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BRIEF REPORT

Can 5 Minutes of Finger Actions Boost Creative Incubation?

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Abstract
Previous studies suggest that the activation of the motor system – either via action, motor imagery, or brain stimulation – may increase subsequent performance on divergent thinking tasks (e.g., the alternate uses task; AUT). We tested this idea in a within-subjects design by administering the AUT using four different target objects and four different 5-min incubation tasks that differed in terms of arm and finger movements. In between-subjects designs, 0-back incubation has been shown to yield more creative responses than rest. Additionally, we included two new incubations that both involved arm actions, but differed in the amount of finger actions (Iranian dance, ballet dance). Incubation tasks involving finger actions (Iranian dance, 0-back) were predicted to increase creativity for objects that are typically manipulated with the fingers. There was a main effect of object. Alternate uses given to the paperclip were rated as more creative than those given to the other objects. With our within-subjects design, we could not replicate the previously described difference between 0-back and rest incubations. However, hypothesis-driven comparisons showed that, although the interaction of object and incubation was not significant, Iranian dance yielded more creative usages for paperclip than for sheet of paper, cup and brick, and all other incubations yielded more creative usages for paperclip than for brick. Iranian dance also generated marginally more creative usages than ballet. Our results suggest that if the hypothesized effects exist, they are likely to be small. Overall, AUT performance seems more influenced by the AUT object than by type of incubation.

Keywords Creativity · Alternate Uses Task (AUT) · Divergent thinking · Dancing · Movement · Motor cortex · Motor system · Health care settings · Dance · Mental health · Exercise

Introduction

Efforts to elucidate how creativity may be facilitated have increased in recent decades (Kim, 2011; Newton & Newton, 2010; Remoli & Santos, 2017; Ritter & Mostert, 2017; Runco, 2004). Data from experimental psychology and cognitive neuroscience is used to develop neuropsychological models about how creative thoughts are generated in the human mind (Boot et al., 2017; Chrysikou et al., 2013; Gilhooly et al., 2007; Khalil et al., 2019). Much research in this area has focused on the importance of the interplay between distributed networks of brain regions (e.g., default mode network, executive control network; Beaty et al., 2018, 2019; Pinho et al., 2016). However, a recent proposal by Matheson and Kenett (2020) is that the generation of creative ideas may also be supported by the motor system.

One possible mechanism could be mental simulation. Thinking about the sensory consequences of actions activates the motor system (Kilteni et al., 2018), as does mental imagery of tool use (Jacob & Jeannerod, 2005; Jeannerod, 2001, 2004). In creative tasks like the alternate uses task (AUT; Guilford, 1967), participants are asked to produce several different action alternatives for an object (e.g., ways to use a tool), and mental simulation of actions may be used as a cognitive strategy for idea generation (Matheson & Kenett, 2020). Results from a handful of studies with varying conceptual and methodological backgrounds support this hypothesis. In a functional MRI study, Matheson et al. (2017) investigated the importance of motor imagery for creative cognition. Multivariate analyses of patterns of brain

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activity in the dorsal tool use network supported the notion that motor stimulation and neural processing in sensorimotor brain areas may contribute to creative generation of unusual actions with an object.

Furthermore, activation of the motor system, either through brain stimulation or overt action, has been reported to increase creativity. Anic et al. (2018) applied direct current stimulation (tDCS) of left motor cortex to pianists performing improvisations. As compared to a group receiving inhibitory (cathodal) stimulation, a group receiving excitatory (anodal) stimulation produced more creative improvisations as rated by expert judges and in terms of fluency (number and variety of notes and pitch range) (Anic et al., 2018). Friedman and Förster (2002, Exp. 2) found that activation of the motor system via motor actions (arm flexion, but not arm extension) increased creative fluency (i.e., number of alternate uses generated for a familiar object). The creativity enhancing effects of arm actions and upper body posture have been replicated (Hao et al., 2014), and expanded to specific body actions, like standing while spreading the arms to the side (Hao et al., 2017). Similarly, activating the motor system by squeezing an object with the hand has been shown to boost subsequent creative performance (Goldstein et al., 2010; Rominger et al., 2014). Even though the theoretical background of these previous studies is heterogeneous, there are nevertheless indications that motor activation may, under some circumstances, facilitate creative thinking.

Dancing is an easily accessible, cheap, and fun way to increase the excitability of the brain's motor system, both in the organizational work-context, as well as in private settings (Schmidt et al., 2023). Simple dance actions with the arms can be choreographed to include precisely the arm and finger movements proposed in previous studies. Given that some evidence exists for neural effector-specificity in mental simulation (Gallivan et al., 2011; Leoné et al., 2014; Willems et al., 2010; though see also: Lorey et al., 2014; Sobierajewicz et al., 2017), we set out to determine, whether a short 5-min 'dance-break' may boost subsequent creativity on a classical divergent thinking task, the AUT and, if so, whether the boosting effect is specific to the actual types of movements performed, and effectors used, during the dance intervention.

