Psychology Research and Behavior Management

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

The Unconscious Tug-of-War: Exploring the Effect of Stimulus Selection Bias on Creative Problem Solving with Multiple Unconscious Stimuli

Chengzhen Liu[1,2], Shen Tu[3], Shikang Gong[1], Jinliang Guan[1], Zifu Shi[1], Yi Chen[2]

[1]Department of Psychology, Cognition and Human Behavior Key Laboratory of Hunan Province, Hunan Normal University, Changsha, 410081, People's Republic of China; [2]School of Humanities and Management Science, Southwest Medical University, Luzhou, 626000, People's Republic of China; [3]Department of Psychology, School of Public Administration, Guizhou University of Finance and Economics, Guiyang, 550025, People's Republic of China

Correspondence: Zifu Shi; Yi Chen, Email shizf@hunnu.edu.cn; chenyi@swmu.edu.cn

Psychology Research and Behavior Management downloaded from https://www.dovepress.com/
For personal use only.

Objective: This study innovatively investigated the potential selection bias involved in processing multiple subliminal stimuli during creative problem-solving (CPS). It addresses the existing gap in specialized research on how the handling of multiple unconscious stimuli influences higher-order cognitive processes, particularly creativity.

Methods: The study utilized a masked priming paradigm and a remote association task (RAT). Two experiments were conducted. Experiment 1 presented two stimuli simultaneously, with one being the correct answer, to examine whether there was a bias in the location of subliminal stimuli. In Experiment 2, two stimuli were presented sequentially, with one serving as the answer, to investigate whether there was a temporal bias in unconscious processing.

Results: Our findings revealed that when solving easy RATs, subliminal stimuli presented on the left side had a negative priming effect compared to the right side. The results revealed that unconscious processing of subliminal stimuli enhanced performance on difficult CPS. Additionally, a temporal bias was observed, with more recent subliminal stimuli having a stronger effect than earlier stimuli.

Conclusion: Unconscious processing can improve CPS, especially for difficult tasks, and there is a bias towards processing stimuli on the left and more recently presented stimuli. These findings contribute to our understanding of unconscious processing, particularly the processing of multiple subliminal stimuli in CPS, and provide insights into the biases that exist in unconscious processing.

Keywords: unconscious priming, creative problem solving, remote association test, unconscious processing bias, multiple unconscious influences

Introduction

Numerous researchers have focused on understanding the role of unconscious processes in Creative problem-solving (CPS). Researchers have sought to elucidate the mechanisms through which unconscious cognition influences key CPS phases such as idea generation, incubation, and insight.[1–4] The exploration of the role of unconscious processes in CPS has been approached from diverse theoretical perspectives, including cognitive psychology, neuropsychology, and social psychology. Such investigations have contributed to the development of various models and frameworks that aim to explicate the nature of unconscious processing in CPS, such as the associative activation hypothesis,[5–7] the unconscious-thought theory,[8] and Wallas' four-stage model.

Numerous empirical studies have demonstrated the positive incubation effect, wherein temporarily setting aside a creative problem that has reached an impasse leads to better creative results.[1,3] Based on these findings, researchers have proposed the unconscious work hypothesis, suggesting that the positive incubation effect occurs unconsciously during problem-solving.[3,9–11] Additionally, Dijksterhuis and Nordgren proposed the theory of unconscious thought (UT)[12] after conducting a series of experiments, which has since been widely discussed in the literature on decision-

Received: 27 May 2023
Accepted: 19 September 2023
Published: 27 September 2023

© 2023 Liu et al. This work is published and licensed by Dove Medical Press Limited. The full terms of this license are available at https://www.dovepress.com/terms.php and incorporate the Creative Commons Attribution – Non Commercial (unported, v3.0) License (http://creativecommons.org/licenses/by-nc/3.0/). By accessing the work you hereby accept the Terms. Non-commercial uses of the work are permitted without any further permission from Dove Medical Press Limited, provided the work is properly attributed. For permission for commercial use of this work, please see paragraphs 4.2 and 5 of our Terms (https://www.dovepress.com/terms.php).

making and problem-solving. Dijksterhuis et al found that UT can be more effective than conscious thought in generating creative ideas, particularly for complex and novel problems.[13–15] The superiority of UT may be due to its ability to generate a wider range of ideas or its better associative search, which draws on a broader range of knowledge and experiences to generate creative solutions.[12]

Despite extensive empirical research on CPS, the phenomenon of generating new and innovative ideas through unconscious processes remains an unresolved issue in the field. CPS involves finding semantic connections between seemingly unrelated concepts and combining them in novel and meaningful ways, which requires generating associations between mental elements to create new combinations of ideas. According to Campbell,[16] automatic spreading activation along associative connections in a semantic network can lead to remote and unusual associations without requiring conscious awareness. Additionally, subliminal activation, especially of unmet goals during incubation periods following unsuccessful conscious work, may also play a role in unconscious processing. Gilhooly conducted a series of experimental studies on the incubation effect,[2,17] which suggests that insight in CPS occurs when a semantic activation network system is triggered. The associated solution or relevant information is repeatedly activated until it reaches a conscious threshold level and generates a new solution. The associated solutions initially possess unique properties as subthreshold information or are the result of the integration and filtering of multiple subthreshold information. Therefore, the second question is how to select from a large amount of subthreshold information in the semantic network and whether certain features of the information associated with the answers make them more easily activated, such as unique positioning and appropriate timing.

Notably, the utilization of unconscious processes to generate novel and inventive ideas is posited to be a critical mechanism in the domain of creativity. The process involves the subconscious filtering of seemingly unrelated information, which may be accompanied by a selection bias towards certain choices. This stimulus selection bias refers to the tendency of individuals to favor certain stimuli over others when multiple subliminal stimuli are presented simultaneously.[18] Selective attention is defined as a cognitive process of attending to one or fewer sensory stimuli (i.e., external and internal) while ignoring or suppressing all other irrelevant sensory inputs.[19,20] It is a critical aspect of daily functioning as it allows individuals to selectively attend to certain stimuli while filtering out others.[19,20] Several different theories of selective attention have focused on the flow and filtering of information,[21] such as Broadbent's filter theory,[22] the late selection theory of Deutsch and Deutsch,[23] and Treisman's attenuation theory.[24] Traditional attention research suggests that selective attention is an adaptive mechanism that allows us to cope with rapidly changing environmental developments, facilitating the processing of relevant information and is typically automatic.[25] Thus, individuals might process certain subliminal stimuli more than others based on their relevance to the current problem-solving task. However, it is important to consider whether this bias towards selective processing mechanisms is also applicable to situations where multiple unconscious processing influences affect CPS. Therefore, further research is needed to clarify the role of unconscious processing selection bias in CPS. This experiment aims to investigate this issue by manipulating multiple unconscious stimuli using a masked priming paradigm.

Research has shown that unconscious priming can enhance individuals' creative performance. Studies that have combined the masked priming paradigm with creativity experiments have discovered that unconsciously presented information can influence creative thinking. For example, Katz found that subliminal word materials could affect the structure and content of participants' responses when completing creative tasks such as writing stories.[26] Similarly, Förster discovered that unconsciously reminding participants of cities they associated with creativity could increase their creativity.[27] However, this effect was only observed in participants who had already established a link between creativity and a specific city in their long-term memory. Another study by Chen et al[28] combined a revised masked prime paradigm with the RAT and found that unconscious priming and CPS contributions were distinct processes. While the aforementioned studies have demonstrated the influence of unconscious priming on CPS performance, the priming stimuli used were either directly related to the creative task or constituted a single, comprehensive unconscious stimulus. Therefore, how the unconscious processing selects multiple pieces of information in CPS remains unexplored.

In recent years, researchers have conducted experiments on unconscious cognition to examine how different subliminally perceived stimuli are processed. Many studies have shown that subliminally presented words can be integrated and filtered, including research by Van Gaal, Naccache & Meuwese,[29] Armstrong & Dienes,[30] and Sklar et al[31] For instance, Armstrong and Dienes investigated the subliminal processing of syntax, demonstrating that individuals can process the linguistic element "not" and derive meaning from word combinations unconsciously.[30] This indicated that unconscious cognition can filter out useful information from complex multiple stimuli at a semantic level. Sklar et al[31] utilized continuous flash suppression (CFS) to reveal that incongruent sentences, like "I ironed coffee", break through inter-ocular suppression and enter consciousness faster than congruent sentences, such as "I ironed clothes". These findings suggest that multiple words can be integrated unconsciously, and semantic violations can be detected, and it may be because the incoherent verbal stimuli are more surprising, so compared to coherent stimuli, they break through inhibition faster. Another study by van Gaal et al used behavioral priming and electroencephalography (EEG) to examine a specific rule-based linguistic operation (i.e the modifier–adjective pair on the processing of the subsequent target noun).[29] Their results indicated that multiple unconscious words can be rapidly integrated, and an unconscious negation can automatically reverse the meaning of an unconscious adjective. Based on their study's finding of the subliminal negation effect, it can be inferred that there may be a biased processing of negating modifiers in unconscious integration.

