How do multiple masked relevant prime stimuli affect a conscious response: Two prime arrows produce independent priming effects on the target response

Shen Tu (✉ shentu614@vip.163.com)
Jiuhong Yan
Chengzhen Liu
Jieyu Lv
Jerwen Jou
Jiang Qiu

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Abstract

Since there are a lot of sources of unconscious information in our mind, there is a possibility that multiple channels of unconscious information can affect a response at the same time. However, this question has been largely ignored by the researchers. In the present study, we presented two opposite pointing arrows as the masked primes followed by a target arrow. The results suggested that the two pointing directions of the two prime arrows influenced the response to the target simultaneously and independently, i.e. the overall priming effect caused by the two opposite pointing prime arrows was equal to the net effect of the individual congruent effect elicited by the same pointing prime arrow and the individual incongruent priming effect induced by the opposite pointing prime arrow. In addition, in Experiment 1, a biased delayed response to the target was observed when the target arrow and the opposite pointing prime arrow were closely positioned in space due to Gestalt proximity grouping.

Introduction

With lots of information impinging on us at each moment, the selection of information plays an important role in our daily information processing. Selection of information is involved in which object we pay attention to and what we think about at each moment. It is difficult to pay attention to two objects at the same time and consequently, under normal circumstances, only one unit of information can enter our consciousness at each moment (Pohl, Kiesel, Kunde, & Hoffmann, 2010). To explain the selectivity of information processing, several attention selection theories have been proposed, such as the bottle-neck model (Broadbent, 1957), the attenuation model (Treisman, 1960), the late-stage selection model (Deutsch & Deutsch, 1963), and the energy distribution model (Kahneman, 1973), among others. These theories focus on the conditions in which some of the surrounding information can enter our consciousness, but relevant experiments were restricted only to supraliminal stimuli.

Recently, based on a large amount of evidence of unconscious processing (Bruno et al., 2020; Chen, Chen, Ma, & Jiang, 2020; Eriksson, Fontan, & Pedale, 2020; Soto, Sheikh, & Rosenthal, 2019), it has been found that multiple subliminal stimuli can integrate with each other. This finding greatly advanced the understanding of unconscious information processing and integration (Hirschhorn, Kahane, Gur-Arie, Faivre, & Mudrik, 2021; Tu et al., 2020; Van Opstal, 2021; Wang et al., 2017). To demonstrate unconscious integration among stimuli, multiple unconscious, masked stimuli need to be used. At each moment, there are multiple sources of unconscious information in our mind, such as linguistic knowledge, episodic memory, representation of habitual stimuli, to name a few (Baars, 1993). Therefore, it is possible that multiple channels of unconscious information can simultaneously affect a response or behavior. But how do they affect the response? For example, do they produce their own effects independently, or is there a priority in selecting and processing some of the multiple unconscious stimuli over others? Can any of the attention selection theories be applied to explain how multiple unconscious stimuli influence a conscious response? The answer to these questions is crucial for better understanding the mechanism of conscious information processing. It is possible that the processing of multiple channels of unconscious information involves selection priority and so the information that gets selected goes into consciousness first. This issue of how multiple unconscious stimuli are selected in processing and their effects on a response has been largely ignored by the researchers.

For a long time, the popular tip- of- the- iceberg hypothesis holds that a conscious experience emerges from the interaction among a large number of unconscious processes (Ellenberger, 1970). If the hypothesis is reasonable, it is almost inevitable that multiple unconscious processes affect a behavioral response at the same time. Otherwise, how can so much unconscious information establish a relationship with the current behavior? Compared with a one-to-one unconscious influence on a conscious experience, many-to-one unconscious influences on a conscious experience seems to be more adaptive, more able to make the best of the benefits of an individual’s past experiences, and can provide alternative perspectives to explain individual psychological and behavioral differences.

To investigate simultaneous multiple unconscious influences on a response, one needs to present multiple pieces of unconscious information that have to be all relevant to the supraliminal stimulus. Previous research using multiple unconscious stimuli had no intention to investigate this particular issue. For example, in the studies of unconscious integration, researchers focused on how the new, integrated representation from multiple unconscious stimuli affected the subsequent response (Faivre, Mudrik, Schwartz, & Koch, 2014; Liu et al., 2016), rather than how the multiple unconscious stimuli separately influenced the response.