For our experimental design, we relied on extant literature about the effect of 'incubation periods' on creative performance. An incubation period is a period of time, during which the participants' attention is directed away from a problem they have been presented with (resting or engaging in an unrelated task), before they are asked to provide the solution (Csikszentmihalyi & Sawyer, 2014; Segal, 2004). Meta-analytic work lends support to the creativity-enhancing effect of incubation periods (Sio & Ormerod, 2009), although results of individual studies remain mixed (Kazemian et al., 2024; Olton & Johnson, 1976; Vul & Pashler, 2007). A reason for this variability could be that the neurocognitive mechanisms which cause the creative advantages after certain types of incubation (e.g., action-based vs. rest-based incubations) are still poorly understood, as are the inter-individual differences that modulate these.

We choose two established incubations (rest and 0-back; Baird et al., 2012; Remoli & Santos, 2017) to compare our two new incubations against (Iranian dance, ballet). In a study using a between-subjects design, 0-back incubation was shown to yield more creative responses than rest (Baird et al., 2012). We expected to replicate this effect with our within-subjects design. Besides, we predicted that that incubation tasks involving finger actions (Iranian dance, 0-back) would boost creativity, i.e., the generation of alternate uses for objects that involved the same effectors that were activated during the incubation task.

To test the motor excitability account, we tailored the actions to be performed, and the effectors used during the incubation tasks, to four different objects (commonly used in AUT research) that participants were to find alternate uses for, after incubation. Based on the motor actions employed in previous studies, the choreographies of both dance styles contained arm extensions and flexions in equal measure, and used the same spatial orientations and movement trajectories. The two dance styles (Iranian dance and ballet), however, differed in terms of the amount of finger movements. In Iranian dance, much emphasis is on energetic hand movements including hand and finger curls, while in ballet dance, the fingers are held soft and there are no curls (Christensen et al., 2024; Khorsandi, 2015), see Fig. 1.

The subtle differences between the two dance styles in terms of finger movements are important because we used four classical objects for the AUT to test the effect of motor activation: paperclip, sheet of paper, cup, and brick. Actions with a paper clip or a sheet of paper are usually confined to the fingers and hands, allowing for more degrees of freedom, while actions with a brick or a cup usually require arm movements (flexion and extension), and are more restricted. We therefore predicted that Iranian classical dance (which includes delicate finger movements) would increase creativity for the objects paperclip and sheet of paper.

We used a mixed within-subjects design which is statistically stronger than the between-subjects designs (traditionally used in incubation experiments), because the former accounts for individual differences. In addition, we collected a series of interindividual difference measures, which previously have been linked to creative idea generation, as covariates for the analyses, i.e. mood (Baas et al., 2008; Isen et al., 1987; Ritter & Ferguson, 2017; Yamada & Nagai, 2015), openness to experience (Batey & Furnham, 2006; Kandler et al., 2016; Kaufman et al., 2016; Shaw & Choi, 2023; Vartanian et al., 2018), gender (Abraham, 2016; Baer & Kaufman, 2008), and aesthetic responsiveness (Myszkowski