Relevantly, several studies have examined the selection bias of unconscious stimuli through experiments involving multiple related stimuli, but the results have been mixed. Some studies have found no clear preferential processing bias for individuals with these unconscious stimuli, such as two fruit words[32] or two arrows,[33] indicating that individuals do not exhibit a selection bias towards a particular word or arrow. On the other hand, other experiments have demonstrated that certain unconscious stimuli out of a set of multiple stimuli are more likely to be preferentially processed by individuals, indicating a bias towards attention and selection. For instance, studies have found that the brain tends to process visual information and imagery when presented with unconscious stimuli with multiple attributes, such as words and pictures or visual and auditory information.[34,35] In Jiang et al's experiment,[36] the presentation of unconscious nude and mosaic pictures side by side induced unconscious spatial attention, which affected behavioral responses. However, it is important to note that this particular experiment did not directly explore the selection bias between unconscious stimuli, as it employed mosaic pictures instead of meaningful ones and had a different experimental purpose. Taken together, the above-mentioned research indicates that the unconscious level is capable of processing various unconscious stimuli and may exhibit multiple selection biases in the process.

It is worth mentioning that the experimental tasks in these studies primarily focused on evaluating the valence (positive or negative) of given targets[30] or different tasks with the same stimuli.[37] There has been no direct investigation into the effects of processing multiple unconscious stimuli on CPS. Nevertheless, these selection biases at the unconscious level may have significant implications for our creative behavior, as biased processing of unconscious information can unconsciously influence our creative thinking. Consequently, more research is needed to explore the effects of processing multiple unconscious stimuli on CPS.

To better investigate the impact of unconscious stimuli on creative tasks, this study also controlled for the difficulty variables in the RATs. Chen et al discovered a clear facilitation effect of unconscious priming on CPS,[28] but this effect was only observed in the high-difficulty RAT condition, aligning with notion of Dijksterhuis and Meurs notion that difficult decision-making should be entrusted to unconscious thought.[8] Therefore, our study hypothesized that unconscious information would influence creative performance, especially in facilitating difficult problem solving. Furthermore, there are variations in multiple unconscious processing and unconscious selection biases when solving creative problems of different difficulties.

This study innovatively explored whether there is a selection bias in multiple unconscious processing in creative tasks, i.e., what kind of unconscious stimuli with specific spatial and temporal presentation features can be better processed to enhance creative performance. Experiment 1 simultaneously presented two stimuli, one of which is the correct answer, to test whether there is a bias in the location of subliminal stimuli. Experiment 1 may include our daily habit of reading from left to right. In Experiment 2, we presented two stimuli one after another, one of which is the answer, to test whether there is a time bias in unconscious processing. If biases in different positions and different time presentation orders are successfully observed, this will indicate that the mechanism of multiple unconscious information selections may be involved in CPS. Essentially, this experiment aims to reveal the mechanism of unconscious processing in CPS by manipulating multiple unconscious stimuli.

Experiment 1

Experimental 1 examined the bias in unconscious processing towards different locations. Specifically, by examining whether individuals exhibit a selective bias towards unconscious stimuli presented on the left or right side. According to our habitual visual scanning order, the left-to-right sequence is the more natural reading condition.[38,39] Therefore, we hypothesized that in the resolution of CPS tasks, when multiple unconscious stimuli are presented, unconscious processing may exhibit a selection bias towards the left-sided information, prioritizing the processing of left-sided information over right-sided information.

Method

Participants

This study was approved by the institutional review board at Hunan Normal University and participants provided written informed consent prior to the commencement of data collection. We conducted an a-priori power analysis with G*Power 3.1.9.7.[40] Based on the classic study by Kouider and Dupoux investigating the reference perceptual threshold,[41] the effect size of the subliminal repetition priming effect is $\eta_p^2 = 0.24$ ($f = 0.56$). For a 4×2 two-factor within-subjects experimental design, assuming an alpha of 0.05, power of 0.95, and a small effect size $f = 0.56$, the analyses suggested 7 participants. Taking into account the potential for participants to respond inattentively and the possibility of data loss, and to ensure the reliability of the data, we recruited a total of 25 participants for the study. Participants had a mean age of 20.42 (*SD* = 0.67). All participants included in this study were right-handed, had a normal or corrected-to-normal vision, and had no history of, or current neurological or psychiatric conditions. Prior to participation, informed consent was obtained from each participant, following a detailed explanation of the study's nature and purpose. In exchange for their participation, participants received either course credits or a modest amount of compensation.

Design

The current experiment employed a 4x 2 within-subjects design, with two factors manipulated: prime condition (left-answer vs right-answer vs irrelevant word vs no-prime) and RAT difficulty (easy vs difficult RATs).

Apparatus and Materials

Chinese test materials were created based on Mednick's Remote Associates Task (RAT).[5] The 108 experimental materials were taken from a research group focused on creativity at Southwest University and had been used in prior studies on creative performance.[28] The RAT problems involved finding a word related to three given words. The difficulty of the 96 RAT items was determined in a pre-experiment, with accuracy rate used as a reference index. The average accuracy ranged from 0.1 to 0.97, with RATs scoring between 0.1 to 0.45 considered difficult, and those between 0.60 to 0.95 deemed easy. Two sets of RATs (48 each for easy and difficult items) were selected from the 108 RAT items, and assigned randomly to four priming conditions. The priming material consisted of the RAT answer word and other words unrelated to the answer.

Threshold priming involves presenting two words simultaneously, with the left-prime referring to an answer word of the RAT on the left and an irrelevant word on the left, and the right-prime referring to an answer word presented on the right. The irrelevant word condition involves presenting two words that are both unrelated to the answer word. The no-prime condition involves not presenting any words. However, to maintain consistency between conditions, two identically timed fragmented pictures are presented in the same position.

The total set of 96 target stimuli was presented in eight different blocks of 16 trials each, and 48 items for the difficult group and 48 items for the easy group. The dependent variables in this study were the participants' accuracy rate, response times (RTs), and insight (a sudden awareness of the RAT) in response to correct answers. The difference in difficulty between the easy set and the difficult set was highly significant (F (1, 94) = 238.266, $p < 0.05$; M=0.305 vs M = 0.681). However, there were no significant differences in overall RAT difficulty between the three prime conditions without distinguishing difficulty (F (2, 93) = 0.004, $p > 0.05$). Similarly, there were no significant differences in the overall difficulty between the three prime conditions of RATs for the easy set (F (2, 45) = 0.066, $p > 0.05$), or for the difficult set (F (2, 45) = 0.001, $p > 0.05$). Twelve RAT items from the remaining materials were selected as practice materials.

The stimuli were displayed on a 15-inch SVGA color computer screen with a gray background and black text, using E-prime 2.0, with a refresh rate of 60 Hz. The target words and prime words were presented in the center of the screen. The image stimuli masks had a visual angle ranged from 8.26 to 8.738 (height), and 7.56 to 8.438 (width), with a resolution of 221 *255 pixels.

Procedure

Participants sat in a comfortable chair before a computer monitor in a semi-dark room. Before the experiment began, participants were informed that, in each trial, they might see a brief flash of a stimulus before or after they saw the target stimulus. Figure 1 presents the sequence of events in a trial. At the beginning of the experiment, a fixation cross appeared in the center of the screen for a randomly determined duration of 600 ms. Subsequently, the target task was displayed for 1000 ms. Then, a forward mask (a scrambled word), a prime, and a backward mask were presented sequentially for 100, 16, and 50 ms, respectively. The prime was presented as two words simultaneously, with one word on the left and the other on the right, in a parallel fashion (Figure 2). After the backward mask, the target appeared again for 6000 ms or until the participant made a response, whichever occurred first. Participants were required to provide a common associate word as the answer to the target. Based on previous research indicating that activating regions associated with semantic processing during preparation can facilitate problem-solving,[42] we hypothesized that presenting unconscious stimuli after a creative task may have an even greater impact. Thus, in our experimental procedure, we presented the target stimulus for 1 second prior to the unconscious priming in order to enhance the ecological validity of the study.