The process of multiple sources of unconscious information affecting a reaction may involve unconscious selection of individual sources of information. There is sporadic evidence showing the selectivity on the sources of unconscious information although the phenomenon was rarely studied in the context of how multiple pieces of unconscious information affect a response. For instance, Finkbeiner et al. (2004) used polysemous words as the masked prime and found a priming effect on semantic categorization in favor of a particular meaning of the word. In the Finkbeiner et al.’s experiment, only one of the meanings of the prime word was related to the target’s meaning. Participants seemed to select the relevant meaning of polysemous word for their responses to the target. In another study, a nude image and its mosaic version were unconsciously presented on the left and right side of the focus point, respectively. The nude image induced an unconscious spatial attention bias effect in the modified Posner cuing paradigm (Jiang, Costello, Fang, Huang, & He, 2006; Posner, Snyder, & Davidson, 1980). This study clearly revealed the unconscious selective processing bias in that only the nude image was capable of inducing the spatial attention. In these studies, only one element of the unconscious stimuli was relevant to the supraliminal target. We are interested in finding out how multiple pieces of masked information that are all relevant to the target stimulus can affect the response to the target.

In the present study, we investigated multiple simultaneous unconscious influences on a response by presenting two masked priming stimuli at the same time that were both related to the target. Specifically, in one condition, we presented two opposite pointing arrows as the masked primes followed by a target arrow pointing in a direction that was the same as one prime arrow but opposite to the other prime arrow (we called this arrangement the mixed condition). There is evidence that masked prime arrow(s) could facilitate the response to target arrow(s) pointing in the same direction but inhibit the response to a target arrow(s) pointing in the opposite direction (Eimer, 1999; Schlaghecken & Eimer, 2000; Verleger, Jaskowski, Aydemir, Lubbe, & Groen, 2004; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003). Thus, we wanted to see how the response to the target arrow in the mixed condition could be influenced by the two opposite-pointing prime arrows.

Does each prime stimulus influence the response to the target independently, or does the effect tend to be dominated by the facilitating or inhibiting member of the two prime arrows? Here, we define the priming effects caused by the two opposite pointing prime arrows in the mixed condition as *independent* if the effect size is equal to the net summed effect of the individual congruent effect elicited by the same pointing prime arrow and the individual incongruent priming effect induced by the opposite pointing prime arrow. If they are not equal, then the overall priming effect in the mixed condition would be dominated by either the facilitating or the inhibiting effect. In that case, the two opposite pointing arrows in the mixed condition are not considered to produce the effects independently. The definition of independent unconscious priming effect in this study was similar to the analysis of *additive* priming effect in a double semantic priming paradigm (Ovando-Tellez et al., 2021), in which the priming effect of two supraliminal primes (double priming) or only one of them (single priming) on a target word was measured.

Experiment 1

In this experiment, we devised four priming conditions, a neutral, a congruent, an incongruent, and a mixed condition. The target stimulus was an arrow pointing either in the left or right direction. In the neutral condition, the two prime stimuli were equal signs. In the congruent and incongruent conditions, one of the prime stimuli was an equal sign, the other was an arrow pointing either in the same direction (congruent condition) as, or in the opposite direction (incongruent condition) of the target arrow. The mixed condition was the crucial one because both prime stimuli were arrows and hence both were relevant to the target. The target arrow was displayed exactly at the position between the two priming arrows. See **Table 1** for the details of the design.

Insert Table 1 here

Subjects

Twenty-eight subjects from Guizhou University of Finance and Economics volunteered for this study (16 women, 12 men; aged 19-24 years [mean age 21.8 years]). All subjects were right-handed, had normal or corrected-to-normal vision, and no history of current or past neurological or psychiatric conditions. The number of subjects whose data were included in the final analysis (27 subjects) was basically the same as the priorly estimated sample size of 24 from G*Power software (Faul et al., 2007) for achieving an effect size of f = .25, a statistical power of .80, and a p value of .05. They gave the written informed consent before the experiment and were all paid for their participation. The current study was approved by the the Ethics Committee of Institute at the Guizhou University of Finance and Economics.

Design

In the *neutral condition*, two equal signs were displayed side by side in the prime and an arrow pointing to the left or right was presented as the target at the position between the two prime stimuli in the center of the screen. In the *congruent condition*, an arrow and an equal sign were displayed in the prime, with one on the left and one on the right side, and the pointing direction of the target arrow was the same as that of the prime arrow. In the *incongruent condition*, the prime was the same as in the congruent condition, except that the target arrow pointed in the opposite direction to the arrow in the prime. In the *mixed condition*, a pair of arrows pointing in opposite directions (e.g., < > and > <) were presented side by side in the prime, and a target arrow pointing to the left or right was presented spatially between the two prime arrows following a 50-ms mask in the center of the screen. The size of the two paired prime symbols was approximately 0.8 (height) × 2.4 (width) degrees of visual angle.