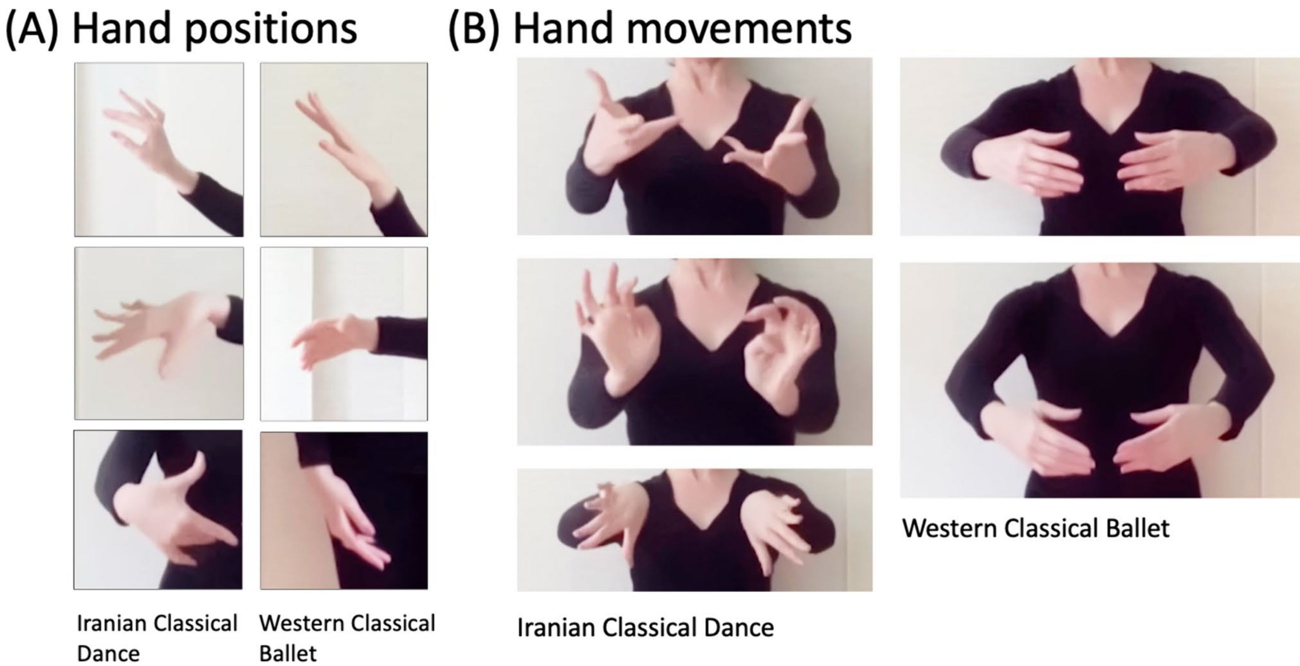

Fig. 1 Hand Positions and Movements in Iranian Classical Dance and Western Ballet. *Note.* (A) Hand positions. In Iranian classical dance, the hands have a lot of tension or energy; hands and fingers make curls and include pincer-grip like movements. In Western classical ballet, the hands are held soft and with the fingers flowing soft and with no pincer-grip like movements. (B) In Iranian classical dance, many movements of the hands include continuous circular curls which do not exist in Western classical ballet, where hands are held in relatively fixed positions throughout movements of the arms. The finger positions and movements of Iranian classical dance draw the dancer's attention toward the finger movements. Both dance videos were accompanied by their traditional music, i.e., classical Western and Iranian music, respectively, to make the task fun

et al., 2014; Scholtz et al., 2020; Welke et al., 2021). Given that our research question involved engagement with an artistic practice previously linked to creative incubation, dance, we included several measures of the above factors into our statistical models.

Method

Ethical approval for the experiment was provided by the Ethics Council of the Max Planck Society (Nr. 2017_12). Informed consent was obtained from all participants. All methods were performed in accordance with the relevant national guidelines and regulations and in accordance with the Helsinki Declaration (World Medical Association, 1964). A coarse pre-registration of our research question is available inside a video about a science outreach event in 2019, during which we piloted our paradigm, and at minute 1:35 we mention our research question[1]: https://youtu.be/8TRT5VVk2lA?t=96

Participants

Eighty-three participants (age: M = 26 years; SD = 5.89 years; range: 18 – 48 years) took part in this experiment (Table 1). Sample size was determined by means of G*Power 3.1. (Faul et al., 2007) – initially for a linear multiple regression. Parameters included were effect size $f^2 = 0.30$; alpha = 0.05; power = 0.95; tested predictors = 7; estimated required sample = 81. Due to a counting error, 83 participants were tested. After performing the experiment, we realised that we may have been underpowered to detect small effects. Therefore, we performed, in addition, a post-hoc power analysis for *F*-tests, using the effect size (f = 0.120), alpha = 0.05, sample size (= 83), number of groups = 1, number of measurements = 4. This gave us an observed power of = 0.73.

A total of 15 trials were excluded from analysis, see Supplementary Materials, Section 1.1.

[1] Please note: clicking on the link takes you to YouTube. The authors take no responsibility for ads or other content available on these sites. Please revisit the data protection before deciding to consume the content. The dancer is Shahrzad Khorsandi from Shahrzad Dance Company, Richmond, California, USA.

Table 1 Sample demographics and questionnaire measures

Baseline characteristic		All ($n = 83$)
Age		26 years (SD = 5.89)
Sex		
	Female	48 (59%)
	Male	34 (41%)
Education		
	A-Levels	58 (71%)
	Bachelor	16 (20%)
	Master / Diploma	7 (8%)
	Other	1 (1%)
BFI-XS		
	Extraversion	20.24
	Agreeableness	22.67
	Conscientiousness	21.59
	Openness to Experience	23.8
	Neuroticism	16.52
AReA		
	Total	25.65
	AA	19.16
	IAE	5.48
	CE	2.83

Note: N = 83. Participants were recruited via the participant database of the Max Planck Institute for Empirical Aesthetics (MPIEA), Frankfurt/M, Germany. The BFI-II-S includes 30 items, with six items for each of the Big Five domains extraversion, conscientiousness, openness to experience, agreeableness, and neuroticism. Responses are given on a 5-point rating scale from *disagree strongly* to *agree strongly*. BFI-XS scores were aggregated as per article instructions (30 items with six items on 5-point rating scale from 1 = *disagree strongly* to 5 = *agree strongly;* aggregated score range for each dimension from 1–30). The Aesthetic Responsiveness Assessment (AReA) contains 14 items with answers given on a 5-point Likert scale (from 0 = never to 4 = very often), and it has three subscales, 1) Aesthetic Appreciation, 2) Intense Aesthetic Experience, and 3) Creative Behaviour. Scores were averaged as per article instructions (score range from 0 = never to 4 = very often)

Materials

The Alternate Uses Task (AUT)

Each participant performed four trials of the alternate uses task (AUT; Guilford, 1967), with unique combinations of incubations and objects, so that each participant received each incubation and object exactly once (as in Kazemian et al., 2024). The name of the object was displayed in text on a computer screen (Hao et al., 2015). See Fig. 2.

Incubation Tasks

Rest incubation: Participants were asked to relax for 5 min.

