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Break the "wall" and become creative: Enacting embodied metaphors in virtual reality

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ABSTRACT

This study investigated whether the experience of "breaking the walls", the embodiment of the metaphor "breaking the rules", could enhance creative performance. The virtual reality technology was used to simulate the scenario where participants could "break the walls" while walking in a corridor. Participants were asked to solve the creativity-demanding problems (ie., alternative uses tasks, AUT) in either the "break" condition in which they had to break the walls to move forward in VR, or the "no-break" condition where no barrier walls would appear. Results showed higher AUT originality and AUT fluency in the "break" condition than in the "no-break" condition. Moreover, the effects of "breaking the walls" on AUT originality were fully mediated by cognitive flexibility and persistence. These findings may indicate that enacting metaphors such as "breaking the rules" contribute to creative performance. The enhanced cognitive flexibility and persistence may account for the benefits.

1. Introduction

The interactive relationship between human mind and body has been widely accepted in the field of *cognitive embodiment* (Barsalou & Lawrence, 1999; Niedenthal, Barsalou, Winkielman, Krauthgruber, & Ric, 2005). On one hand, mind affects bodily experiences. For instance, Zhong and Leonardelli (2008) found that individuals felt much colder when they recalled experiences of being rejected than those of being accepted. In addition, compared to recalling ethical deeds, individuals show higher preference for cleaning products while recalling unethical deeds (Zhong & Liljenquist, 2006). On the other hand, bodily experiences also affect human mind. It has been shown that individuals are more likely to perceive others as tough and rigid persons when they touched a hard wood (Ackerman, Nocera, & Bargh, 2010). Moreover, individuals are more inclined to perceive sex-ambiguous faces as male when they squeeze a hard ball than a soft one (Slepian, Weisbuch, Rule, & Ambady, 2011).

As a special component of human mind, creativity is defined as the ability to produce work that is novel (original and unique) and useful (Runco & Jaeger, 2012; Stein, 1953; Sternberg & Lubart, 1993). Previous studies have explored the relationship between bodily experience and creativity. Slepian and Ambady (2012) reported that individuals who traced fluid drawings performed better on both alternative uses task (AUT) and remote association task (RAT). This indicates that fluid arm movements can facilitate creative cognition. Leung et al. (2012) found that walking freely in an open space encourages individuals to solve problems in a free and broad manner. Another study showed that walking (compared to being seated) led to higher fluency and originality of idea generation (Oppezzo & Schwartz, 2014). In addition, a recent study revealed that the effects of arm postures on creativity can be affected by general body position (Hao, Yuan, Hu, & Grabner, 2014). It was explained that in the horizontal body position condition, arm

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extension decreases the physical distance between the participant and the object in his/her hand and represents an approach motor action, while arm flexion increases the distance and represents an avoidance motor action. The associations between arm extension/flexion and approach/avoidance are reverse in the sitting position or horizontal body position condition. Therefore, compared to the sitting position, arm flexion and extension in the horizontal position affect creative cognition in a reverse pattern. All of this may confirm that bodily experiences can exert effects on creative cognition.

In addition to the concrete bodily experiences of sensations and movements, metaphor has also been widely recognized as an important way to establish links between human mind and body. Higher-order, abstract mental representations are ultimately grounded in bodily states. Our everyday language is full of "dead metaphors" (Stanciu, 2015). For instance, the sentence "we are on top of the situation", in which "on top of" implies "control and dominance", indicates that "the situation is under control". When we say "look forward to meeting someone", it seems that time intervals are considered as spatial distances (Boroditsky, 2001). In addition, when we call others "sweet heart", we actually use "sweet" to imply "kindness and beauty".

Recently, researchers in the field of embodied cognition have paid increasingly higher attention to the effects of metaphors on cognitive performance. Leung et al. (2012) found that embodying the metaphor "thinking outside of the box" can enhance creative performance. They reported that participants showed better performance on the RAT when they completed the task outside the box than standing inside it. Another metaphor "squeeze your head" is commonly used to encourage individuals to generate novel ideas. Kim (2015) asked participants to squeeze balls with different properties to embody the metaphor "squeeze your head". Results revealed that squeezing a soft deformable ball can enhance divergent thinking, whereas squeezing a hard ball can facilitate convergent thinking. These findings suggest that embodied metaphors can also affect creative cognition.