Procedure

First, the subjects were trained in eight practice trials with two in each condition. Subsequently, two experimental blocks were run. Each block consisted of 128 trials, with 32 trials per condition. The different conditions were mixed and presented randomly in each block. Between the blocks, the subjects could take a short break. In each trial, a fixation cross appeared in the center of the screen for 200 ms. Subsequently, the prime was presented on the screen for 32 ms (two screen refreshes), followed by a backward mask (e.g., ) for 50 ms. After the mask, the target arrow was displayed for 1500 ms. Subjects were asked to indicate in which direction the target arrow was pointing by pressing 1 or 2 with their right index and middle fingers, respectively, as quickly and accurately as possible. Subjects were told that the stimuli prior to the appearance of the arrow were distractions and should be ignored. The response mapping to the two keys was counterbalanced across subjects. Lastly, a blank screen appeared for 1000 ms before the start of the next trial.

After the priming experiment, the subjects were asked to report whether they saw anything in the priming phase before the target arrow appeared. Then, a forced-choice discrimination task followed to test the subjects' ability to recognize the masked symbols. In the forced-choice task, after a 200 ms fixation cross, two arrows pointing in opposite directions were presented for 32 ms, followed by a backward mask for 50 ms. Subjects were asked to determine or guess whether the two arrows were facing inward or outward. There were 104 trials in the visibility test, with 52 trials for each facing arrow condition. Before performing this task, subjects were informed that the probability of the two arrows facing inward or outward was equal, and that only the accuracy, not the speed of the response, was important.

Results

Prime visibility

All subjects reported that they could not detect anything other than the target arrow. However, one subject scored above chance level at the recognition test, with her mean percentage of correct recognition above

58%, $p < .05$, by a binomial test. This subject's data were excluded from further analyses. The remaining 27 subjects performed at chance level in the recognition test. The mean percentage of correct recognition was 49.7±1.1%, not significantly different from chance level, $t(26) = -.233$, $p = .818$, nor was the mean d' value (mean = -.033, SE = 0.063) significantly different from zero, $t(26) = -.525$, $p = .604$.

Overall effect

Insert Table 2 here

A one-way repeated measures analysis of variance (ANOVA) was conducted on the RT (see the four conditions in **table 1**). The results indicated that the main effect of condition was significant (**Figure 1**), $F(3, 78) = 35.223$, $p < .001$, $\eta_p^2 = .575$. Post-hoc tests demonstrated a significant RT difference between all the compared conditions, $ts < -3.243$, $ps_{bonf} < .019$ (see **table 2** in detail). Overall, the results showed a significant congruency effect: the RT was significantly shorter in congruent condition than in the neutral condition and that the mean RT of the neutral condition was significantly shorter than that in the incongruent condition. More importantly, the mean RT in the mixed condition was shorter than that in the incongruent condition but longer than that in the neutral condition (RT congruent < RT neutral < RT mixed <RT incongruent).

Insert Figure 1 here

A similar repeated measures ANOVA on accuracy showed that the main effect of condition was significant, $F(3, 78) = 5.309$, $p = .002$, $\eta_p^2 = .170$. The post-hoc tests showed that the neutral condition mean accuracy was higher than the incongruent condition mean, $t = 3.238$, $p_{bonf} = .020$ (see **table 3** in detail). The other post-hoc comparisons revealed no significant accuracy difference between the compared conditions.

Insert Table 3 here

Comparison of sizes of congruent and incongruent effects

In this analysis, the size of the incongruent priming effect (RTincongruent - RTneutral, mean = 18 ms) was compared with that of the congruent priming condition (RTneutral - RTcongruent, mean = 8 ms). The difference of 10 ms was significant, $t(26) = 3.133$, $p = .004$, Cohen's $d = .603$. In other words, the incongruent priming effect was stronger than the congruent priming effect.

