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Motor creativity: the roles of attention breadth and working memory in a divergent doing task

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ABSTRACT

We evaluated the dual-pathway model to creativity in a motor context. The model describes separate flexibility and persistence pathways that are affected differently by breadth of attention and working memory. Motor creativity was tested using a divergent doing task. In Experiment 1 participants performed the divergent doing task after attention was broadened, narrowed or not manipulated. In Experiment 2, the divergent doing task was performed with a low or high working memory load. We found that a broad attention increased flexibility but not persistence. Also originality was unaffected. Taxing working memory did not affect persistence, flexibility or originality. The results provide partial support for the dual-pathway model in motor creativity. Discusion focusses on increased demands for the appropriatness of a solution in divergent doing relative to divergent thinking and to degree to which this implies a more general shortcoming of the dual-pathway model.

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Creativity; motor creativity; breadth of attention; dual pathway; working memory

Creativity is defined as the generation of original, yet appropriate ideas, insights and solutions for problems (e.g. Runco, 2007; Sternberg & Lubart, 1999). Most theoretical and empirical efforts in creativity addressed problem solving in the arts, science and cognition. However, resourcefulness in the motor domain has barely been examined (cf. Bernstein, Latash, & Turvey, 1996). In fact, the majority of studies that did examine motor creativity are directed towards a better understanding of creativity in the cognitive domain. That is, to study the development of creativity, researchers have typically examined motor creativity, because young children – being in the sensorimotor stage of development – are thought to more easily express creativity through movement (e.g. Bournelli, Makri, & Mylonas, 2009). In doing so, the assumption is that finding solutions for cognitive and motor problems is not fundamentally different. Yet, there has been little research that examined the extent to which the factors that constrain finding original solutions in the cognitive domain, do also constrain resourcefulness in solving motor problems. Hence, the main purpose of the current paper is to explore to what degree breadth of attention and working memory, factors that have been shown to affect creativity in cognitive tasks (i.e. divergent thinking), also constrain finding creative solutions in motor tasks (i.e. divergent doing).

A recent influential model for creativity in cognitive problem solving is the so-called dual pathway to creativity model (Nijstad, De Dreu, Rietzschel, & Baas, 2010). The dual-pathway model proposes that two functionally different manners towards finding original solutions exist: flexible and persistent thinking. Flexible thinking, which builds on traditional approaches to creativity (Friedman, Fishbach, Förster, & Werth, 2003; Kasof, 1997; see also Memmert, 2007; Nijstad et al., 2010), refers to the notion that original solutions can be generated by the combination of, and switching between ideas and concepts that are normally not associated with each other. In contrast, persistent thinking reflects the idea that original solutions can arise from a focused and structured search of limited number of ideas and concepts only (De Dreu, Nijstad, Baas,

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Wolsink, & Roskes, 2012). For example, in divergent thinking tasks, in which participants are presented with a problem for which they are requested to find as many different solutions as possible, the number and originality (e.g. reflected by ratings of independent judges) of solutions are used to assess creativity in problem solving. Accordingly, flexible thinking is typically measured by counting the total number of different, mutually exclusive, cognitive categories from which the solutions originate (often denoted as flexibility), while persistent thinking is measured by the average number of solutions derived from one and the same category (sometimes referred to as within-category fluency).

The dual-pathway model holds that flexible and persistent thinking both lead to the generation of original solutions, but are differentially affected by factors such as breadth of attention, working memory capacity and mood (De Dreu, Baas, & Nijstad, 2008; De Dreu et al., 2012; Nijstad et al., 2010). First, with respect to breadth of attention, Friedman et al. (2003) have argued that a relatively broad focus facilitates the accessibility of remote categories and the forming of new connections between these categories (i.e. increase in flexibility), leading to an increase in original solutions (Friedman et al., 2003; Friedman & Förster, 2010; see also Kasof, 1997; Memmert, 2007). In contrast to flexible thinking, persistent thinking should remain unaffected by breadth of attention. For example, Nijstad et al. (2010) discuss unpublished work that manipulated the breadth of attention using a Navon task (i.e. participants are presented with a large letter made up of small letters, and either have to read the large or small letter, which induces a broad or narrow focus of attention respectively) in two divergent thinking tasks. In divergent thinking on a broad topic, which strongly relies on flexible thinking, a broad focus of attention resulted in more solutions from different categories (i.e. increased flexibility) relative to a narrow focus of attention. However, in divergent thinking on narrow topics, which more strongly involves persistent thinking, neither the number of solutions across categories (i.e. flexibility) nor the number of solutions within categories (i.e. within-category fluency) was affected by the attention manipulation (see also Friedman et al., 2003).