Participants were instructed to provide their answer by pressing the "space" key as quickly and accurately as possible, while also verbally stating their response which was recorded by a separate recording device. The participants were asked to rate their sense of insight on a 4-point scale, by pressing a key corresponding to their level of feeling: (1) "no feeling at

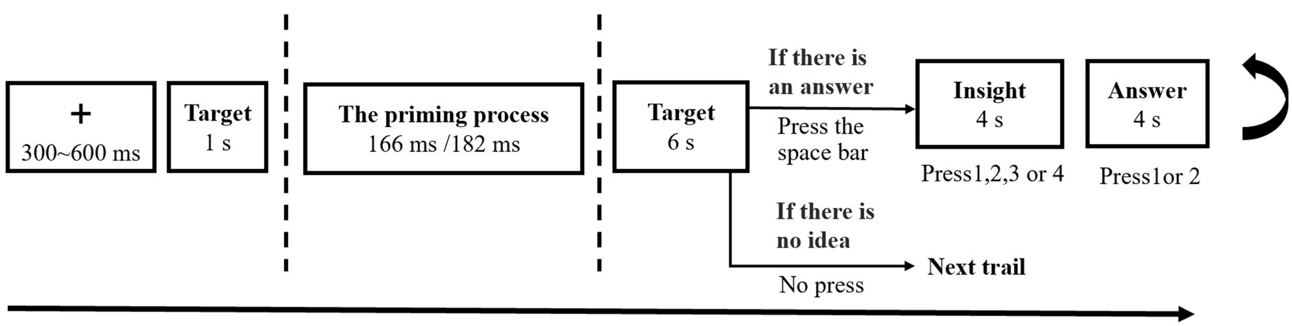

Figure 1 Schematic illustration of the sequentially displayed stimuli of one trial. Between the two dashed lines is the masking phase of the prime stimuli. The prime stimuli were subliminally shown following the display of the target, with a duration of 1s. The procedures for the two experiments were the same except for differences in the priming phase involving the presentation of the prime stimuli, as shown in Figure 2.

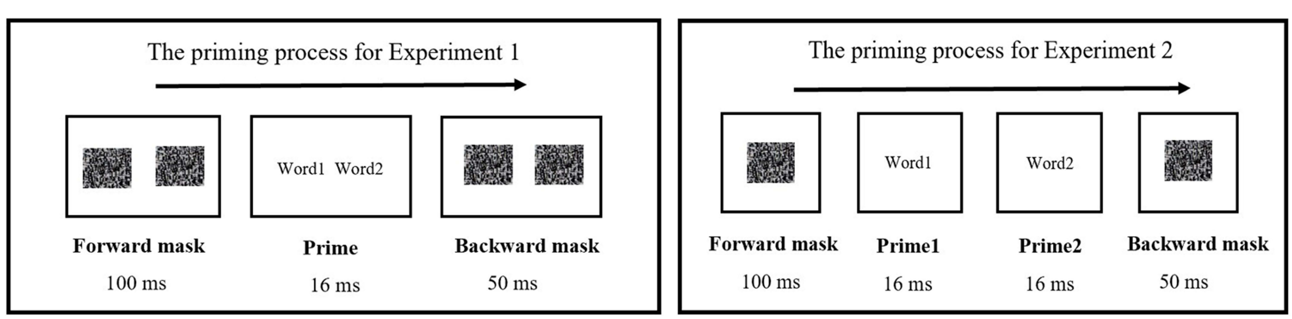

Figure 2 The specific presentation of stimuli during the priming phase differed between Experiment 1 and Experiment 2. In Experiment 1, two stimuli were presented simultaneously, while in Experiment 2, two stimuli were presented sequentially with a duration of 16 ms each.

all", (2) "a little bit of feeling" (feeling uncertain about the answer), (3) "almost clear feeling", and (4) "absolutely clear experience". They were provided with instructions beforehand that explained insight as a sudden awareness of the RAT. Immediately after giving their answer, the correct answer was displayed on the screen, and the participants had to indicate if their response was consistent with it by pressing "1" or "2". This method was adapted from previous studies,[43–46] and Figure 1 illustrates the trial sequence. After the participant responded, a grey empty screen appeared for 1 second before the fixation point for the next trial was presented. Prior to the formal experiment, participants underwent a practice block of eight trials to become familiar with the procedure.

After the participants completed the preceding phase of the experiment, they were asked to report on whether they saw anything between the two masks to assess their ability to recognize the prime stimulus. Following this, participants engaged in a forced-choice task to assess their recognition of the masked word. The task began with a fixation cross displayed at the center of the screen for 600 ms. Subsequently, a forward mask appeared for 100 ms, followed by a word serving as a prime stimulus for 16 ms; this was followed by a backward mask for 50 ms. The prime stimuli used in this task were similar to those employed in the main experiment, where two words were simultaneously displayed in a parallel manner. Participants were instructed to identify whether the two priming words shared a common category, such as both being fruits or animals. They indicated their response by pressing "1" for affirmative or "2" for negative. Subsequently, participants rated the quality of their subjective experience regarding the visibility of the prime stimulus on a four-point scale using the Perceptual Awareness Scale (PAS): (1) "no experience" (2) "brief glimpse" (a feeling that something appeared but nothing more specific than that), (3) "almost clear experience", and (4) "absolutely clear experience".[47,48] The degree to which the participant perceived the prime stimulus was used as an important indicator to determine whether the prime was processed subliminally.[49] There were 40 discrimination trials, randomly presented across participants. All words used in the forced-choice task were randomly selected from the main experiment, consisting of 20 object names and 20 object usage words. Prior to performing this task, participants were informed that response accuracy, rather than speed, was the primary concern.

Previous research on unconsciousness has typically conducted the visibility test either after the priming experiment[50–52] or at the end of each trial.[48,53] However, administering the visibility test at the end of each trial may potentially influence the forced-choice response, particularly if the target judgment and forced-choice task require identical responses. Tu et al found that participants tend to avoid providing two consecutive identical responses.[54] Therefore, to avoid any possible carry-over effects from the target assessment, we administered the visibility test separately from the main experiment.

Results

Prime Visibility Test results

All participants were included in further analyses. No participant selected "almost clear experience" more than thrice in the PAS test. Out of the total number of participants, data from 25 were used in subsequent analyses. The average percentage of correct recognition was 48.44%, which did not differ significantly from chance (t (24) = −1.150, p = 0.261). Additionally, the mean d' score (M = −0.329, SE = 2.3123) did not differ significantly from zero (t (24) = −0.774, p = 0.447).

Accuracy Analysis

Our analysis focused on participants' accuracy rates, which were determined by whether they provided an associated word that was consistent with the correct answer. During the task, participants were instructed to press the "1" key as quickly and accurately as possible when they thought of a word that was consistent with the correct answer. Responses were considered incorrect if participants failed to generate any associated words, or if the words they thought of were inconsistent with the correct answer. The results of the study are summarized in Table 1, which shows the accuracy rates for each condition. We conducted an analysis of variance (ANOVA) to investigate the influence of the prime condition and RAT difficulty on accuracy rates. Results showed a significant interaction between the prime condition and RAT difficulty, F (3, 72) =5.123, p = 0.003, η_p^2 = 0.176. Additionally, the main effects of RAT difficulty (F (1, 24) = 21.833, p < 0.001, η_p^2 = 0.476) and the prime condition (F (3, 72) = 4.112, p = 0.009, η_p^2 = 0.146) were significant.

