (ART) posits that walking in natural environments invokes "soft fascination," which does not require direct attention and allows for the renewal of directed attention capacities. Berman, Jonides, and Kaplan (2008) found that compared with an urban walk, a walk in nature restored people's previously exhausted attentional capacities, resulting in improved performances at difficult tasks when no longer walking. There are also additional calming effects (Hartig, Evans, Jamner, Davies, & Garling, 2003).

ART studies have isolated the nature of the environment rather than the impact of walking, and they have favored serene green environments. In the current study, participants walked through a busy, albeit lovely, university campus. The study did not compare walking in different contexts, but it did code whether participants' alternate uses referred to an outdoor or indoor context. By comparing the relative number of indoor and outdoor uses across conditions, it is possible to assess the relative contribution of outdoor stimulation.

Experiment 3 filled out the partial factorial designs of Experiments 1 and 2. For a sit–sit condition, we had participants switch between rooms for each session to equate any effects of context switching. A walk–sit condition determined if the residual effects found in Experiment 2 would replicate. A sit–walk condition was the third replication of the basic finding. Finally, a walk–walk condition tested whether the benefits of walking attenuate over time.

Method

Participants. Forty-nine university students began the experiment, but nine were dropped prior to their data being examined because they incurred acute outdoor distractions that interfered with the time-sensitive GAU. These included the rapid onslaught of fast-moving bikes, very large trucks without apparent mufflers, and a participant answering his phone mid-test. Enrollment continued until reaching 40 participants.

Design and procedure. There were four conditions: sit–sit, sit–walk, walk–sit, and walk–walk. The procedure differed from Experiment 2 in two ways. First, people walked along a predetermined path through a university campus. Second, after taking the first GAU test, those in the sit–sit condition moved to a different indoor room. Those in the walk–walk condition took a brief break before continuing on the outdoor path.

Coding. Codes were similar to those in the first two experiments, except for the addition of an *alfresco* code (Italian for outdoors). Alfresco responses included applications that normally occur outside ("frisbee"), implied an outdoor component ("to pop a bike tire"), or explicitly mentioned the outdoors ("to pick up sand at the beach"). Two coders achieved $r = .74$ agreement on the number of alfresco codes per transcript.

Results

Figure 3 shows that the effects of walking are similar to the effects in the previous studies, with the additional information that the effect of walking does not attenuate over time.

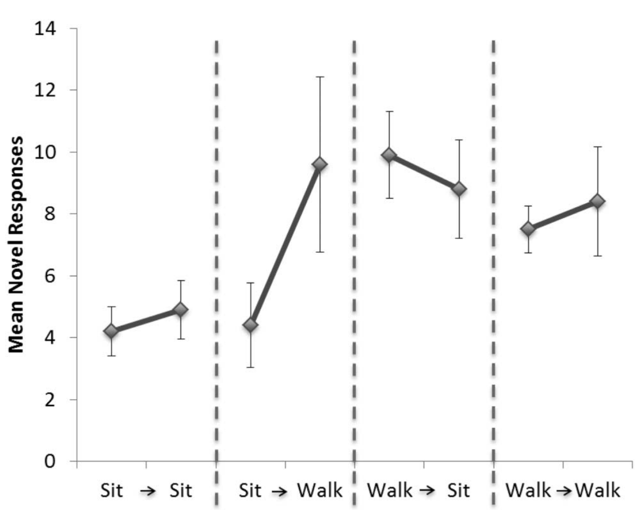

Figure 3. Mean appropriate novel responses by condition and time. Error bars are standard errors of the mean.

To simplify the statistical analyses, we again begin with the between-subjects Time 1 results. The combined walking treatments doubled the number of novel responses compared with the combined sitting treatments (8.7 vs. 4.3), $t(38) = 3.91$, $p < .001$. This generalizes the treadmill walking effect to outdoor walking.