Second, working memory is thought to facilitate persistent thinking reflected in an in-depth exploration of a few categories only. Accordingly, enhanced working memory should result in an increased number of original within-category solutions, while not affecting flexible thinking (De Dreu et al., 2012; Oberauer, Süss, Wilhelm, & Wittmann, 2008; Süss, Oberauer, Wittmann, Wilhelm, & Schulze, 2002; but see Furley & Memmert, 2015; Takeuchi et al., 2011). Working memory keeps new information in a heightened state of availability and ascertains the relevance of information for the task at hand (Unsworth & Engle, 2007). By prolonging access to new information, working memory allows for overriding habitual tendencies such as sticking to the more readily available solutions, and relating it to information retrieved from long-term memory. De Dreu et al. (2012) showed that participants performing a remote associates test, in which they are presented with three words that have to be connected by finding a word that is related to all three (e.g. “swimming”, “cue”, “car” relates to “pool”), solved less problems when their working memory was taxed by a high load dual task compared to a dual task that required less working memory capacity. Subsequently, De Dreu et al. (2012) demonstrated that individual working memory capacity predicted persistent thinking, but not flexible thinking. That is, the within-category fluency and originality of the solutions generated by the participants on a divergent thinking task correlated with the working memory capacity as measured with the OSPAN task. The number of different categories from which these solutions were sampled (i.e. flexibility) did not relate to working memory capacity. In other words, working memory capacity promotes “deeper” thinking rather than “wider” thinking. Importantly, De Dreu et al. (2012) provide initial evidence that the dual-pathway model may bear on other domains, not only on the cognitive. That is, originality in musical improvisation is shown to relate to working memory capacity. Here, we are interested whether the dual-pathway model for creativity can be extended into the motor domain, also because attention and working memory have been shown to constrain performance and learning of new motor tasks (e.g. Buszard, Farrow, Zhu, & Masters, 2016; Janacsek & Nemeth, 2013; Kasper, Elliott, & Giesbrecht, 2012).

In order to investigate motor creativity (i.e. finding original solutions to motor problems), a few researchers have modified the divergent thinking task into a divergent doing task (Cleland & Gallahue, 1993; Scibinetti, Tocci, & Pesce, 2011; Wyrick, 1968). Divergent doing tasks require participants to solve a motor problem in as many ways as possible by actually producing them, rather than listing the possible actions. However, this previous work focused on the number and originality of the motor solutions, but did not investigate the degree to which these solutions reflect the flexibility or persistence pathways. Hence, the main purpose of the current paper is to examine the validity of the dual-pathway model to creativity for motor creativity, and, in particular, whether flexibility and persistence can be distinguished in generating original *and* appropriate solutions to motor problems.

Addressing this is the more important, because in divergent doing tasks the capability to actually perform the action restricts the number and originality of solutions that can be found. Consequently, the appropriateness of the solution is a much more critical constraint in divergent doing than in divergent thinking. In fact, although appropriateness is a pertinent criterion in most descriptions of creativity (e.g. Amabile, 1983; Runco, Illies, & Eisenman, 2005; Sternberg & Lubart, 1999), studies using divergent thinking tasks typically do not take a solution's appropriateness into account (e.g. De Dreu et al., 2008; Friedman et al., 2003). Hence, in divergent thinking tasks, a participant can propose an original solution that turns out to be inappropriate (e.g. opening the fridge to cool down the house). In divergent doing tasks, a participant can think of an original solution, but to be appropriate, they must also be capable of acting it out, at least to some extent.

Moreover, several authors have pointed out the necessity of replicating effects found with one set of stimuli (e.g. in cognitive tasks) with stimuli that differ in complexity (e.g. in motor tasks) to ensure that the observed phenomenon is real and ubiquitous (Fiedler, 2011; Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003; Simmons, Nelson, & Simonsohn, 2011). Hence, we performed two studies that examined the involvement of flexible and persistent thinking in divergent doing tasks. Experiment 1 examined the effects of individual breadth of attention on producing creative motor solutions, while Experiment 2 assessed the effects of working memory load.

Experiment 1

The dual-pathway model argues that breadth of attention affects flexible thinking, but not persistent thinking (e.g. Nijstad et al., 2010). In flexible thinking, a broad focus would result in solutions from more categories (i.e. flexibility) than a narrow focus of attention (Friedman et al., 2003). With regard to the motor domain, Memmert (2007) manipulated the breadth of attention by providing different sets of instructions related to game tactics (see Memmert & Furley, 2007) to two groups of young children during a 6-month physical education programme. The group that received instructions aimed at the broadening of attention showed more creative tactical solutions in a game tactic test (Memmert, 2010) performed after the programme, whereas narrow attention instructions did not affect motor creativity. However, the authors did not differentiate between flexible and persistent thinking. For Experiment 1, we therefore designed a divergent doing task that allowed us to classify the solutions according to action categories, and hence determine the number of solutions across (i.e. flexibility) and within categories (i.e. persistence). That is, participants were required to produce as many actions as they could on an agility ladder (e.g. stepping, hopping, skipping, walking on hands and feet, walking on hands and so on). An agility ladder is a rope ladder, laid on the ground, forming spaces to move in and out to in a consistent pattern (Figure 1). The agility ladder is used as a training device to develop agility and coordination by athletes from many different sports. Typically, athletes are challenged to perform a variety of drills, which makes the agility ladder a natural choice for studying motor creativity among athletes with from a background in different sport disciplines. Hence, students from a Sport University were assigned to one of the three groups

