Creativity Research Journal

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/hcrj20

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To cite this article: Jennifer Haase & Paul H. P. Hanel (29 Apr 2024): Spillover Effects in Creative Thinking: The Impact of Gaming and Mathematics on Creativity and Emotions, Creativity Research Journal, DOI: 10.1080/10400419.2024.2347778

To link to this article: https://doi.org/10.1080/10400419.2024.2347778

CREATIVITY RESEARCH JOURNAL
https://doi.org/10.1080/10400419.2024.2347778

Spillover Effects in Creative Thinking: The Impact of Gaming and Mathematics on Creativity and Emotions

Jennifer Haase [a,b] and Paul H. P. Hanel [c]

[a]Humboldt Universität; [b]Weizenbaum-Institut; [c]University of Essex

ABSTRACT
As automation advances and markets transform, creative skills are becoming increasingly important. In the present study ($N = 813$), we therefore investigate how creative performance can be enhanced. Participants either participated in a fun recreational game, a fun-focused game, a math task, or none (control condition). This allowed us to analyze the impact of tasks that elicit positive emotions due to their fun nature and more stressful tasks, such as math, on later creative task performance. Contrary to our predictions, prior engagement in joyful or arithmetic tasks did not notably affect creativity, indicating a multifaceted relation among task categories, creativity metrics, and task-switching. Exploratory analyses revealed that fluency, but not originality and convergent thinking, was positively associated with creative self-efficacy and growth mind-set and negatively with fixed mind-set. The sequence in which divergent and convergent thinking tasks were presented affected originality but not fluency. In summary, our research underlines the intricacies of task categories, individual differences, and creative performance. Implications for creative enhancement methods across diverse contexts are discussed.

ARTICLE HISTORY
Received June 27, 2023

Introduction

In the contemporary working environment, creative abilities are becoming increasingly important, mainly as numerous simple tasks are delegated to technology (Berg, 2019). This shift has engendered an amplified demand for workers to engage in creative endeavors (Henard & McFadyen, 2008; Nisula & Olander, 2021). As a result, organizations and educational institutions are increasingly focusing on fostering creative skills and promoting innovative thinking to remain competitive and adaptable in the face of rapid technological advancements and global market transformations.

Research has shown that creative abilities are not fixed within a person but instead depend heavily on situational conditions that influence an individual's cognitive ability to associate freely (Haase, Hanel, & Gronau, 2023; Sassenberg, Moskowitz, Fetterman, & Kessler, 2017; Scott, Leritz, & Mumford, 2004). To improve work-related creative thinking, we need a more detailed understanding of these procedural situational factors influencing such thinking abilities.

We investigate the effects of various activities on cognitive influences and creative thinking through an experimental online setting. Our study concentrates on the influence of immediately preceding activities on subsequent creative thinking tasks. The impacts of one task on another can be observed in terms of activated arousal (through emotions) and the mode of thinking (through spillover effects). We differentiate between two types of tasks in terms of arousal: tasks eliciting positive emotions versus neutral emotions. This study operationalizes this distinction using games vs. math tasks in experimental conditions. Joyfulness is aimed to be induced through games, as they are meant to be fun (Deterding, Dixon, Khaled, & Nacke, 2011). They usually trigger a positive mood and a broad association network (Yeh, 2015).

In contrast, neutral tasks require concentration and mental effort and are even connected to negative emotions (for math see Haase, Guimarães, & Wood, 2019). Additionally, we distinguish between two task modes: recreational vs. focused. The recreational task does not follow a precise aim, as the interaction is done for fun, whereas a focused task aims to solve concrete tasks, like arithmetic calculations. Thus, we can distinguish between joyful-recreational, joyful-focused, and neutral-focused tasks by comparing three experimental conditions. Applying this

CONTACT Jennifer Haase jennifer.haase@hu-berlin.de Department of Computer Science, Humboldt Universität, Unter den Linden 6, Berlin 10099, Germany
Supplemental data for this article can be accessed online at https://doi.org/10.1080/10400419.2024.2347778

conceptual setting, we can distinguish between the emotions evoked by a task and the mental effort required to solve a task on the subsequent creative task performances.

Creative mind-set

The creative mind-set is a mental state characterized by diverse and abstract thinking and is the underlying mechanism activated by manipulations to enhance creativity (Sassenberg, Moskowitz, Fetterman, & Kessler, 2017). A creative mind-set facilitates broad associations across cognitive categories, producing global and flexible information processing (Dreu, Nijstad, & Baas, 2010). As Kaufman and Sternberg (2019) put it, "The major variable in creativity is simply a mindset toward thinking in novel, surprising, and compelling ways," p. 88).

Mind-sets, in general, are mental adjustments that prepare individuals for typical task demands, improving their performance (Gollwitzer & Keller, 2016). While there are limited studies that directly apply mind-set theory to explain the enhancement of creative thinking skills, it is worth noting that both training and manipulation methods may activate a creative mind-set. Training methods involve a more deliberate learning process than manipulation methods, which often rely on subtle, indirect cues or primes (Haase, Hanel, & Gronau, 2023). Spillover effects, which describe how the cognitive processes from one task can influence subsequent tasks, can be linked to creative mind-sets that facilitate cognitive flexibility and promote global perception and enhanced working memory capacity (Dreu, Nijstad, & Baas, 2010; Sassenberg, Moskowitz, Fetterman, & Kessler, 2017, 2022).

