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Creativity and the Simon Task Performance

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Abstract

The aim of this study was to examine performance in the Simon task regarding individual differences in creative behavior measured by The Inventory of Creative Activities and Achievements (ICAA; Diedrich et al., 2018). The study included 105 students and 57 younger working-age individuals (from 19 to 36 years of age). Three-way analyses of variance were carried out on the reaction time in the Simon task given the congruence of the previous and current trials and below/above average results on creative activities and achievements scales. The reaction time in the Simon task was on average shorter in congruent than in incongruent trials (the Simon effect), as well as in the trials preceded by congruent than in those preceded by incongruent trials. The Simon effect was only present in trials preceded by a congruent trial, while reaction times in the trials preceded by incongruent trials were shorter in incongruent than in congruent trials (the Gratton effect). However, neither the Simon nor the Gratton effect were more pronounced within more or less creative participants, but the participants with an above average result on the scale of creative activities reacted on average more slowly than individuals with below the average score. The correlations between the scores on the creativity measures and the different reaction times and indices of the Simon and Gratton effect were not significant. The expected effects related to the Simon task have been obtained in this study, but further research is needed to try to replicate the findings regarding the flexibility of inhibitory control measured by performance in the Simon task and creative behavior.

Keywords: creativity, Simon task, Gratton effect, inhibitory control

Introduction

Despite the potential for wide applications of the findings within the field, the study of creative cognition is a relatively young scientific field of growing popularity. In the cognitive approach to creativity, the focus is placed on elementary cognitive

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processes that are believed to underlie creative thinking and on interindividual differences in the use of these mechanisms. The basic premise of this approach is that individual differences in creativity can be largely described in terms of elementary cognitive processes, i.e., differences in the manner of combining certain processes, the intensity of their application, the flexibility of cognitive structures to which the processes are applied, working memory capacity, and similar processes (Benedek & Fink, 2018). According to various models of creative thinking, such as the Geneplore model (Finke et al., 1992), the Model of the dual state of creative cognition (Howard-Jones, 2002), and the Model of the dual path to creativity (Nijstad et al., 2010), it is the flexible change of cognitive processes, which, among other things, also differ in the degree of cognitive control, that fosters creativity. In other words, a combination of associative and controlled processes seems to be most appropriate for the generation of new and contextually appropriate ideas. Associative processes allow for unusual conceptual associations, while controlled processes provide an evaluation of the importance and appropriateness of the associations for a current problem or situation (Chrysikou, 2018).

Inhibitory control is an executive function, and its most important aspect relates to the ability to exploit the influence of internal goals on top-down processing, when there is a potential conflict between competing representations or task requirements. This is particularly pronounced in situations where goal-related processing refers to new and still insufficiently established behavior, and, to successfully achieve a goal, it is necessary to ignore disruptive information or reacting out of habit (Egner, 2017). The most known examples of response inhibition tasks are the Stroop task (Stroop, 1935), Eriksen Flanker (Eriksen & Eriksen, 1974), negative priming (e.g., Vartanian et al., 2007; Dorfman et al., 2008), and the Simon task (Simon & Small, 1969). A typical finding is that the reaction time is longer and the error rate is higher when a relevant and irrelevant characteristic (for the task) are associated with different responses (incongruent trials) than when they are related to the same response (congruent trials), which is referred to as the congruence effect. A slower response in incongruent trials can therefore be considered an index of the relative effectiveness of cognitive control, so a higher level of descending control should be associated with a smaller congruence effect (Cohen et al., 1990). The congruence effect depends on the contextual information in a task – the frequency of incongruent trials and congruence of the previous trial. The congruency proportion effect refers to the fact that the difference in reaction time between incongruent and congruent stimuli is smaller in a set with more incongruent stimuli than the one with more congruent stimuli, while the series congruency effect or Gratton effect implies a smaller congruency effect after incongruent than congruent trials (Gratton et al., 1992).

The findings of experimental studies of the relationship between inhibitory control and creativity are quite inconsistent and can be classified into three general points of view. Some earlier models emphasize the role of automatic processes in creative thinking, i.e., the lack of inhibitory control is considered to favor the creation of more distant associations and intuitive thinking, which in turn favors the development of original ideas (Eysenck, 1995; Martindale, 1999). In contrast, the results of a part of the research highlight the importance of executive functions in creative processes, especially in divergent thinking. It is hypothesized that generating more creative ideas primarily requires the inhibition of dominant and common pathways leading to fixation effects (Benedek et al., 2012; Camarda et al., 2018; Edl et al., 2014). According to a third point of view, creativity is associated with a flexible modulation of cognitive control, i.e., inhibition. Namely, it was found that creativity was positively associated with the reaction time in tasks requiring the inhibition of interfering information (negative priming), while in non-interference tasks creativity and the reaction time were negatively associated (concept verification task) (Dorfman et al., 2008; Vartanian et al., 2007). Zabelina and Robinson (2010) also found that creativity, operationalized both as divergent thinking and creative achievement, is positively associated with the flexibility of inhibitory control in the Stroop task. The authors assumed that more creative people better recognize and use the value of automatic processing and, therefore, in a context where control does not seem necessary, do not interrupt it. Since congruent trials do not cause interference (signaling that control is not needed), more creative individuals "relax" control resources, which results in a greater effect of interference in subsequent trials, and ultimately greater modulation of inhibitory control. It is important to emphasize that the cognitive control of creative individuals in this case is not observed in terms of stable characteristics, but in terms of changing states (modulation "from one trial to another").