"Breaking the rules" is another common metaphor. It indicates a state of breaking away from the old-fashioned modes of thinking, namely, solving problems in novel ways rather than following the traditional approach passively. In both Chinese and English language contexts, the symbolic meanings of "walls" can be rules, laws, traditions, constraints, or confinement. In this sense, the implication of "breaking the walls" can be equal to "breaking the rules". Based on embodied theories, it can be expected that when individuals bodily break the walls, the sense of "breaking" will spread to concepts. When participants experience a feeling of breaking the rules or being capable to break the rules, they will experience a sense of liberation. In daily life, breaking the traditional rules has been regarded as a key factor to stimulating creativity, while sticking to ordinary ways or conventional rules is a sign of low creativity. In this study, we aimed to investigate whether the experience of "breaking the walls" in a virtual reality (VR) context (the embodiment of the metaphor "breaking the rules"), will enhance individuals' creative performance. If so, how does the experience of "breaking the walls" exert positive effects on creative performance?

Previous studies demonstrated that mentally embodying metaphors by mere imagining can produce equal effects on creative performance as physical enacting (Leung et al., 2012). In addition, it is feasible to use the virtual reality (VR) technology to create a circumstance where participants can experience "breaking the walls". In this study, participants were either assigned to the "break" condition in which they had to break the walls to move forward in VR, or to the "no-break" condition where no barrier walls would appear. They were asked to report ideas while walking in VR during one task, and report ideas after the walking during the other task. This allowed us to test whether the effects of "breaking the walls" were sustained. Participants' openness, emotional state, ideation in daily life, personal need for structure, self-rated enjoyment and difficulty of experimental tasks were all taken into account. Therefore, we could testify whether the observed effects of embodiment metaphor on creative performance were independent from these mentioned factors. We predicted that: (1) participants in the "break" condition would exhibit better creative performance than those in the "no-break" condition. Given that previous studies have demonstrated physical experiences affect creative performance both during and after performing physical actions (Kim, 2015; Leung et al., 2012) and "breaking the walls" might induce higher level of cognitive flexibility (get rid of the constraint of conventional thinking manner and explore other potential new ways), which would contribute to creative performance (De Dreu, Baas, & Nijstad, 2008), we also predicted that: (2) participants would show no difference of creative performance between reporting while walking in VR and after the walking, and (3) the effects of "breaking the walls" on creative performance would be mediated by cognitive flexibility.

2. Method

2.1. Participants

Forty-one undergraduates (38 females; *age*: 21 ± 1.98 years) participated in the study. They were recruited by a school-wide online advertising. They were all right handed, with normal or corrected-to-normal vision. Informed consents were obtained from participants before the experiment. Each participant was paid ¥ 20 for the participation. The study procedure was approved by the University Committee on Human Research Protection of East China Normal University.

2.2. Experimental tasks and procedure

The alternative uses task (AUT; Guilford, 1967) was used to assess creative performance in this study. It requires respondents to generate as many unusual and original uses as possible for common objects. The AUT is a well-established divergent thinking task (Guilford, 1967; Runco, 1991; Runco & Mraz, 1992). Performance on this task has been demonstrated to be a reliable predictor of creative potential (Runco & Acar, 2012).

This study was a 2 (Condition: break the walls vs. not to break the walls) × 2 (Reporting Mode: report while walking vs. report after walking) mixed design. The former variable was a between-subject factor, while the later was a within-subject factor.

Fig. 1. The experimental scene. (*A*) The scene participants saw in VR in the "break" condition. (*B*) The scene participants saw in VR in the "no-break" condition. (*C*) One participant was performing the tasks.

Participants were randomly assigned to either "break" or "no-break" condition. Before they performed the AUT in VR, participants were asked to complete several pre-experiment tests (see details below). In the VR scene, a zigzag one-way and fixed-route corridor, which consisted of 11 small corridors with ten turns (five left and five right turns) was constructed. The first person view setting was adopted. Participants could move forward by clicking the forward button on the Gamepad and control the turn direction by their own body movement (see Fig. 1). In the "break" condition, a wall would appear in the middle of each small corridor. Participants needed to break the wall by clicking the backward button or knocking it with the gamepad. In the "no-break" condition, participants would encounter no barrier (walls). The hand movements in these two conditions were almost same.