Task-driven cognitive spillover effects

Different types of cognitive tasks activate and demand various cognitive functions. Spillover effects explain the transfer of thinking patterns necessary for one task to the following tasks. For instance, games typically require free-associative thinking (Cheng, 2021), whereas math tasks necessitate analytical and logical reasoning (Suherman & Vidákovich, 2022). Research has demonstrated that the spillover effects of cognitive tasks depend on several factors, including the nature of the tasks, cognitive load, and individual differences in cognitive abilities. Specifically, the spillover effect can be positive or negative, depending on how much cognitive resources are depleted or the cognitive processes overlap between tasks (Redifer, Bae, & DeBusk-Lane, 2019). According to Cognitive Load Theory, learning and problem-solving are constrained by an individual's limited working memory capacity (Paas & Ayres, 2014). Math or logic tasks often demand more cognitive capacity, which can mentally tire the individual for subsequent tasks. This "cognitive fatigue effect" posits that prolonged engagement in demanding cognitive tasks may lead to a depletion of cognitive resources, negatively impacting subsequent creative performances (Redifer, Bae, & DeBusk-Lane, 2019).

When examining the spillover effect within the context of creative tasks, studies have shown that exposure to specific cognitive tasks can promote divergent or convergent thinking, depending on the prior task structure, requiring broad associations or focused attention. Engaging in well-defined problems can activate a convergent thinking approach that can impede the divergent processing required to address ill-defined creative problems, resulting in suboptimal performance (Xu & Schwarz, 2018). Further, when a task requires a strong focus on a fixed goal, the individual's engagement in divergent thinking is hampered in subsequent creative tasks. Further, participants preferred similarly well-structured tasks when choosing a task, indicating a motivational preference to engage within a similar cognitive mind-set (Moreau & Engeset, 2016). Such effects indicate that the carryover effects of cognitive thinking patterns to subsequent tasks depend on the prior task structure and not the actual content of these tasks. Studying the impact of games on subsequent learning performances showed that these enhance learning performance as long as the player enjoys the gameplay (Xanthopoulou & Papagiannidis, 2012). This suggests that emotions mediate the spillover effects. Based on the correlations and effects found in the literature, the distinction between divergent and convergent thinking is further addressed, and the impact of different task types and the influence of emotions are considered in more detail.

Divergent vs. convergent thinking

Creative thinking can be categorized into free-associative or divergent thinking, which generates multiple possible solutions to open-ended problems, and convergent thinking, which finds a single solution to a closed problem (Cropley, 2006; Runco & Acar, 2012). Divergent thinking is often considered a core competence associated with creativity. In a meta-analysis, da Costa, Páez, Sánchez, Garaigordobil, and Gondim (2015) found a significant relationship between divergent thinking and creative outcome measures, with a mean effect size of $r = .27$. However, divergent thinking should not be equated with creativity; instead, it should be viewed as an indicator of the potential to think creatively (Runco, 2011). The widespread perception of divergent thinking as synonymous with creative thinking may stem from the prevalence of divergent thinking tests in creativity research. Popular tests such as the Alternate Uses Test (Christensen, Guilford, Merrifield, & Wilson, 1960) and the Torrance Test of Creative Thinking (Torrance, 1972) directly assess divergent thinking or incorporate association tasks as a significant component. Consequently, many studies investigating the relationship between creativity and associated concepts often analyze the connection between divergent thinking and these concepts.

In contrast, convergent thinking involves focusing on a single solution to a problem, typically by applying logic and analytical reasoning. Convergent thinking is essential for solving well-defined problems with clear, correct answers (Cropley, 2006). Although not typically associated with creativity, convergent thinking plays a crucial role in the creative process by helping individuals refine and evaluate their ideas. A balanced approach to studying creativity should incorporate divergent and convergent thinking to better understand the complex interplay of cognitive processes that underlie creative problem-solving and idea generation.

Emotions

Emotions are crucial in fostering creative task motivation and performance (Khalil, Godde, & Karim, 2019). Especially positive emotional states have been shown to facilitate the flow of associations and enhance creativity (Amabile, Barsade, Mueller, & Staw, 2005; Baas, De Dreu, & Nijstad, 2008). While negative emotions such as frustration and pain can also lead to increased creativity after an extended period, they initially lower task motivation (Khalil, Godde, & Karim, 2019). Due to ethical considerations, our research focuses on leveraging positive and engaging emotions to boost creative performance.

There exists a reciprocal relation between positive situational emotions and individual self-evaluation. Students experiencing positive emotions exhibit higher creative self-efficacy, engage more in learning opportunities, and report higher creative self-efficacy throughout the learning experience (Tan, Ho, Ho, & Ow, 2008). Interventions like playing games that evoke heightened emotions have improved creative performance (e.g., tabletop role-playing games, Dyson et al., 2016; short online games; Haase & Hanel, 2022). Games can enhance positive and negative emotions, depending on the content (Cheng, Huang, & Hsu, 2020; Ninaus et al., 2019), and gamifying learning content leads to increased engagement and more positive learning experiences (Zatarain Cabada, Barrón Estrada, Ríos Félix, & Alor Hernández, 2020). This connection suggests that incorporating game content in digital learning environments may positively impact creative performance by amplifying task motivation through emotions.