Table 1 Means and Standard Error of Accuracy (%) for All the Conditions in Experiment 1

	Difficult RAT M (SE)	Easy RAT M (SE)
Left-answer prime	60.96 (5.21)	68.48 (4.79)
Right-answer prime	57.40 (5.56)	58.16 (5.27)
Irrelevant word prime	55.92 (4.85)	68.56 (4.11)
No-prime	53.04 (5.10)	74.00 (3.80)

Simple effect analyses were conducted to further investigate the significant interaction between the prime condition and RAT difficulty (Figure 3), and results indicated that: (1) for the difficult RAT items, the difference in accuracy between the left-prime condition (mean =60.96%) and the no-answer prime (mean =53.04%) condition was significant (p = 0.031). But the difference in accuracy between the left-prime condition and the right-prime condition (mean =57.40%) was not significant (p = 0.336). (2) for the easy RAT items, the difference in accuracy between three levels of the prime condition was significant, F (3, 22) = 4.828, p = 0.01. Specifically, accuracy for the left-answer prime condition (mean =68.48%), the irrelevant word prime condition (mean = 68.56%), and the no-prime condition (mean = 74.00%) were significantly higher than for the right-answer condition (mean = 58.16%) (all $p < 0.05$). However, the difference in accuracy between the no-prime condition and the left-answer prime condition was not significant (p = 0.06).

In summary, the analysis of accuracy in the current study indicates that a positive priming effect was observed in resolving difficult RATs, but only when the subliminal answer was presented on the left side, with no significant difference observed between the left and right-prime conditions. On the other hand, a negative priming effect was observed in solving easy RAT items, with the left-prime condition significantly greater than the right-prime condition.

RT Analysis

A summary of participants' reaction times (mean and standard error) for each condition is shown in Table 2. A two-factor ANOVA was conducted to examine the effects. The results indicated that all effects were not statistically significant. Specifically, for the main effect of RAT difficulty, F (1, 24) =3.770, p = 0.064, η_p^2 = 0.136. For the main effect of the prime condition, F (3, 72) = 0.017, p = 0.997, η_p^2 = 0.001. Lastly, for the interaction between the prime condition and the RAT difficulty, F (3, 72) =2.059, p = 0.113, η_p^2 = 0.079.

Insight Analysis

Table 3 provides a summary of the participants' insights for each condition. The same two-factor ANOVA used for analyzing the RT revealed a significant interaction between the prime condition and RAT difficulty, F (3, 72) =2.972, p = 0.037, η_p^2 = 0.110. The main effect of RAT difficulty was not significant, F (1, 24) = 3.121, p = 0.09, η_p^2 = 0.115, and the

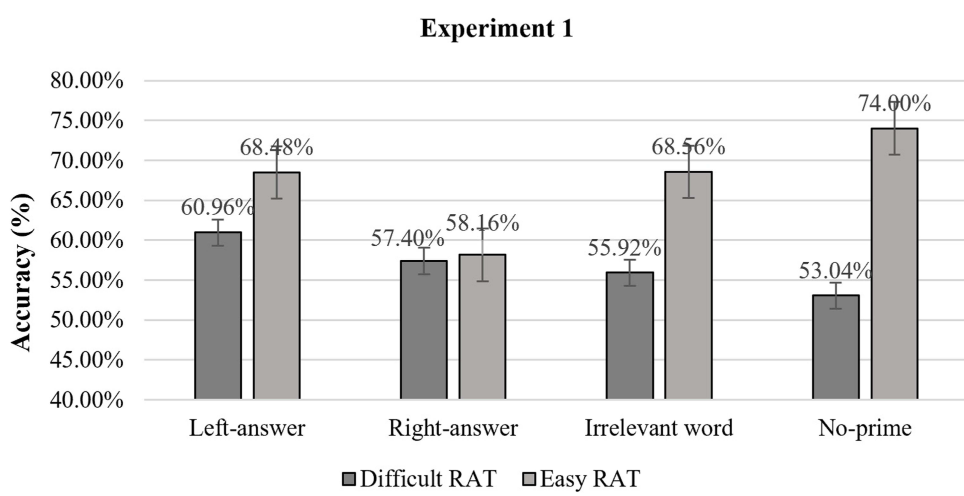

Figure 3 Means of accuracy (%) for each Condition of Prime condition and RAT difficulty in Experiment 1. The error bars represent one standard error of the mean.

Table 2 Means and Standard Error of Reaction Times (Ms) for All the Conditions in Experiment 1

	Difficult RAT M (SE)	Easy RAT M (SE)
Left-answer prime	2408 (165)	2748 (193)
Right-answer prime	2377 (174)	2749 (210)
Irrelevant word prime	2585 (197)	2566 (187)
No-prime	2560 (167)	2549 (165)

Table 3 Means and Standard Error of Insight for All the Conditions in Experiment 1

	Difficult RAT M (SE)	Easy RAT M (SE)
Left-answer prime	2.52 (0.16)	2.50 (0.14)
Right-answer prime	2.43 (0.15)	2.40 (0.17)
Irrelevant word prime	2.25 (0.11)	2.49 (0.15)
No-prime	2.31 (0.15)	2.61 (0.16)

main effect of prime condition was also not significant, F (3, 72) = 1.992, p = 0.123, $\eta_p{}^2$ = 0.077. However, simple effect analyses were conducted to further investigate the significant interaction between the prime condition and the RAT difficulty, and results indicated that both for the difficult RAT items and for the easy RAT items, there were no significant differences in insight between the four levels of the prime condition (F (3, 22) = 2.095, p = 0.130; F (3, 22) = 2.038, p = 0.138; respectively).

Overall, our study found that unconscious priming can facilitate CPS, as evidenced by a positive priming effect in resolving difficult creative problems and a negative priming effect in resolving easy creative problems. Specifically, the positive priming effect was observed only when the priming stimulus was presented on the left side during the resolution of difficult problems, while the left priming condition was superior to the right priming condition during the resolution of easy problems. In summary, the left-prime condition was more effective in facilitating creative problem-solving, and individuals may prioritize processing of stimuli presented on the left side in CPS.

Experiment 2

Experiment 1 suggested that the left-prime condition is more effective in facilitating creative problem-solving, and individuals may prioritize processing of stimuli presented on the left side during CPS. The left-to-right reading order is actually a common reading habit for individuals. However, the issue of sequential effects needs to be clarified. Therefore, in Experiment 2, stimuli were presented in a sequential manner to investigate whether individuals exhibit a selective bias towards the order of presentation of two subthreshold stimuli.[47] In summary, Experiments 1 and 2 investigated the effects of location and presentation timing, respectively.

Method

Participants

Twenty-seven participants (15 women and 12 men) from Hunan Normal University in China volunteered for this experiment. The participants had a mean age of 21.25 (SD = 0.27). All participants were right-handed, had either normal vision or vision that was corrected to normal using glasses or contact lenses, and had no prior history of neurological or psychiatric illnesses. They were offered either course credits or a small compensation as a token of gratitude for participating in the study.

Materials

The RAT items and the prime stimulus used in this experiment were the same as those used in Experiment 1.

Design and Procedure

Experiment 2 shared the same design and procedures with Experiment 1, except for the priming process of the subliminal stimuli (see Figure 2). In Experiment 1, two stimuli were presented simultaneously. However, in Experiment 2, the two subliminal words were presented in succession with a duration of 16ms each. This current experiment utilized a within-subjects design of 4 x 2, where two factors were manipulated: prime condition (the first-answer, the last-answer, the irrelevant word, and no-prime) and RAT difficulty (easy and difficult RATs). The first-answer prime condition refers to a sequence in which two subliminal stimuli are presented, with the first stimulus being the answer word. In contrast, the last-answer condition refers to a sequence in which the second word presented is the answer word.

Results

Prime Visibility Test results

Data for 27 participants were included in the following analyses. The mean percentage of correct recognition was 49.22%, which was not significantly different from chance, t (26) = −0.688, p = 0.497; nor was the mean d' (M = −0.2398, SE = 0.652) significantly different from zero, t (26) = −1.912, p = 0.067.

Accuracy Analysis

The method used to calculate accuracy for the analysis of variance was the same as that used in Experiment 1. A summary of participants' accuracy (means and standard error) for each condition is shown in Table 4. The ANOVA results revealed a significant interaction between the prime condition and RAT difficulty, F (3, 78) =15.889, $p < 0.001$, $\eta_p^2 = 0.379$. The main effect of RAT difficulty was also significant, F (1, 26) = 81.425, $p < 0.001$, η_p^2 = 0.758, while the main effect of prime condition was not significant, F (3, 78) = 0.655, p = 0.582, η_p^2 = 0.025.