The inconsistency of the results of research on the relationship between inhibitory control and creativity is largely caused by different conceptualizations and operationalizations of these constructs, making direct comparisons of findings difficult. The processes assumed to underlie volitional inhibitory control are most often examined using the conflict paradigm, but although the Simon, Stroop, and Eriksen Flanker tasks are often considered very similar, there are certain differences between them. For example, although in the Stroop and Simon tasks interference arises as a result of conflict, its sources are not the same, and there are indications that it appears in different stages of processing (Scerrati et al., 2017). Interference in the Stroop task can arise between 1) two dimensions of a stimulus (i.e., word and color), causing semantic or stimulus conflict and 2) two contrasting response alternatives (i.e., a response key attributed to a word vs. response key attributed to a color), resulting in response conflict (Scerrati et al., 2017; Van Den Wildenberg et al., 2010). In the Simon task, interference is the result of conflict between irrelevant characteristics of the stimulus and response (Van den Wildenberg et al., 2010). Even in a simple version in which participants respond by pressing keys, conflict is possible between the representational characteristics of the stimuli and between the representational responses associated with relevant and irrelevant characteristics. For example, if participants are instructed to respond to the color red with the left key, and the incongruent word "green" appears, poorer performance may result from a conflicting representation of the two stimulus characteristics (color and word meaning) or/and from two responses related to green and red color. The nature of the Stroop interference effect seems to be composite, that is, it seems that task, semantic, and response conflicts are coexisting (Burca et al., 2021). These multiple conflicts make it difficult to directly interpret the effects, which makes the Simon task a theoretically and methodologically "cleaner" measure (Hommel, 2011). Thus, one would choose the Simon task as a measure with fewer sources of conflict. Therefore, this study sought to verify findings in terms of the relationship with creativity using the Simon task.

Furthermore, creativity is operationalized in most of the mentioned research with tests of divergent thinking, which is not the same as creative thinking, but represents its potential (Plucker et al., 2006). For a broader understanding of the construct, it is necessary to consider some other aspects of creativity, such as creative achievements and creative activities that people engage throughout their lives. The number of studies on the relationship between inhibitory control and creative behaviors is very small, and the results are inconsistent (Edl et al., 2014; Zabelina & Robinson, 2010). This research, therefore, aimed to examine the effect of inhibitory control measured by the Simon task regarding individual differences in creative behaviors (activities and achievements).

Given several empirical findings on the Simon and Gratton effect (Gratton et al., 1992; Kerns, 2006; Simon & Small, 1969), we first assumed that these effects would be found in this study as well. The Simon effect is manifested through a prolonged reaction to incongruent (the stimulus and response are on opposite sides) in comparison to congruent trials (the stimulus and response are on the same side). The Gratton effect would be manifested through an interaction of the congruence of the current and the previous trial, i.e., the effect of sequence congruency (Gratton et al., 1992), indicating the flexibility of cognitive control (Kerns, 2006). In other words, the Gratton effect implies a smaller congruency (Simon) effect after incongruent than after congruent trials. More specifically, the difference in the reaction time between congruent and incongruent trials following incongruent trials is smaller than when following congruent trials. When it comes to interpretations of the sequence congruency effect, it is still unclear which exact process(es) underlie it. One point of view, which includes several models such as the conflict monitoring model (Botvinick et al., 2001), expectation model (Gratton et al., 1992), and negative affect model (Dreisbach & Fischer, 2012), highlights trial-by-trial adjustments of attention/effort (Schmidt & Weissman, 2014). More precisely, these accounts propose that congruency in the current trial impacts the attention distribution in the next trial in a way that reduces the size of the congruency effect. Another explanation of the effect has to do with learning and memory processes, which are confounded with sequence congruency. The Feature integration Model (Hommel, 2004) proposes that the performance adjustments are the result of complete repetitions or changes of stimuli. The contingency learning account views the sequence congruency effect as a result of the strengthened association between a distracter and the congruent response (Schmidt & De Houwer, 2011).

Furthermore, given the results of studies reporting that more creative individuals have slower reactions in tasks that require the inhibition of interfering information than less creative individuals (Dorfman et al., 2008; Vartanian et al., 2007) and that their attention filter lets more 'irrelevant' information through (Zabelina et al., 2015), it was assumed that the reaction time in the Simon task would be associated with higher results on the measures of creative activities and achievement. In addition, given that flexibility in the alteration of less and more focused states is considered most suitable for creativity (Chyrsikou, 2018; Sowden et al., 2015), it was assumed that the Gratton effect (a more pronounced Simon effect) after congruent trials, and a less pronounced or reversed Simon effect after incongruent trials would be associated with higher results in the creativity measures.