Creative self-concept

Connecting to the introduction of the creative mind-set, another kind of creative mind-set describes the relatively stable perception of individual creative abilities – for the sake of differentiation, we refer to it as the creative self-concept (Karwowski & Brzeski, 2017). Our study defines a creative self-concept as composed of two concepts, leading to an enduring belief in one's creative abilities – through the fixed-vs.-growth mind-set – and situational cognitive conditioning – through creative self-efficacy beliefs. The fixed-and-growth mind-set captures two contrasting perspectives on creativity development. The growth mind-set posits that creativity can be cultivated and improved through effort and practice, whereas the fixed mind-set asserts that creativity is an innate and unchangeable trait (Karwowski, 2014). In addition, creative self-efficacy is the belief in one's creative abilities (Tierney & Farmer, 2002) and is positively associated with creative outcome measures (Haase, Hoff, Hanel, & Innes-Ker, 2018). Individuals who have confidence in their creative competencies (high creative self-efficacy beliefs) and belief that effort matters (high growth mind-set are more likely to tackle creative challenges and persevere through difficulties (Beeftink, Eerde, Rutte, & Bertrand, 2012).

Study aims and hypotheses

Study Primary hypotheses

The main aim of our study is to understand the impact of preceding activities on subsequent creative tasks in a work context (Hypotheses 1 and 2; cf. Figure 1). We hypothesize that the activated arousal and the mode of thinking of the preceding task influence individual creative thinking patterns (Kaufman & Sternberg, 2019; Sassenberg et al., 2022). Based on the theory of spillover effects on modes of thinking, we hypothesize

H1: Recreational tasks such as playing a fun game will enhance divergent thinking more than doing math-game, solving arithmetic problems, and control condition, while the focused mode (solving math problems) will enhance convergent thinking more than the fun game condition and the control group.

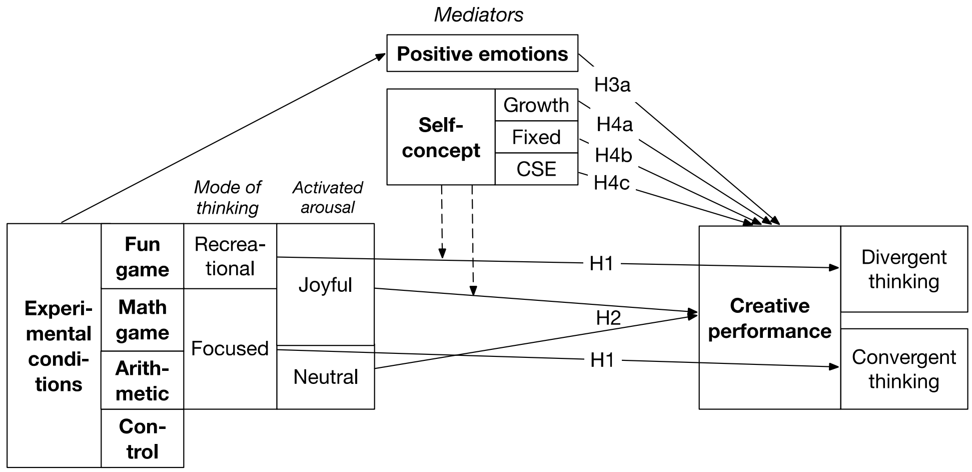

Figure 1. Overview of the experimental conditions, measurements, and moderators with expected hypotheses. Growth and fixed relate to the growth- and fixed-mindset (Karwowski & Brzeski, 2017); CSE = Creative-self-efficacy beliefs; dashed arrows refer to expected moderating effects.

Based on the connection between spillover effects and emotions, interaction with joyful tasks, like games, would facilitate a creative-free associative mind-set. In contrast, tasks eliciting neutral emotions, like math, would diminish creative performance (Redifer, Bae, & DeBusk-Lane, 2019; Xu & Schwarz, 2018). We thus hypothesize

H2: Joyful tasks (fun- and math-game) will enhance creative performances, whereas tasks eliciting neutral emotions (arithmetic condition) will worsen consecutive creative performances.

Secondary hypotheses

As secondary hypotheses we also postulate that emotions directly facilitate a creative mind-set, particularly positive ones (Amabile, Barsade, Mueller, & Staw, 2005; Baas, De Dreu, & Nijstad, 2008; Xanthopoulou & Papagiannidis, 2012). We operationalize positive emotions as those associated with excitement and happiness, while negative emotions relate to boredom, exhaustion, and frustration (cf. Baas, De Dreu, & Nijstad, 2008). Specifically, we propose an additional hypothesis related to the impact of emotions on creative performance.

H3: Positive emotions are positively correlated with creative performance.

Concerning the creative self-concept, including the individual beliefs of the adaptability of creativity in general (fixed-vs.-growth mind-set, Karwowski, 2014), and one's skills (creative self-efficacy beliefs, Tierney & Farmer, 2002), we propose that those relate to individual creative performances.

H4a: There is a positive association between a growth-mind-set mind-set and creative performance.

H4b: There is a negative association between a fixed-mind-set mind-set and creative performance.

H4c: There is a positive association between creative self-efficacy beliefs and creative performance.

Since spillover effects refer to immediate cognitive stimulation, they can also be evoked in the testing context. Subjects should perform better on the assessment presented first, depending on the experimental condition. We, therefore, expect sequence effects in the measurement of divergent and convergent thinking, for which we control for. Further, we test the potential moderating impact of the individual creative self-concept on creative performances and individual characteristics such as gender, age, and educational background. The relation of gender and creative performance is a fuzzy one, with one potential explainer between the sexes being physiologically predisposed cognitive styles (Abraham, 2016). Age and educational background both go together with the aspect of experience and skills necessary for creativity (e.g., Amabile & Pratt, 2016), which both can be higher, the older and more well-trained a person is.