0-back incubation: 1-digit letters appeared on the screen for 5 min (ITI = 2000 ms; stimulus duration = 500 ms). Participants used index and middle finger to press the right key if a target letter (e.g., "L") was presented within the string of letters; left key if not.

Iranian classical dance incubation: Participants stood and imitated an Iranian classical dance choreography with arms only. The arm movements used were from the Iranian dance syllabus (Khorsandi, 2015). See video here[2]: https://youtu.be/Ue6n2lbl7h8

Western ballet dance incubation: As above, with ballet. The arm movements used were from the ballet syllabus (Vaganova, 1969). See video here[2]: https://youtu.be/tGTixyHFoTY

Questionnaires

Personality was assessed with the Big-Five-Inventory-II-short (BFI-II-S) in German (Rammstedt et al., 2018; Soto & John, 2017a, b).

Aesthetic responsiveness was assessed via the Aesthetic Responsiveness Assessment (AReA; Schlotz et al., 2020).

Software

Presentation version 20.0 was used to deliver the experiment, using a custom-made user interface (Muralikrishnan, 2019). SPSS 25 was used for statistical analyses.

Procedure

Participants were tested during the Covid-19 pandemic (October 2020 – July 2021) and received a compensation of 14 €/hour.

Participants performed the tasks of the experiment in a dimly lit 3 × 3 m cubicle. Because the study was conducted during the Covid-19 pandemic, the hygiene protocol was very strict. The experimenter could see the participant inside the booth through a transparent plastic-tent-like structure and made sure they were moving.

Task instructions and AUT trials were administered using the software Presentation version 20.0 on a Microsoft Windows computer with a 24 × 14 cm Dell monitor (1920 × 1080 px resolution); viewing distance was about 30–35 cm. On-screen instructions before each AUT trial read: "*You will now be given the name of an object and have 10 s to think*

[2] Please note: clicking on the link takes you to YouTube. The authors take no responsibility for ads or other content available on these sites. Please revisit the data protection before deciding to consume the content. The dancer is Shahrzad Khorsandi from Shahrzad Dance Company, Richmond, California, USA.

