Valence makes a stronger contribution than arousal to affective priming

Zhao Yao [1, 2], **Xiangru Zhu** [Corresp., 3, 4], **Wenbo Luo** [Corresp. 5]

1 Research Center of Shaanxi intelligence society development, Xidian University, Xi'an, Shaanxi, China

2 School of Humanities, Xidian University, Xi'an, Shaanxi, China

3 Institute of Cognition, Brain and Health, Henan University, Kaifeng, Henan, China

4 Institute of Psychology and Behavior, Henan University, Kaifeng, Henan, China

5 Research Center of Brain and Cognitive Neuroscience, Liaoning Normal University, Dalian, Liaoning, China

Corresponding Authors: Xiangru Zhu, Wenbo Luo
Email address: zhuxiangru@gmail.com, luowb@lnnu.edu.cn

Background: Recent data suggest that both word valence and arousal modulate subsequent cognitive processing.However, whether valence or arousal makes a stronger contribution to cognitive processing is less understood.

Methods: The present study performed three experiments that varied the valence (positive or negative) and arousal (high or low) of prime-target word pairs in a lexical decision-priming task. Affective priming was derived from pure valence (Experiment 1), pure arousal (Experiment 2), or a combination of valence and arousal (Experiment 3).

Results: By comparing three types of priming effects, we found an effect of valence on affective priming was obvious regardless of whether the relationship of the prime-target varied with valence, arousal, or the combination of valence and arousal. In contrast, an effect of arousal on affective priming only appeared in the condition that based on the arousal relationship of the prime-target pair. Moreover, the valence-driven priming effect, arousal-driven priming effect, and emotional-driven priming effect were modulated by valence type but not by arousal level of word stimuli.

Conclusion: The present results revealed a pattern of valence and arousal in semantic networks,indicating that the valence information of emotional words tends to be more stable than arousal information within the semantic system, at least in the present lexical decision-priming task.

Introduction

Emotions influence our everyday lives in several ways. In a continuous flow of information, we must focus, select, store, and retrieve relevant information. Amazingly, we are able to automatically evaluate the affective value of all incoming stimulus information within a few milliseconds. Evaluation that is associated with affect and feelings helps people initiate subsequent appropriate behavioral responses. Although the processing of affective information has traditionally been assessed using self-reports, in which participants explicitly evaluate the affective information of stimuli, self-reports have inherent limitations. For example, if participants do not want to report their true feelings or deliberate on some stimuli, they might misreport their attitude and affective evaluations (Herring et al., 2013).

To minimize the bias of self-report evaluations, Fazio (2001) developed an affective priming paradigm to investigate automatic stimulus evaluation. In a typical affective priming study, an affective/evaluative relation between the prime and target is manipulated, and participants are asked to respond on the basis of particular feature (e.g., emotional or non-emotional) of the target stimuli. A common finding in this paradigm is that performance is typically faster and more accurate when a prime and target are congruent and have the same emotional information (e.g., "*flower*" – "*wedding*") compared with when they are incongruent and have different emotional information (e.g., "*party*" – "*corpse*"). This performance has been called an affective priming effect (for reviews, see Fazio, 2001; Klauer & Musch, 2003). Crucially, such an effect shows that the emotional information of stimuli can be implicitly and automatically evaluated. The affective priming effect can typically be explained by hypotheses of the spreading of activation (Fazio, 2001) or response competition (Spruyt et al., 2007). Throughout the history of investigations of affective priming, many studies have investigated the effects of valence and arousal on affective priming in various cognitive tasks because valence and arousal were identified as the most basic dimensions of emotional information (Russell, 2003). Still unclear, however, is whether valence and arousal have similar effects on target processing.

Much experimental evidence has revealed the influence of primed valence and arousal on affective priming (Zhang et al., 2006; Zhang, Kong & Jiang, 2012; Herring et al., 2011; Herring et al., 2015; Hinojosa et al., 2009; Hinojosa, Méndez-Bértolo & Pozo, 2012). For instance, a series of studies by Zhang et al. (2006; 2012) suggested that the participants responded faster in valence (arousal) congruent trials than in valence (arousal)-incongruent trials in a valence decision task. Moreover, previous studies suggest that the affective priming effect of positive primes differs from negative primes (e.g., Pan et al., 2016; Kissler & Koessler, 2011; Spruyt et al., 2007; Rossell & Nobre, 2004; Aguado et al., 2018). For example, Yao and Wang (2013) reported that a significant affective priming effect was observed with positive primes but not with negative primes in a lexical decision-priming task.