Method

Participants

A power analysis conducted with G*Power 3.1.9.4 (Faul, Erdfelder, Buchner, & Lang, 2009) revealed that to identify a small-to-medium effect size of f = 0.15 with a power of 0.95 in a one-way factorial design with four levels, a minimum sample size of 768 participants was necessary. The four levels are the four conditions: fun game, math game, math, and control. In total, 874 participants were recruited online via Prolific and compensated with US-$11 per hour. Participants were English native speakers from the UK or the USA. 21 participants withdrew their consent, 39 reported not having been able to play the game because of technical difficulties, and another 2 for not provided any answer to the divergent thinking task and were therefore excluded. The final sample consisted of 813 participants (M_{age} = 40.29, SD = 12.36; 379 men, 385 women). 92 participants were students. 667 participants were white, 43 Asian, 20 Black, 28 mixed, and 6 other. 311 participants had an undergraduate degree, 137 had a graduate degree (e.g., MSc, MA), 134 had a high-school diploma (A-levels), 80 had technical or community college, 76 secondary education, 19 a PhD, and 7 had no formal qualification.

Material and procedure

We used a one-factorial between-subject design with four levels. The study lasted approximately 17 minutes (13 minutes for participants in the control group). Games were incorporated into the online survey as embedded web pages using HTML. The specific games were selected based on a pilot study: eight participants were presented with six HTML-based online games in random order. Participants were instructed to play each game for approximately 5 minutes and then share their associations and thoughts on the type of cognition necessary to play the game. To prevent the influence of previous games on the evaluation of subsequent ones, participants assessed one game per day. Based on the participants' comments, a bubble-shooter game (see Figure 2, left panel, https://doondook.studio/games/bubble-up/v1.0.5/) was selected for the joyful-recreational task (fun game condition). Participants described it as engaging, joyful, and offering numerous potential actions simultaneously. A math game was chosen for the joyful-focused task (math-game condition). Here, blocks with numbers had to be connected so that a target number results. The level is won when all the blocks are connected (see Figure 2, right panel; https://doondook.studio/games/new/equalz/). Participants reported it as fun, engaging, and somewhat tricky as it requires a specific solution path. For the neutral-focused task (arithmetic condition), participants tackled arithmetic problems (e.g., 20 + x = 67; 45–33 = x; 80/x = 4): Participants were given a random list of 90 problems and instructed to complete as many as possible.

Participants were randomly assigned to one of the four conditions in our main experiment. 1. The bubble-shooter game that permitted multiple solutions (fun game condition). 2. The math game, which required simple calculations (math-game condition). 3. Arithmetic tasks (arithmetic condition). Participants were allotted three minutes for each of the three

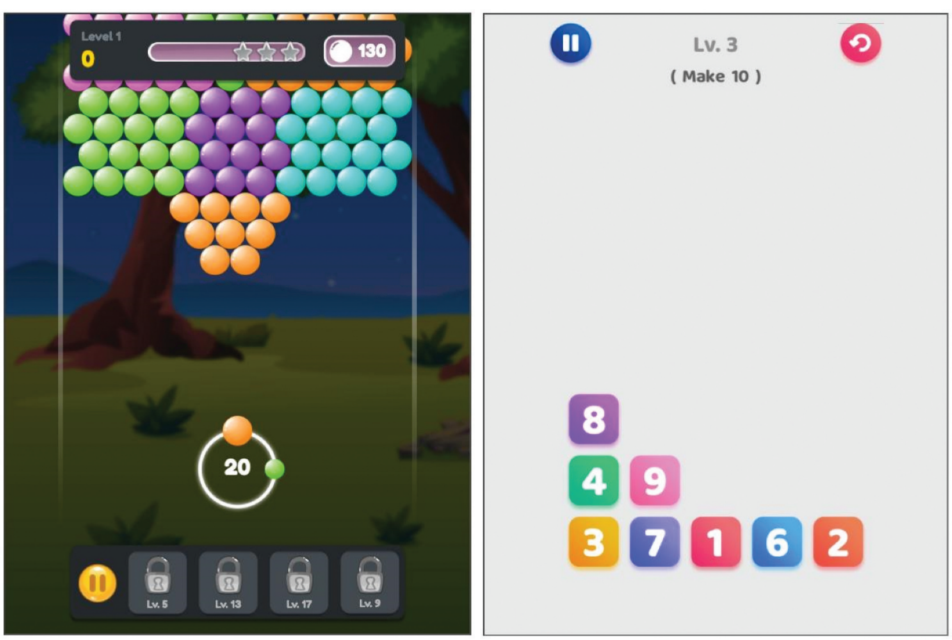

Figure 2. Bubble-shooter game used as prime in the fun game condition (left), and the math game used for the math-game condition (right).

conditions to play the game or solve arithmetic problems. Lastly, the fourth condition served as a passive control group. Subsequently, all participants completed two assessments of creative performance. For divergent thinking, they undertook the Alternate Uses Task (AUT; Christensen, Guilford, Merrifield, & Wilson, 1960), with the prompt "shoe," asking, "What can you do with a shoe?." Divergent thinking scores for fluency and originality were evaluated as measures of creative output's quantity and quality (Reiter-Palmon, Forthmann, & Barbot, 2019). Fluency was quantified, and originality scores were assessed using an automated scoring method called Ocsai (Open Creativity Scoring with Artificial Intelligence, https://openscoring.du.edu/scoringllm). This method employs deep neural network-based large-language models trained and evaluated using an extensive collection of human-judged AUT responses, consisting of over 27 thousand responses from nine studies. In line with the authors' recommendations, our study utilized the gpt-DaVinci model (Organisciak, Acar, Dumas, & Berthiaume, 2023). The automated scoring method calculates the originality level of each answer on a scale of 1.0–5.0. For the prompt "shoe," the gpt3-DaVinci model's assessments correlate with human ratings at $r = .91$ (Organisciak, Acar, Dumas, & Berthiaume, 2023; see also Haase & Hanel, 2023).