To examine the within-subject changes of treatment, we take each condition in turn. Again, the sit–walk participants did much better when walking. They increased their creative production more than two-fold, $t(9) = 2.73$, $p = .023$, and 100% of the participants increased their number of novel responses when walking. The sit–sit condition did not exhibit a change in creative production from Time 1 to Time 2, $t(9) = 1.25$, $p = .242$. Switching rooms did not make a difference. The walk–walk condition yielded the same level of performance for both walking periods, $t(9) = 0.690$, $p = .507$. Walking maintains its positive effect, at least over 16 min.

The walk–sit condition replicated the residual effect found in Experiment 2. When people sat after walking, they exhibited nearly the same level of creative production as when they were walking, $t(9) = -1.02$, $p = .335$. The strength of the residual effect can be noted by comparing the walk–sit condition to the walk–walk condition in a 2 (time) × 2 (walk–sit vs. walk–walk) repeated-measures analysis. There were no significant effects of time, $F(1, 18) = 0.014$, $p = .907$; condition, $F(1, 18) = 0.58$, $p = .458$; or Time × Condition, $F(1, 18) = 1.40$, $p = .253$. Walking once was just as good as walking for both sessions.

Does walking outdoors provide special stimulation for creativity? We restricted the analysis to Time 1, when participants had only been indoors or outdoors so far. Walking outdoors led to more alfresco uses than indoor sitting ($M = 2.6$, $SD = 1.93$, and $M = 0.7$, $SD = 1.13$, respectively) and more non-alfresco uses ($M = 6.2$, $SD = 2.52$, and $M = 3.6$, $SD = 2.82$). Thus, 30% of the total uses were alfresco for outdoor walking compared with 16% for sitting indoors. The difference, however, is not significant. In a repeated-measures test, we compared use type (alfresco vs. non-alfresco) by treatment (sitting vs. walking). There was a main effect of more non-alfresco uses overall, $F(1, 38) = 59.77$, $p < .001$, and a main effect of walking outside, $F(1, 38) = 15.84$, $p < .001$. There was not a significant interaction of condition by use type, $F(1, 38) = 0.693$, $p = .410$.

Discussion

As before, walking—in this case, outside—led to improved creative performance on the GAU. Also as before, walking left a residue that produced strong performance when participants were subsequently sitting. The effect of walking did not attenuate when people walked twice.

The effect of being outdoors was inconclusive. Walking outdoors descriptively increased the ratio of alfresco (outdoor) uses compared with sitting indoors, but the effect was not significant. In Experiment 4, we took an experimental approach to separate the effects of moving outdoors from the effects of walking outdoors. People walked outdoors, or they were pushed in a wheelchair outdoors.

Experiment 4

Experiment 4 introduced two major changes. It employed a different measure of creativity. It experimentally separated walking from moving through an outdoor space. The new creativity task was Barron's symbolic equivalence task (BSE; Barron, 1963). The BSE depends on the generation of analogies, which Gentner (2002) has called, "the engine of creativity" (p. 37). People produce analogies to base statements (e.g., "a candle burning low"). This requires abstracting the relational structure of the base statement (a positive force extinguishing itself) and repopulating the structure in a different domain (the last hand of a gambler's last game). The BSE is more complex than the GAU, which would only require identifying a surface attribute (flame) and using it to determine a use (to burn a moth). External validation of BSE includes a correlation between BSE scores and a rank ordering of participants' professions, with famous writers at the top (Eysenck, 1995). Barron (1988) also found a positive correlation with an individual's BSE score and external criteria for creativity within that person's professional standing.

Experiment 4 separated the effect of moving through the outdoors from the effect of physically walking. Participants completed one of four conditions. In a sitting outside condition (SitOut), participants were pushed in a wheelchair along the same university path as participants in a walking outside condition (WalkOut). Thus, both groups of participants had the dynamic flow of outdoor stimulation, but only one group walked. The study also included an indoor treadmill condition (WalkIn) and a sitting inside condition (SitIn).

Method

Participants. Forty adults at a large private university were recruited through e-mail and randomly assigned to condition.