Simple effect analyses were conducted to further investigate the significant interaction between the prime condition and the RAT difficulty (Figure 4), and results indicated that for the difficult RAT items, there was a significant difference in accuracy between the four levels of the prime condition (F (3, 24) = 6.744, p = 0.002). Specifically, the accuracy for the first-answer condition (mean = 41.67%), the irrelevant word (mean = 37.00%), and no-prime (mean = 40.37%) were all significantly lower than for the last-answer prime condition (mean = 48.41%) (p = 0.031, $p < 0.001$, and p= 0.024 respectively). However, there was no significant difference in accuracy between the first-answer condition and the irrelevant word condition (p = 0.083), or between the first-answer condition and the no-prime condition (p = 0.682). For the easy RAT items, there was also a significant difference in accuracy between the four levels of the prime condition (F (3, 24) = 7.270, $p < 0.001$). Specifically, the accuracy for the no-prime condition (mean = 63.59%) was also significantly higher than the last-answer prime condition ($p < 0.001$). The accuracy for the irrelevant word condition (mean = 65.41%) was significantly higher than the last-answer prime (mean = 50.93%) ($p < 0.001$) and the first-answer prime (mean = 55.93%) (p = 0.015), while the difference in accuracy between the last-answer prime and the first-answer prime was not significant (p = 0.181).

In summary, our analysis of variance revealed a positive priming effect on solving difficult RAT items when an answer word prime was included, as indicated by an increase in accuracy. Conversely, when attempting to solve easy RAT items under the same conditions, a negative priming effect was observed, resulting in a decrease in accuracy. The results of Experiment 2 were consistent with those of Experiment 1. Moreover, we observed a difference in priming order

Table 4 Means and Standard Error of Accuracy (%) for All the Conditions in Experiment 2

	Difficult RAT M (SE)	Easy RAT M (SE)
First-answer prime	41.67 (3.83)	55.93 (4.15)
Last-answer prime	48.41 (3.61)	50.93 (3.60)
Irrelevant word prime	37.00 (3.79)	65.41 (2.70)
No-prime	40.37 (3.64)	63.59 (2.45)

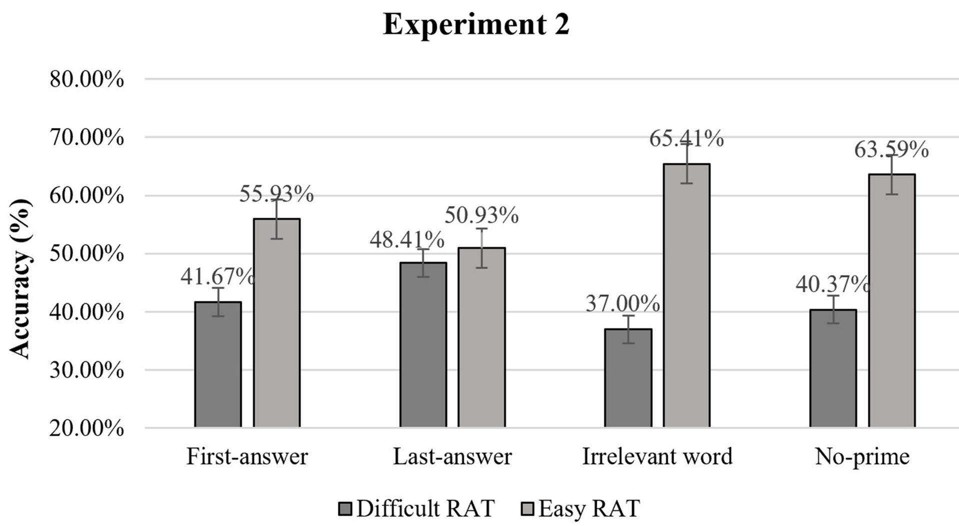

Figure 4 Means of accuracy (%) for each condition of prime condition and RAT difficulty in Experiment 2. The error bar represents one standard error of the mean.

for difficult problems, with significantly higher accuracy under the last-prime condition compared to the first-prime condition. However, this difference was not observed in solving simple problems.

RT Analysis

A summary of participants' reaction times (RT) (means and standard error) for each condition is shown in Table 5. A two-factor ANOVA showed a significant interaction between the prime condition and RAT difficulty, F (3, 78) =3.815, p = 0.013, η_p^2 = 0.128. The main effect of RAT difficulty was also significant, F (1, 26) = 4.287, p = 0.048, η_p^2 = 0.142, while the main effect of prime condition was not significant, F (3, 78) = 0.163, p = 0.921, η_p^2 = 0.006.

We conducted simple effect analyses to further investigate the significant interaction between the prime condition and the RAT difficulty (Figure 5). The results indicated that for the difficult RAT items, there was a significant difference in RT between the four levels of the prime condition (F (3, 24) = 3.784, p = 0.024). Specifically, the RT for the first-answer condition (mean = 2533) was significantly faster than the last-answer prime condition (mean = 2957) and the no-prime condition (mean = 3003) (p = 0.044, p = 0.007, respectively). However, there was no significant difference in RT between the last-answer prime condition and the irrelevant word condition (mean = 3043) (p = 0.771), or between the last-answer prime and the no-prime condition (p = 0.855). For the easy RAT items, there was also a significant difference in RT between the four levels of the prime condition (F (3, 24) = 3.824, p = 0.023). Specifically, the RT for the first-answer condition (mean = 2917) was significantly slower than the irrelevant word condition (mean = 2600) (p = 0.007) and the no-prime condition (mean =2520) (p = 0.004). However, the difference in RT between the last-answer prime and the first-answer prime was not significant (p = 0.138).

Table 5 Means and Standard Error of Reaction Times (Ms) for All the Conditions in Experiment 2

	Difficult RAT M (SE)	Easy RAT M (SE)
First-answer prime	2533 (162)	2917 (157)
Last-answer prime	2957 (176)	2620 (193)
Irrelevant word prime	3043 (253)	2600 (135)
No-prime	3003 (257)	2520 (133)

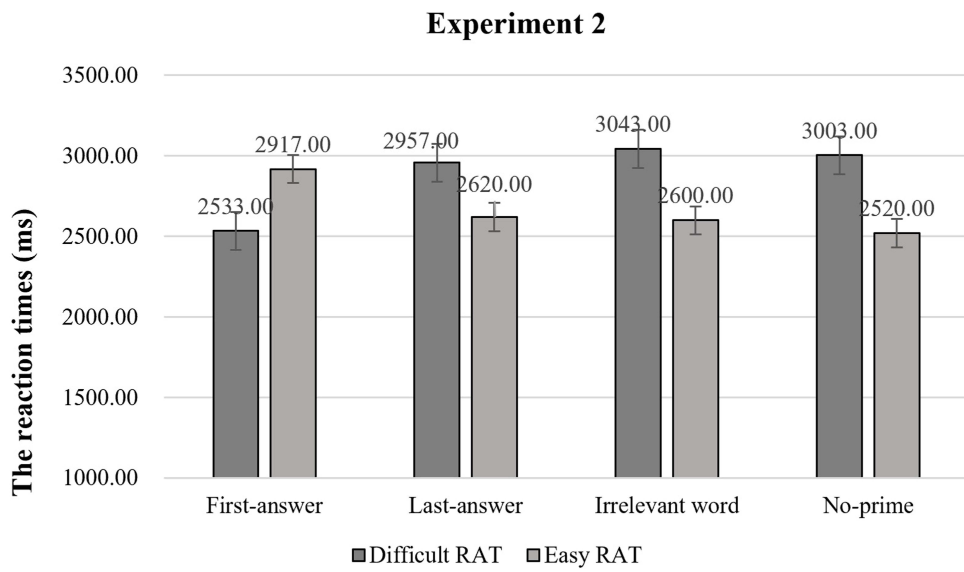

Figure 5 Means of reaction times (ms) for each condition of prime condition and RAT difficulty in Experiment 2. The error bar represents one standard error of the mean.

In summary, our RT analysis showed consistent results with the accuracy analysis in that a positive priming effect was observed when solving difficult RAT items under the answer word prime condition, while a negative priming effect was observed when solving easy items. Additionally, the result showed that during the resolution of difficult RATs, the RT in the first-prime condition was significantly faster than the RT in the last-prime condition. This finding is contrary to the analysis of accuracy, as the accuracy in the first-prime condition was significantly lower than the accuracy in the last-prime condition.