Although much is known about the roles of valence and arousal in affective priming, but less is known about whether valence and arousal have the same ''power'' to trigger affective priming. Three studies have systematically manipulated the valence (positive, negative) and arousal (high, low) of primes and targets (Herring et al., 2015; Zhang, Kong & Jiang, 2012), but their findings

41 were inconsistent. Apart from differences in experimental stimuli (e.g., pictures-words, pictures-
42 pictures, and faces-faces) and prime position (foveal vs. parafoveal), we inferred that such
43 inconsistencies might arise from differences between judgment tasks that encouraged participants
44 to selectively assign attention to valence and/or arousal, or neither. In previous studies, the
45 participants were asked to complete a valence decision task or an arousal decision task (Zhang,
46 Kong & Jiang, 2012; Herring et al., 2015). These two types of tasks require explicit processing of
47 the valence or arousal of stimuli, with selective attention directed toward a specific affective
48 feature. Spruyt and colleagues provided evidence that task-dependency of the affective priming
49 effect can be modulated by feature-specific attention allocation (Spruyt et al., 2007; Spruyt et al.,
50 2012). Therefore, to determine whether valence and arousal play similar roles in affective priming
51 and to avoid attention being assigned to a specific affective dimension, we employed a lexical
52 decision-priming task, in which the participants were asked to judge whether the target is a real
53 word as quickly and accurately as possible.

54   We used a lexical decision-priming task for two reasons. First, this task does not require
55 participants to have an explicit evaluative processing goal (e.g., to process either the valence or
56 arousal of stimuli). Therefore, all of the words are explicitly processed in the same way, and
57 differences in performance between words that differ in valence or arousal will be attributable to
58 their emotional dimension *per se*, without additional influence from top-down, task-dependent
59 processes (Citron, 2012). The contribution of valence and arousal to affective priming would be
60 relatively equally accessible in the lexical decision-priming task compared with the evaluative
61 decision task. Second, although the evaluative decision task is most widely employed in the
62 relevant literature (for review, see Herring et al., 2013), affective priming effects have been
63 observed in non-evaluative tasks, such as the lexical decision task (e.g., Kissler & Koessler, 2011;
64 Yao & Wang, 2013, 2014; Hinojosa, Méndez-Bértolo & Pozo, 2012) and in the
65 naming/pronunciation task (e.g., Spruyt et al., 2007). Some researchers suggested that a minimum
66 degree of linguistic processing modulates the allocation of attentional resources to the affective
67 feature of words, even in a more superficial structural task. In the lexical decision-priming task,
68 participants need to access a word's meaning when they judge that the target is a real word or a
69 pseudoword, which allows their attention to be divided across various stimulus dimensions,
70 including the inherently important affective feature (Spruyt et al., 2007; Citron, 2012). Therefore,
71 to obtain and compare pure valence-driven or pure arousal-driven priming effects, we adopted the
72 lexical decision-priming task, which produces a neutral processing mindset and allows valence
73 and arousal to influence affective priming as equally as possible.

74   We assume that valence and arousal do not produce parallel priming effects, even when they
75 are equally handled in an affective priming task. First, previous studies have provided evidence
76 that valence and arousal are associated with different physiological and affective responses and
77 activate partially dissociable brain networks (Estes & Adelman, 2008; Delaney-Busch, Wilkie &
78 Kuperberg, 2016). For example, an event-related potential study explored the time course of brain
79 electric activity evoked by information about the valence and arousal of emotional words and
80 found first valence then arousal (Gianotti et al., 2008). Second, some evidence has shown that the

81 valence of a stimulus is associated with higher-order cognitive, whereas arousal is associated with
82 more automatic physiological reactions that are less cognitively accessible (Nicolle & Goel, 2013;
83 Citron, 2012). Nicolle and Goel (2013) asked participants to rate sentences along cognitive
84 dimensions (i.e., believable, unbelievable) and affective dimensions (i.e., valence, arousal) and
85 suggested that valence responses may require internal computations and are more likely to be
86 influenced by our beliefs, whereas arousal-related responses do not rely on evaluation of the
87 stimulus and may be considered to occur at a more stimulus-driven level. Third, rating studies
88 reported the high variability of arousal ratings compared with valence ratings (e.g., Yao et al.,
89 2017). Arousal may show bigger differences between individuals. That is, the same valence word
90 may activate different degree of physiological activation for different groups of people. Take the
91 word "*wedding*", it was rated as positive valence and higher arousal due to more excited feeling
92 for people in love, but for others, it may elicit less excited feelings, but almost no one regard as
93 the word "*wedding*" is negative valence. Given these findings, we reasoned that valence and
94 arousal may have differential effects on affective priming because of their unequal ability to
95 engage emotional processing.

96   Taken together, the aim of the present study was to examine whether valence and arousal
97 have the same priming "power" in modulating affective priming in the lexical decision-priming
98 task. We manipulated the affective relationship between primes and targets in terms of valence
99 (positive, negative) and arousal (high, low). In Experiment 1, valence was manipulated so that the
100 prime-target word pairs were valence-congruent (positive-positive, negative-negative) or valence-
101 incongruent (positive-negative, negative-positive). The level of arousal of the pairs (low or high)
102 was equated in four prime-target conditions. In Experiment 2, arousal of the prime-target word
103 pairs was manipulated so that word pairs were arousal-congruent (high-high, low-low) or arousal-
104 incongruent (high-low, low-high) but were equated with regard to valence (positive or negative)
105 in four prime-target conditions. In Experiment 3, we used emotional words as primes and
106 neutral/emotional words as targets. Half of the word pairs were emotionally congruent (emotional
107 words-emotional words; i.e., the prime and target had similar valence and arousal), and the other
108 half were emotionally incongruent (emotional words-neutral words; i.e., the prime and target
109 differed in both valence and arousal). Therefore, affective priming in Experiment 1 reflected
110 valence priming effect, which refers to a facilitated response to a target when it is preceded by a
111 valence-congruent prime compared with a valence-incongruent prime. Affective priming in
112 Experiments 2 and 3 reflected arousal priming effect (i.e., faster responses in arousal-congruent
113 trials than in arousal-incongruent trials within the same valence) and emotional priming effect (i.e.,
114 faster responses in emotionally congruent trials than in emotionally incongruent trials),
115 respectively.