Independent priming effect

Here, we tested whether the two prime arrows in the mixed condition influenced the response to the target independently by comparing the size of the mixed effect (RTmixed – RTneutral = 7 ms) with the size of synergistic effect of congruent and incongruent conditions [(RTincongruent - RTneutral) - (RTneutral - RTcongruent) = 10 ms]. The result did not show a significant difference, $t(26) = -1.281$, $p = .211$, Cohen's d

= .247. The results of a separate Bayesian paired-samples *t* test using JASP also did not support the alternative hypothesis, BF_{10} = .425.

Experiment 2

Although in general the results in Experiment 1 suggested that the two relevant prime stimuli exerted independent effects on the response to the target, there was one feature in the design that warranted further investigation. In Experiment 1, the target arrow was displayed exactly at the position between the two symbols in the prime. This made the target arrow and one prime arrow in the mixed condition appear closely adjacent in spatial position (e.g. “< >” in prime and “>” in target leading to an apparently combined display of the left prime arrow and target arrow in “<>>”; or “> <” in prime and > in target leading to a combined display of the right prime arrow and the target in “>><”). Based on the Gestalt proximity grouping principle, the closer two stimuli are positioned, the more likely they will be seen as belonging to one group (Palmer, 2000). Therefore, in Experiment 1 the target was more likely to be influenced by the opposite-pointing arrow in the prime, leading to slower responses to the mixed condition compared to the neutral condition. In Experiment 2, we increased the gap between the two symbols in the prime, and therefore the two opposite-pointing arrows in the prime and target arrow were not as closely positioned as they were in Experiment 1.

Method

Subjects

Twenty-two subjects from Guizhou University of Finance and Economics volunteered for this study (13 women, 9 men; mean age 20.6 years). They did not participate in Experiment 1. All subjects were right-handed, had normal or corrected-to-normal vision, no history of current or past neurological or psychiatric conditions. The number of subjects whose data were included in the final analysis (22 subjects) was also basically the same as the priorly estimated sample size of 24 from the G*Power program. They gave the written informed consent before the experiment and were paid for participation. The current study was approved by the the Ethics Committee of Institute at the Guizhou University of Finance and Economics.

Design and procedure

The design and procedure were the same as in Experiment 1 except that the gap between the two arrow symbols in the prime was increased to twice the width of a symbol.

Results

Prime visibility

All subjects reported that they could not detect anything other than the target arrow. Every subject scored at chance level. The mean percentage of correct recognition was 50.9±1.2%, not significantly different from chance level, $t(21) = .800$, $p = .432$, nor was the mean d' value (mean = .041, SE = 0.066) significantly different from zero, $t(21) = .611$, $p = .548$.

Overall effect

A one-way repeated measures ANOVA was conducted on the RT (see the four conditions in table 1). The results indicated that the main effect of condition was significant (**Figure 1**), $F(3, 63) = 17.885$, $p < .001$, $\eta_p^2 = .460$, Cohen's $f = .869$. Post-hoc tests demonstrated a significant RT difference between all the compared conditions, ts < -2.993, $p_{bonf} < .024$ except that between the neutral and mixed conditions (see **table 4** in detail). Overall, the results showed a significant congruency effect: the RT was significantly shorter in congruent condition than that in neutral condition and significantly shorter in the neutral than in the incongruent condition (RT congruent < RT neutral < RT incongruent). However, the mean RTs were not significantly different between the mixed condition and neutral condition.

Insert Table 4 here

A similar repeated measures ANOVA on accuracy showed that the main effect of condition was marginally significant, $F(3, 63) = 2.352$, $p = .081$, $\eta_p^2 = .101$. Due to the marginally significant main effect of condition, the post-hoc tests were conducted but did not find a significant accuracy difference between the compared conditions, ts < 2.327, $p_{bonf} > .139$ (see **table 5** in detail).

Insert Table 5 here

Comparison of sizes of congruent and incongruent effects

The size of the incongruent priming effect (RTincongruent - RTneutral, mean = 13 ms) was compared with that of the congruent priming condition (RTneutral - RTcongruent, mean = 9 ms). The difference between the 13 ms and 9 ms was not significant, $t(21) = .819$, $p = .422$.

Independent priming effect

Using similar analysis as in experiment 1, we compared the size of the mixed effect (RTmixed – RTneutral = 2 ms) with the size of synergistic effect of congruent and incongruent conditions [(RTincongruent - RTneutral) - (RTneutral - RTcongruent) = 4 ms]. The difference between the 2 ms and 4 ms was not significant $t(21) = -.521$, $p = .608$, Cohen’s $d = .111$. The results of a separate Bayesian paired-samples t test using JASP also showed a moderate evidence for the null hypothesis, $BF_{10} = .252$.