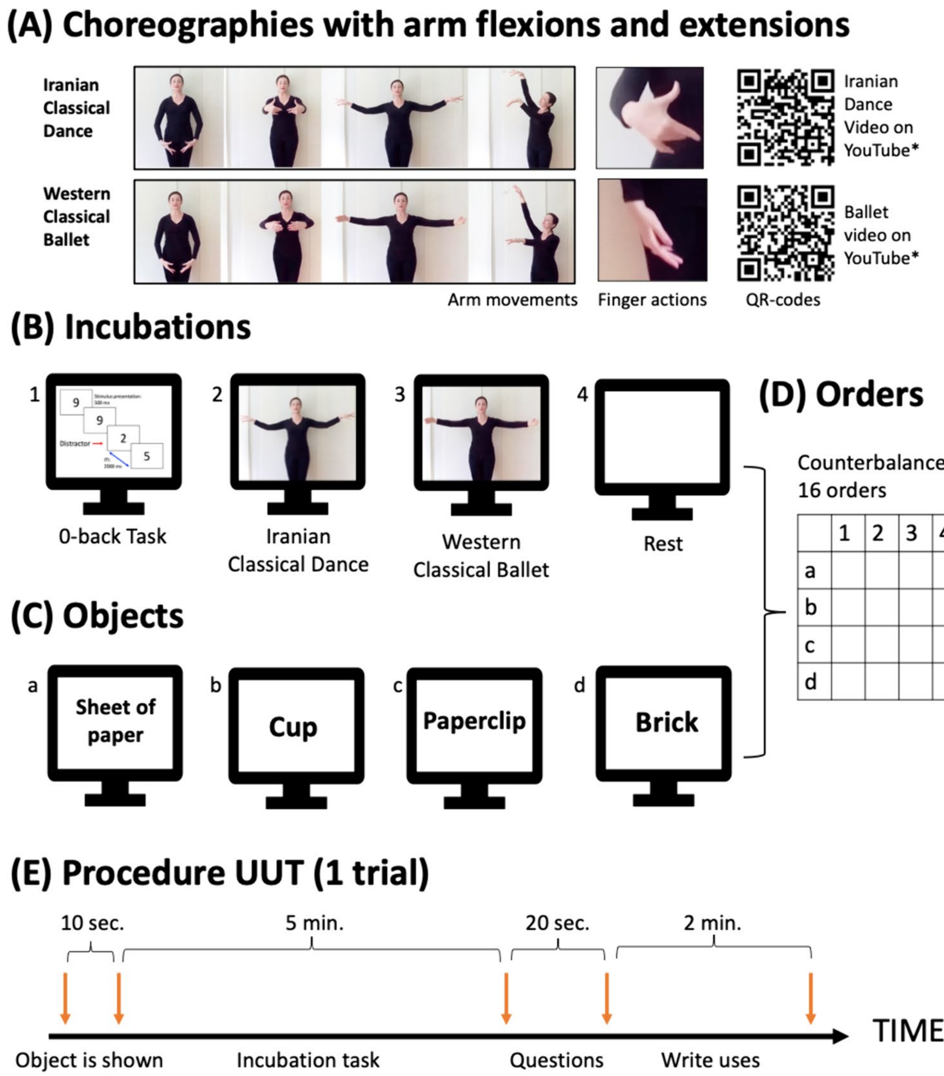

Fig. 2 Tasks, Manipulation Checks and Procedure of the Experiment. *Note.* A) Choreographies of Iranian and Ballet arm movements, including extensions and flexions (both dance styles) and finger actions (only Iranian dance). (B) Four incubation phases: 1) 0-back, 2) Iranian dance, 3) ballet dance, 4) rest. (C) Four objects: a) sheet of paper, b) cup, c) paperclip, d) brick. (D) Orders: Sixteen combinations of objects and incubation tasks that counterbalanced the combination of objects (paperclip, sheet of paper, cup, or brick) and incubation tasks (rest, 0-back, Iranian or Western classical ballet). Curly brackets: illustrates the 16 combinations for counterbalancing (order factor was not significant ($p = 0.256$), and was therefore disregarded from subsequent analyses). (E) Procedure. On-screen instructions before each AUT trial: "*You will now be given the name of an object and have 10 s to think about it. At a later point of the experiment, you will be asked to write alternate uses for this object*". Then the name of the object was displayed (10 s), followed by five minutes incubation, followed by the manipulation checks and then 2 min of writing down alternate usages. Manipulation checks: cognitive load during incubation: "*how many times did you think of the object?*" (Likert scale 0 to 10) – no main effect in the main analysis ($p = 0.355$). Question about mood after incubation: *"how do you feel right now?"* (Likert scale 1 (extremely happy) to 9 (extremely sad)) – no main effect in the main analysis ($p = 0.195$). For the 0-back task, 1-digit letters appeared on the screen for 5 min (ITI = 2000 ms; stimulus duration = 500 ms). Participants used index and middle finger to press the right key if a target letter (e.g., "L") was presented within the string of letters; left key if not. Accuracy range: 84.2% – 100% ($M = 96.8\%$, $SD = 2.16$). A univariate ANOVA for the 0-back incubation revealed no main effect of accuracy on creativity ($p = 0.822$), nor did 0-back accuracy correlate with creativity after the n-back incubation ($r = 0.189$, $p = 0.094$). Participants were given a shorter practice trial. This data was discarded before analysis. *Please note: clicking on the QR codes takes you to YouTube. The authors take no responsibility for ads or other content available on these sites. Please revisit the data protection before deciding to consume the content. The dancer is Shahrzad Khorsandi from Shahrzad Dance Company, Richmond, California, USA

about it. At a later point of the experiment, you will be asked to write alternate uses for this object". Then the name of the object was displayed (10 s), followed by five minutes incubation, followed by the manipulation checks and then 2 min of writing down alternate usages.

Response coding followed standard procedures for AUT coding (Amabile, 1982; Jung et al., 2010; Michael & Wright, 1989), see Supplementary Materials, Section 1.1. Four independent judges, who were blind to the incubation tasks, rated the creativity of each proposed usage on a scale from 1 (not very creative) to 5 (very creative) for each object. To compute interrater agreement of the average creativity scores of four judges, Cronbach's alpha and Intraclass Correlation Coefficient (ICC) are both useful measures (Cortina, 1993; Koo & Li, 2016; Kramer et al., 2018). Agreement was acceptable with an overall ICC = 0.643 (95% CI [0.623, 0.672]), with ICCs ranging from 0.489 (95% CI [0.409, 0.561]) to 0.728 (95% CI [0.699, 0.765]) for the four objects separately.

Additional creativity metrics for each participant were obtained via coding procedures (fluency, flexibility, originality scores; see supplementary materials, sections 1.2. and 2). These three additional measures correlated between each other (all rs > 0.460, ps < 0.001). The judges' creativity scores (analyses reported below) also correlated significantly with fluency ($r = 0.116$, $p = 0.037$) and with originality ($r = 0.353$, $p < 0.001$), but not with flexibility ($r = 0.071$, $p = 0.204$). All data are freely available for secondary analyses on the Open Science Framework, see the below Data Availability Statement.

Results

A univariate two-factor Repeated Measures (RM) ANOVA was conducted, with the within-subjects factors Incubation (4 levels; rest, 0-back, Iranian dance, ballet dance), and Object (paperclip, sheet of paper, cup, brick). The mean creativity score across the four judges was the dependent variable.

There was a main effect of Object ($F(3, 324) = 13.977$, $p < 0.001$, partial $\eta^2 = 0.120$), but no main effect of Incubation ($F(3, 324) = 0.647$, $p = 0.586$, partial $\eta^2 = 0.006$), nor of the Incubation x Object interaction ($F(9, 324) = 0.992$, $p = 0.447$, partial $\eta^2 = 0.028$).