116   By comparing the priming effects of valence, arousal, and the combination of valence and
117 arousal on subsequent target processing, we could determine whether valence and arousal have the
118 same affective priming strength. And then, we sought to determine whether valence or arousal
119 who play a more relatively stable role in affective priming. If valence plays a stronger role in
120 affective priming, then valence priming effects may still be evident when the arousal and emotional

121 dimensions of primes-targets are manipulated. Conversely, if arousal plays a stronger role in
122 affective priming, then arousal priming effects may still be evident when the valence and emotional
123 dimensions of primes-targets are manipulated.

124 Experiment 1: Affective priming was derived from pure valence relationship
125 of primes and targets

126 Method

127 *Participants*
128   Twenty-nine native Chinese speakers (17 men, 12 women; age in years: $M = 18.2$, $SD = 1.8$,
129 range = 17-21) participated in Experiment 1. They were all right-handed with normal or corrected
130 to normal vision. None had any history of neurological or psychiatric disorders. They all gave
131 informed consent before the experiment. The study was approved by the local Ethics Committee
132 of Henan University (HUSOM-2018-102).

133 *Stimuli*
134   All of the stimuli that were presented were selected from a database of 1100 Chinese two-
135 character words (Yao et al., 2017). This database provides mean ratings and standard deviations
136 (SDs) of valence, arousal, and concreteness for each word. Each word was rated by at least 48
137 participants using a 9-point scale. We considered words with valence values that ranged from 1 to
138 4 as negative and words with values that ranged from 6 to 9 as positive. Words with arousal values
139 greater than 6.5 were considered high arousal words. Words with arousal values that ranged from
140 5 to 6 were considered as low arousal words.
141   From this database, the final stimulus set included 120 experimental nouns, 30 high-arousal
142 positive (PH; e.g., *gold medal, miracle*), 30 low-arousal positive (PL; e.g., *flowers, serenity*), 30
143 high-arousal negative (NH; e.g., *renegade, hatred*) and 30 low-arousal negative words (NL; e.g.,
144 *scar, lengthiness*). Four types of words were matched with regard to word frequency ($F_{3,116} = 1.03$,
145 $p = .38$), concreteness ($F_{3,116} = .16$, $p = .92$), and character strokes ($F_{3,116} = 1.07$, $p = .37$). Positive
146 and negative words had comparable arousal ($F_{1,118} = 0.26$, $p = .61$) but differed in valence ($F_{1,118}$
147 $= 19.83$, $p < .001$). High- and low-arousal words had comparable valence ($F_{1,118} = 0.03$, $p = .96$)
148 but differed in arousal ($F_{1,118} = 24.631$, $p < .001$). Word characteristics (means and SDs) are
149 presented in Table 1. A further paired sample t-test (2-tailed, more details are listed in Table 2)
150 comparing the four condition types revealed that there was no significant different in valence rating
151 between PH and PL, NH and NL, also in arousal rating between PH and NH, PL and NL.

152   (Insert Table 1)
153   (Insert Table 2)

154   All 240 prime-target word pairs were constructed based on the four types of words. There
155 were 120 valence-congruent pairs (30 PL-PL, 30 PH-PH, 30 NL-NL, 30 NH-NH) and 120 valence-
156 incongruent pairs (30 PL-NL, 30 PH-NH, 30 NL-PL, 30 NH-PH). Moreover, a total of 240 trials

157   were conducted that consisted of PL/PH/NL/NH prime-pseudoword target (60 trials in each pair).
158   In order to create the pseudowords, based on the 120 experimental words, one character was
159   randomly changed in each word to produce pronounceable pseudowords. During the experimental
160   session, the four types of experimental words as primes and targets were repeated four and two
161   times, respectively, and pseudowords were presented two times. Moreover, we carefully excluded
162   possible semantic relationship of primes-targets by an additional rating experiment using a 5-point
163   scale (from 1 point to 5 point, a higher score indicates a higher level of semantic relatedness) with
164   another sample of 12 participants, ensuring that no word pairs had a high level of semantic
165   relatedness (1.22-1.93).