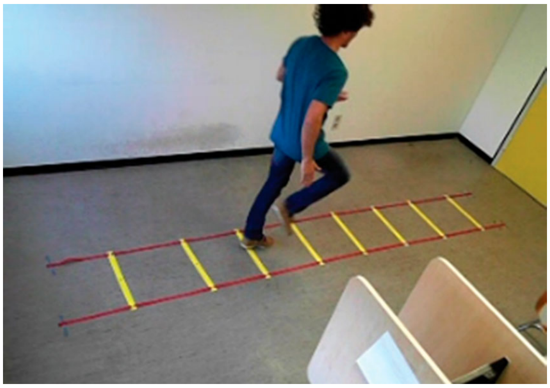

Figure 1. The agility ladder task. A drill consists of a regular pattern of foot-placements inside and/or outside the squares from one end to the other end of the ladder. Participants were asked to perform as many different drills as they could. [To view this figure in color, please see the online version of this journal.]

and asked to perform as many different drills as possible. The participants in the broad attention focus group read the large letters of the Navon-reading task before performing the divergent doing task. The participants in the narrow attention focus group read the small letters of the Navon-reading task before performing the divergent doing task. Finally, the participants in the control group read a mix of both large and small letters of the Navon-reading task. Following the dual-pathway model, it was hypothesised that the broad attention focus group would produce an increased number and originality of solutions from different categories (i.e. flexibility, which should also be reflected by shorter median length of bouts of consecutive solutions from within the same category), whereas the narrow focus group would show a reduced number and originality of solutions from different categories. In contrast, no differences were expected with respect to motor solutions within a category (i.e. persistence).

Methods

Participants

Fifty-seven sport university students (28 female; $age_M = 22.6$, $age_{SD} = 3.4$) volunteered to participate. They were non-elite athletes, yet had practiced 4.4 different sports on average, with an average of 10.5 years of experience in their current main sport. The study was carried out in accordance with the Helsinki Declaration, and written informed consent was obtained from each participant before the start of the experiment.

Material and apparatus

The experiment was conducted in a laboratory equipped with a computer and monitor, and a 4 m agility ladder laid on the ground. A space of at least 1.5 m surrounded the ladder, which guaranteed unrestricted performance of the drills. The computer and monitor provided the written instructions and were used to administer the Navon-reading task. A Microsoft 1080p HD Sensor webcam, which was secured in one of the top corners of the room, was used to record participants' performance on the divergent doing task.

Procedure and design

Before the start of the experiment, participants were told they would participate in an experiment about attention and creativity in sports. They were then seated at the desk in front of the monitor to perform the Navon-reading task (Navon, 1977). Participants were randomly assigned to either the broad or narrow attention focus or control group. The procedure was identical to the one used by Förster (2009) (see also De Dreu & Nijstad, 2008). Participants were presented with a series of large letters (2.5 cm × 2.5 cm), each consisting of small letters (0.5 cm × 0.5 cm; i.e. each horizontal or vertical line forming a large letter consisted of five closely spaced small letters, Figure 2). Participants were instructed to identify the target letters H or L. For the broad attention focus group, these target letters were always large, whereas for the narrow attention group the target letters were always small. In the control group, a mix of both large and small target letters was presented in a random order. For the broad and narrow focus conditions, there were four variations of the stimulus, two containing the target letter "H" and a non-target letter, and two containing the target letter "L" and a non-target letter. On each trial, participants were first presented with a fixation cross "+" in the centre of the screen for 500 ms. Then, one of the four variations of the stimulus was randomly presented. Participants were instructed to press the "L"-key, if the stimulus contained the letter L, and to press the "H"-key, if the stimulus contained the letter H. They were instructed to respond as quickly as possible. The four variations of the stimuli were repeated 12 times in a random order, resulting in either 48 trails with a large letter stimulus (i.e. broad focus) or 48 trials with a small letter stimulus (narrow focus) trials. The procedure of the Navon task was identical for the control condition, except that the

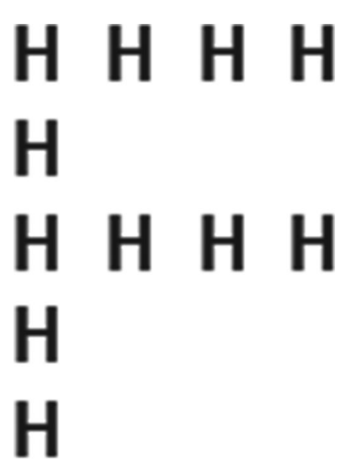

Figure 2. An example of a Navon letter, with the target letter "H" making up a large non-target letter "F".

four stimulus variations of both the broad and narrow condition were used resulting in a total of eight different stimuli. These were presented six times in a random order, totalling 48 trials.