Discussion

In the present study, two simultaneously presented prime arrows pointing in opposite directions were used to investigate the influence of multiple pieces of unconscious information on a response to a target arrow. The results of both experiments suggested that the two prime arrows influenced the response to the target arrow independently.

In Experiment 1, the results showed a significantly larger incongruent priming effect (RTincongruent - RTneutral = 18 ms, e.g. “=<>” a combination of the prime and the target symbols in which the middle arrow was the target and the symbols on two sides were the primes) than the congruent priming effect (RTneutral - RTcongruent = 8 ms, e.g. “=>>”). It indicated that the response to the target was more likely to be influenced by the opposite pointing arrow than by the same-direction arrow in the prime. Most importantly, the response to the target was significantly slower in the mixed condition (e.g. “><<”) compared to that in the neutral condition (e.g. “=<=”), with the effect size being 7 ms (see **table 2**). The results of independent priming effects in Experiment 1 revealed that in the mixed condition, the two prime arrows had individual priming effects on the response to the target arrow, i.e, the larger incongruent priming effect than the congruent priming effect led to the slower response in the mixed condition than the neutral condition.

As for the reason why the incongruent priming effect was larger than the congruent priming effect, there was evidence that attention can be captured without awareness (Jiang et al., 2006; Lin, Murray, & Boynton, 2009) but that inconsistent information is more noticeable (Howard & Holcombe, 2010). However, in Experiment 1, the target arrow was displayed exactly at the position between the two arrows in the prime. This made the target arrow and the prime arrow pointing in the opposite direction appear fused together in both the mixed and the incongruent conditions (e.g. “<>>” in the mixed condition, and “><=” in the incongruent condition). Based on the Gestalt proximity grouping principle, the closer stimuli are positioned, the more they will be seen as belonging to one group. There is also evidence of unconscious perceptual grouping of stimuli by proximity (Kimchi, Devyatko, & Sabary, 2018; Montoro, Luna, & Ortells, 2014). Therefore, in Experiment 1, the slower response in the mixed condition than in the neutral condition might be due to the proximity of the target arrow to the opposite pointing arrow in the prime.

However, in Experiment 1, the target arrow and the prime arrow were separated by the mask, creating a kind of proximity different from the traditional proximity in which the multiple stimuli were displayed simultaneously. In order to determine whether the selectively larger incongruent priming effect in Experiment 1 was due to the spatial proximity of the prime and the target, we increased the gap between the two symbols in the prime in Experiment 2. The results showed a congruent effect (9 ms) similar to that of Experiment 1 (8 ms), but a smaller incongruent priming effect (13 ms) than that in the Experiment 1 (18 ms) (see **table 2 and 4)**. Most importantly, the significant RT difference between the mixed and the neutral conditions disappeared. These results showed that with the increase in distance between the two prime arrows, unconscious prime-stimulus selective bias between the two subliminal arrows no longer existed. Thus, the unconscious selective processing of one stimulus in the prime of Experiment 1 was likely due to the close proximity between one prime arrow and the target arrow. This hypothesis was supported by the almost same congruent priming effect in Experiment 2 as in Experiment 1, but the smaller incongruent priming effect in Experiment 2 than in Experiment 1.

In theory, the nonsignificant RT difference between mixed condition and neutral condition in Experiment 2 can be attributed to no unconscious processing of the two prime arrows in the mixed condition. However, the arrows in the prime were shown to produce stable congruent and incongruent priming effects in both experiments. Therefore, we believed that the opposite priming effects of the two subliminal arrows in the mixed condition must have canceled each other out. In addition, a comparison of the size of the mixed effect (RTmixed - RTneutral) with the size of synergistic effect of congruent and incongruent conditions [(RTincongruent - RTneutral) - (RTneutral - RTcongruent)] indicated a nonsignificant difference. The nonsignificant difference between these two effects in both experiments suggested that the two prime arrows in the mixed condition influenced the response to the target independently, irrespective of the extent of the proximity. To our knowledge, this is the first time the fact that two unconscious stimuli can independently affect a response was observed.