166   ***Task and procedure***
167   All 480 trials were presented to every participant in four blocks of trials. The four blocks were
168   randomized across participants and began with PL primes, PH primes, NL primes, and NH primes,
169   respectively, consisting of a total of 120 trials (30 valence-congruent trials, 30 valence-incongruent
170   trials, and 60 PL/PH/NL/NH-pseudowords trials). Within each block, the sequence of trials was
171   pseudorandom, with the constraints that identical trials were not repeated two times in a block. A
172   meta-analysis of a quarter century of affective priming study revealed that separated compared to
173   intermixed stimulus sets produce enhanced affective priming (Herring et al., 2013). From an
174   attentional sensitization perspective, having stimulus sets remain constant in a block can enable
175   richer processing of the emotional dimension of stimuli via reducing stimulus variability (also see
176   Herring et al., 2015).
177   Participants were tested individually and were instructed to answer as quickly and accurately
178   as possible. Stimuli and instructions were presented in a white font on a black background. Target
179   words had to be judged as a real word or a pseudoword by pressing the "Z" and "D" keys on the
180   keyboard (assignment of the two keys to response categories was counterbalanced across
181   participants). Instructions emphasized that the first word appearing in each trial (prime) were
182   silently read, and the second word (target) had to be responded in each trial.
183   Each trial started with the presentation of a fixation cross for 300 ms, followed by a prime
184   word for 200 ms. After the prime, a blank screen was shown for 100 ms before the target was
185   presented until the participant responded or 1500 ms elapsed. After an inter-trial interval of 1000
186   ms, the next trial started. In order to participants completely understood the trial procedure, they
187   were given 14 practice trials and an additional feedback screen after erroneous or slow responses
188   before beginning the experiment. After each block, the participants were allowed to have short
189   pauses between two blocks.
190   This task was presented via E-prime 2.0 software (Psychology Software Tools Inc.,
191   Sharpsburg, PA, USA).

192   **Results**
193   Overall accuracy was high (98.5%) and did not significant difference between experimental
194   conditions (range: 96.9-99.4%). Response times (RTs) were 2.5 SDs above or below the mean of
195   each participant were excluded from analysis (0.2% of the data). The reaction time (RT in ms) is

196   reported only for correct responses. All calculations were conducted using an SPSS statistical
197   package (version 18, SPSS inc., IBM company).
198   A repeated-measures ANOVA was run on response times in the eight prime-target conditions:
199   prime valence (positive, negative) × valence congruency (congruent, incongruent) × arousal level
200   of word pairs (high, low). The results revealed a significant main effect of prime valence ($F_{1,28}$ =
201   5.42, p = .03, ω^2 = .13), responses to negative primes (572.0 ± 4.4 ms) were slower than responses
202   to positive primes (556.4 ± 5.8 ms). A significant main effect of valence congruency was
203   significant ($F_{1,28}$ = 46.34, p < .001, ω^2 = .61), with longer response times in valence-incongruent
204   trials (570.8 ± 4.0 ms) than in valence-congruent trials (557.6 ± 3.9 ms). There was a significant
205   interaction between prime valence and valence congruency ($F_{1,28}$ = 57.86, p < .001, ω^2 = .84).
206   Moreover, a significant three-way interaction was found between prime valence, arousal level of
207   word pairs, and valence congruency ($F_{1,28}$ = 8.86, p = .006, ω^2 = .21; Fig. 1). The simple-effect
208   analysis showed that response times in incongruent trials (574.6 ± 6.9 ms) were significantly longer
209   than in congruent trials (540.3 ± 5.7 ms) in PL primes ($F_{1,28}$ = 29.95, p < .001, d' = 1.06). Similarly,
210   response times in incongruent trials (581.8 ± 8.1 ms) were significantly longer than in congruent
211   trials (529.0 ± 7.7 ms) in PH primes ($F_{1,28}$ = 33.03, p < .001, d' = 1.15). Conversely, the participants
212   responded faster in incongruent trials (558.3 ± 2.3 ms) than in congruent trials (572.8 ± 2.5 ms) in
213   NL primes ($F_{1,28}$ = 23.89, p < .001, d' = .45). In NH primes, the participants also responded faster
214   in incongruent trials (568.5 ± 7.5 ms) than in congruent trials (588.2 ± 8.4 ms) ($F_{1,28}$ = 24.67, p <
215   .001, d' = .48). There was no significant main effect ($F_{1,28}$ = 1.14, p = .30, ω^2 = .04) and interactions
216   of arousal level of word pairs (all p > .05).
217
218   (Insert Figure 1)

219   **Discussion**
220   Experiment 1 focused on the ways in which valence relationships between primes and targets
221   influence affective priming. The results showed significant main effects of prime valence and
222   valence congruency and significant interactions between prime valence, prime arousal, and
223   valence congruency. In contrast, no main effect and related interactions of arousal level of word
224   pairs were found to be significant. These results replicated previous studies, demonstrating that
225   participants are quicker when responding to targets that are valence-congruent with primes
226   compared with targets that are valence-incongruent with primes (Zhang et al., 2006; Herring et al.,
227   2011). In Experiment 1, when the valence information of primes was evaluated implicitly,
228   encoding and response mechanisms were activated by the same valence information of primes-
229   targets, thus allowing valence-congruent targets more accessibility and allowing the participants
230   to respond more easily relative to valence-incongruent targets (Fazio, 2001; Klauer & Musch,
231   2003). However, the valence-driven priming effect in Experiment 1 was inconsistent with
232   attentional sensitization models (Spruyt et al., 2007; 2012). One possible reason is that we did not
233   procedurally manipulate the participants' selective attention in stimulus processing, so that the
234   participants could freely attend to certain affective features in the lexical decision-priming task.