After completing the Navon-reading task, the participants were introduced to the agility ladder and received the instructions for the divergent doing task. The current instructions were adapted from the divergent thinking instructions as used by De Dreu et al. (2008; see also Nijstad, Stroebe, & Lodewijkx, 2002; Rietzschel, Nijstad, & Stroebe, 2007): (1) think of and execute as many different drills as possible; (2) you have a total of 6 minutes for this; (3) the drills you do may be existing drills, but you are encouraged to produce new drills; (4) you do not have to be able to perform the drills at top speed; (5) the drills you produce will not be shared with and judged by others. Hence, do not criticise your own ideas or drills.

After completing the divergent doing task, participants completed a questionnaire to assess demographic data and sports experience. Participants were also invited to voice any suspicion regarding the relationship between the Navon-reading task and the agility ladder task. None of the participants commented regarding the purpose of the Navon-reading task relative to the divergent doing task.

Data analysis

To assess the number and originality of the motor solutions, each drill was categorised. Basically, each action was classified according to the mode of locomotion (i.e. coordination modes), taking into account the number of limbs that were involved in propulsion and the way they were temporally coordinated. Hence, categories included (combinations of) alternated stepping, hopping on two feet, hopping on one foot, skipping, locomoting on hands and feet and so on. Within-categories solutions were defined as using the same mode of locomotion but moving with a different spatial pattern across the ladder (see Figure 3). A random subset of 20% of the videos was coded by two independent observers. The interrater agreement (Cohen's κ) among raters was .77 ($p < .01$), which is commonly seen as good (Altman, 1991; Landis & Koch, 1977). Subsequently, fluency (the total number of different solutions, i.e. across and within categories), flexibility (the total number of different categories used) and persistence (the average number of within-category solutions) were calculated. As flexible thinking is thought to manifest itself through frequent switching between categories and persistent thinking through in-depth exploration of a specific category, we also sought to measure these concepts by determining the median length of bouts of consecutive solutions within a category. This new measure is presumed to point two ways: longer bouts point to increased persistence and shorter bouts to increased flexibility. For each participant, we calculated the median bout length. A low median bout length reflects switching frequently between categories, while a high median bout length reflects in-depth exploration. A frequency distribution for the median bout length is shown in Figure 4.

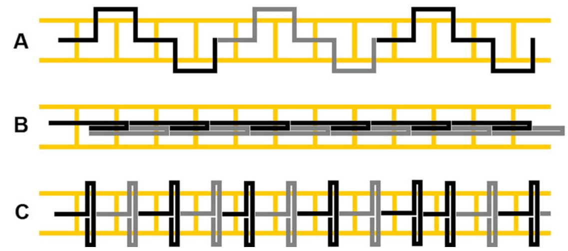

Figure 3. Three examples of spatial patterns for stepping that can be performed on the agility ladder. A: going one square forward, one left, one forward, one right, one forward, one right, one forward, one left, etc. B: moving two squares forward, then one back, etc. C: moving one square forward, then stepping out on both sides, then stepping inside the ladder again. [To view this figure in color, please see the online version of this journal.]

Finally, after the drills were categorised, the 6-minute performance on the divergent doing task as a whole was rated for originality, being defined as "a performance containing drills that were infrequent, novel and unique" (1 = *not original at all* to 5 = *very original*, compare Memmert, 2007; Memmert & Roth, 2007). Scoring originality based on one overall evaluation of all the solutions a participant generates

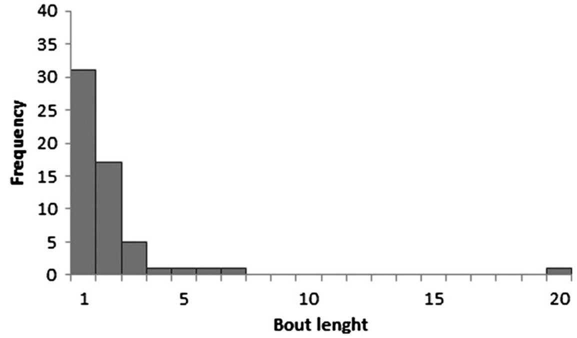

Figure 4. The frequency distribution of median bout lengths in Experiment 1.

is a common way of rating for originality in divergent thinking tasks (Silvia, Martin, & Nusbaum, 2009). Participants of the broad and narrow attention focus groups were rated in random order, while performances of the control group were rated later.[1] All performances were rated by two independent raters in different random orders. Interrater agreement was good with intraclass-correlation (ICC) = .76 (Cicchetti & Sparrow, 1981). The average score for each participant between raters was used as measure for originality.