Method

Participants

The study involved 162 participants from Croatia, of which 105 were students and 57 were individuals from the younger working population (total length of service: M = 4.42, SD = 2.8). The aim was to recruit participants who would be heterogenous according to their levels of creativity, to obtain greater variability of results on the creativity measures. We did not consider it plausible to divide students according to their creative studies/professional vs. other orientation, because someone could be, for example, a medical student and have creative hobbies and achievements. However, there is a greater likelihood that there will be those pursuing creative activities and achievements among those who do it professionally. Among the students, 24 of them were studying creative courses, with architecture students and design students (industrial, fashion, graphic, and visual communication design) being the most represented. Among the working population, 17 of them were engaged in creative occupations, of which architects and graphic designers were also the most represented. Of other creative studies and occupations, there were one to two in fine arts, academic restoration and conservation, music, dance and choreography, culinary arts, writing and academic graphics, and film and video. Other students and professionals represented fields of humanities and social sciences (mostly linguistics and languages and psychology), computer sciences, engineering and technology, and social work. The age range was from 19 to 36 years (M = 25.92, SD = 3.8), and the sample consisted of 66 men and 96 women.

Measuring Instruments

The sociodemographic data questionnaire contained questions on age, gender, study orientation, occupation, and job position, as well as on the total and current length of service.

The Inventory of Creative Activities and Achievements (ICAA; Diedrich et al., 2018) was used as a measure of creativity. The inventory consists of two scales that measure creative activities (1) and achievements (2) through eight separate domains – literature, music, arts and crafts, creative cooking, sports, visual arts, performing arts, and science and engineering (an English (https://osf.io/ht98r), German (https://osf.io/u8yws), and French (https://osf.io/c3q9s) version is available via the Open Science Framework Creativity and Arts Tasks and Scales: Free for public use at https://osf.io/4s9p6/). *The Scale of Creative Activities* measures the frequency of performing these activities in the last 10 years. Responses are recorded on a 5-point Likert scale, with 0 denoting the answer '*never*' and 4 '*more than 10 times*'. *The Creative Achievements Scale*, on the other hand, contains 11 different levels of achievement for each of the domains, with participants responding by marking all the levels they achieved in each domain, ranging from *"I have never been involved in activities in this domain"* to *"I have already sold my work in this domain"*. For the purposes of this study, the inventory was translated to Croatian, and a satisfactory reliability was determined calculating the Cronbach alpha coefficient α = .88 for the scale of creative activities and α = .90 for the scale of creative achievements. The Croatian version is provided in the Supplementary materials.

The Simon task (Simon & Small, 1969) was used as a measure of inhibitory control, i.e., a measure of individuals' ability to inhibit irrelevant stimuli, one of the functions of inhibitory control (Manard et al., 2014). This version of the Simon task consists of responding to a stimulus color with a correspondent key, ignoring its location (e.g., a green stimulus is always responded to with the left key, regardless of whether it is depicted on the left or right on the screen). To create and present the task, an online version of PsyToolKit experiment creation software was used (http://www.psytoolkit.org; Stoet, 2010, 2017a). The reaction time experiment is not computationally intensive and can run reliably on standard desktop computers (for a demo, see http://www.psytoolkit.org/psychological_research_demo). The PsyToolkit option was used to exclude mobile devices (phones and tablets), which are known for their unreliable reaction time measurement. The stimuli, which consisted of red and green circles, were presented on a black background of a computer screen. First, a fixation cross was presented at 300 ms, and then a stimulus (one red or green circle at a time) would appear to the left or right of it, at a maximum of 2000 ms or until a keystroke response occurred. The task of the participants was to react to the green stimulus with the right key, i.e., to press the "l" key with their index finger, or to react to the red stimulus with the left key, i.e., to press the "a" key with their index finger, regardless of the location of the stimulus. Each trial was either congruent (green circle presented on the right and red on the left) or incongruent (green circle presented on the left and red on the right). The task was divided into 5 blocks – one for training and four experimental, and the participants themselves determined when to continue to the next block by pressing the space bar. Each block consisted of 21 trials, and, except for the exercise block, the order of the blocks was rotated randomly, with the goal of balancing different conditions (combinations) and minimizing possible systematic effects. Given that the impact of the trials that preceded the current trial was also important for the task, the trials were coded in pairs, in four possible combinations: CC (a congruent trial preceded by a congruent trial), CI (an incongruent trial preceded by a congruent trial), IC (a congruent trial preceded by an incongruent trial) and II (an incongruent trial preceded by an incongruent trial). Each block consisted of 20 pairs of trial combinations, with each combination being presented equally often. In other words, within each block, each of the four combinations of pairs appeared five times. The number of congruent and incongruent trials was also standardized in such a way that a total of 42 congruent and 42 incongruent trials were presented in all four experimental blocks.

Procedure

The survey/online experiment was conducted in the period from October to December 2018. The link with the online experiment and questionnaires was published in several groups on Facebook social network and was forwarded to the Croatian Society of Designers. Considering the limited capacity of attention, all participants first solved the Simon task, and then the two questionnaires rotated randomly. The study was approved by the Ethical Committee of the Department of Psychology at the University of Zadar.