It was mentioned in Experiment 1 that there was unconscious biased processing of the two subliminal arrows due to the spatial proximity. It should be noted that before the target arrow had appeared, the observer should not have been biased toward processing any of the two subliminal opposite pointing arrows. Therefore, the different priming effect sizes caused by the two prime arrows could not be attributed to pre-target processing. Instead, the different priming effect sizes had to be attributed to the proximity of one prime stimulus to the target when the target arrow appeared. In other words, the biased unconscious effect in Experiment 1 probably came from the delayed response to the target arrow due to the stimulus proximity while the activity caused by the prime arrows did not change. However, because the unconscious grouping by proximity occurred after the presentation of target arrow, the target could have played a role of top-down selection. That is, the proximity between the target and the opposite-pointing prime arrow might have cause an enhanced/selective response to the opposite-pointing prime arrow (but only at the brain activity level, not at the behavioral level due to the prime's unconscious processing) leading to the unconscious selective effect. We called it *Reverse Unconsciously Picked Advantage* because it was different from the conscious top-down influence on unconscious processing that other studies reported in which the conscious attention is invoked before the presentation of unconscious stimulus (Kimchi, Devyatko, & Sabary, 2018; Montoro, Luna, & Ortells, 2014). If the later assumption is verified, the paradigm in the present study may be used in the future to study the unconscious top-down effect on the processing of subliminal stimuli.

In conclusion, much evidence has been provided for the unconscious processing of single stimuli and recently also for the integration between different subliminal stimuli. Yet, there is little evidence so far for the influence from multiple, relevant unconscious stimuli on a response. In the present study, we found multiple independent unconscious influences on a response. It might be a general brain processing mechanism. At any rate, there is a lot of unconscious information in brain, and a one-to-one information-processing mode seems too simple for our brain. More research is needed in the future to find out the detailed mechanisms of multiple unconscious influences on a response. Lastly, the question of the origin of the unconscious selective priming effect needs to be investigated further in future research.

Declarations

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References

Baars, B. J. (1993). *A cognitive theory of consciousness*. Cambridge: Cambridge University Press.

Broadbent, D. E. (1957). A mechanical model for human attention and immediate memory. *Psychological review, 64*(3), 205-215.

Bruno, N. M., Embon, I., Díaz Rivera, M. N., Giménez, L., D'Amelio, T. A., Torres Batán, S., et al. (2020). Faster might not be better: Pictures may not elicit a stronger unconscious priming effect than words when modulated by semantic similarity. *Consciousness and Cognition, 81*, 102932.

Chao, H. (2018). The role of awareness in the cognitive control of single-prime negative priming. *Consciousness and Cognition, 57*, 94-105.

Chen, J., Chen, H., Ma, L., Jiang, Y. (2020). A Review of Studies on Unconscious Emotional Priming. *Open Access Library Journal, 7*, e6284.

Deutsch, J. A., Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological review, 70*(1), 80-90.

Eimer, M. (1999). Facilitatory and inhibitory effects of masked prime stimuli on motor activation and behavioural performance. *Acta Psychologica, 101*(2-3), 293-313.

Ellenberger, H. F. (1970). *The Discovery of the Unconscious: The History and Evolution of Dynamic Psychiatry*. New York: Basic Books.

Eriksson, J., Fontan, A. L., Pedale, T. (2020). Make the Unconscious Explicit to Boost the Science of Consciousness. *Frontiers in Psychology, 11*, 260.

Faivre, N., Mudrik, L., Schwartz, N., Koch, C. (2014). Multisensory Integration in Complete Unawareness Evidence From Audiovisual Congruency Priming. *Psychological science, 25*(11), 2006-2016.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical science. *Behavior Research methods, 2007, 39 (2),* 175-199.

Finkbeiner, M., Forster, K., Nicol, J., Nakamura, K. (2004). The role of polysemy in masked semantic and translation priming. *Journal of memory and language, 51*(1), 1-22.

Hirschhorn, R., Kahane, O., Gur-Arie, I., Faivre, N., Mudrik, L. (2021). Windows of Integration Hypothesis Revisited. *Frontiers in Human Neuroscience, 14*, 617187.

Howard, C. J., Holcombe, A. O. (2010). Unexpected changes in direction of motion attract attention. *Attention, Perception, & Psychophysics, 72*(8), 2087-2095.

Jiang, Y., Costello, P., Fang, F., Huang, M., He, S. (2006). A gender- and sexual orientation-dependent spatial attentional effect of invisible images. *Proceedings of the National Academy of Sciences, 103*(45), 17048-17052.

Kahneman, D. (1973). *Attention and effort* (Vol. 1063). Englewood Cliffs, New Jersey: Prentice-Hall.