To assess the effects of breadth of attention, fluency (i.e. the total number of solutions), flexibility (i.e. the total number of categories) and persistence (i.e. the average number of within-category solutions) were compared between the three groups using a one-way independent ANOVA. The η^2 was used as measure of effect size. Significant effects were followed up with Tukey-HSD tests, and Cohen's *d* was used as measure of effect size. In addition, the originality ratings and the mean bout length of the three groups were compared using the Kruskal–Wallis test, and follow-up Mann–Whitney tests with a Bonferroni correction were planned to identify differences between groups. Finally, to examine the degree to which originality relates to fluency, flexibility and persistence, Spearman ρ correlations were calculated.

Results

The majority of participants reported to be familiar with the agility ladder, although they only used it incidentally during practice. To check if familiarity is associated with the main dependent variables of creativity, correlation analyses were performed. Spearman ρ correlations did not reveal a significant relationship between years of experience with the agility ladder and originality ($\rho = -.04$, $p = .77$), or median bout length ($\rho = .01$, $p = .99$). In addition, Pearson correlations between years of experience and fluency ($r = .05$, $p = .70$), flexibility ($r = -.13$, $p = .34$) and persistence ($r = -.10$, $p = .47$ were non-significant as well.

Table 1 reports the number and originality of motor solutions for the three groups. It appears that a broad focus of attention resulted in more flexible (i.e. solutions from more categories) and original motor solutions than a narrow focus of attention. A one-way ANOVA confirmed this by a significant effect of attentional focus for flexibility, $F(2, 54) = 3.22$, $p < .05$, $\eta^2 = .12$. Post-hoc comparisons indicated that the broad attention group ($M = 4.11$, SD = 0.74) was significantly more flexible than the narrow attention group ($M = 3.32$, SD = 1.16; $p < .05$, $d = .82$). The flexibility of the control group ($M = 3.63$, SD = 0.96) was exactly in between the two experimental groups, but did not differ significantly from either of them. The anticipated effect for originality, however, failed to reach significance, $H(2) = 3.48$, $p = .18$, $\eta^2 = .06$.

With respect to the median bout length of consecutive within-category solutions, Table 1 suggests that the narrow attention group performed longer bouts compared to the broad attention and control group, however, this effect just failed to reach significance, $H(2) = 5.96$, $p = .051$, $\eta^2 = .10$.

Finally, attentional focus did not affect fluency, $F(2, 54) = .37$, $p > .05$, $\eta^2 = .01$, or persistence, $F(2, 54) = 1.43$, $p > .05$, $\eta^2 = .05$.

Table 2 reports the correlations among the dependent variables. Spearman rank correlations revealed associations between originality and fluency ($\rho = .45$, $p < .001$) and originality and flexibility ($\rho = .59$, $p < .01$). The relation between originality and the median bout length ($\rho = -.24$, $p = .08$) failed to reach significance. No relation was found between originality and persistence ($\rho = .09$, $p = .95$). Finally, flexibility and persistence were found to correlate negatively ($\rho = -.55$, $p < .01$).

Discussion

Experiment 1 assessed the effects of attentional breadth on a divergent doing task. Analogous to observations for divergent thinking tasks (e.g. De Dreu et al., 2008; Nijstad et al., 2010), the present results point towards separate contributions of the flexibility and persistence pathways. More

Table 1. Descriptive statistics (Experiment 1).

	Condition	Mean	SD
Originality	Control	3.00	0.93
	Broad	3.53	0.87
	Narrow	3.18	0.77
Fluency	Control	21.58	5.05
	Broad	23.16	6.46
	Narrow	21.84	6.52
Flexibility	Control	3.63	0.96
	Broad	4.11	0.74
	Narrow	3.32	1.16
Persistence	Control	3.84	3.27
	Broad	5.76	1.78
	Narrow	7.45	3.93
Median bout length	Control	1.26	0.54
	Broad	1.55	0.60
	Narrow	3.03	4.34

Table 2. Spearman correlations (Experiment 1; $N = 57$).

	Originality	Fluency	Flexibility	Persistence	Median bout length
Originality	1	.45**	.59**	.09	−.24
Fluency		1	.19	.62**	.14
Flexibility			1	−.55**	.44**
Persistence				1	−.38**
Median bout length					1