235   Furthermore, the direction of priming effects is different between positive and negative
236   primes, the participants responded faster in congruent trials than in incongruent trials in positive
237   primes, instead, faster in incongruent trials than in congruent trials in negative primes. These
238   results suggested that positive primes played a facilitative role in affective priming, opposite to the
239   role of negative primes, which is in line with findings of previous studies (Pan et al., 2016; Kissler
240   & Koessler, 2011; Rossell & Nobre, 2004; Yao & Wang, 2013). According to the affect-as-
241   information approach, there is an associative network of memory and emotion where emotional
242   information (i.e., valence and arousal) can be represented as nodes in a semantic network, in which
243   accessibility and use of the associative network could be the cause for asymmetric effects of
244   positive and negative primes (Clore & Storbeck, 2006).

245   According to the density hypothesis, one possible explanation for the facilitation of positive
246   primes is the higher density of positive information compared with negative information in
247   semantic memory. The density hypothesis states that positive information is generally more similar
248   to other positive information compared with negative information's similarity to other negative
249   information. In visualizations of mental representations, positive information is thus more densely
250   clustered (Unkelbach et al., 2008; Koch et al., 2016). This asymmetry of similarity might explain
251   valence asymmetries at all levels of cognitive processing.

252   The opposite priming effect for negative primes in the present study can be explained by the
253   automatic vigilance hypothesis of emotion that was proposed by Estes and Adelman (2008). This
254   model proposes that negative words may hold attention longer (i.e., delayed disengagement) than
255   positive or neutral words in color naming, word naming, and lexical decision tasks, thus leading
256   to slower responses to negative words (Estes & Adelman, 2008; Larsen et al., 2008). According to
257   this hypothesis, attention disengages more slowly from negative prime-target trials than from
258   negative prime-positive (neutral) target trials. The processing of a negative target when it is
259   preceded by a negative prime may produce "double negative delay", making the accessibility and
260   use of an affective association between negative primes and negative targets become reduced or
261   restricted. As a result, the participants responded slower in negative prime-positive(neutral) target
262   trials than in negative prime-negative target trials.

263   In Experiment 1, a pure valence-driven priming effect was observed when the valence
264   relationship of primes-targets was manipulated in the lexical decision-priming task. In Experiment
265   2, we manipulated the arousal relationship of primes-targets and explored pure arousal-driven
266   priming effects in the same task.

267   **Experiment 2: Affective priming was derived from pure arousal relationship**
268   **of primes and targets**

269   **Method**

270   *Participants*

271   Thirty-two university students (18 females; 17-22 years old, mean age = 19.5 years, SD =
272   2.3) who did not participate in Experiment 1 participated in Experiment 2 and received financial
273   compensation for their participation (see Experiment 1 for further details).

274   *Stimuli*
275   Although the four pools of stimuli and pseudowords were the same as in Experiment 1. There
276   were 120 arousal-congruent pairs (30 PL-PL, 30 PH-PH, 30 NL-NL, 30 NH-NH) and 120 arousal-
277   incongruent pairs (30 PL-PH, 30 PH-PL, 30 NL-NH, 30 NH-NL).

278   *Task and procedure*
279   The experimental task and procedure were the same as in Experiment 1.

280   **Results**
281   Overall accuracy was high (98.3%) and did not significant difference between experimental
282   conditions (range: 97.6-99.3%), and thus only correct response times was reported. Response times
283   were 2.5 SDs above or below the mean of each participant were excluded from analysis (0.3% of
284   the data). All calculations were conducted using an SPSS statistical package (version 18, SPSS
285   inc., IBM company).
286   The 2 (prime arousal: high, low) × 2 (arousal congruency: congruent, incongruent) × 2
287   (valence type of word pairs: positive, negative) repeated-measures ANOVA of response times
288   revealed a main effect of valence type of word pairs ($F_{1,31}$ = 47.21, p < .001, ω^2 = .59; 562.3 ±
289   14.1 ms for positive pairs and 584.6 ± 15.1 ms for negative pairs) and arousal congruency ($F_{1,31}$ =
290   33.41, p < .001, ω^2 = .50; 578.0 ± 15.1ms for arousal-congruent pairs and 569.0 ± 14.8 ms for
291   arousal-incongruent pairs). A significant arousal congruency × valence type of word pairs was
292   found ($F_{1,31}$ = 11.35, p = .002, ω^2 = .24. see Fig. 2). The simple-effect analysis showed that
293   response times in arousal-incongruent trials (578.6 ± 15.4 ms) were significantly longer than in
294   arousal-congruent trials (546.11 ± 13.2 ms) for positive pairs ($F_{1,31}$ = 39.93, p < .001, d' = .39).
295   For negative pairs, no difference between arousal-congruent (580.5 ± 14.0 ms) and arousal-
296   incongruent trials (588.8 ± 16.5 ms) was observed ($F_{1,31}$ = 2.89, p = 0.1, d' = .10). No significant
297   main effect of prime arousal was observed ($F_{1,31}$ = 1.64, p = .21, ω^2 = .02), with no other arousal-
298   related effects (all p >.05).
299
300   (Insert Figure 2)