Insight Analysis (INS)

A summary of participants' insights (means and standard error) for each condition is shown in Table 6. A two-factor ANOVA showed that only the main effect of difficulty was significant, $F\,(1, 26) = 31.507$, $p < 0.001$, $\eta_p^2 = 0.548$. A post hoc comparison showed that insight in the easy RAT condition (mean = 3.191) was significantly higher than in the difficult condition (mean = 2.876). However, the main effect of the prime condition was non-significant, $F\,(3, 78) = 1.153$, $p = 0.333$, $\eta_p^2 = 0.042$. Additionally, the interaction between the prime condition and the RAT difficulty was also non-significant, $F\,(3, 78) = 0.531$, $p = 0.662$, $\eta_p^2 = 0.020$.

To summarize, the study revealed a positive priming effect in successfully solving challenging RAT items and a negative priming effect in attempting to solve simple RAT items. These effects were observed in both accuracy and response time, but no significant difference was found in terms of insight. Notably, when dealing with difficult problems, the accuracy of the last-prime condition was significantly higher than that of the first-prime condition, but the last-prime condition showed a significantly slower reaction time compared to the first-prime condition.

Table 6 Means and Standard Error of Insight for All the Conditions in Experiment 2

	Difficult RAT M (SE)	Easy RAT M (SE)
First-answer prime	2.92 (0.14)	3.25 (0.10)
Last-answer prime	2.88 (0.12)	3.09 (0.12)
Irrelevant word prime	2.94 (0.11)	3.24 (0.09)
No-prime	2.77 (0.12)	1.18 (0.13)

 https://doi.org/10.2147/PRBM.S420942

Discussion

As the relationship between unconsciousness and creativity attracts increasing attention, it is crucial to investigate the mechanisms of unconscious processing involved in CPS. The current study controlled two subliminal words to examine the selection bias of the unconscious processing for multiple stimuli from a cognitive-behavioral perspective. This study innovatively examined the location and time bias of two unconscious stimuli during the process of CPS by using the masked priming paradigm and the Remote Associates Test. Experiments 1 and 2 focused on investigating the effects of location and presentation timing, respectively. Both experiments revealed an unconscious priming effect, suggesting that unconscious stimuli were processed and affected CPS. Specifically, a negative priming effect was observed in easy problems, whereas a positive priming effect was found in difficult problems, which is highly consistent with previous research in this area.[1,3] Experiment 1 found that when two unconscious words appear simultaneously, the stimulus on the left side produces better creative performance than the stimulus on the right side. Experiment 2 revealed that in a sequence of two subliminal words, presenting the second word resulted in higher accuracy but slower response times, compared to presenting the answer word as the first word. These results suggest that multiple unconscious processes can occur during CPS, and that there are location and timing biases, with left stimuli and the most recently presented stimulus being more effective in facilitating CPS.

Upon further analysis, we found that regardless of whether the unconscious stimuli were presented on the left or right, or whether they appeared first or second, the presence of a cue associated with the correct answer differed significantly from the presence of an irrelevant stimulus or no cue at all. This suggests that the mechanism underlying the effects of multiple unconscious processes may involve the simultaneous influence of multiple unconscious stimuli on behavioral responses.[34,37,55] However, it should be noted that specific responses are influenced by the bias in unconscious selection.

In Experiment 1, we observed a bias in location selection, with unconscious processing tending to favor the left stimulus when two stimuli were presented simultaneously. When solving easy RATs, the correct response rate was significantly higher when the cue associated with the answer was presented on the left rather than the right. When solving difficult RATs, we found a significant difference in the correct response rate only when the subliminal answer word was presented on the left compared to when it was on the right. These findings suggest that during the resolution of creative problems, multiple unconscious stimuli exhibit a clear bias towards the left location.

Most researchers in the field of cognitive research adopt the method of simultaneously presenting two or more subliminal stimuli to explore the influence of the relationship between subliminal stimuli on subsequent responses to a supraliminally presented target.[56–58] However, these studies did not directly investigate selection bias. Jiang et al simultaneously presented a nude image and its mosaic version on the left and right sides and found that the nude image can elicit unconscious spatial attention and affect subsequent decisions,[36] revealing the presence of an unconscious selection bias in processing. However, because of different experimental goals, mosaic images rather than meaningful images were used in their study. In our experiment, both sides were presented with meaningful words, which better revealed the priority of unconscious stimuli in two meaningful conditions, with stimuli on the left side receiving priority processing.

This selection bias towards the left side may be related to our habit of reading from left to right,[38,39] resulting in a preference for processing even subliminal stimuli on the left. Does stimulus processing have a temporal order effect, as left information is processed first due to our reading habits, followed by the right stimulus? Experiment 2 further explores processing bias in the temporal order of stimulus presentation. Our results showed that when solving difficult RATs, compared with the condition of presenting the answer word first, the accuracy of the condition of presenting the word later was higher, but the response time was slower. This suggests the possibility of a temporal order effect, which is reflected only in the speed of behavioral responses. Regarding CPS, we are more concerned about the ability to correctly solve problems, that is, accuracy. In Experiment 1, no significant difference was found in response times between the left and right sides. Combined with the higher accuracy of the word-later condition than the word-first condition in Experiment 2, we can conclude that the location bias found in Experiment 1 is not due to temporal order. This supports the view of Mudrik et al who found that presenting two prime stimuli simultaneously can be considered the ultimately shortest temporal separation.[58] The significant differences in reaction time in Experiment 2 may be attributed to a motion effect in behavioral response, which is caused by the activation of visual features.[33,56]

According to the results of Experiment 2, we found that the most recently presented word was better for helping to correctly solve the creative problem, indicating that the stimulus processed first is not necessarily the preferred object of unconscious processing. Furthermore, the results of Experiment 2 indicate that when two stimuli are presented in succession, unconscious processing tends to favor the later stimulus. Until now, most researchers have utilized the sequential presentation of two or more subliminal words to investigate the integration of unconscious stimuli,[59–61] but have not explored the order processing bias of unconscious stimuli. Our study results revealed a selection bias in temporal processing, indicating an unconscious processing preference for the second stimulus when presented successively with another stimulus. This suggests that the second stimulus may further shorten the time window of semantic integration. Participants begin making semantic associations and diffusion after seeing the RAT task, and unconscious stimuli appearing at this time close the distance between the unconscious information and the target task, thereby facilitating the generation of correct answers.

Most importantly, while previous research on the integration of multiple unconscious processes suggests that multiple unconscious stimuli may jointly influence the target task through integration, our findings regarding the bias in stimulus selection suggest that the mechanism of multiple unconscious processing may involve each stimulus independently affecting creative performances and coexisting with the bias in stimulus selection. The discovery of unconscious selective processing can enhance our understanding of the creative processes such as Aha experience and incubation. It also contributes to a better understanding of the global workspace theory, various theories of consciousness, and broad cognitive processes such as resting state, sleep, and more.[47] Ultimately, a deeper understanding of the nature of unconscious processing and its role in creative cognition has the potential to inform a range of practical applications, from improving creativity training programs to enhancing problem-solving strategies in a variety of contexts.

The human mind is often engaged in a fascinating and complex battle, known as the unconscious tug-of-war. Within a vast amount of unconscious information, there exists such a tug-of-war that manifests as a bias in information selection. In the context of CPS, there is a tendency to favor certain information, particularly those with specific spatiotemporal features (such as being on the left side or recently encountered). These types of information are more likely to be associated with new ideas or activate related information, thus fostering the generation of creativity. This may be the key to solving creative problems.

The unconscious tug-of-war can be seen as a competitive mechanism for information processing, where different pieces of information compete for priority in our thinking. In this battle, information relevant to our current task or goal often gains an advantage, while information with certain distinctive features (such as being on the left side or recent in occurrence) is more likely to undergo processing. This processing advantage enables our brains to establish new associations more readily, leading to the creation of novel ideas and solutions. This process is crucial for the expression of creativity. By leveraging information with specific spatiotemporal features, we can more easily activate relevant knowledge and experiences, providing robust support for creative problem-solving. We can utilize this unconscious tug-of-war mechanism more flexibly, thus enhancing our creative abilities.

After controlling for the difficulty level of the RAT, we investigated the impact of subliminal stimuli processing at varying levels of difficulty on task performance. The results showed that unconscious priming can facilitate CPS, as evidenced by a positive priming effect in resolving difficult creative problems and a negative priming effect in resolving easy problems. These results support earlier research indicating that the unconscious mind can enhance problem-solving ability and confirm the effectiveness of unconscious processing for creative thinking.[28,62] These findings are consistent with prior research, providing evidence for the effectiveness of unconscious processing in creative thinking and supporting Dijksterhuis and Meurs' theory of unconscious thought,[8] which suggests that unconscious thinking may have potential advantages over conscious thinking in solving complex problems requiring information integration and association.