Design and procedure. A between-subjects 2 (indoors vs. dynamic outdoors) × 2 (sitting vs. walking) design had the four conditions of sitting inside (SitIn), walking on a treadmill inside (WalkIn), sitting in a moving wheelchair outside (SitOut), and walking outside (WalkOut).

After receiving task instructions, participants heard three prompts: a robbed safe, a light bulb burning out, and a budding cocoon. They had 5 min to generate analogies for all three. They could re-request the prompts at any time. All responses were audio-recorded.

Coding. Barron's original scoring procedure depended on intuitive judgments. We developed a more readily replicated coding scheme based on Gentner (1983). Each statement was coded for *appropriateness*, which was defined as being a legitimate analogy. Abstractions and restatements did not qualify (e.g., given the prompt of *a robbed safe*, inappropriate responses include "an empty box" or "someone taking something out of a protected space"). The appropriate analogies were coded for *novelty*, defined as being unique within the corpus of the experiment.

The novel analogies were further coded for *high quality*, determined by three criteria: the level of detail found in the analogy (vague, precise), the semantic proximity to the base statement (near, far); and the relational mapping to the base statement (low, high; see Gentner, 1983). Appendix A provides examples. *High-quality* analogies are specific and semantically far, and retain a high level of the base statements' relational structure. On a random subset of the total 587 statements, interreliabilities of two coders were $r = 1.0$ for detail level and $r = .98$ for semantic distance. For relational structure, we used Amabile's (1996) consensual assessment technique, where two judges, blind to condition discussed each response to reach consensus (cf. Niu & Sternberg, 2001).

Results

Figure 4 shows the average number of high-quality analogies and the subsets that were novel for each of the four conditions. Walking had a strong effect on creative production whether indoors or out. Table 1 provides a series of ANOVAs at the various coding levels. They each cross walking (sitting vs. walking) and place (indoors vs. dynamic outdoors). For high-quality novel analogies, there is only an effect of walking. Of those who walked, 95% generated at least one novel high-quality analogy compared with 50% of those who sat. When relaxing the constraint to include low-quality novel analogies, there is a double main effect indicating that both walking and being outdoors independently increased novelty. Thus, walking appears to prompt high structure and novelty, whereas the outdoors seems to influence novelty.

Table 1 also indicates that walking increased general talkativeness as measured by the average number of separate statements. Walking increased the tendency to talk, and people were especially loquacious when walking outside.

The effect of walking on relational structure was surprisingly apparent in the most creative analogies, which had a recursive quality. Using a post hoc coding scheme, we identified responses where the main object in the response played two roles. Given the prompt "a robbed safe," a recursive response was "a father abusing his young daughter." The source of protection is also the violator of the protected. Appendix B provides more details. There is a strong main effect of walking on increased recursive analogies, but there is no effect of location. This makes some sense in that outdoor stimulation provides topics for creative ideas, but it seems less likely to offer up a recursive or relational structure for those topics.

Discussion

Walking led to an increase in analogical creativity. Walking, rather than being outdoors, was the driver of novel, high-quality

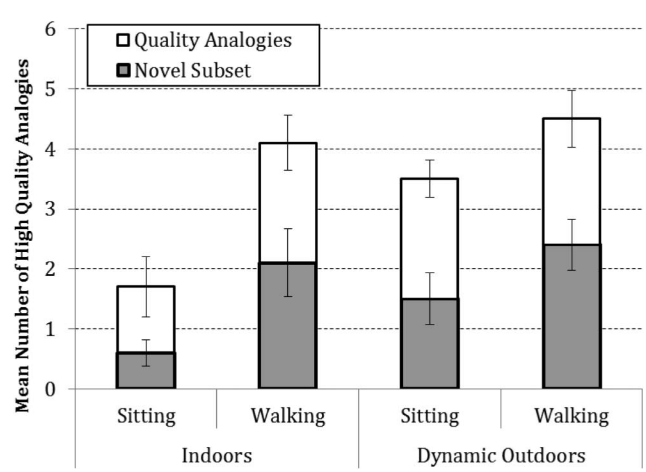

Figure 4. Mean number of high-quality and high-quality novel analogies by condition. *Quality* analogies refer to the full height of the bar, whereas *novel* refers to the subset that was unique to the sample. Error bars are standard errors of the mean.