Sidak adjusted pairwise comparisons revealed that alternate uses for paperclip (*EMM* = 2.48; *SE* = 0.034; 95% CI [2.41, 2.55]) were rated as more creative than for cup (*EMM* = 2.31; *SE* = 0.034; 95% CI [2.24, 2.38], $p = 0.002$; Cohen's $d = 0.56$) and for brick (*EMM* = 2.18; *SE* = 0.034; 95% CI [2.10, 2.25]; $p < 0.001$; Cohen's $d = 0.98$). Furthermore, responses to brick (*EMM* = 2.18; *SE* = 0.034; 95% CI [2.10, 2.25]) were less creative than responses to cup (*EMM* = 2.31; *SE* = 0.034; 95% CI [2.24, 2.38]; $p = 0.040$; Cohen's $d = 0.43$), and sheet of paper (*EMM* = 2.38; *SE* = 0.034; 95% CI [2.31, 2.44]; $p < 0.001$, Cohen's $d = 0.66$). See Fig. 3.

We had specifically predicted facilitation effects of the different incubation tasks on the creativity for different objects. Single univariate F-tests for each Incubation become all significant, with the strongest result for Iranian dance ($p < 0.001$). See Table 2.

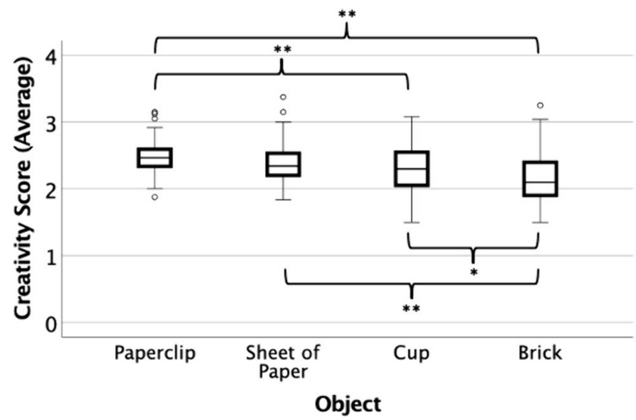

Fig. 3 Main Effect of Object. *Note*: Graph shows the average creativity scores (across judges) for each of the four objects (paperclip, sheet of paper, cup, brick). The creativity scores for the objects appear 'sorted' by weight – with paperclip (the lightest) yielding the top creativity scores, followed by sheet of paper, cup and brick. Whiskers show 95% confidence intervals. Circles show outliers. ** = $p < 0.001$, * = $p = 0.05$

Conservative Sidak-corrected pair-wise comparisons (controlling for all possible pairings = 120) within the same model revealed that after the Iranian dance incubation (which has finger pincer movements), alternate uses for paperclip were more creative (*EMM* = 2.60; *SE* = 0.07; 95% CI [2.49, 2.75]) than for sheet of paper (*EMM* = 2.37; *SE* = 0.07; 95% CI [2.23, 2.50]; $p = 0.046$, Cohen's $d = 1$), cup (*EMM* = 2.26; *SE* = 0.06; 95% CI [2.13, 2.38]; $p = 0.001$; Cohen's $d = 1.23$), and brick (*EMM* = 2.21; *SE* = 0.07; 95% CI [2.10, 2.35]; $p < 0.001$, Cohen's $d = 1.33$). Notably, there was a significant difference between paperclip and brick for all the other incubation tasks too: After 0-back incubation, participants' creative usages were more creative for paperclip (*EMM* = 2.44; *SE* = 0.07; 95% CI [2.31, 2.60]), than for brick (*EMM* = 2.16; *SE* = 0.07; 95% CI [2.00, 2.30]; $p = 0.025$, Cohen's $d = 0.83$). After Ballet incubation, participants' creative usages were more creative for paperclip (*EMM* = 2.43; *SE* = 0.07; 95% CI [2.30, 2.60]), than for brick (*EMM* = 2.16; *SE* = 0.07; 95% CI [2.00, 2.30]) ($p = 0.034$, Cohen's $d = 0.82$). After rest, participants' creative usages were more creative for paperclip (*EMM* = 2.44; *SE* = 0.07; 95% CI [2.30, 2.60]), than for brick (*EMM* = 2.17; *SE* = 0.07; 95% CI [2.00, 2.30]) ($p = 0.043$, Cohen's $d = 1.43$). None of the other comparisons were significant (all ps > 0.079). These hypothesis-driven, significant Sidak-corrected comparisons of the (non-significant) interaction are shown in Fig. 4A. Figure 4B shows the same comparisons with Least Significant Difference (LSD) correction.