The Remote Associates Test (RAT) assessed convergent thinking (Bowden & Jung-Beeman, 2003). The test requires individuals to form connections and associations between distinct concepts, emphasizing their ability to think convergently and find the correct solution. Participants are presented with three seemingly unrelated words and asked to find a fourth word that connects or relates to all three. Participants were asked to complete two sets of 10 items and were given three minutes each. The difficulty of the RAT items ranged from very easy to very difficult and was presented randomly. The RAT score was calculated as the total number of correct responses. The order of the AUT and the RAT were randomized. We explored whether the order impacted the outcome (see Exploratory Analysis subsection below).

In both games and arithmetic conditions, participants' emotions were evaluated before and after the intervention with six items: bored, exhausted, excited, frustrated, happy, and active. Responses were given on a scale from 0–100%. A principal component analysis revealed that all items loaded on one component. Hence, the three negatively worded items were reverse scored and averaged (a_t1 = .71, a_t2 = .73) with high test-retest reliability (r_{it} = .63, $p < .001$). Additionally, however, we decided to also analyze the positive (a_t1 = .74, a_t2 = .80, r_{it} = .72, $p < .001$) and negative (a_t1 = .64, a_t2 = .61, r_{it} = .66, $p < .001$) emotions separately to test whether the effects were moderated by valence.

After the games or arithmetic task, participants rated the concentration level needed when playing, their excitement, and the perceived difficulty from 0–100%.

Creative self-efficacy (CSE) was measured using the 3-item scale proposed by Tierney and Farmer (2002; α = .89). An example sample item was, "I have confidence in my ability to solve problems creatively." Fixed and growth mind-sets were assessed using the 10-items Creative Mindset Scale (CMS, Karwowski, 2014). Example items included "Some people are creative, others aren't, and no practice can change it," fixed mind-set, α = .81) and "Anyone can develop his or her creative abilities up to a certain level," growth mind-set, α = .74). Both scales, CSE and CMS, were administered at the end of the survey, as they measure stable constructs (Karwowski, 2016; Tierney & Farmer, 2011). Including them prior to the manipulation might have resulted in priming CSE or CMS, which would have been a threat to the validity.

The full data set and data-analysis R-script can be found on OSF: https://osf.io/ubr9t/?view_only=7e55aae5bbd84d6aab2c2c4391822ca8.

Results

Primary hypotheses

To test Hypothesis 1 – recreational tasks improving divergent thinking, whereas focused tasks improving convergent thinking – we ran three one-way between-subjects ANOVA, one for each dependent variable fluency, originality, and RAT. Only the last one was significant (Table 1). Follow-up Tukey-HSD tests revealed that participants in the math-game condition scored lower on the RAT than in the other three conditions, $ps < .033$, cf. Figure 3 (Figure S1-S3 in Supplemental material). Thus, Hypothesis 2 – joyful tasks like games improving and neutral tasks such as arithmetic worsening creative performance – was also not supported. Importantly, none of these effects were moderated by the order in which the AUT and RAT were presented. In other words, the effect of our condition was not dependent on whether participants completed the AUT first or the RAT first.

Secondary hypotheses

To test Hypothesis 3 – positive emotions are associated with better creative performance – we correlated positive emotions with fluency, originality, and the RAT-

Table 1. Descriptive statistics of the creative measurements of the four experimental conditions, with ANOVA results comparing the conditions.

	Fun game		Math game		Arithmetic		Control		ANOVA		
	M	SD	M	SD	M	SD	M	SD	F	p	$\hat{\eta}^2_G$
AUT-F	10.50	5.23	10.12	5.82	11.10	5.90	9.86	5.25	1.92	.124	.01
AUT-O	2.58	0.68	2.52	0.66	2.51	0.61	2.63	0.69	1.65	.177	.01
RAT	6.25	3.95	5.24	3.70	6.36	3.42	6.74	3.80	5.52	<.001	.02
ΔEmotion	8.76	12.25	4.06	13.13	3.13	11.91	/	/	11.14	<.001	.04
+ΔEmotion	6.35	14.76	0.55	17.14	1.02	14.10			7.75	<.001	.03
−ΔEmotion	−11.17	14.94	−7.56	15.90	−5.24	16.08			7.18	<.001	.03
CSE	4.7	1.21	4.61	1.3	4.66	1.31	4.48	1.24	1.18	.317	.00
Concen-tration	41.74	24.56	59.16	24.03	76.37	21.3	/	/	105.77	<.001	.28
Difficulty	17.83	24.46	35.76	26.25	41.74	25.11	/	/	45.19	<.001	.14
Excitement	52.04	25.15	47.69	25.01	51.05	28.56	/	/	1.11	.332	.00

AUT-F = Fluency, as the number of generated ideas; AUT-O = Originality of generated ideas (divergent thinking); RAT: Remote Associates Test (convergent thinking); ΔEmotion: Positive emotions pre-task - positive emotions post-task; CSE: Creative self-efficacy. Concentration, difficulty, and excitement refer to perceptions towards the game/task.