Table 1
Means (SD) and Factorial Results for Novelty, Alfresco, High-Quality Novel, and Recursive Analogies by Condition

Variable	Indoors		Dynamic outdoors		Main effect $F(1, 36)$		Interaction $F(1, 36)$
	Sitting	Walking	Sitting	Walking	Sit vs. walk	In vs. out	2 × 2
Ideation	13.20 (5.20)	13.70 (3.56)	12.00 (4.06)	19.80 (7.51)	6.12*	2.13	4.73*
High-quality novel analogies	0.60 (0.70)	2.10 (1.79)	1.50 (1.35)	2.40 (1.35)	7.83**	1.96	0.49
Novel	3.50 (2.17)	5.30 (2.00)	4.90 (2.28)	9.30 (5.27)	9.21**	6.99*	1.62
Recursive	1.10 (1.10)	2.00 (0.94)	1.10 (1.29)	2.40 (1.51)	8.04**	0.27	0.27

Note. F test comparisons for analysis of variance factorial.
* $p < .05$. ** $p < .01$.

analogies. While research indicates that being outdoors has many cognitive benefits, walking has a very specific benefit—the improvement of creativity.

The advantage of walking for highly structured analogies appeared for both the a priori coding scheme of high-quality analogies and for the emergent scheme for recursive analogies. The increased talkativeness that comes with walking may have contributed. People talked through the base prompts, iterating to find the deep structure of the prompt. This set the stage for retrieving an analogy that matched the deep structure. A transcript provides a sense of the typical process. The following participant was working on the prompt "a robbed safe."

> The idea is of something that is protected that is supposed to be safe that is being violated. So it's the loss of something protected and cherished. The idea is of something that is taken away. It's in a safe so it's something of value that needs to be protected. So . . . the loss of innocence. The loss of liberty.

One concern is that being rolled in a wheelchair is unusual and may have suppressed creativity. The wheelchair did not seem to bother or overly intrigue participants. A future experiment should test other ways of moving people through the environment (e.g., a slow golf cart). Regardless, these results do not imply that people who require wheelchairs cannot partake of the benefits found here. Walking is only one way to engage in mild exercise. For example, rolling oneself in a wheelchair may be equally effective.

General Discussion

Walking substantially enhanced creativity by two different measures. For the three alternate uses studies, 81%, 88%, and 100% of participants were more creative walking than sitting. For the BSE, 100% of those who walked outside generated at least one novel high-quality analogy compared with 50% of those seated inside. Walking worked indoors on a treadmill and outdoors at a bustling university.

Walking is an easy-to-implement strategy to increase appropriate novel idea generation. When there is a premium on generating new ideas in the workday, it should be beneficial to incorporate walks. In addition to providing performance benefits, it would address concerns regarding the physiological effects of inactivity (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008;. Hamilton, Hamilton, & Zderic, 2007). While schools are cutting back on physical education in favor of seated academics, the neglect of the body in favor of the mind ignores their tight interdependence, as demonstrated here.

Theoretically, we can eliminate several explanations for the results. First, the effect cannot be due to real-time competition between physical and mental activity for shared cognitive resources, although this does occur. For instance, one study showed a dual-task cost for 60-year-olds walking a difficult obstacle course while performing a word-recall task (Li et al., 2001). Here, when people sat down after walking, they continued to be more creative even though they no longer needed to attend to walking.

Second, the residual effects also block an embodied account, because when seated after walking, there were no longer moving legs to semantically prime cognition. Third, the causal pathway is likely to differ from the mechanisms that translate exercise into global protective factors for cognition. Walking was selectively beneficial for divergent thinking, not convergent thinking. Finally, the effect is not due to the external flow of stimulation that normally occurs with walking. Walking on a treadmill facing a blank wall improved creativity.