**Correlation is significant at the .01 level (two tailed).

specifically, we observed a significant negative relation between flexibility and persistence, which means participants who tended to use more different modes of locomotion also on average found less solutions within a particular mode. More importantly, we found distinct effects of breadth of attention on flexibility and persistence. We showed that a broad focus of attention increased the number of locomotion modes that participants used in performing the agility ladder drill compared to a narrow focus of attention (and the control group). However, the number of different spatial patterns for a particular mode of locomotion was not affected by attentional focus. In other words, in accordance with predictions of the dual-pathway model, breadth of attention influenced flexibility, but not persistence. Interestingly, however, a non-significant trend was found concerning the length of the bouts of consecutive spatial patterns from within the same category or mode of locomotion. This suggested that the narrow attention group used longer bouts than the broad attention and the control groups. Hence, although all three groups produced the same number of spatial patterns, a narrow attention focus might lead to more persistent exploration of solutions within a category or mode of locomotion and less switches between categories than a broad or neutral attention focus. Although the originality of the motor solutions was only related to flexibility and not persistence, the originality of the motor solution was not rated differently as a function of attentional focus. Hence, Experiment 1 did not provide full support that – next to the total number of categories of locomotion – broad attention increases motor creativity (i.e. original and appropriate motor solutions) through the flexibility pathway. Because in the divergent doing task the criterion of appropriateness pertains much more strictly, it is possible that the divergent doing tasks are more constrained than the divergent thinking tasks with respect to demonstrating originality. Similarly, emphasising appropriateness or feasibility has been shown to reduce the originality of solutions in creative thinking tasks (e.g. Runco et al., 2005). Accordingly, future research may want to increase the number of participants or the duration of the divergent doing task, to increase power for identifying differences in originality as a function of the breadth of attention.

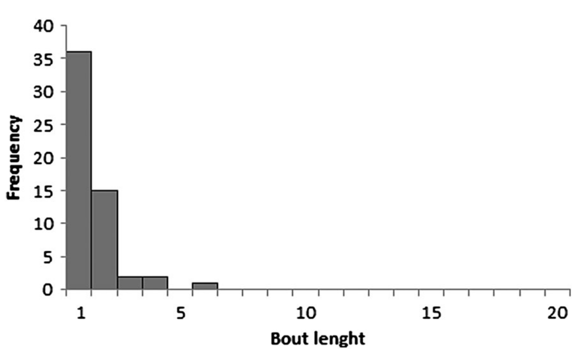

Figure 5. The frequency distribution of median bout lengths in Experiment 2.

Experiment 2

The dual-pathway model predicts that working memory capacity affects creativity through enhancing the in-depth exploration of within-category solution, and hence, persistence thinking, but not flexible thinking (De Dreu et al., 2012). Yet, although working memory has been indicated as a predictor of explicit motor learning (Buszard, Farrow, Zhu, & Masters, 2013; Buszard et al., 2016; Janacsek & Nemeth, 2013), we are not aware of any studies examining the relationship between working memory and motor resourcefulness or creativity. Experiment 2, therefore, aimed at assessing the degree to which working memory affects motor creativity, thereby differentiating between flexible and persistent thinking. Hence, participants' performance was compared for the same divergent doing task (i.e. the agility ladder) as for Experiment 1, but with their working memory taxed to different degrees (see De Dreu et al., 2012). Based on the dual-pathway model, we hypothesised that relative to a low working memory load, a high working memory load would reduce the number and originality of within-category solutions (i.e. persistence), and would lead to a lower median bout length of consecutive within-category solutions. With respect to the total number of motor solutions and number of different categories (i.e. flexibility), we expected no effects of taxing working memory.

Methods

Participants

Fifty-six sport university students (36 female; $age_M = 20.6$, $age_{SD} = 1.9$) participated voluntarily in Experiment 2. They were non-elite athletes, but on average did practice 3.7 different sports, and had an average of 8.6 years of experience in their current main sport. The study was carried out in accordance with the Helsinki Declaration. Written informed consent was obtained from each participant before the start of the experiment.

Material and apparatus

The material and recording devices for the agility ladder task (i.e. the divergent doing task) were identical to Experiment 1.

Procedure

The procedure and instruction for the agility ladder task were identical to Experiment 1. The only difference was that, instead of receiving different breadth of attention manipulations, participants were required to perform a secondary number-recall task that differentially taxed working memory during the agility ladder task. First, participants were randomly assigned to the low working memory load group or high working memory load group. Cognitive load was manipulated by asking participants to keep in mind a string of either two digits (i.e. low working memory load condition) or five digits (high working memory load condition) while they performed the agility ladder task (De Dreu et al., 2012). Just before starting the agility ladder task, a string of digits was shown on the monitor and participants had 10 seconds to memorise it, before the digits disappeared from the monitor. They then started the agility ladder task. After one minute a tone would sound, upon which the participants interrupted the agility ladder task and entered the memorised string in the computer. They then received a new string of digits and, following the same procedure, would continue the agility ladder task until after another minute the tone would sound again and so on until the total of 6 minutes on the agility ladder task were completed. Based on Baddeley (2003; see also De Dreu et al., 2012), we was assumed that the two-digit task taxed working memory less than the five-digit task and that, under the five-digit task, working memory would not be fully occupied.