Analytic Strategy

The data analysis was conducted using the program STATISTICA 13.5 and started with the inspection and exclusion of extreme results from the research data. The participants were divided into two groups according to a below and above-average result on a) the scale of creative activities and b) the scale of creative achievement and further analyses were conducted considering this division. The distribution and descriptive statistics of the results in each variable for each group of participants were checked to ensure the preconditions for the use of parametric analyses were satisfied. To answer the research questions and test the research hypotheses, two three-way analyses of variance were conducted (3 X 2 mixed samples design). One analysis was carried out to compare the reaction times in congruent and incongruent previous and current trials in the Simon task of those with below average results on the creative activities scale to those with above average results. Another analysis was carried out on the reaction times in the Simon task given the congruence of the previous and current trials and below/above average results on the creative achievements scales. Additionally, bivariate correlations between the creativity measures and the reaction times of different trials in the Simon task, along with the calculated indexes of the Simon ($M_{NONCONGRUENT}$-$M_{CONGRUENT}$) and Gratton effect [($M_{CONGRUENT/NONCONGRUENT}$-$M_{CONGRUENT/CONGRUENT}$) - ($M_{NONCONGRUENT/NONCONGRUENT}$-$M_{NONCONGRUENT/CONGRUENT}$)] were calculated to examine whether they are in line with the findings obtained in the analyses of variance, where the results in the measures of creativity were dichotomized.

Results

All reaction times deviating from the average by more than 3 standard deviations as well as incorrect responses were not included in the analysis (this was a setting of the program). The average accuracy of the responses was high, with the average error rate being significantly higher in incongruent (M = 6.06%, SD = 5.77) than in congruent (M = 3.37%, SD = 4.00) trials ($t(322) = - 4.87$, p <.01). Since the results on the scale of creative activities were normally distributed, two groups of less and more creative individuals were divided according to the arithmetic mean, while on the scale of creative achievements the groups were determined according to the median (Table 1).

Table 1

Descriptive Parameters of Reaction Time in the Simon Task Variables for Groups of Participants Divided in Two Groups According to the Result on the Used Scales

	Variable		*M*	*SD*	Range	*K-S d*	*S*	*K*
a) Creative activities $N_1 = 77, N_2 = 85$	CC	1	423.36	53.4	337.15-624.45	$p > .20$	1.19	2.40
	CI	1	478.47	69.78	370.74-836.60	**$p < .05$***	2.25	8.88
	IC	1	465.17	66.62	354.30-690.00	$p < .20$	0.96	0.84
	II	1	462.33	59.76	356.10-723.15	$p > .20$	1.31	4.38
	CC	2	444.21	59.32	352.37-642.50	$p > .20$	0.80	0.49
	CI	2	505.58	70.48	381.55-745.45	$p > .20$	0.71	0.64
	IC	2	491.08	71.16	358.65-669.85	$p > .20$	0.33	-0.56
	II	2	478.71	58.33	385.47-692.35	$p > .20$	0.61	1.06
b) Creative achievement $N_1 = 81, N_2 = 81$	CC	1	428.77	47.27	342.30-553.35	$p > .20$	0.53	-0.33
	CI	1	486.57	65.45	377.00-667.95	$p < .15$	0.76	0.07
	IC	1	473.63	65.12	367.45-624.58	$p < .15$	0.43	-0.94
	II	1	468.79	57.81	356.10-692.35	$p > .20$	0.78	1.91
	CC	2	439.83	65.78	337.15-642.50	$p > .20$	0.98	0.78
	CI	2	498.81	76.50	370.74-836.60	$p < .20$	1.67	4.90
	IC	2	483.89	74.69	354.30-690.00	$p > .20$	0.66	0.10
	II	2	473.06	61.23	359.60-723.15	$p > .20$	1.02	2.71

Note. 1 – below average result, 2 – above average result; C – congruent trial; I – incongruent trial; *S* – Skewness; *K* – Kurtosis.

Descriptive parameters on the scales of creative activities and creative achievements are in accordance with the parameters from the original research of the authors of these scales (Table 1). The distribution of results on the creative achievement scale is expected to be positively asymmetric, as most people do not reach high levels of creative achievement (Diedrich et al., 2018). Although the distributions of some variables show deviations from normality, the skewness and kurtosis indices show that there are no major deviations (S < +/-3 and K < +/- 10; Kline, 2005). For this reason, parametric analyses were used in further data analysis. To examine the differences in the reaction time with respect to the congruence of the current and previous trial and the result on the Inventory of creative activities and achievements, two three-way analyses of variance for the creative activity and the creative achievement scale were performed (Table 2 and Table 3).