301   **Discussion**
302   The goal of Experiment 2 was to investigate the effect of prime arousal on affective priming.
303   In line with prior study by Zhang, Kong and Jiang (2012), the results of Experiment 2 showed a
304   significant arousal-driven priming effect only in positive word pairs. The participants responded
305   faster in positive arousal-congruent than arousal-incongruent trials, suggesting that the arousal
306   information of prime stimuli is able to automatically capture attentional resources with a help of
307   positive valence, thereby influencing the processing of target stimuli. One likely interpretation is

308   that arousal cue of a prime has the ability but alone is insufficient to activate all other concepts of
309   the same arousal in semantic network, and thus has to need a support of positive valence. Because
310   positive information of prime stimuli facilitated the processing of subsequent related stimuli that
311   has been demonstrated by numerous studies (e.g. Kissler & Koessler, 2011; Yao & Wang, 2014),
312   but there have mixed findings of the effect of arousal on affective priming in both behavior and
313   electrophysiology studies (Herring et al., 2015; Zhang, Kong & Jiang, 2012; Hinojosa, Méndez-
314   Bértolo & Pozo, 2012; Hinojosa et al, 2009).
315   In Experiment 2, the prime-targets relationship was based on arousal, and a significant arousal
316   priming effect was observed in positive pairs. In Experiment 3, we systematically varied the
317   affective relationship of primes-targets along valence and arousal dimensions to explore pure
318   emotional-driven priming effects in the lexical decision-priming task.

Experiment 3: Affective priming was derived from emotional relationship of primes-targets

319
320

Method

321

Participants

322
323   Thirty-one university students (13 females; age 18-25 years old; mean age ± SD = 22.3 ± 2.1
324   years) who did not participate in Experiment 1 and 2 participated in Experiment 3 and received
325   compensation for their participation (cf. Experiment 1 for other details).

Stimuli

326
327   To observe the effect of affective priming that was triggered by the combination of valence
328   and arousal, 60 neutral nouns (e.g., *rule*, *desk*) were selected from the same database as in
329   Experiment 1 according to the same criteria. We considered words with valence values that ranged
330   from 4 to 6 and word with arousal values less than 5 as neutral words. The same emotional words
331   were used in Experiment 3 as in Experiment 1. They shared similar concreteness ($F_{4,174}$ = .18, p =
332   .95), word frequency ($F_{4,174}$ = 1.92, p = .11), and character strokes ($F_{4,174}$ = 1.48, p = .21) but
333   differed in valence ($F_{4,174}$ = 26.86, p < .001) and arousal ($F_{4,174}$ = 19.68, p < .001).In Experiment
334   3, half of the pairs were emotional primes-emotional targets; the other half were emotional primes-
335   neutral targets. Different from Experiments 1 and 2, the target stimuli in the emotional incongruent
336   conditions were neutral words (see the last row of Table 1).
337   The 240 word-word pairs comprised 120 emotionally congruent pairs (30 PL-PL, 30 PH-PH,
338   30 NL-NL, 30 NH-NH) and 120 emotionally incongruent pairs (30 PL-neutral targets, 30 PH-
339   neutral targets, 30 NL-neutral targets, 30 NH-neutral targets). The 240 word-pseudoword pairs
340   were the same as in Experiment 1.

Task and procedure

341
342   The experimental procedure was the same as in Experiment 1.

Results

344   Only correct response times were analyzed and reported, because overall accuracy was high
345   (98.1%) and did not significant difference across all experimental conditions (range: 97.9-99.8%).
346   Response times with 2.5 SDs above or below each participant's mean were excluded from analysis
347   (.1% of the data). All calculations were conducted using an SPSS statistical package (version 18,
348   SPSS inc., IBM company).
349   The 2 (emotional congruency of prime-target: congruent, incongruent) × 2 (prime valence:
350   positive, negative) × 2 (prime arousal: high, low) repeated-measures ANOVA of response times
351   revealed a significant main effect of prime valence ($F_{1,30} = 48.7$, $p < .001$, $\omega^2 = .61$; 538.7ms for
352   positive primes and 575.9 ms for negative primes). An interaction between prime valence and
353   emotional congruency of the pairs was significant ($F_{1,30} = 59.82$, $p < .001$, $\omega^2 = .66$; Fig. 3). The
354   simple-effect analysis showed that response times of incongruent trials (547.8 ± 4.1 ms) were
355   significantly longer than of congruent trials (529.7 ± 5.0 ms; $F_{1,30} = 16.73$, $p < .001$, $d' = .57$) in
356   positive primes, whereas response times of incongruent trials (565.2 ± 3.3 ms) were significantly
357   shorter than of congruent trials in negative primes (585.5 ± 4.1 ms; $F_{1,30} = 55.58$, $p < .001$, $d' =$
358   .65). No significant main effect of prime arousal was observed ($F_{1,30} = 3.1$, $p = .09$, $\omega^2 = .06$), with
359   no other arousal-related effects (all $p > .05$).
360
361   (Insert Figure 3)