After completion of the agility ladder task, participants completed a questionnaire to assess demographic data and sports experience. Participants were also invited to voice any suspicions concerning the cognitive load manipulation and its relation to the performance on the agility ladder task. No relevant suspicions were voiced by the participants.

Data analysis

Data analysis was identical to Experiment 1, with the comparisons now being made between the low and high working memory load conditions using independent *t*-test and Mann–Whitney test. A frequency distribution for the median bout length is shown in Figure 5. In addition, as a manipulation check, the number of correctly recalled strings was counted and submitted to an independent *t*-test.

Results

Again, the majority of participants were already familiar with the ladder, although they only had used it incidentally during practice. Spearman ρ correlations did not reveal a significant relationship between years of experience with the agility ladder and originality ($\rho = .12$, $p = .39$), or median bout length ($\rho = .03$, $p = .85$). In addition, Pearson correlations between years of experience and fluency ($r = -.16$, $p = .23$), flexibility ($r = -.26$, $p > .05$) and persistence ($r = .09$, $p = .49$) were non-significant.

As can be seen in Table 3, participants in the low working memory load condition recalled more strings correctly than participants in the high working memory condition group, $t(54) = 2.50$, $p < .05$, Cohen's $d = .67$, indicating that the working memory manipulation was indeed successful. Table 3 also reports the number and originality of motor solutions for the two groups. There were no clear differences between the groups. Hence, we did not find significant effects of working memory load on fluency, $t(54) = -.08$, $p = .94$, $d = -.02$) and flexibility, $t(54) = -.11$, $p = .91$, $d = -.03$, nor on persistence, $t(54) = .44$, $p = .66$, $d = .12$ or median bout length, $U = 381.50$, $Z = -.20$, $p = .84$, $r = -.03$. Also, the ratings

Table 3. Descriptive statistics (Experiment 2).

	Condition	Mean	SD
Originality	Low tax	3.09	1.03
	High tax	3.13	0.83
Fluency	Low tax	27.29	6.63
	High tax	27.43	6.79
Flexibility	Low tax	3.64	1.25
	High tax	3.68	1.16
Persistence	Low tax	8.97	5.69
	High tax	8.38	4.23
Median bout length	Low tax	1.45	0.82
	High tax	1.55	1.07

for originality did not significantly differ between groups, $U = 385$, $Z = -.12$, $p = .91$, $r = -.02$. Finally, Spearman rank correlations revealed significant associations between originality and fluency ($\rho = .40$, $p < .01$), and originality and flexibility ($\rho = .36$, $p < .01$), but not between originality and persistence ($\rho = .05$, $p = .97$) or originality and median bout length of consecutive within-category solutions ($\rho = .02$, $p = .88$). Additionally, the number of correctly recalled strings did not correlate with any of the measures of creativity (Table 4).

Discussion

Experiment 2 examined the effects of working memory load on the performance of divergent doing task. Based on the dual-pathway model, we hypothesised that enhanced loading would adversely affect persistence, but not flexibility. At best, the findings can be interpreted as partially confirming these conjectures. That is, motor creativity in the ladder agility task was stable in the face of different working memory loads. This was expected for flexibility, but not for persistence. At this point, we can only speculate as to causes of the absence of any effect. Potentially, divergent doing tasks, or at least the current agility ladder task, are performed much more implicitly than the previously reported divergent thinking tasks. As a result, a much stronger taxing of working memory may has been required to disrupt performance on the divergent doing task. Noteworthy is that fluency and flexibility in Experiment 2 are of the same order of magnitude as in Experiment 1, while if anything, persistence scores seem a little higher compared to Experiment 1.

Alternatively, it might be that, relative to divergent thinking, performance on divergent doing tasks capitalise more strongly on the flexibility pathway than on the persistence pathway (cf. Lee & Therriault, 2013). Additionally, it has to be noted that the role of working memory in cognitive creativity has not been unequivocally established, with some authors reporting a relationship, while others do not (see Furley & Memmert, 2015 for a discussion).

General discussion

We assessed the merits of the dual pathway to creativity model (Nijstad et al., 2010) for motor creativity; that is, for finding original and appropriate solutions to motor problems. The model distinguishes between flexible and persistent pathways for finding creative solutions, particularly for cognitive problem solving. A key observation that supports the existence of two separate pathways is that they are differentially constrained by breadth of attention and working memory (De Dreu et al., 2008, 2012; Nijstad et al., 2010). Accordingly, we examined whether the two pathways could also be differentiated in the case of motor creativity. Specifically, we sought to demonstrate that in a divergent doing task, breadth of attention primarily influences motor solutions supported by the flexible pathway, while working memory mainly affects motor solutions from the persistent pathway. In brief, our studies showed that with regard to flexibility (i.e. the number of different modes of locomotion performed by the participant), motor solutions were affected by breadth of attention but not by working memory. However, as far as it concerns persistence (i.e. the average number of different spatial patterns for a specific mode of locomotion), we found neither an effect of breadth of attention nor an effect of working memory. Consequently, the

Table 4. Spearman correlations (Experiment 2; $N = 56$).