Table 2

The Results of Two Three-Way Analyses of Variance to Examine the Reaction Time in the Simon Task With Respect to the Congruence of the Previous and Current Trial and the Result an A) the Scale of Creative Activities and B) the Scale of Creative Achievement (N_{a1} = 77; N_{a2} = 85; N_{b1} = 81; N_{b2} = 81)

	F	df	p	η_p^2
Creative activities (less vs. more)	6.00*	1/160	.015	.04
Congruence of previous trial (I vs. C)	28.58*	1/160	<.001	.15
Congruence of p.a. x Creative activities	0.44	1/160	.508	.44
Congruence of current trial (I vs. C)	91.55*	1/160	<.001	.36
Congruence of c.a. x Creative activities	0.10	1/160	.758	.00
Congruence of p.a. x Congruence of c.a.	220.56*	1/160	<.001	.58
Congr. of p.a. x Congr. of c.a. x Creat. activities	3.17	1/160	.077	.02
Creative achievement (less vs. more)	1.02	1/160	.313	.01
Congruence of previous trial (I vs. C)	28.41*	1/160	<.001	.15
Congruence of p.a. x Creative achievement	1.06	1/160	.305	.01
Congruence of current trial (I vs. C)	91.54*	1/160	<.001	.36
Congruence of c.a. x Creative achievement	0.21	1/160	.650	.00
Congruence of p.a. x Congruence of c.a.	220.26*	1/160	<.001	.58
Congr. of p.a. x Congr. of c.a. x Creat. achievem.	0.65	1/160	.422	.00

Note. η_p^2 = partial eta squared. $^*p$ < .05.

As expected, a significant main effect of congruence of the current trial was established (Table 2), which confirmed the classical finding of the Simon effect – the reaction time was shorter in congruent ($M_{activities/achievement}$ = 456.53; $SD_{activities/achievement}$ = 60.75) than in incongruent trials ($M_{activities/achievements}$ = 481.81; $SD_{activities/achievement}$ = 62.76). Furthermore, a significant main effect of the congruence of the previous trial was found (Table 2), where the reaction time was shorter in the trials preceded by the congruent ($M_{activities/achievements}$ = 463.5; $SD_{activities/achievement}$ = 61.16) than in those preceded by incongruent trials ($M_{activities/achievements}$ = 474.84; $SD_{activities/achievement}$ = 60.78). Also, a significant main effect of results on the scale of creative activities was determined (Table 2); individuals with an above-average result on the scale of creative activities (*M* = 479.89; *SD* = 59.22) reacted on average significantly slower than individuals with a below-average score (*M* = 457.33; *SD* = 57.78). The same main effect was not statistically significant for creative achievements (Table 2; $M_{below\text{-}average}$ = 464.44; $SD_{below\text{-}average}$ = 53.55; $M_{above\text{-}average}$ = 473.9; $SD_{above\text{-}average}$ = 64.79). The interaction of the congruence of the previous and current trial proved to be significant, in line with the expected Gratton effect (Table 2). In both groups of participants, when preceded by a congruent trial, the reaction time was shorter in congruent than in incongruent trials, while in the trials that preceded by an incongruent one, the opposite was the case – the reaction time was shorter in incongruent than in congruent trials (Table 3).

Table 3

The Results of Post-Hoc Analyses (Bonferroni Test) to Examine the Reaction Time in the Simon Task With Respect to the Congruence of the Previous and Current Trial and the Result on the Scales of A) Creative Activities and B) Creative Achievement (N_{a1} = 77; N_{a2} = 85; N_{b1} = 81; N_{b2} = 81)

	Creative activities	Previous trial	Current trial	{1} 423.36	{2} 478.47	{3} 465.17	{4} 462.33	{5} 444.21	{6} 505.58	{7} 491.08	{8} 478.71
1	1	C	C		**<.01**	**<.01**	**<.01**	1.00	**<.01**	**<.01**	**<.01**
2	1	C	I	**<.01**		.11	**.01**	.32	1.00	1.00	1.00
3	1	I	C	**<.01**	.11		1.00	1.00	.08	1.00	1.00
4	1	I	I	**<.01**	**.01**	1.00		1.00	**.04**	.93	1.00
5	2	C	C	1.00	.32	1.00	1.00		**<.01**	**<.01**	**<.01**
6	2	C	I	**<.01**	1.00	.08	**.04**	**<.01**		**.03**	**<.01**
7	2	I	C	**<.01**	1.00	1.00	.93	**<.01**	**.03**		.13
8	2	I	I	**<.01**	1.00	1.00	1.00	**<.01**	**<.01**	.13	
	Creative achievements	**Previous trial**	**Current trial**	**{1} 428.77**	**{2} 486.57**	**{3} 473.63**	**{4} 468.79**	**{5} 439.83**	**{6} 498.81**	**{7} 483.89**	**{8} 473.06**
1	1	C	C		**<.01**	**<.01**	**<.01**	1.00	**<.01**	**<.01**	**.04**
2	1	C	I	**<.01**		.11	**<.01**	**.02**	1.00	1.00	1.00
3	1	I	C	**<.01**	.12		1.00	.38	1.00	1.00	1.00
4	1	I	I	**<.01**	**<.01**	1.00		.96	.79	1.00	1.00
5	2	C	C	1.00	**.02***	.38	.96		**<.01**	**<.01**	**<.01**
6	2	C	I	**<.01**	1.00	1.00	.79	**<.01**		**.03**	**<.01**
7	2	I	C	**<.01**	1.00	1.00	1.00	**<.01**	**.03**		.46
8	2	I	I	**.04**	1.00	1.00	1.00	**<.01**	**<.01**	.46	

Note. 1 – below average result, 2 – above average result; C – congruent; I – incongruent.
Bolded *p*-levels indicate differences significant at $p < .05$.