Discussion

363   Experiment 3 explored the ways in which a combine of valence and arousal of primes-targets
364   modulate affective priming. No significant main effect of prime arousal and no interactions with
365   prime arousal were observed. However, a significant main effect of prime valence was found, with
366   a significant interaction between prime valence and emotional congruency. These findings are
367   similar to Experiment 1 and suggest that prime valence rather than prime arousal influences the
368   subsequent processing of target words when the emotionality of the prime-target varies with
369   valence and arousal. Positive words as primes yielded a significant effect of affective priming, in
370   which emotionally congruent trials were associated with shorter response times than incongruent
371   trials. Negative words as primes yielded an opposite effect of affective priming, in which
372   emotionally incongruent trials were associated with shorter response times than congruent trials.
373   These findings are consistent with previous studies and provide additional evidence that the
374   direction of priming effects is different between positive and negative prime words (Pan et al.,
375   2016; Kissler & Koessler, 2011; Rossell & Nobre, 2004). The results of Experiment 3 can be
376   explained by the affect-as-information approach (Clore & Storbeck, 2006), the density hypothesis
377   (Unkelbach et al., 2008; Koch et al., 2016) and the automatic vigilance hypothesis (Estes &
378   Adelman, 2008).

General Discussion

380   The present study investigated whether valence and arousal play equal roles in the subsequent
381   processing of target words. We manipulated the relationship between primes and targets in terms
382   of valence and arousal in a lexical decision-priming task. By comparing three types of priming
383   effects that were triggered by pure valence information (Experiment 1), pure arousal information
384   (Experiment 2), or a combination of the two (Experiment 3), we found an effect of valence on
385   affective priming was obvious regardless of whether the relationship of the prime-target varied
386   with valence, arousal, or the combination of valence and arousal. In contrast, an effect of arousal
387   on affective priming only appeared in the condition in which the relationship of the prime-target
388   varied with arousal level. Moreover, the valence-driven priming effect, arousal-driven priming
389   effect, and emotional-driven priming effect were modulated by valence type but not by arousal
390   level of word stimuli. These findings suggested that valence might a more robust and stable
391   influence on affective priming compared with arousal, at least in the present lexical decision-
392   priming task.

393   ***Priming effects of valence, arousal, and a combination of valence and arousal***
394   Our findings indicated a significant valence-driven priming effect in Experiment 1 and a
395   significant arousal-driven priming effect in Experiment 2. In Experiment 3, although the
396   emotional-driven priming effect did not reach statistical significance, a significant priming effect
397   was found for positive primes, with an opposite effect for negative primes. These results indicated
398   that affective priming effect was modulated by primed affective cues included valence, arousal
399   and or a combination of the two. These findings are consistent with previous studies that
400   demonstrated that responses to congruent pairs are significantly faster than responses to
401   incongruent pairs when the emotional dimension is primed in a lexical decision task (e.g. Kissler
402   & Koessler, 2011; Yao & Wang, 2013; 2014; Hinojosa, Méndez-Bértolo & Pozo, 2012). The
403   priming effects of valence, arousal, and emotionality can be explained by spreading activation
404   within semantic networks. When the prime valence and/or arousal is evaluated implicitly,
405   affectively congruent targets are more accessible, and participants can respond more easily relative
406   to affectively incongruent targets (Fazio, 2001; Klauer & Musch, 2003).
407   However, our findings are seemingly inconsistent with the results of a noteworthy meta-
408   analysis (Herring et al. 2013). The meta-analysis covered 25 years of affective priming studies (k
409   = 125) and suggest that significant affective priming occurs in pronunciation (or naming) and
410   evaluative decision tasks but not in lexical decision task. However, as mentioned by Herring et al.,
411   regard to the priming effect of the lexical decision task should be taken with more caution, due to
412   their meta-analysis only includes six effect sizes (from five experiments and four publications)
413   that employed the lexical decision task, whereas includes 37 effect sizes (from 31 experiments and
414   20 publications) that employed the pronunciation/naming task. The smaller number of effect sizes
415   makes it difficult to examine variables that moderate affective priming in the lexical decision task.

416   ***Arousal priming effect only appeared under specific conditions***
417   In Experiment 2, we manipulated the relationship of primes-targets based on arousal, and
418   found a significant arousal-driven priming effect only in positive word pairs. The participants

419 responded faster in arousal-congruent trials than in arousal-incongruent trials when the prime-
420 target pairs were positive valence, which suggest that positive primes with high- or low-arousal
421 can facilitate the processing of related positive targets, leading to differences in the activation of
422 related arousal nodes between congruent and incongruent conditions. We infer possible reason for
423 this result is that the arousal cue of a prime has the ability but alone is insufficient to activate all
424 other concepts of the same arousal in semantic network, and thus has to need a support of positive
425 valence. That is, spreading activation across an associative network of interconnected arousal
426 nodes may be increased by positive information, arousal with a help of positive valence can easily
427 capture a viewer's attention and increase cognitive resources during stimulus processing, and thus
428 accelerate the semantic processing of target words.