This phenomenon may be due to the limited experiences or thought fixations of individuals when processing difficult creative problems, making it challenging for them to extract as many perceptual patterns as possible. Unconsciously activated information can assist in the acquisition of critical information, making it easier to search for answers in the meta-level space to facilitate problem-solving. Kaplan and Simon's theory of information processing suggests that information processing can occur at both conscious and unconscious level and that unconscious processing can aid in the discovery of new connections and patterns.[63] Similarly, Knoblich et al argued that creative problem-solving often involves the integration of disparate pieces of information,[64] a task at which unconscious processing may excel. Furthermore, difficult RAT problems require more extensive information searching, and unconscious semantic processing of subliminal stimuli can aid in this search. Unconscious processing has a higher capacity and can search for more extensive and broader information than conscious thinking, which has a limited capacity.[8,65] In summary, our study supports the idea that unconscious processing can facilitate CPS by generating accurate problem representations and associations, contributing to our understanding of its potential advantages in complex problem-solving.

Incidentally, we did not find significant evidence of unconscious priming effects in our measurements of insight. Moreover, the differences observed in response time measures were not sensitive and did not align with the discrepancies observed in accuracy levels. This could be due to the fact that the RAT task requires longer processing time compared to consistency judgment tasks, and unconscious processing may not be sensitive to facilitating or inhibiting insight and reaction time in behavioral responses. This is consistent with previous research on the use of the RAT task.[28] In order to deepen our understanding of the role of unconscious processing in insight, future research could benefit from exploring potential physiological mechanisms using techniques such as electroencephalography (EEG).

Overall, we innovatively manipulated two unconscious stimuli to investigate the key mechanisms of multiple unconscious processing in CPS. Our findings revealed a bias towards processing stimuli on the left and recently presented stimuli during unconscious processing, which may be an important mechanism in CPS involving multiple unconscious processing. These results expand the scope of research on unconscious information processing through the utilization of RAT tasks, providing important theoretical implications for understanding multiple unconscious processing in higher cognitive functions such as CPS. In addition, we observed a positive priming effect in difficult creative problems and a negative priming effect in easy ones, consistent with the traditional perspective on this phenomenon. However, our use of multiple unconscious stimuli in the context of unconscious information selection provides a new explanation for the attentional selection of unconscious processing in CPS, potentially offering a significant mechanism for CPS. A definitive exploration to this question will require further research.

Conclusion

The current study offers behavioral evidence supporting the enhancement of creative performance through multiple unconscious processes, especially in challenging creative tasks. The observed biases and insights into the nature of unconscious cognitive operations deepen our understanding of the intricate dynamics of unconscious processing and its implications for creative problem-solving (CPS). Despite the relatively limited literature in this area, future research should conduct more extensive investigations, encompassing behavioral and neuroimaging methodologies. A comprehensive comprehension of the multifaceted mechanisms governing unconscious processing in CPS is crucial for advancing both the fields of unconsciousness and creativity. Therefore, this endeavor significantly contributes to our theoretical understanding of these domains.

Ethical Declarations

We confirm that this study complies with the principles outlined in the Declaration of Helsinki.

Acknowledgments

We thank the students for their support and participation.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure

The authors declare that they have no conflicts of interest/competing interests for this work.

References

1. Dodds RA, Ward TB, Smith SM. A memory advantage for creative analogical problem solving. *Psychon Bull Rev.* 2012;19(4):666–671.
2. Gilhooly KJ. *Incubation in Problem Solving and Creativity: Unconscious Processes*. Routledge; 2019.
3. Na Sio U, Ormerod TC. Does Incubation Enhance Problem Solving? A Meta-Analytic Review. *Psychol Bull*. 2009;135(1):94–120. doi:10.1037/a0014212
4. Wallas G. *The Art of Thought*. Harcourt, Brace and Company; 1926.
5. Mednick SA. The associative basis of the creative process. *Psychol Rev.* 1962;69(3):220–232. doi:10.1037/h0048850
6. Gilhooly KJ, Fioratou E, Anthony SH, et al. Divergent thinking: strategies and executive involvement in generating novel uses for familiar objects. *Br J Psychol*. 2007;98(4):611–625.
7. Kershaw TC, Ohlsson S. Multiple causes of difficulty in insight: the case of the nine-dot problem. *J Exp Psychol Learn Mem Cogn*. 2004;30(1):3–13. doi:10.1037/0278-7393.30.1.3
8. Dijksterhuis A, Meurs T. Where creativity resides: the generative power of unconscious thought. *Conscious Cogn*. 2006;15(1):135–146. doi:10.1016/j.concog.2005.04.007
9. Seifert CM, Meyer DE, Davidson N, et al. Demystification of cognitive insight: opportunistic assimilation and the prepared-mind hypothesis. *Adv Exp Soc Psychol*. 1995;27:321–379.
10. Smith SM, Blankenship SE. Incubation and the persistence of fixation in problem solving. *Am J Psychol*. 1991;104(1):61–87. doi:10.2307/1422851
11. Yaniv I, Meyer DE. Activation and metacognition of inaccessible stored information: potential bases for incubation effects in problem solving. *J Exp Psychol Learn Mem Cogn*. 1987;13(4):577–585. doi:10.1037/0278-7393.13.2.187
12. Dijksterhuis A, Nordgren LF. A Theory of Unconscious Thought. *Perspectives Psychol Sci*. 2006;1(2):95–109. doi:10.1111/j.1745-6916.2006.00007.x
13. Zhong CB, Dijksterhuis A, Galinsky AD. The merits of unconscious thought in creativity. *Psychol Sci*. 2008;19(9):912–918. doi:10.1111/j.1467-9280.2008.02176.x
14. Ritter SM, Dijksterhuis A. Creativity and incubation: disentangling the effects of "sleep on it" and "keep at it" strategies. *Mem Cognit*. 2014;42(8):1326–1338.
15. Ritter SM, Van Baaren RB, Dijksterhuis A. Creativity—the unconscious foundations of the incubation period. *Front Hum Neurosci*. 2012;6:126. doi:10.3389/fnhum.2012.00126
16. Campbell DT. Blind variation and selective retentions in creative thought as in other knowledge processes. *Psychol Rev.* 1960;67(6):380–400. doi:10.1037/h0040373
17. Gilhooly KJ. Incubation and Intuition in Creative Problem Solving. *Front Psychol*. 2016;7:1076. doi:10.3389/fpsyg.2016.01076
18. Bar-Haim Y, Lamy D, Pergamin L, et al. Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol Bull*. 2007;133(1):1. doi:10.1037/0033-2909.133.1.1
19. McLeod SA. Selective attention. *J Pediatric Genetics*. 2021;10:250. doi:10.1055/s-0040-1713431
20. Murphy G, Groeger JA, Greene CM. Twenty years of load theory-Where are we now, and where should we go next? *Psychon Bull Rev.* 2016;23(5):1316–1340. doi:10.3758/s13423-015-0982-5
21. Bater LR, Jordan SS. Selective attention. In: Zeigler-Hill V, Shackelford T, editors. *Encyclopedia of Personality and Individual Differences*. Cham: Springer; 2019.
22. Broadbent D. *Perception and Communication*. London: Pergamon Press; 1958.
23. Deutsch JA, Deutsch D. Attention: some theoretical considerations. *Psychol Rev.* 1963;70(1):80–90. doi:10.1037/h0039515
24. Treisman AM. Strategies and models of selective attention. *Psychol Rev.* 1969;76(3):282. doi:10.1037/h0027242
25. Güldener L, Jüllig A, Soto D, Pollmann S. Frontopolar activity carries feature information of novel stimuli during unconscious reweighting of selective attention. *J Dev Study Nervous System Behav.* 2022;153:146–165. doi:10.1016/j.cortex.2022.03.024
26. Katz N. Cognition and attribution in social interaction. *J Pers Soc Psychol*. 1973;25(2):223–241.
27. Förster J. *The Unconscious City: How Expectancies About Creative Milieus Influence Creative Performance*. Springer Netherlands; 2009.
28. Chen QL, Long JL, Jiang J, et al. Effects of unconscious processing on creativity problem solving. *Psychol Dev Educ*. 2012;6:569–575.
29. van Gaal S, Naccache L, Meuwese JDI, et al. Can the meaning of multiple words be integrated unconsciously? *Philosophical Trans Royal Soc*. 2014;369(1641):1–11. doi:10.1098/rstb.2013.0212
30. Armstrong A-M, Dienes Z. Subliminal understanding of negation: unconscious control by subliminal processing of word pairs. *Conscious Cogn*. 2013;22(3):1022–1040. doi:10.1016/j.concog.2013.06.010
31. Sklar AY, Levy N, Goldstein A, et al. Reading and doing arithmetic nonconsciously. *Proc Natl Acad Sci U S A*. 2012;109(48):19614–19619. doi:10.1073/pnas.1211645109
32. Tu S, Liu C, Zhu S, et al. The Semantic Integration Between Two Subliminally Perceived Words Simultaneously Presented at Different Locations. *J Psycholinguist Res*. 2019;48(5):1087–1110. doi:10.1007/s10936-019-09648-9
33. Wang D, Tang L, Liang Q, et al. Unconscious integration of pointing relation between two masked arrows. *Vis cogn*. 2017;25(9/10):928–939. doi:10.1080/13506285.2017.1358785
34. Faivre N, Mudrik L, Schwartz N, Koch C. Multisensory integration in complete unawareness: evidence from audiovisual congruency priming. *Psychol Sci*. 2014;25(11):2006–2016. doi:10.1177/0956797614547916
35. Ruch S, Henke K, Heimberger F. The multiple faces of novelty: effects of novelty segment formation on liking and memory of consumer goods. *J Consumer Psychol*. 2016;26(4):551–561.
36. Jiang Y, Costello P, Fang F, et al. A gender- and sexual orientation-dependent spatial attentional effect of invisible images. *Proc Natl Acad Sci*. 2006;103(45):17048–17052. doi:10.1073/pnas.0605678103
37. Van Opstal F. The same-different task as a tool to study unconscious processing. *Curr Opin Behav Sci*. 2021;37:35–40. doi:10.1016/j.cobeha.2020.06.014
38. Henderson JM, Ferreira F. Effects of foveal processing difficulty on the perceptual span in reading: implications for attention and eye movement control. *J Exp Psychol Learn Mem Cogn*. 1990;16(3):417–429. doi:10.1037/0278-7393.16.3.417