The two-way interaction effects of below/above average creativity and the congruence of the current as well as the congruence of the previous trial were not statistically significant. The three-way interaction effects of the creativity level, congruence of the previous, and congruence of the current trial were also non-significant, i.e., the Gratton effect was not significantly larger in individuals with above average creative activities/achievements than in individuals with below-average creative activities/achievements.

The bivariate correlations between the scores on the creativity measures and the reaction times of different trials in the Simon task, along with the calculated indexes of the Simon and Gratton effect were not significant when considering the entire sample (Table 4).

Table 4

Pearson Coefficients of Correlation between the Results on the Creativity Measures (Achievement and Activities) and the Simon Task Reaction Times and Simon and Gratton Effect Indexes (N = 162)

	ICAA activities	ICAA achievements
$M_{CONGRUENT/NONCONGRUENT}$	.13 $p = .109$	.04 $p = .646$
$M_{NONCONGRUENT/CONGRUENT}$	.08 $p = .284$	.04 $p = .632$
$M_{CONGRUENT/CONGRUENT}$	.11 $p = .166$	.06 $p = .439$
$M_{NONCONGRUENT/NONCONGRUENT}$	.09 $p = .238$	.03 $p = .684$
$M_{PREVIOUS\ TRIAL\ CONGRUENT}$	.12 $p = .113$	.05 $p = .528$
$M_{PREVIOUS\ TRIAL\ NONCONGRUENT}$	.09 $p = .233$	.04 $p = .635$
$M_{CONGRUENT}$	.10 $p = .203$	.05 $p = .521$
$M_{NONCONGRUENT}$	.12 $p = .143$	.04 $p = .650$
$M_{ALL\ TRIALS}$	.11 $p = .154$	.04 $p = .571$
Simon effect index	.02 $p = .765$	-.04 $p = .627$
Gratton effect index	.05 $p = .489$	-.00 $p = .970$

Discussion

The results of numerous research studies in the domain of creative cognition indicate that the cognitive processes behind creative thinking are not qualitatively different than typical cognitive processes, that is, that creative thinking is based on elementary processes that result in something extraordinary (Benedek & Fink, 2018). Knowledge on how elementary cognitive processes form creative thought can be used to enhance creative thinking (e.g., for the problem of fixation when generating ideas). Different models of dual creative processes (Allen & Thomas, 2011; Finke et al., 1992; Howard-Jones, 2002; Nijstad et al., 2010) emphasize that cognitive processes of varying degrees of control are important in different stages of creative processing. The aim of this study was to examine the effect of inhibitory control measured by the Simon task with respect to individual differences in creative behavior. We chose to use the Simon task and the Inventory of Creative Activities and Achievements, because these tasks measure different aspects of inhibitory control and creativity than are typically measured in the literature (Dorfman et al., 2008; Vartanian et al., 2007; Zabelina et al., 2015).

As expected, the Simon effect was observed, with the average difference between responding to incongruent and congruent trials being 25.28 ms, which is similar to the results of previous studies (Kerns, 2006; Stoet, 2017b). This effect was observed for both groups of participants according to the below/above average of creative activities and achievements, and the scores on the creativity measures did not correlate with the index of the Simon effect. The Simon effect is most often explained in the context of a dual-route model of response selection (Hommel, 2011; Kornblum et al., 1990) according to which there are conditioned (automatic) and unconditioned (controlled) processing paths, which take place in parallel but independently of each other. It is assumed that the conditioned path is fast and that it automatically prepares a response on the side where the stimulus appears, that is, that it connects the stimulus and response directly, based on the dimension in which they overlap (in this case the location). On the other hand, the controlled processing path is slower, allows intentional selection of responses, and connects the characteristics of the stimulus with the reaction (response) indirectly, through the task instructions. The controlled path is assumed to be activated when the automatically selected response does not follow the instructions. In congruent trials, the automatic and controlled paths activate the same code and therefore the selection of responses is simplified. Conversely, in incongruent trials, by activating different response codes (e.g., red stimulus on the right – the automatic path connects the right stimulus location to the right-hand response, while the controlled path, according to the instruction, requires a left-hand response) conflict arises, resulting in a slower response selection. The longer response time in trials preceded by incongruent trials than in those preceded by congruent trials can be explained by a greater degree of caution after experiencing conflict in incongruent trials (Zabelina & Robinson, 2010).