Kimchi, R., Devyatko, D., Sabary, S. (2018). Can perceptual grouping unfold in the absence of awareness? Comparing grouping during continuous flash suppression and sandwich masking. *Consciousness and Cognition, 60*, 37-51.

Lin, J. Y., Murray, S. O., Boynton, G. M. (2009). Capture of attention to threatening stimuli without perceptual awareness. *Current Biology, 19*(13), 1118-1122.

Liu, C., Sun, Z., Jou, J., Cui, Q., Zhao, G., Qiu, J., et al. (2016). Unconscious Processing of Facial Emotional Valence Relation: Behavioral Evidence of Integration between Subliminally Perceived Stimuli. *Plos One, 11*(9), e162689.

Montoro, P. R., Luna, D., Ortells, J. J. (2014). Subliminal Gestalt grouping: Evidence of perceptual grouping by proximity and similarity in absence of conscious perception. *Consciousness and Cognition, 25*, 1-8.

Nakamura, K., Dehaene, S., Jobert, A., Le Bihan, D., Kouider, S. (2007). Task-specific change of unconscious neural priming in the cerebral language network. *Proceedings of the National Academy of Sciences of The United States of America, 104*(49), 19643-19648.

Ovando-Tellez, M., Rohaut, B., George, N., Bieth, T., Hugueville, L., Ibrahim, Y., et al. (2021). Does adding beer to coffee enhance the activation of drinks? An ERP study of semantic category priming. *Cognitive Neuroscience*, 1-16.

Palmer, S. E. (2000). Encyclopedia of psychology, Vol. 6. In A. E. Kazdin (Ed.), *Encyclopedia of Psychology* (Vol. 6, pp. 93-97). Washington, DC: American Psychological Association.

Pohl, C., Kiesel, A., Kunde, W., Hoffmann, J. (2010). Early and late selection in unconscious information processing. *Journal of experimental psychology. Human perception and performance, 36*(2), 268-285.

Posner, M. I., Snyder, C. R., Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology General, 109*(2), 160-174.

Schlaghecken, F., Eimer, M. (2000). A central-peripheral asymmetry in masked priming. *Attention, Perception, & Psychophysics, 62*(7), 1367-1382.

Shin, K., Stolte, M., Chong, S. C. (2009). The effect of spatial attention on invisible stimuli. *Attention, Perception, & Psychophysics, 71*(7), 1507-1513.

Soto, D., Sheikh, U. A., Rosenthal, C. R. (2019). A Novel Framework for Unconscious Processing. *Trends in Cognitive Sciences*.

Treisman, A. M. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12*(4), 242-248.

Tu, S., Wan, S., Jou, J., Ma, Y., Zhao, G., Pan, W. (2020). Can unconscious sequential integration of semantic information occur when the prime Chinese characters are displayed from left to right? *Attention, Perception, & Psychophysics, 82*(3), 1221-1229.

Van Opstal, F. (2021). The same-different task as a tool to study unconscious processing. *Current Opinion in Behavioral Sciences, 37*, 35-40.

Verleger, R., Jaskowski, P., Aydemir, A., Lubbe, R. H. V. D., Groen, M. (2004). Qualitative differences between conscious and nonconscious processing? On inverse priming induced by masked arrows. *Journal of Experimental Psychology-General, 133*(4), 494-514.

Vorberg, D., Mattler, U., Heinecke, A., Schmidt, T., Schwarzbach, J. (2003). Different time courses for visual perception and action priming. *Proceedings of the National Academy of Sciences of the United States of America, 100*(10), 6275-6280.

Wang, D., Tang, L., Liang, Q., Jou, J., Ma, Y., Pan, W., et al. (2017). Unconscious integration of pointing relation between two masked arrows. *Visual Cognition, 25*(9-10), 928-939.

Tables

Table 1. The experimental design and the results of each condition (mean±standard errors) in both experiments.