How, then, might one explain the effect of walking? The explanation will eventually comprise a complex causal pathway that extends from the physical act of walking to physiological changes to the proximal cognitive processes. These studies eliminated alternatives but did not isolate mechanisms. Nevertheless, it may be useful to consider each link in the chain with the results in hand.

Walking constitutes the first part of the causal chain. Is it walking per se, or would other forms of mild physical activity have similar elevating effects? Moreover, it may be the mind-freeing quality of engaging in a comfortable task (e.g., knitting), rather than exercise. A second issue is the manner of walking. We asked people to walk at their natural gait. When people walk outside their natural stride, it demands more cognitive control (Brisswalter, Durand, Delignieres, & Legros, 1995). Whether these mild attentional demands or more aerobic walking would detract is unknown. A third question considers the context of walking. Walking outdoors on a busy campus did not significantly increase appropriate novelty compared with walking indoors, although the more varied stimulation did appear to increase novelty. This suggests that walking may be effective in many locations that do not have acute distractions. The social context also needs investigation. Participants were encouraged to talk aloud to a friendly researcher. Will the effects generalize to solitary walks?

Leg movement and external stimulation were not direct causes of increased creativity, given the residual effects of walking when seated. This implicates biological mediators that may range from circulatory to chemical changes. Mood is also a possible mediator. Physical exercise is linked to mood enhancement (Rethorst, Wipfil, & Landers, 2009), and an increase in positive mood might in turn improve divergent thinking (Bar, 2009; Chermahini & Hommel, 2012). The meta-analysis by Baas, De Dreu, and Nijstad (2008) revealed that positive mood states correlate with higher creativity; however, other research has shown that negative emotions can lead to increased artistic creativity (see review by Akinola & Mendes, 2008). Compared with taking physiological measures, folding in mood assessments may be a simpler first step for future studies (e.g., Steinberg et al., 1997).

Finally, there are the proximal cognitive mechanisms that produce greater creativity. Walking had a strong influence on the expression of associative memory. People presented more ideas, and the ideas tapped each person's unique associative network, which led to an increase in novelty compared with other people's ideas.

One possible explanation is that walking taxed executive function to handle the dual-task nature of walking while thinking, and a side effect of this distraction was that it allowed more creativity to seep in. This seems unlikely given that creativity performance was resilient to mild distractions that require executive function management. When comparing across experiments, people's GAU performance walking outdoors was similar to participants' performance walking on a treadmill in a stimulus-impoverished room. In Experiment 4, walking outdoors also yielded descriptively more complex relational structure than walking inside.

Moreover, the evidence that walking had general effects on executive function is mixed. People performed somewhat more poorly on the working-memory-intensive CRA task when walking, but people also produced more cognitively demanding recursive structures for the BSE. It is unknown whether the modest decline in CRA performance in Experiment 1 ($d = 0.38$) had a functional relation to the larger increase in creativity ($d = 0.70$). A useful study would determine if CRA performance remains impaired when participants are subsequently seated after walking. If so, then there would be evidence for a common mechanism behind the decrease in CRA and the increase in GAU performance. Alternatively, CRA performance may bounce back when participants are subsequently seated, which would indicate that the CRA is sensitive to mild distractions (Cranford & Moss, 2012; De Dreu, Nijstad, Baas, Wolsinki, & Roskes, 2012) including walking, but unrelated to performance on the GAU, which remained elevated when participants were subsequently seated.

An alternative explanation specifically emphasizes the regulation of associative memory. For instance, Mackey, Whitaker, and Bunge (2012) found that training for the Law School Admission Test (LSAT) increased connectivity between prefrontal and parietal regions, with the hypothesized consequence of aiding people's abilities to down-regulate associative memories. (Suppressing everyday knowledge is important for staying within the bounds of the stated premises of an LSAT problem.) Conversely, walking may relax suppression of memories, which would yield increased associative ideation (see Chrysikou & Thompson-Schill, 2011). This would open the "flexibility pathway" of the dual pathway creativity model (Baas, De Dreu, & Nijstad, 2008; De Dreu, Baas, & Nijstad, 2008; Nijstad, De Dreu, Rietzschel, & Baas, 2010). These authors have argued that unlike the "persistence pathway," the flexibility pathway does not require strong cognitive control (also see Dreisbach & Goschke, 2004; Martindale, 1995), which can help explain why any modest dual-task demands of walking did not interfere with ideation.