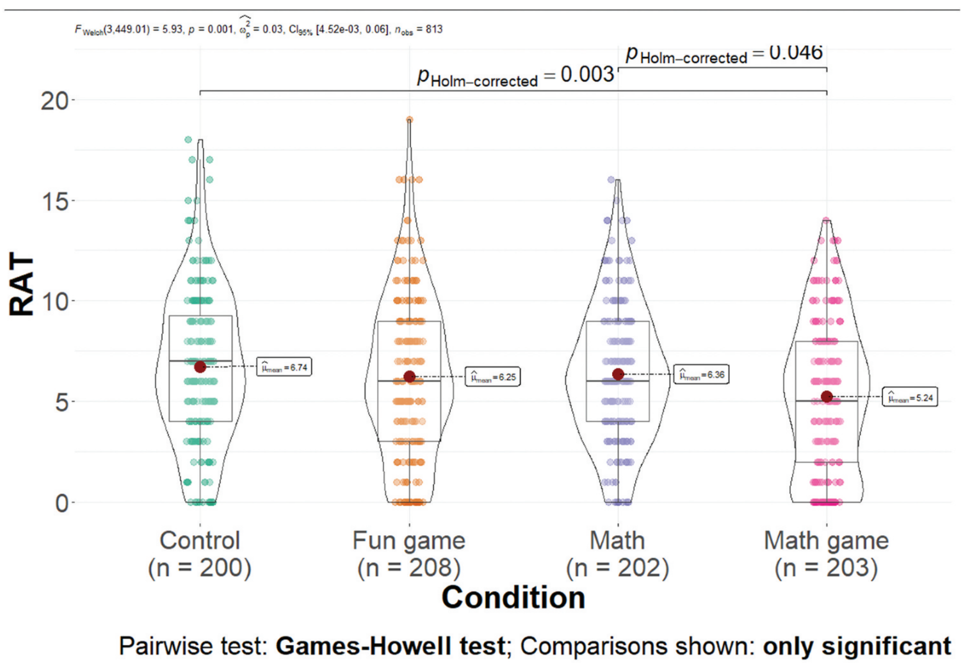

Figure 3. Comparing experimental conditions on the RAT.

score (Table 2). However, positive emotions were uncorrelated with all three creativity measures. The only exception was fluency, which correlated negatively with emotions before the game, $r(572) = -.10$, $p = .012$, indicating that participants who produced fewer ideas tended to report more negative emotions before the experimental intervention.

Further, fluency was positively correlated with creative self-efficacy and a growth mind-set and negatively with a fixed mind-set supporting Hypotheses 4a-4c. However, contrary to our prediction, originality and the RAT-score were uncorrelated with creative self-efficacy, growth, and a fixed mind-set. Thus, Hypotheses 4a-4c are only partly supported.

Exploratory analysis

To test whether there are ordering effects of RAT-first vs. AUT-first, we ran two analyses, for each order: first, for participants who did the AUT first, we ran two independent sample *t*-tests with AUT presented first vs. second as a between-subject factor. For originality, participants who completed the AUT first scored higher on originality ($M = 2.64$, $SD = 0.65$) compared to those who completed the AUT after the RAT ($M = 2.49$, $SD = 0.65$), $t(772) = 3.26$, $p = .001$, $d = 0.24$. For fluency, participants who completed the AUT first did not score higher on fluency ($M = 10.15$, $SD = 5.04$) than those who completed the AUT after the RAT ($M = 10.49$, $SD = 6.08$), $t(772) = -0.86$, $p = .391$.

Table 2. Correlations between all variables.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	AUT-O																	
2	AUT-F	−.17***																
3	RAT	.20***	.05															
4	CSE	−.04	.10**	.04														
5	Growth	0	.09	−.07	.37***													
6	Fixed	−.08*	−.11**	.01	−.20***	−.46***												
7	Emo1	.04	−.06	−.01	.21***	.12**	.02											
8	Emo2	.08*	−.10*	−.02	.17***	.11*	.02	.70***										
9	ΔEmo	.03	−.06	−.02	−.03	0	−.01	−.44***	.34***									
10	+Emo1	−.01	−.07	−.07	.22***	.12***	.06	.81***	.60***	−.31***								
11	+Emo2	.06	−.14***	−.03	.15***	.09*	.09*	.59***	.85***	.29***	.72***							
12	+ΔEmo	.06	−.10*	0	−.05	.02	.01	−.22***	.41***	.80***	−.28***	.47***						
13	-Emo1	−.07	.02	−.05	−.12**	−.07	.04	−.81***	−.54***	.41***	−.32***	−.26***	.09*					
14	-Emo2	−.08*	.01	.01	−.13**	−.08	.08	−.53***	−.76***	−.25***	−.20***	−.31***	−.17***	.66***				
15	-ΔEmo	.01	0	.03	0	.02	.03	.49***	−.13**	−.81***	.23***	0	−.30***	−.57***	.24***			
16	Concentration	−.03	−.06	0	.01	.01	.02	.13**	.12**	−.02	.14***	.15***	.02	−.07	−.03	.06		
17	Difficulty	−.02	.01	.06	−.02	.01	.11**	.09*	−.05	−.18***	.14***	.04	−.12**	−.02	.13**	.16***	.38***	
18	Excitement	−.02	−.08	−.06	.10*	.09	.04	.31***	.56***	.28***	.32***	.58***	.39***	−.19***	−.29***	−.07	.31***	.11**

Emo1: Emotions pre-task (higher scores indicate more positive emotions); Emo2: Emotions post-task (higher scores indicate more positive emotions); *Δ*Emo: Emotions pre-task - positive emotions post-task; +Emo1: Positive emotions pre-task; +Emo2: Positive emotions post-task; +*Δ*Emo: Positive emotions pre-task - positive emotions post-task; -Emo1: Negative emotions pre-task; -Emo2: Positive emotions post-task; −*Δ*Emo: Positive emotions pre-task - positive emotions post-task; AUT-O = Originality of generated ideas (divergent thinking); AUT-F = Fluency, as the number of generated ideas; RAT: Remote Associates Test (convergent thinking); CSE: Creative self-efficacy; Growth: Growth mindset; Fixed: Fixed mindset; Concentration, difficulty, and excitement refer to perceptions towards the game/task. $*p < .05$, $**p < .01$, $***p < .001$.