Furthermore, the expected interaction of the congruence of the current and the previous trial was determined, i.e., the effect of the congruence of the sequence or the so-called Gratton effect (Gratton et al., 1992). Namely, the Simon effect occurred only in trials preceded by a congruent trial, while in trials that followed an incongruent trial, the opposite effect was observed, indicating the flexibility of cognitive control (Kerns, 2006). Contrary to expectations, no three-way interaction was found between the congruence of the previous and current trial and the results on the scale of creative activities. Also, the bivariate correlation between the calculated index of the Gratton effect and the scores on the creativity measures were also not significant. In words, the flexibility of inhibitory control (the Gratton effect) was not more pronounced in more creative individuals compared to less creative individuals, which contrasts with the finding of the study conducted by Zabelina and Robinson (2010). The different findings could be a result of differences between the Stroop and the Simon task. The reaction time distributions of the two effects differ; the magnitude of the Stroop effect increases with increasing reaction time, while the magnitude of the Simon effect decreases (Hommel, 2011). Therefore, although both tasks can be used as measures of inhibitory control, the reaction time modulation levels may be different. In addition, unlike the mentioned research conducted in a laboratory, this research was conducted in the form of an online experiment, which made it impossible to control some external factors that could have affected the performance of the task such as the time of day, the level of fatigue of participants and similar. Also, it is important to note that in the aforementioned study by Zabelina and Robinson, the sample consisted of 50 psychology students who agreed to participate in the experiment in exchange for additional points in the course, which could have favorably affected their motivation. The sample in this research is three times larger and more diverse in terms of study orientations and occupations, but the level of motivation and effort they have invested in solving the task is questionable. Regarding the average reaction time and the size of the Gratton effect, a moderate positive correlation was found between them ($r = .50$; $p < .001$), that is, the longer the reaction time, the greater the Gratton effect, i.e., the flexibility of inhibitory control was more pronounced. Given that those who engage in more creative activities in this research were shown to be slower in the task on average than those who engage in a below-average amount of activities, this result follows the findings of Zabelina and Robinson (2010).

The only significant role of creativity obtained in this study was the main effect of the below/above average creative activities (but not creative achievements) on the overall average reaction time in the task. In other words, the group of participants with an above-average result on the scale of creative activities, regardless of the congruence of previous and current trials, on average reacted more slowly than the group with below-average results. This finding suggests that only engagement in creative activities, but not necessarily success in it, influences inhibitory control. In other words, not everyone who engages in a creative activity necessarily reaches creative achievement, in the sense that creative potential is important even if it is not socially recognized as an achievement. Such findings are consistent with those from the study by Dorfman and colleagues (2008), in which creativity (defined as the ability to think divergently) was positively associated with reaction times in a task requiring inhibitory control in which the level of potential interference was high, while in a non-interference task this relationship was reversed. It is assumed that a less focused state of attention can be useful in earlier stages of the creative process, when the problem itself is not yet clearly defined and, therefore, both interfering and seemingly irrelevant information could be helpful in finding a solution. A broader focus of attention thus enables the creation of more unusual and potentially more creative associations (Mednick, 1962). It is possible that more creative individuals automatically switch to a less focused state of attention in more complex tasks, which ultimately results in a slower response. This is supported by finding reporting a positive correlation between the number of creative achievements and the reduced ability to ignore “irrelevant” sensory information (Zabelina et al., 2015). However, the partial eta squared shows the size of the effect is small and the bivariate correlations between the creativity measures and the reaction times of different trials, as well as the overall average reaction time, in the Simon task, were not significant. One of the possible reasons are methodological differences, that is, the use of different measures of creativity and inhibitory control. In the study by Dorfman and colleagues (2008), creativity was operationalized by success on the Test of Alternative Uses of Subjects, which measures the ability of divergent thinking, while in our study self-assessment measures of creative behavior were used. In addition, in the aforementioned research, the measure of inhibitory control was the negative priming task, which measures automatic inhibitory processes (reactive inhibition), while the Simon task measures the voluntary or controlled suppression of a dominant reaction (Miyake et al., 2000). Given that both creativity and inhibitory control can be operationalized in multiple ways, the inconsistency of findings in this area is likely due to the measurement of different aspects of creativity and different types of inhibition. This also calls on the drawbacks of dichotomizing data, being problematic since it reduces the information contained in the data and increases the likelihood of a type 1 error (Cohen, 1983). Therefore, it is questionable to draw strong conclusions based on the only obtained effect of creativity in this study. It may be important to also consider some moderator variables of the relationship between creativity and inhibitory control such as metacognitive abilities, which would also be useful for improving techniques to encourage creative thinking.