	Originality	Fluency	Flexibility	Persistence	Median bout length
Originality	1	.40**	.36**	.01	−.02
Fluency		1	.18	.46**	.17
Flexibility			1	−.73**	−.24
Persistence				1	.26
Median bout length					1

*Correlation is significant at the .05 level (two tailed).
**Correlation is significant at the .01 level (two tailed).

present studies provide evidence – at least partial – that supports the existence of a flexible pathway for motor creativity or resourcefulness, but fail to do so for the persistence pathway.

Thus, it seems that the present findings support the notion of a flexible pathway for motor creativity that is constrained by breadth of attention, but not working memory, similar to what has been previously observed for cognitive creativity (Friedman et al., 2003; Friedman & Förster, 2010; Kasof, 1997; Nijstad et al., 2010). In particular, inducing a broad focus of attention enhanced the number of different modes of locomotion that participants performed on the ladder agility task. However, it is important to note that a broader attentional focus did not lead to a significant increase in originality. It is not particularly clear why this is the case. One interpretation would be that rating (and defining) the originality of a solution typically is done relative to other solutions – including those made by others. Consequently, a solution that is rare is more likely to be rated as original (De Dreu et al., 2012; Torrance, 1966). Indeed, the positive relationship between originality and fluency (i.e. the total number of locomotor solutions) and flexibility (i.e. the number of different modes of locomotion), irrespective of attention focus and working memory load, affirms such an interpretation. In addition, it is also clear that in divergent doing tasks the criterion of appropriateness is much more limiting than in divergent thinking tasks. If motor ability is insufficient (e.g. only few people can walk on hands), then the thought of action cannot be performed. This is in line with earlier observations in divergent thinking that showed that increasing the demand on appropriateness makes it harder for people to find original solutions (Runco et al., 2005).

The current study does not provide unambiguous evidence for a persistence pathway for motor creativity. An increased working memory load did not reduce the number and originality of spatial displacements across the ladder for a given mode of locomotion. Instead, the negative correlations between persistence and flexibility might even point to persistence and flexibility being two ends of a continuum, rather than separate processes. There may be two possible interpretations. First, an interpretation with wider implications is one that questions the anticipated link between working memory and creativity through the persistence pathway in general, also for cognitive tasks. That is, although some authors have indeed found evidence for such a relationship in divergent thinking tasks (De Dreu et al., 2012; Oberauer et al., 2008; Süss et al., 2002), these findings have not been left undisputed (Furley & Memmert, 2015; Lee & Therriault, 2013; Takeuchi et al., 2011). A second, currently more viable explanation, would be that even though motor skills are normally executed implicitly, performing new or unlearned skills requires a high degree of conscious control and active involvement of working memory (e.g. Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007; Beilock & Carr, 2001; Masters, 1992). For instance, research has shown that well-practiced motor skills remain much more stable in the face of a cognitive dual task than unpracticed motor skills. And despite the fact that the motor dexterity of the current sport student participants was above average relative to the normal population, they were clearly not experts on the agility ladder tasks. It is therefore not unlikely that for the more uncommon modes of locomotion or spatial displacements, they needed to invest relatively high levels of conscious control to perform the intended actions. Indeed, it may be hypothesised that the associated high working memory load may have adversely affected the engagement of the persistence pathway. Accordingly, establishing to what degree the level of motor skill interacts with working memory in finding original solution remains an important avenue for further research.

To summarise, we tested the viability of the dual-pathway model in motor creativity. Our study has been the first to do so. In support of the model, a broad focus of attention resulted in increased flexibility on a divergent doing task. However, the jury is still out, given that working memory load did not influence persistence. In this respect, one promising avenue may be to make a more formal conceptualisation based on the dynamical systems approach is perhaps to consider focus of attention and working memory capacity as control parameters for creativity (Hristovski, Davids, Araujo, & Passos, 2011; Hristovski, Davids, Passos, & Araújo, 2012). For example, Hristovski et al. (2011) argue that the manipulation of constraints can influence the likelihood that a participant will vary either within one category or between different categories, that is, influence the extent to which the solution space is explored. If the solution spaces for cognitive and motor problems differ, then control parameters may not be the same, or similar change in the control parameter may have quite different effects on creativity (e.g. as in the cusp catastrophe model, see Wimmers, Savelsbergh, van der Kamp, & Hartelman, 1998). However, the amount of formal modelling needed to genuinely evaluate the fruitfulness of such a general approach to creativity is clearly beyond the scope of this paper.

Future research should evaluate the mechanisms and the interaction of cognitive and motor creativity more in-depth, to refine theoretical models and practical implications for many areas ranging from everyday life situations to the workplace.

Note

1. The control group was just added on the recommendation of one of the reviewers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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