Second, for those participants doing the RAT first, we ran one independent sample *t*-test with the RAT presented first vs. second as a between-subject factor. Participants who completed the RAT first did not score higher on the RAT ($M = 6.36$, $SD = 3.58$) than those who completed the RAT after the AUT ($M = 6.55$, $SD = 3.59$), $t(772) = 0.73$, $p = .466$.

To test the effect of tasks on emotions, excitement, perceived difficulty, and concentration, we ran another series of one-way between-subject ANOVAs (Table 1). Interestingly, playing the fun game increased people's positive emotions more than playing the math game or solving the arithmetic questions, *p*s < .001, as a TukeyHSD follow-up test revealed (Figure S4 in Supplemental material). Similarly, playing the fun game reduced negative emotions compared to solving arithmetic questions (Figures S5-S6). Further, concentration was highest when solving the arithmetic tasks and lowest when playing the game, with the math game being in the middle (*p*s < .001 for all three pairwise comparisons). Interestingly, solving the arithmetic tasks and playing the math game were perceived as more difficult than playing the fun game, *p*s < .001, but the former two conditions did not differ significantly (Figure S7-S9 in Supplemental material). Finally, the tasks did not impact CSE and excitement (Figure S10 in Supplemental material).

Further, we tested whether the effect of condition on originality, fluency, and the RAT-score were moderated by positive emotions pretest, creative self-efficacy, growth, and a fixed mind-set, as well as gender and age. Of the 3 (DVs) x 6 (moderators) = 18 moderated regressions with the control group as the reference group, only age interacted with arithmetic vs. control condition for originality, $B = -.02$, $SE = .005$, $p < .001$. Note that because of the large number of comparisons, we had set our alpha threshold to $.05/18 = .0028$. Follow-up analyses revealed that the difference between the arithmetic and control conditions was not significant for younger participants, $p = .89$. Still, older participants achieved higher originality scores in the control condition ($M = 2.86$, $SD = 0.65$) than in the arithmetic condition ($M = 2.46$, $SD = 0.61$), $p < .001$. Thus, indicating that arithmetic tasks reduce the originality scores of older but not younger participants.

Finally, we tested whether emotions moderated the effect of condition on fluency, originality, and convergent thinking (RAT), because past research suggested that emotions might also function as a moderator (Xanthopoulou & Papagiannidis, 2012). The interaction of pretest emotions with control vs math game was significant for the RAT score, $B = .05$, $SE = .02$, $p = .017$. Follow-up analyses revealed that when participants were experiencing lower levels of pretest emotions (i.e., below median), participants in the math game condition scored lower on the RAT ($M = 4.83$, $SD = 3.86$) than in the control condition ($M = 7.05$, $SD = 3.90$), $p < .001$. When participants experienced higher levels of emotions (above median), this difference was not significant, $p = .213$.

Discussion

Our study examined the influence of engaging in short games and arithmetic tasks on creative performance compared to a no-intervention control condition. Contrary to our expectations and related experimental research (Haase & Hanel, 2022), the findings indicate that creativity, as measured through divergent and convergent thinking, was not influenced by prior interaction with games or arithmetic tasks (cf. Figure S1-S3 in the Supplemental material). Specifically, the experimental results lack support for Hypothesis 1 and Hypothesis 2, which posited that recreational tasks would improve divergent thinking. In contrast, tasks requiring highly focused thinking would enhance convergent thinking, and the fun game would boost divergent thinking, while math-related conditions would boost convergent thinking. The results did not support these predictions, suggesting that the relationship between task types and creativity measures might be more complex than initially hypothesized. Indeed, research on multitasking shows that switching tasks overall leads to enhanced flexible thinking patterns, improving subsequent creative performances (Kapadia & Melwani, 2021). Potentially, such an effect might also be found for one task switch, as analyzed in this study. Kapadia and colleagues explain that activated energy (potentially through solving somewhat demanding math tasks) can spill over to subsequent tasks like creativity assessments.

The assessment of emotions before and past the task interaction, as well as the assessment of the task concentration and difficulty (cf. Figure S6 and S7 in the Supplemental material), indicate that the experimental conditions had an intended effect on participants: the fun game condition required somewhat less concentration and was assessed as fun and relatively easy, whereas both math-tasks were assessed as similarly difficult, with arithmetic-tasks requiring more concentration than the game. Interestingly, there are no differences between the three experimental tasks and the evaluated excitement. The range of individual assessment varies greatly for each condition, indicating that in all three task conditions, some participants found the intervention very exciting, whereas others found it very dull. However, the correlation (Table 2) shows no relation with the creativity assessments. Whether someone felt excitement from the task or found it very difficult did not seem to impact the following creative performance. Nor did the assessed emotions (which differ between the conditions, with games inducing more fun, cf. Figure S4 in the Supplemental material) relate to differences in individual creative performances. Exploratory analysis show that emotions play a moderating role in the relationship between task conditions and creative thinking. Specifically, when participants had lower pretest emotional states, those in the math game condition showed significantly reduced performance in convergent thinking (RAT scores) compared to the control group. However, this effect was not observed in participants with higher emotional levels, indicating that emotional state can influence the impact of different activities on creative problem-solving.