Suggestions for Future Research and Implications

Alongside the already mentioned drawback of dichotomizing the sample according to the results on the creativity measures, one of the disadvantages of this research was the inability to control the influence of external factors, as mentioned before. Due to the experiment being conducted online, it is questionable whether (and to what extent) all participants, in accordance with the instructions, provided conditions in which they could completely focus on the task, and it is also possible that they used different strategies not including active inhibition. The variability of the results could have also been influenced by the time of day at which the participants solved the task, since the processes of executive functions show a circadian rhythm (Lustig et al., 2007). Although there are findings that data collected online are generally similar to lab-collected data (e.g., Buso et al., 2021; Crump et al., 2013) this is true when the subjects truly take the task seriously and ensure appropriate external conditions. It could, in any case, be useful to conduct this research in a laboratory setting as well to verify the results. Also, there were five experimental trials per participant for each of the four combinations made (congruent/incongruent-C/I, C/C, I/I, and I/C) which is a relatively low number compared to the number of combinations and elicits the question of whether multiple comparisons could have affected the results. However, considering the total number of trials per participant in the overall task (84) and the other instruments that were to be completed, we believe that the number is sufficient, lowering the cases of motivation decrease and fatigue increase and, thus, the number of those who withdrew before finishing the measurement. It must be noted that even the current total of 162 participants was a result of three months of intensive recruiting. Nonetheless, it could be preferable to slightly increase the number of trials per combination to, we suggest, maximally ten trials. Another important limitation was that we, unfortunately, did not check whether the participants were color blind, but we can only assume that such participants would not have managed to complete the training and go further in the experiment.

Furthermore, since creativity was measured by the self-assessment of creative behaviors, biases in participants' responses arising from different levels of metacognitive abilities and a propensity to give socially desirable responses are possible (Batey & Hughes, 2017). In addition, since the inventory of creative activities and achievements required participants to mark all creative activities within a domain that they have been involved in during the last 10 years, the accuracy of their recollection is also questionable. Self-assessment measures could be combined with the method of creative performance being assessed by an expert jury, and the sample could be extended to professionals working in other creative fields such as literature and music. This way, in addition to the overall result on the scale of creative activities / achievements, the results within individual domains could also be observed. Also, a larger and more representative sample would be preferred.

It is already noted that the results of research within the cognitive approach to creativity provide valuable information on how elementary cognitive processes can result in something extraordinary (Benedek & Fink, 2018). Based on this, guidelines can be developed to improve the creative way of thinking, which could be applied in all areas of human activity such as the education system, work efficiency, innovation, science, and society as a whole. Given the complexity of the creativity construct, a methodologically diverse approach to the problem is needed. Valuable knowledge about creative cognition comes from neuroscientific research. For example, it has been found that using short behavioral exercises such as ad-hoc categorization of common objects, breaking down an object into parts, or interrupting a routine can improve creativity. Also, it has been found that non-invasive brain stimulation processes that inhibit the inferior frontal or temporal cortex favor creativity (Chrysikou, 2018). Such discoveries are truly inspiring for scientists because they reveal novelties about the functioning of the brain and testify the importance of the interchange of automatic and controlled processing in a very important adaptive ability - creativity. Importantly, future studies should consider that individual differences in creativity could affect the results obtained in conflict paradigm tasks (or at least, in the Simon task). Given the results of previous similar research, for example, the study by Edl and colleagues (2014), where creative individuals were faster at solving the Stroop task than less creative individuals, it is essential for researchers to keep in mind that creativity can affect measurement results and the effect can obviously go in different directions. Further research is needed to try to replicate our findings, particularly regarding the Simon task.

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Kreativnost i izvedba Simonova zadatka

Sažetak

Cilj je ovoga istraživanja bio ispitati uspješnost u Simonovu zadatku s obzirom na individualne razlike u kreativnome ponašanju mjerene Inventarom kreativnih aktivnosti i postignuća (ICAA; Diedrich i sur., 2018). U istraživanju je sudjelovalo 105 studenata i 57 mlađih radno sposobnih osoba (u dobi od 19 do 36 godina). Provedene su trosmjerne analize varijance vremena reakcije u Simonovu zadatku s obzirom na podudarnost prethodnih i trenutnih pokušaja te ispodprosječne/iznadprosječne rezultate na ljestvicama kreativnih aktivnosti i postignuća. Vrijeme reakcije u Simonovu zadatku bilo je u prosjeku kraće u kongruentnim nego u nekongruentnim pokušajima (Simonov efekt), kao i u pokušajima kojima su prethodili kongruentni u odnosu na pokušaje kojima su prethodili nekongruentni pokušaji. Simonov efekt bio je prisutan samo u pokušajima kojima je prethodio kongruentni pokušaj, dok su vremena reakcije u pokušajima kojima su prethodili nekongruentni pokušaji bila kraća u nekongruentnim nego u kongruentnim pokušajima (Grattonov efekt). Međutim, ni Simonov ni Grattonov efekt nisu bili izraženiji kod više ili manje kreativnih sudionika, već su sudionici s iznadprosječnim rezultatom na ljestvici kreativnih aktivnosti u prosjeku sporije reagirali od pojedinaca s ispodprosječnim rezultatom. Korelacije između rezultata na mjerama kreativnosti te različitih vremena reakcije i indeksa učinka Simona i Grattona nisu bile značajne. U ovome su istraživanju utvrđeni očekivani efekti povezani sa Simonovim zadatkom, no potrebna su daljnja istraživanja da bi se pokušali replicirati nalazi povezani s fleksibilnošću inhibicijske kontrole mjerene izvedbom Simonova zadatka i kreativnim ponašanjem.

Ključne riječi: kreativnost, Simonov zadatak, Grattonov efekt, inhibicijska kontrola

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