In both conditions, participants solved two AUT problems in two reporting modes respectively. In the "report while walking" mode, participants reported the generated ideas orally while walking in the VR scene. Once they completed the prescribed routes, the task would be terminated and the elapsed time (started from walking) was recorded. In the "report after walking" mode, participants merely thought about the AUT problems while walking in the VR scene. After completing the routes, they were asked to stand and report their ideas immediately. The reporting time was unlimited. When no more ideas could be obtained further, participants could say "stop". Then, the task was terminated and the elapsed time (started from reporting) was also recorded. The sequence of these two AUT problems and reporting modes were balanced among participants.

2.3. Pre- and post-experimental tests

Before the experiment, participants completed the Runco Ideational Behavior Scale (RIBS) (the internal consistency reliability was satisfactory, $\alpha = 0.90$ in current study), the openness subscale of NEO-PI-R ($\alpha = 0.82$), and the personal need for structure scale (PNS) ($\alpha = 0.80$). Participants were also required to rate the valence and arousal of their emotional states by completing Self-Assessment Manikin (SAM; Bradley & Lang, 1994).

Immediately after the first AUT problem, participants were required to rate their emotional states by SAM again. Afterwards, participants rated their feeling of depletion by four items ("How they felt tired/weary/depleted/energetic at this moment?") which are scored on 7-point Likert scale ranging from 1 ("not at all") to 7 ("very much"). They also rated the difficulty of task, the enjoyment of task, the difficulty to control themselves in VR, and the feeling of embodiment on scales ranging from 1 ("not at all") to 7 ("very much"). Then, participants continued with the second AUT problem, after which the tests aforementioned were performed again.

2.4. Assessment of performance on AUT problems

Participants' performance on AUT problems was measured using the (1) fluency, (2) originality, (3) flexibility and (4) persistence (Guilford, 1967; Runco, 1991). Fluency scores were based on the total number of ideas reported. Originality scores were based on