This unexpected finding of a missing link between emotions and creative performance challenges the idea that positive emotions universally enhance creative performance. Indeed, several phenomena involving the simultaneous activation of conflicting elements have been linked to increased creativity. These include emotional ambivalence, which refers to the concurrent experience of two opposing emotions (Fong, 2006); and paradoxical framing, or mental templates that embrace seemingly contradictory statements or task dimensions (Miron-Spektor, Gino, & Argote, 2011). The experimental interventions potentially evoked several effects for some individuals: potential positive effects due to elicited emotions and thought-provoking effects for others due to the mismatch between the intervention and the following creative tasks.

The partial support for Hypotheses 4a-4c highlights the importance of individual differences in creative self-efficacy and mind-set. Fluency was positively correlated with creative self-efficacy and a growth mind-set and negatively correlated with a fixed mind-set, as expected. As the creative self-efficacy scores do not differ across conditions (cf. Figure S8 in the Supplemental material), we can rule out group differences as an alternative explanation. However, originality and the RAT score were uncorrelated with these variables, indicating that the relationship between mind-set self-efficacy and creativity might be more nuanced.

When testing the ordering effects of the divergent and convergent thinking assessments, the findings suggest that the order in which the AUT and RAT are presented influenced certain aspects of creative performance, specifically originality, but not fluency. This raises questions about the underlying cognitive mechanisms that might be differentially affected by the sequencing of these two creativity tasks. The RAT might prime or inhibit the generation of original ideas in the subsequent AUT as it requires focused thinking to solve the RAT items. Interestingly, this potential effect only leads to less original, but not fewer ideas overall.

Examining the potential moderation effects of pretest positive emotions, creative self-efficacy, growth and fixed mind-set, gender, and age on the relationship between the condition and the dependent variables yielded a significant interaction between age and the arithmetic condition for originality. This finding suggests that age may play a role in how different tasks impact creativity, with older participants experiencing a reduction in originality scores after the arithmetic condition.

In conclusion, the present study highlights the complexities of the relationship between task types, individual differences, and creative performance. The findings underscore the need for further research to better understand the factors influencing creativity and how interventions can be tailored to optimize creative potential across various contexts. Understanding the interplay between cognitive tasks and creative performance is essential for optimizing the design of research studies and work routines. By considering the spillover effects of cognitive tasks on subsequent tasks, researchers and practitioners can make informed decisions about the sequencing of activities to foster creative thinking.

Limitations

The present study has several limitations that should be acknowledged. First, the limited generalizability of our findings is a concern, as the sample drawn from Prolific may not be representative of the broader population. This restricts our ability to extrapolate the results to other groups or contexts. With participants performing the test without direct control, we cannot ensure that they have fully used the experimental condition for the given 3 min. Future research should include more diverse samples to validate and extend our findings.

Second, our choice of tasks (AUT and RAT) might not capture the full range of creative abilities or processes, potentially overlooking other aspects of creativity. On that note, these creativity assessments are somewhat artificial and lack a real-life application of actual work-related creative tasks. Other scientific methods, like ethnographical observation in the field, would be needed to ensure a more reliable assessment of the spillover effects of consecutive tasks and their impact on emotions and creative performance.

Third, the study focused on the immediate impact of tasks on creativity, leaving it unclear whether these effects persist over time or are transient. For example, the effect of our manipulations could depend on the order in which the creativity measures are presented. However, we could not find any interaction between condition and order of the creativity measures. Furthermore, our experimental administered relatively short interventions of games and arithmetic for only three minutes, which includes the risk of simply being too short of creating an actual cognitively relevant impact. Prior studies had similar short-intervention approaches and found effects on creativity (e.g., Sassenberg et al., 2022; Slepian et al., 2010); however, other designs applying games allowed longer game-play (e.g., Minas et al., 2016; Wang et al., 2018). Longitudinal research could shed light on the durability of the observed effects and their potential consequences on creative performance in the long run.

Fourth, the study may have been influenced by potential confounding variables that were not controlled for, such as individual differences, motivation, or fatigue. The controls we aimed for (emotions and task evaluation) did not reveal effects that would explain the individual performance differences. Future investigations should consider these factors and employ appropriate control measures to better isolate the effects of task sequencing on creativity.

Lastly, our reliance on self-report measures introduces the possibility of biases inherent in these methods, such as social desirability or response biases. Utilizing additional objective measures and experimental methodologies could help mitigate these biases and strengthen the validity of the findings.

Considering these limitations, further research is needed to validate and expand our findings. This includes exploring alternative task combinations, diverse populations, and a broader range of creativity measures to better understand the nuances of creative performance and its influencing factors.

Conclusion

The study explores the impact of preceding activities on creative thinking. The experimental design compared modes of thinking (recreational vs. focused) and the activated arousal of the task interaction (joyful vs. neutral). The results indicate that prior interaction with games or arithmetic tasks did not influence creativity, suggesting a more complex relationship between task types, evoked emotions, and creativity measures. The study also highlights the importance of individual differences in creative self-efficacy and mind-set. In conclusion, further research is needed to better understand the factors influencing creative performance and optimize creative potential across various contexts and task settings.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was partly supported by the German Federal Ministry of Education and Research (BMBF), grant number 16DII133 (Weizenbaum-Institute). The responsibility for the content of this publication remains with the authors.

ORCID

Jennifer Haase http://orcid.org/0000-0001-8450-7252
Paul H. P. Hanel http://orcid.org/0000-0002-3225-1395

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