39. Rayner K. Eye movements in reading and information processing: 20 years of research. *Psychol Bull*. 1978;85(3):618–660. doi:10.1037/0033-2909.85.3.618
40. Faul F, Erdfelder E, Lang AG, et al. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175–191. doi:10.3758/BF03193146
41. Kouider S, Dupoux E. Subliminal speech priming. *Psychol Sci*. 2005;16(8):617–625. doi:10.1111/j.1467-9280.2005.01584.x
42. Kounios J, Fleck JI, Green DL, et al. The origins of insight in resting-state brain activity. *Neuropsychologia*. 2008;46(1):281–291. doi:10.1016/j.neuropsychologia.2007.07.013
43. Metuki N, Sela T, Lavidor M. Enhancing cognitive control components of insight problems solving by anodal tDCS of the left dorsolateral prefrontal cortex. *Brain Stimul*. 2012;5(2):110–115. doi:10.1016/j.brs.2012.03.002
44. Ludmer R, Dudai Y, Rubin N. Uncovering camouflage: amygdala activation predicts long-term memory of induced perceptual insight. *Neuron*. 2011;69(5):1002–1014. doi:10.1016/j.neuron.2011.02.013
45. Luo J, Li H, Li X, et al. Hyper-priming in Chinese sentence comprehension: accessing the underlying semantic representations. *Neuropsychologia*. 2011;49(8):2027–2036.
46. Qiu J, Li H, Jou J, et al. Visual form processing involves emotional decision-making in the human amygdala. *Neuropsychologia*. 2008;46(14):394–402.
47. Atas A, Vermeiren A, Cleeremans A. Repeating a strongly masked stimulus increases priming and awareness. *Conscious Cogn*. 2013;22(4):1422–1430. doi:10.1016/j.concog.2013.09.011
48. Szczepanowski R, Traczyk J, Wierzchoń M, et al. The perception of visual emotion: comparing different measures of awareness. *Conscious Cogn*. 2013;22(1):212–220. doi:10.1016/j.concog.2012.12.003
49. Van den Bussche E, Notebaert K, Reynvoet B. Masked primes can be genuinely semantically processed: a picture prime study. *Exp Psychol*. 2009;56(5):295–300. doi:10.1027/1618-3169.56.5.295
50. Chen Q, Saunders JA. Embodied cognition in mental rotation: a secondary somatosensory area response to unseen rotation stimuli. *J Cogn Neurosci*. 2016;28(2):238–246.
51. Naccache L, Dehaene S. The priming method: imaging unconscious repetition priming reveals an abstract representation of number in the parietal lobes. *Cerebral Cortex*. 2001;11(10):966–974. doi:10.1093/cercor/11.10.966
52. Ortells JJ, Morillas A, Llorens A. The mediating role of cognitive flexibility between neuroticism and schizotypy: a structural equation modeling analysis. *Personal Individ Differ*. 2016;90:134–139.
53. Atas A, Faivre N, Timmermans B, et al. Nonconscious learning from crowded sequences. *Psychol Sci*. 2014;25(1):113–119. doi:10.1177/0956797613499591
54. Tu S, Zhu S, Liang Q, et al. Unconscious integration of sequentially presented subliminal arrow pointing directions. *Aust J Psychol*. 2020;72(1):82–92. doi:10.1111/ajpy.12252
55. Lin J, Murray SO. The neural substrates of visual form and motion processing. *Annu Rev Neurosci*. 2014;37:1–24. doi:10.1146/annurev-neuro-071013-013950
56. Liu C, Sun Z, Jou J, et al. Unconscious Processing of Facial Emotional Valence Relation: behavioral Evidence of Integration between Subliminally Perceived Stimuli. *PLoS One*. 2016;11(9):e0162689. doi:10.1371/journal.pone.0162689
57. Montoro PR, Luna D, Maldonado A, et al. Role of facial attractiveness in moderating the influence of social anxiety on approachability judgments. *PLoS One*. 2014;9(4):e95636. doi:10.1371/journal.pone.0095636
58. Mudrik L, Faivre N, Koch C. Information integration without awareness: (Trends in Cognitive Sciences 18, 488-496; September, 2014). *Trends Cogn Sci*. 2016;20(7):559. doi:10.1016/j.tics.2016.05.005
59. Zhou J, Lee CL, Li KA, et al. Does temporal integration occur for unrecognizable words in visual crowding? *PLoS One*. 2016;11(2):e0149355. doi:10.1371/journal.pone.0149355
60. van Gaal S, Naccache L, Meuwese JDI. Auditory attentional control with or without consciousness: evidence from event-related potentials. *Front Hum Neurosci*. 2014;8:339.
61. Yang Y-H, Tien Y-H, Yang P-L, et al. Role of consciousness in temporal integration of semantic information. *Cogn Affect Behav Neurosci*. 2017;17(5):954–972.
62. Sio UN, Monaghan P, Ormerod T. Sleep on it, but only if it is difficult: effects of sleep on problem solving. *Mem Cognit*. 2013;41:159–166.
63. Kaplan CA, Simon HA. In Search of Insight. *Cogn Psychol*. 1990;22(3):374–419. doi:10.1016/0010-0285(90)90008-R
64. Knoblich G, Ohlsson S, Raney GE. An eye movement study of insight problem solving. *Mem Cognit*. 2001;29(7):1000–1009. doi:10.3758/BF03195762
65. Dijksterhuis A, Strick M. A case for thinking without consciousness. *Perspect Psychol Sci*. 2016;11(1):117–132. doi:10.1177/1745691615615317

Psychology Research and Behavior Management Dovepress

Publish your work in this journal

Psychology Research and Behavior Management is an international, peer-reviewed, open access journal focusing on the science of psychology and its application in behavior management to develop improved outcomes in the clinical, educational, sports and business arenas. Specific topics covered in the journal include: Neuroscience, memory and decision making; Behavior modification and management; Clinical applications; Business and sports performance management; Social and developmental studies; Animal studies. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit http://www.dovepress.com/testimonials.php to read real quotes from published authors.

Submit your manuscript here: https://www.dovepress.com/psychology-research-and-behavior-management-journal