A related explanation is that walking may have increased the activity of associative memory. Executive function can set constraints on acceptable retrieval and filter retrieved ideas. However, associative memory has to provide the candidate ideas. Walking may have increased the ease with which associative memories activated, for example, by relaxing inhibitory competition among memories and allowing ideas with low levels of activation to push through. If true, then we should expect walking to enhance performance on tasks that are otherwise marked by the dominance of single memories, as in the case for functional fixedness (e.g., Thompson-Schill, Ramscar, & Chrysikou, 2009) and other *Einstellung* effects.

Clearly, there are a number of theoretical and practical directions available, now that the basic demonstration is in hand. In the meantime, many people anecdotally claim they do their best thinking when walking. We finally may be taking a step, or two, toward discovering why.

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(*Appendices follow*)

Appendix A

Examples of Responses and Respective Codes for Barron's Base Analogs

	Three prompts used in Experiment 4		
Code	Robbed safe	Budding cocoon	Light bulb blowing out
Detail			
Vague	"the idea is you have something precious to protect but then someone tries to steal it"	"anything that has to do with growing or beginning"	"an explosive thing that happened and leaves you in darkness"
Precise	"pyramid that's been ransacked by tomb raiders"	"pregnant woman giving birth"	"lightening hitting a tree"
Distance			
Near	"robbed bank"	"hatching egg"	"candle blowing out"
Far	"cheating on a partner"	"grand opening of a restaurant opening its doors"	"Emirates Stadium when an Arsenal player scores in football"
Relational structure			
Low structure	"studying for the test after it's happened"	"tadpoles"	"getting shot and dying"
High structure	"honey being taken out of a bee's nest—honeycomb"	"idea that's on the tip of the tongue about to come out"	"love—intense passionate relationship that burned really brightly but it was SO bright that it couldn't last so burns really brightly but flickers out"
High-quality analogies			
Specific, far, high structure	"cheating off someone on a test"	"coming out of a meditation retreat"	"throwing up while you're drinking"
Recursively high structure	"soldier coming back from war with severe PTSD" (self is stolen of self)	"apprentice coming out of the shadows of his master" (self causes self to emerge)	"flooding of water that rushes over the riverbank" (self extinguishes self)

Appendix B

Recursion Rubrics and Responses

For a robbed safe, there were three types of recursive structures:

1. The contents themselves are fleeing or leaving the space of protection.

   "*empty bus to the bus driver after kids peel out*"

2. The space of protection itself is being taken, or the thing you are losing is also the thing that is protecting you.
   "*banished dog*"

3. The protector is also the thief or the violator.
   "*sex abuse of a father to younger girl*"

For a light bulb blowing out:

1. The light going out causes other lights to go out, or the breakage causes other breaking.
   "*a student under high academic pressure unfortunately going on a Columbine-type style shooting rampage*"

2. Turning on a light blows out other lights.
   "*a completed Hail Mary pass in the Superbowl to win the game; you've extinguished somebody's hopes*"

3. The source of the power gets rid of the power itself instead of the source of power getting rid of the light.
   "*a nuclear reactor melting down*"

For a budding cocoon:

1. The thing that is changing is the cocoon or "wrapper" itself.
   "*losing virginity*"

2. Cocoon creates itself, or the object of change is becoming the cocoon that buds.
   "*dust in the cosmos surrounding each other with infinite possibilities, there are stabilities there that aid in the formation of life and solar system, couldn't have happened without certain conditions*" 3.

The cocoon is what is creating the thing that is budding out, or the cocoon is the engine of transformation, rather than just a protective casing.
"*an apprentice coming out of the shadows of his master*"

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