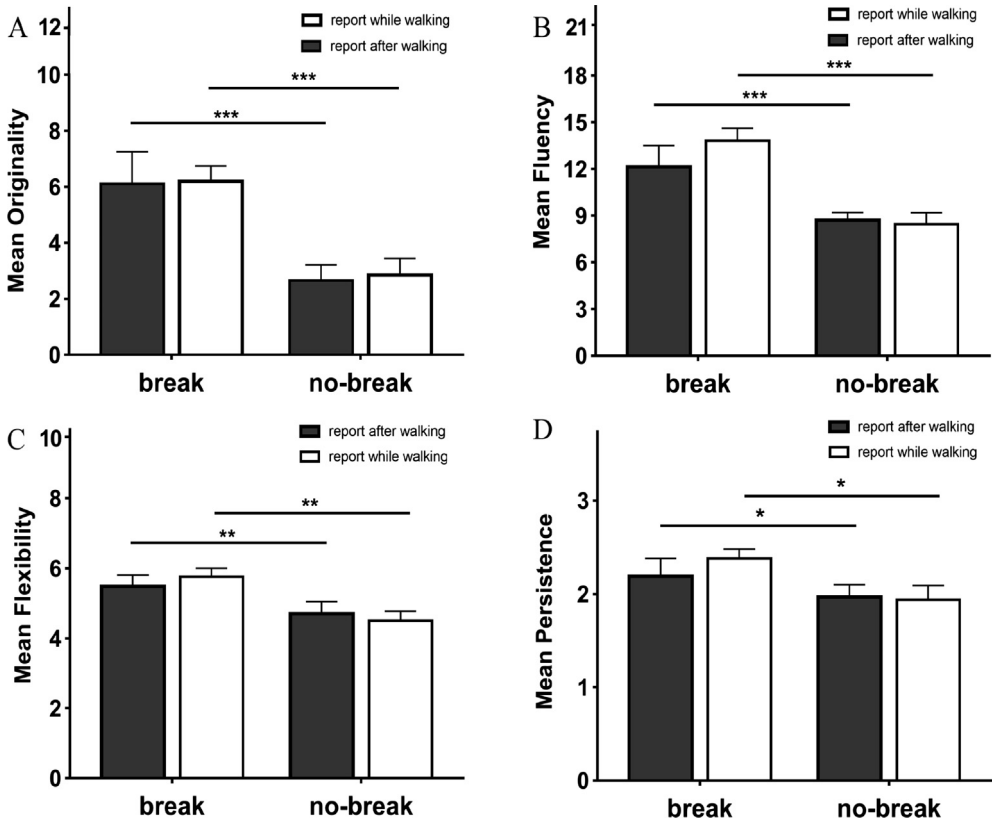

Fig. 2. The effects of Condition on creative performance. (*A*) Originality scores. (*B*) Fluency scores. (*C*) Flexibility scores. (*D*) Persistence scores. Error bars indicate standard errors of the mean. *$p < 0.05$, **$p < 0.01$.

statistically infrequent responses. To this end, the ideas that all participants generated for each AUT task were collected into a comprehensive lexicon. Synonyms were identified and ideas collapsed accordingly. If a response was statistically infrequent (i.e., if 5% or fewer participants in the sample gave the response), then it was scored "1". All other responses were scored "0", regardless of the frequency of their appearance. Following this scoring procedure, two trained raters independently assessed the originality of the two AUT tasks for each participant. The inter-rater agreement (Internal Consistency Coefficient, ICC = 0.95) was satisfactory. The final originality score of each participant was computed by averaging the two raters' ratings. Flexibility scores were coded as the number of categories of responses generated in one task (categories included, e.g., arts and crafts, weapons, and shelter). The inter-rater agreement (ICC = 0.90) of two raters was also satisfactory. Persistence scores were calculated by means of "fluency scores/flexibility scores", which indicates the persistence participants dig out ideas and construct responses within one category (Nijstad, De Dreu, Rietzschel, & Baas, 2010; Nijstad, Stroebe, & Lodewijkx, 2003).

3. Results

3.1. Performance on AUT problems in different conditions

Two-way mixed-design ANOVA, with Condition (i.e., break vs. no-break) as the between-subject factor and Reporting Mode (i.e., reporting while walking vs. reporting after walking) as the within-subject factor, was performed on AUT originality. Results demonstrated a significant main effect of Condition on AUT originality, F (1, 39) = 18.98, $p < 0.001$, $\eta_p^2 = 0.33$. Post-hoc tests revealed that participants in the "break" condition showed higher originality than those in the "no-break" condition (see Fig. 2A). No significant main effect of Reporting Mode or interaction effect of Condition × Reporting Mode was observed. Similarly, three separated two-way mixed-design ANOVAs using Condition as the between-subject factor and Reporting Mode as the within-subject factor were performed on AUT fluency, AUT flexibility and AUT persistence, respectively. Results revealed a significant main effect of Condition on AUT fluency, F (1, 39) = 16.14, $p < 0.001$, $\eta_p^2 = 0.29$, AUT flexibility, F (1, 39) = 10.71, $p < 0.01$, $\eta_p^2 = 0.22$, and AUT persistence, F (1, 39) = 4.67, $p < .05$, $\eta_p^2 = 0.11$. Post-hoc tests revealed higher fluency, flexibility, and persistence in the "break" condition than in the "no-break" condition (see Fig. 2B–D).

When scores on RIBS, Openness, and PNS were entered into the above ANOVA models as covariates, the main effects of Condition on the originality ($p < 0.001$, $\eta_p^2 = 0.41$), fluency ($p < 0.001$, $\eta_p^2 = 0.36$), flexibility ($p = 0.003$, $\eta_p^2 = 0.22$) and persistence ($p = 0.008$, $\eta_p^2 = 0.18$) remained significant.

Table 1
The means and standard deviations of the covariates in four conditions.