Table 2 Univariate *F*-test results

Contrast	EMM (SE)	Sum of Squares	DF	Mean Square	F	Significance	Effect size (η^2)	Observed Power
Object								
Paperclip	2.48 (.034)	.542	3	.181	1.934	.124	.018	.497
Sheet of Paper	2.38 (.034)	.072	3	.024	.255	.858	.002	.098
Cup	2.31 (.034)	.358	3	.119	1.275	.283	.012	.340
Brick	2.18 (.034)	.038	3	.013	.137	.938	.001	.075
Incubation								
Rest	2.35 (.035)	.281	3	.281	3.004	.031*	.028	.706
Iranian dance	2.36 (.033)	2.089	3	.696	7.450	.001**	.068	.985
0-back	2.33 (.034)	.855	3	.285	3.050	.029*	.029	.713
Ballet dance	2.30 (.034)	1.015	3	.338	3.620	.014*	.034	.793

Note: Within the main univariate ANOVA model, each *F*-tests the simple effects of respectively object (top 4 rows) and incubation task (lower 4 rows), within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means. They are computed using an alpha = .05. EMM = Estimated Marginal Means; SE = Standard Error. Significances are noted *$p < .05$; **$p < .001$

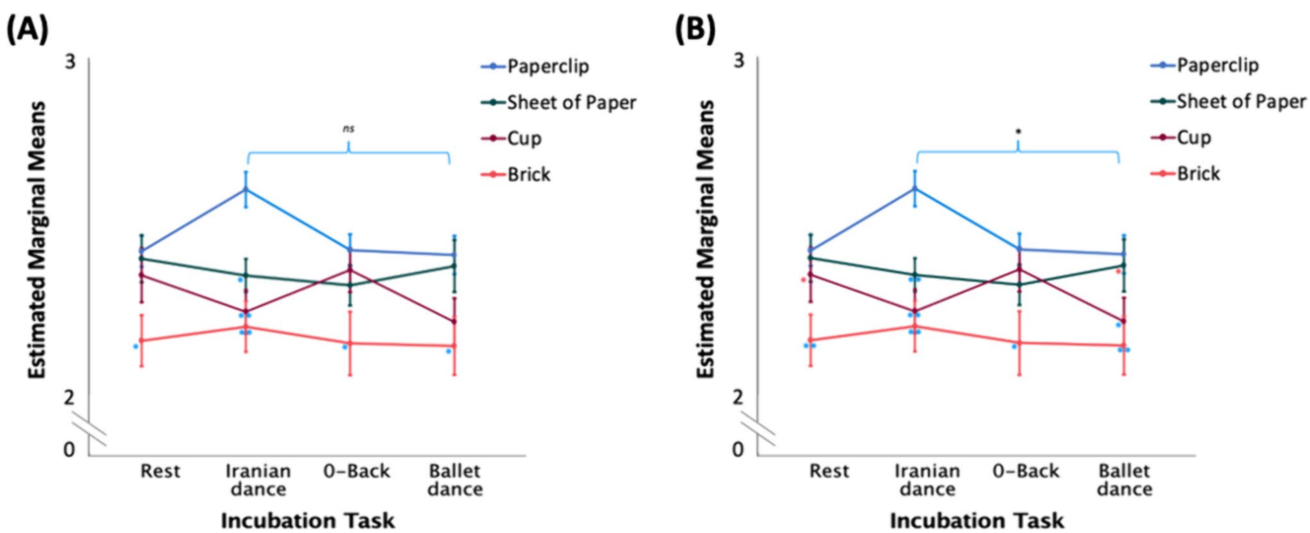

Fig. 4 Interaction of Object with Incubation Task – Sidak (A) and LSD (B) correction. *Note*: Graphs show univariate ANOVA results using two different pair-wise corrections, Sidak and LSD. X-axis shows Estimated Marginal Means of creativity scores for each incubation task (x-axis: rest, Iranian dance, 0-back, Ballet dance) as a function of the object that participants were asked to provide alternate uses for (paperclip, sheet of paper, cup, brick). (A) Sidak pairwise correction: All pairwise differences of the interactions are conservatively corrected with a Sidak correction. Blue asterisks indicate significant differences between paperclip and the object marked with the asterisk. (B) LSD pairwise correction: All pairwise differences are interactions corrected with a LSD pair-wise correction within the main univariate ANOVA. Blue asterisks indicate differences between paperclip and the object marked with the asterisk, orange asterisks describe differences between brick and the other objects. Significances are noted as *$p < 0.05$; **$p < 0.001$

We had predicted differences in creativity between the two dance styles (Iranian and Ballet dance incubations) for the object paperclip, the manipulation of which requires delicate finger movements. However, within the above model, controlling for all possible pairings (= 120), Sidak-corrected pairwise comparisons showed no significant difference between Iranian dance (*EMM* = 2.60; *SE* = 0.07; 95% CI [2.49, 2.75]) and Ballet incubations (*EMM* = 2.43; *SE* = 0.07; 95% CI [2.30, 2.56]; $p = 0.229$; Cohen's $d = 0.78$) (see curly brackets in Fig. 4). Interestingly, for the object paperclip, though non-significant, Iranian dance was the only incubation that showed pair-wise significance estimates with any of the other incubations of below $p = 1$ after correction.

Considering the significant univariate *F*-test for the Iranian dance incubation ($p < 0.001$) (Table 2), and the considerable effect size of Cohen's $d = 0.78$ in this comparison, we speculate that some effect of Iranian dance incubation on paperclip creativity exists. Besides, when using a less stringent pairwise correction, LSD (yet still controlling for all possible pairings = 120), within the same ANOVA model for exploration purposes, the p-value is $p = 0.042$, and with a simple independent t-test, it is $p < 0.001$.