		Neutral Condition		Congruent Condition		Incongruent Condition		Mixed Condition	
		prime	target	prime	target	prime	target	prime	target
		= =	>	> =	>	= <	>	> <	>
		= =	<	= <	<	> =	<	> <	<
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Exp.1	RT (ms)	437±8		429±9		455±8		444±9	
	Accuracy (%)	98.2±.6		98.4±.4		95.9±1.2		97.8±.7	
Exp.2	RT (ms)	461±10		452±10		474±9		463±10	
	Accuracy (%)	98.9±.5		98.9±.3		97.5±.8		98.5±.5	

Table 2. Post-Hoc Comparisons for RT (ms)						
		Mean Difference	SE	*t*	Cohen's *d*	p_{holm}
congruent	neutral	-7.827	2.256	-3.469	-0.668	0.004 **
	mixed	-14.780	2.546	-5.804	-1.117	< .001 ***
	incongruent	-26.063	3.549	-7.344	-1.413	< .001 ***
neutral	mixed	-6.953	2.144	-3.243	-0.624	0.004 **
	incongruent	-18.236	2.594	-7.031	-1.353	< .001 ***
mixed	incongruent	-11.284	2.483	-4.544	-0.875	< .001 ***
* $p < .05$, ** $p < .01$, *** $p < .001$						

Table 3. Post-Hoc Comparisons for accuracy						
		Mean Difference	SE	*t*	Cohen's d	p_{holm}
congruent	neutral	0.002	0.006	0.318	0.061	0.753
	mixed	0.006	0.006	1.007	0.194	0.646
	incongruent	0.026	0.011	2.369	0.456	0.102
neutral	mixed	0.004	0.003	1.464	0.282	0.465
	incongruent	0.024	0.007	3.238	0.623	0.020 *
mixed	incongruent	0.019	0.008	2.521	0.485	0.091
* $p < .05$						

Table 4. Post-Hoc Comparisons for RT (ms) in experiment 2						
		Mean Difference	SE	*t*	Cohen's *d*	p_{holm}
congruent	neutral	-9.298	3.107	-2.993	-0.638	0.008**
	mixed	-10.922	3.107	-3.516	-0.750	0.002**
	incongruent	-22.635	3.107	-7.286	-1.553	< .001***
neutral	mixed	-1.624	3.107	-0.523	-0.111	0.603
	incongruent	-13.336	3.107	-4.293	-0.915	< .001***
mixed	incongruent	-11.712	3.107	-3.770	-0.804	0.001**
** $p < .01$, *** $p < .001$						

Table 5. Post Hoc Comparisons for accuracy in experiment 2						
		Mean Difference	SE	t	Cohen's d	p_{holm}
congruent	neutral	4.545e -4	0.006	0.075	0.016	1.000
	mixed	0.004	0.006	0.601	0.128	1.000
	incongruent	0.014	0.006	2.327	0.496	0.139
neutral	mixed	0.003	0.006	0.526	0.112	1.000
	incongruent	0.014	0.006	2.252	0.480	0.139
mixed	incongruent	0.010	0.006	1.727	0.368	0.356

Figures

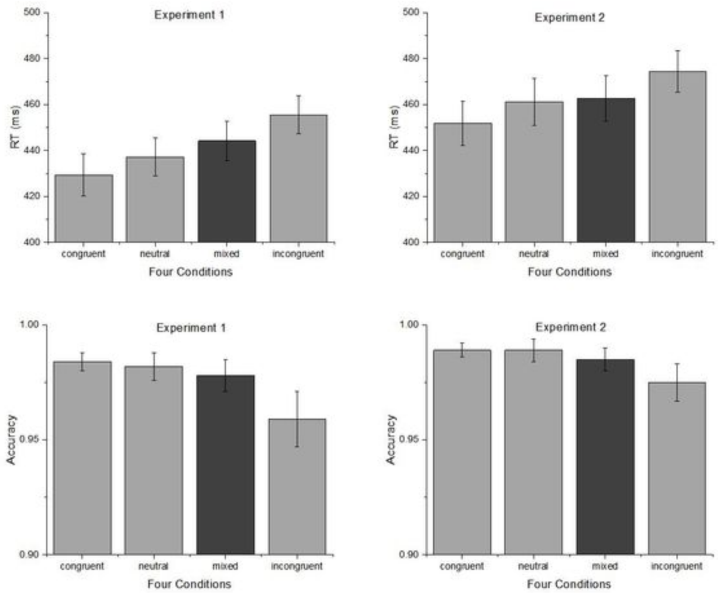

Figure 1. Mean response time (RT; upper panel) and accuracy (lower panel) of each condition in experiment 1 (left panel) and experiment 2 (right panel). Error bars represent standard errors of mean.

Figure 1

Mean response time (RT; upper panel) and accuracy (lower panel) of each condition in experiment 1 (left panel) and experiment 2 (right panel). Error bars represent standard errors of mean.