	Break[a]				No-break[b]			
	Report while walking		Report after walking		Report while walking		Report after walking	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Valence	6.57	1.43	5.90	1.92	6.25	1.25	5.95	1.54
Arousal	5.67	1.74	6.43	1.20	5.65	1.81	5.95	1.70
Difficulty	4.57	1.16	4.33	1.15	5.00	0.72	4.15	1.23
Sense of control	2.71	1.38	2.52	1.36	2.55	1.28	2.85	1.60
Sense of embodiment	5.14	1.01	5.19	1.36	5.05	1.10	5.25	1.12
Effortfulness	12.67	5.76	12.62	5.22	13.65	5.97	13.55	4.15
Time (s)	251.67	32.24	136.67	70.59	228.60	31.47	92.15	29.10

[a] N = 21.
[b] N = 20.

3.2. Differences of other variables in different conditions

Similar two-way mixed-design ANOVAs using Condition as the between-subject factor and Reporting Mode as the within-subject factor were performed on the valence and arousal of emotional state, difficulty of task, sense of controlling, embodiment and effortfulness, and time durations of reporting, respectively. Results showed a significant main effect of Condition on the time durations of reporting, F (1, 39) = 9.93, p = 0.003, η_p^2 = 0.2, with longer time duration in the "break" condition than in the "no-break" condition. In addition, there was a significant main effect of Reporting Mode on the time durations of reporting, F (1, 39) = 196.05, $p < 0.001$, η_p^2 = 0.83. Participants spent much longer time on reporting ideas while walking in VR than after walking (see Table 1). No significant interaction effect of Condition × Reporting Mode was found.

3.3. Mediation effect of flexibility and persistence

To further investigate how "breaking the walls" benefit the originality of idea generation (i.e., through the enhanced flexibility or persistence), we conducted the multiple mediation analyses. Considering no difference in creative performance was found between two reporting modes, data in the "reporting while walking" condition were processed in following analyses. (Note: the analyses based on data in the "reporting after walking" condition demonstrated an almost identical model of mediation effects.)

In the "reporting while walking" condition, the originality was positively correlated with the flexibility scores (r = 0.67, $p < 0.001$) and the persistence scores (r = 0.59, $p < 0.001$). However, the flexibility scores had no correlation with the persistence scores (r = 0.08, p = 0.63).

The structural equation modeling (SEM) using AMOS and the Process 2.15 software for SPSS script were utilized to examine the hypothesized multiple mediation model (see Fig. 3). And the recommended bootstrapping method, a nonparametric resampling procedure, was applied (Hayes, 2009; Preacher & Hayes, 2008).

To evaluate the overall model fit, model fit criteria suggested by Hu and Bentler (1999) was adopted. The Comparative Fit Index (CFI) = 1 > 0.95, Tucker-Lewis Index (TLI) = 1.063 > 0.95, Root Mean Square Error of Approximation (RMSEA) = 0.000 < 0.06. These results suggested the excellent fitness between the model and data. The total effect of Condition on originality was significant, B = 3.34, df = 39, $p < 0.001$, whereas the effect turned non-significant when flexibility and persistence were entered into the model as mediators, B = 0.417, SE = 0.61, t (39) = 0.69, $p > 0.05$. First, the proposed mediators were regressed onto Condition (break vs. no-break). Results showed that the "break" condition was significantly associated with higher flexibility (B = 1.26; t (39) = 3.47, p = 0.001; SE = 0.36) and persistence (B = 0.44; t (39) = 2.43, p = 0.019; SE = 0.18). Next, we estimated the relationships among two mediators and originality. Results indicated that both flexibility (B = 1.40; t (37) = 6.42, $p < 0.001$; SE = 0.22) and persistence (B = 2.61; t (37) = 6.01, $p < 0.001$; SE = 0.43) were positively correlated with originality significantly. These results indicated the full mediation effect of flexibility and persistence in the relationship between Condition and originality. The model explained 76% of the variance in originality, R^2 = 0.76, F (3, 37) = 38.45, $p < 0.001$, indicating a strong effect size (Cohen, 1988). Moreover, pairwise contrasts of the indirect effects were conducted to reveal the difference between the effects of these two mediators. The results suggested that both bootstrapped indirect effects of Condition on originality through flexibility (B = 1.77, SE = 0.64, BC CI [0.74, 3.35]) and persistence (B = 1.16, SE = 0.61, BC CI [0.18, 2.62]) were significant. And the flexibility was a stronger mediator.