We had also predicted more creative responses after 0-back than after rest, following previous studies. However, no such difference was found, neither for all objects together ($p = 1$), nor for the objects separately, no matter the correction method used (with Sidak all $ps > 0.958$, with LSD all $ps > 0.725$).

To explore the effect of inter-individual difference measures of creativity, a univariate ANCOVA was run with sex as an additional between-subjects factor and the covariates BFI openness, aesthetic responsiveness, mood ratings, and mind-wandering. The results remained the same and none of the inter-individual difference measures showed a significant effect, except for BFI openness ($F(3, 307) = 9.725$, $p = 0.002$, partial $\eta^2 = 0.035$).

Discussion

We investigated the notion that action-based incubation tasks may boost creativity when the AUT involves providing alternate uses for objects that are typically manipulated with effectors activated during incubation (Matheson et al., 2017, Matheson & Kenett, 2020). We compared the effects of two dance incubations, ballet and Iranian dance, only the latter of which involves active finger movements. In addition, we included two classical incubation tasks, rest and 0-back, the latter of which also involves delicate finger movements.

Using a well-powered within-subjects design, we were unable to replicate the previously reported difference in creativity after rest and 0-back (Baird et al., 2012), making our study the second with this result (Kazemian et al., 2024). It is unclear why the between-subjects design used in Baird et al., (2012) would result in a difference that would be undetectable in this well-balanced, more sensitive within-subject design.

Although the interaction object x incubation was not significant, our predictions allowed us to explore pairwise comparisons, and we did this using a particularly conservative approach to control Type I error inflation. These prediction-driven comparisons showed that the Iranian dance incubation resulted in significantly more creative generation of alternate uses for paperclip than for all other objects. We observed a similar effect for paperclip and brick for all other incubation tasks, though the effect sizes were largest for Iranian dance incubation. Notably, the paperclip is a small and light object that requires delicate finger movements to be manipulated, in contrast to the other objects, which often are handled with whole hand and arm movements. Univariate F-tests and hypothesis-driven pairwise comparisons suggested that higher creativity scores for the object paperclip *may* be expected after an Iranian dance incubation, as compared to after a Ballet incubation. However, given the non-significant object x incubation interaction, our results provide only weak support for the hypothesis that different incubations facilitate creative cognition for different objects. Rather, there was an overall effect of object across incubations (cf. Fig. 4). Whether the small size or, alternatively, the higher plasticity of a paper clip might be a driver for the observed object effects would require further study. Thus, it seems that objects play a larger role in creative generation than incubations.

Future research may address the effect of several inter-individual differences on creativity, including the cultural familiarity for participants of the contents of incubation tasks (e.g., we used Iranian and Western ballet dance), to assess whether familiarity/novelty of an incubation task affects creative performance. The novelty effect of dancing Iranian dance for our Western participants might well have played a role in producing these creativity effects, as novelty-seeking has been shown to be linked to creativity (Ivancovsky et al., 2023). Also, participants listened to two culturally quite different musical pieces while moving in the dance incubations. Music incubations have previously been shown to boost creativity (Ritter & Ferguson, 2017). The mechanism by which creativity enhancements are said to come about through music is via increases or decreases in mood. We did measure mood after each trial. However, there was no significant effect of mood (in either direction) in our models, which is why we believe that the music did not affect creativity performance, at least not via mood changes. Other individual factors such as personality, aesthetic responsiveness, sex, and mind-wandering during the task did not influence these results, except openness to experience. Previous research has shown effects of these variables, yet we speculate that our stronger within-subject design may have controlled for such differences.

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Author Contributions **Julia F. Christensen**: Conceptualization, Study design, Methodology, Software, Data Collection, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Muralikrishnan, R.** Methodology, Software, Validation, Data Curation, Visualization, Writing – review & editing. **Marco Münzberg**: Data Collection, Validation, Data Curation, Writing – original draft, Writing – review and editing, Visualization. **Bilquis Castano-Manias**: Data Collection, Validation, Data Curation, Writing – review and editing. **Shahrzad Khorsandi**: Conceptualization, Study design, Writing – review and editing. **Edward A. Vessel**: Conceptualization, Study design, Methodology, Writing – review and editing.

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Data Availability Data, stimuli, and analysis code associated with this study are freely available on OSF: https://doi.org/https://doi.org/10.17605/OSF.IO/A9DP2

This study was unfortunately not pre-registered on the OSF; however, we piloted the paradigm at a public outreach event at the Tate Modern in London in 2019 and produced a video about the event. Inside the video, published in August 2019, we specify our research question in a very general manner: We aimed to investigate “whether and how people become more creative, after dancing for two minutes”; at minute 1:44, see (Please note: clicking on the link takes you to YouTube. The authors take no responsibility for ads or other content available on these sites. Please revisit the data protection before deciding to consume the content. The dancer is Shahrzad Khorsandi from Shahrzad Dance Company, Richmond, California, USA.): https://youtu.be/8TRT5VVk2lA?t=96

Declarations

Competing interest The authors have no conflict of interest to disclose. Shahrzad Khorsandi owns a commercial dance school and dance company, however, the remaining authors do not see this as a conflict of interest.

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