4. Discussion

This study aimed to explore whether the embodiment of the metaphor "breaking the rules" could affect creative performance. VR technology was applied to realize the embodiment of "breaking the rules", where participants could experience the scenario of breaking the walls. The results revealed positive effects of "breaking the walls" on creative performance, with higher originality, fluency, flexibility and persistence in the "break" condition than in the "no-break" condition. As we predicted, no significant difference was observed between two reporting modes. Furthermore, the mediation effects of flexibility and persistence was identified

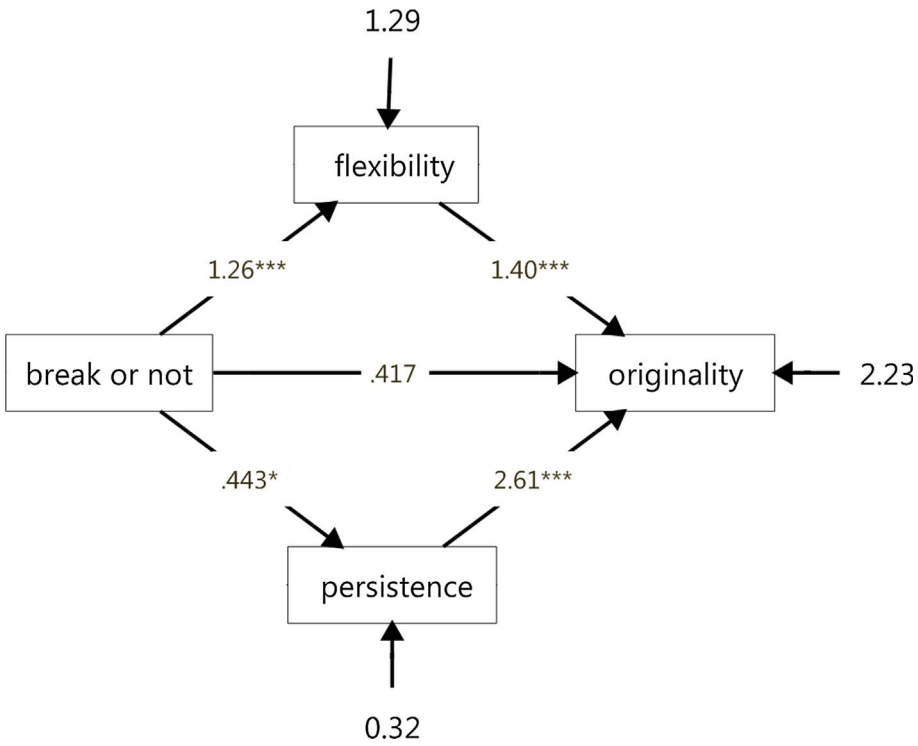

Fig. 3. Mediation effects of flexibility and persistence on the relationship between condition and AUT originality.

on the relationship between "Condition" and originality.

Specifically, superior creative performance was observed in the "break" condition compared with that in the "no-break" condition. Our finding indicated that the experience of breaking the walls in the VR could produce positive effects on creative performance, which also verified the effects of the embodied metaphors on creative cognition. It suggested that once participants bodily experienced the event of "breaking the walls", the sense of "breaking" would spread to conceptual processing. In this case, a feeling of breaking the rules or being capable to break the rules and a sense of liberation might arise. Then, participants might tend to break away from the constraints of conventional mindset and explore other potential new perspectives, which might be reflected in higher cognition flexibility. As shown in Fig. 2, we observed higher flexibility scores in the "break" condition than in the "no-break" condition. Meanwhile, the results revealed cognition flexibility mediated the relationship between "Condition" and originality. These finding may in part mirror that the experience of "breaking the walls" promoted individuals' creative performance by enhancing cognition flexibility (Brenkert, 2009; Lomberg, Kollmann, & Stöckmann, 2017). Intriguingly, we also observed higher persistence scores in the "break" condition than in the "no-break" condition. In addition, cognition persistence also showed a mediation effect on the relationship between "Condition" and originality, which might originate from "breaking the walls all through the whole task". Hence, we proposed that "breaking the walls" might also stimulate individuals' creative performance by enhancing their persistence. According to the Dual Pathway to Creativity Model, both the flexibility pathway and persistence pathway contribute to creative performance (De Dreu, et al., 2008; Nijstad, et al., 2010). While solving the creativity-demanding problems, individuals can generate original ideas through both flexibility pathway and persistence pathway. Our findings might suggest that the embodied metaphor of "break the rules" contributed to both flexibility pathway and persistence pathway, which in turn led to higher AUT originality. Notably, since the mediation effect of flexibility was much stronger, the flexibility pathway was considered as the primary one here.

There were mainly two reporting modes widely applied in previous studies. While some researchers asked participants to complete creative tasks while engaging in physical movements (Kim, 2015; Oppezzo & Schwartz, 2014), others preferred the tasks should be performed after physical movements (Leung et al., 2012). Despite the diversity of these two reporting modes, their potentially various effects on creative performance had not been directly examined. In this study, we found participant spent much longer time on reporting ideas while walking in VR than after walking, however, their creative performance showed no difference between these two reporting mode. These findings indicated the effects of "breaking the walls" on creative performance might be sustained. Nevertheless, the sustainability of effects of various embodied metaphors on creativity might vary, which required further investigation.

In the field of embodied cognition, previous studies using VR have confirmed that embodied cognition can be derived from the psychological representation of the body interacting with the world, and that VR is an effective technique to investigate embodied cognition (Boroditsky & Ramscar, 2002; Leung & Cohen, 2008; Leung et al., 2012; McGlone & Harding, 1998; Zajonc & Markus, 1984). For instance, Leung et al. (2012) asked participants to imagine themselves as avatars in *Second Life*, a popular three-dimensional virtual world, where they could either walk independently or walk along a fixed rectangular path. Results showed that

more novel ideas were generated in the former condition, which mirrored a positive effect of free walking in VR on creative performance. Thus, we suggest that it would be feasible to use the VR technology to investigate the embodied metaphor of "breaking the rules" in the present study. However, it should be pointed out that addressing the issue directly by using exact experimental conditions can lead to more robust findings. Yet, it is almost impossible to manipulate the experience of "breaking real walls" in the real world, because it is dangerous and against experimental ethics. We suggest that future studies could construct a real experimental setting, such as build the walls by foam boards, to investigate the metaphor of "breaking the rules" on creativity.

There were several limitations in this study. First, although the AUT task was widely accepted as a typical divergent thinking test, other creativity-demanding tasks could be tested to enhance the robustness of our findings. Second, we surmised when individuals bodily broke the walls in the VR, the sense of "breaking" would spread to concepts. In the meantime, participants would experience a feeling of breaking the rules. However, whether the experience of breaking other objects can arouse a similar feeling and produce beneficial effects on creative performance should be further investigated. Third, "breaking the walls" is an unusual experience that is likely not part of most participants' daily real world experience. In this study, we observed that the experience of "breaking the walls" in virtual reality led to higher creative performance. However, we could not directly identify whether the embodied metaphor of "break the rules" or just doing something unusual should account for the observed beneficial effects. Further studies are needed to explore this issue. Fourth, previous studies have shown individuals' cognitive performance can be affected by the characteristics (e.g., attractiveness, height, skin tone and other factors) of the avatar in VR (Peck, Fuchs, & Whitton, 2009; Peña, Hancock, & Merola, 2009; Yee & Bailenson, 2007; Yee, Bailenson, & Ducheneaut, 2009). In this study, a first-person perspective was used, and participants were not able to see the avatar during the tasks (even their limbs). Therefore, the observed beneficial effects on creative performance should not be attributed to the attractiveness, height, skin tone and other characteristics of the avatar. In addition, our findings might suggest that not only the characteristics of avatar but also the virtual environment can affect participants' behavior. However, it is interesting to investigate whether the effect of "breaking the walls" on creative performance can be affected by the characteristics of the avatar in virtual reality. Further research is necessary.

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