429 In fact, with regard to arousal priming effect, there has no consistent conclusion. Some studies
430 reported a significant arousal priming effect (e.g., Zhang, Kong & Jiang, 2012), other studies
431 indicated no arousal priming effect or such effect only occurred under specific conditions (e.g.,
432 Herring et al., 2015; Hinojosa et al, 2009; Hinojosa, Méndez-Bértolo & Pozo, 2012). For example,
433 Hinojosa and colleague (2009; 2012) manipulated the arousal level of positive primes and targets
434 and found a significant arousal priming effect at the electrophysiological level but not at behavioral
435 level in an arousal categorization task. This finding suggest that the arousal information of prime
436 stimuli have the capability to automatically pre-activating arousal-congruent targets by spreading
437 activation within a semantic network, but this capability may relatively weaker and become visible
438 by measuring event-related potentials with high temporal resolution.

Stable but asymmetric effect of valence on affective priming

440 In all three of our experiments, we found that the priming effects of valence, arousal, and
441 emotionality were modulated by valence. A standard priming effect (i.e., faster responses in
442 congruent trials) was observed in the positive prime condition in all three experiments. An opposite
443 priming effect (i.e., faster responses in incongruent trials) was observed in the negative prime
444 condition in Experiments 1 and 3. No priming effect was found in the negative rather than positive
445 prime condition in Experiment 2. These results indicated regardless of the relationship of primes-
446 targets based on valence, arousal, or a combination of the two, the effect of valence on affective
447 priming is obvious and stable, and positive and negative primes play either a facilitative or
448 inhibitory role in affective priming. These results support previous findings with regard to the
449 direction of priming effects differs between positive and negative primes (Rossell & Nobre, 2004;
450 Pan et al., 2016), and further suggest that this difference is not varied with affective relation of
451 primes-targets.

452 Specifically, our results showed that for positive primes, shorter latencies for congruent than
453 for incongruent prime-target pairs were observed in all three experiments. The encoding
454 perspective holds that all emotional information can be represented as nodes in semantic memory.
455 Primes activate associations in memory that make the valence of targets more accessible, thus
456 facilitating affective priming (Fazio, 2001). Positive information of primes can stably increase the
457 accessibility and use of associations of prime-target pairs, which makes it easier for spreading
458 activation between connected nodes, thus facilitating positive target encoding (Clore & Storbeck,

459 2006). According to the density hypothesis, another possible explanation is that positive
460 information is more similar to other positive information, and thus an obvious advantage in
461 spreading activation from positive primes to positive targets (Unkelbach et al., 2008; Koch et al.,
462 2016).

463   For negative primes, opposite priming effects were found in Experiment 1 and 3, in which
464 the affective relationship of primes-targets involved valence and the combine of valence and
465 arousal, respectively. By contrast, such effect was not observed in Experiment 2, in which the
466 affective relationship based on arousal level of primes-targets. These results indicate that opposite
467 priming effects might occur under negative prime conditions, but a precondition is that the
468 affective relationship between primes and targets should be based on valence or at least involve
469 valence information. Based on the different organization of positive and negative information in
470 memory, the opposite priming effects may be explained by the spreading inhibition hypothesis
471 (Clore & Storbeck, 2006) or automatic vigilance hypothesis of emotion (Estes & Adelman, 2008).
472 Because of prolonged attention to negative words, the processing of negative prime-negative target
473 trials may produce a "double negative delay," which hinders the spread of negatively-valenced
474 associations and reduces the optimization of word-processing. Consequently, negative targets are
475 more slowly activated compared with positive and neutral targets when they are presented in
476 negative primes. The opposite priming effects for negative primes that were observed in the present
477 study supported and extended the automatic vigilance hypothesis and suggested that prolonged
478 attention to negative words occurred when they were presented in isolation and also occurred when
479 they were presented in the priming experiment.

480   Another interpretation of the present findings is based on the double-check hypothesis
481 (Aguado et al., 2018), which states that the processing of negative stimuli involves a "double
482 check" in terms of both valence and specific emotional content (e.g., anger, sadness, fear, and
483 disgust). Thus, participants more easily judged negative stimuli in a positive context than negative
484 stimuli in a negative context. For example, Aguado et al. (2018) used target faces that expressed
485 happiness, fear, or anger that were presented after the participant had read a sentence that described
486 anger, fear, or happiness-inducing events. The results in a congruency judgment task suggested
487 that happy faces were recognized faster in happy contexts than in negative contexts, whereas angry
488 faces were recognized faster in happy contexts than in negative contexts. In terms of the double-
489 check hypothesis, recognizing a happy face requires only a valence check, whereas judging a
490 negative face requires checks of both valence and emotion. In the present study, negative words
491 were mainly selected based on their emotion dimension (Russell, 2003), without considering the
492 specific emotional content of these words (e.g., anger, sadness, fear, and disgust). As a result, the
493 opposite or null priming effects of negative primes may be explained by the fact that the encoding
494 and processing of negative information is not only based on their valence but also requires the
495 additional check of their specific emotional content.

Conclusions and Limitations

497   In summary, we found that valence exerts a differential and stronger effect than arousal on
498 the subsequent processing of target words. The effect of valence on affective priming was obvious

499 in all three priming conditions regardless of whatever the affective relationship of the prime-target
500 varied with valence, arousal, or the combination of valence and arousal, whereas the effect of
501 arousal on affective priming only appeared when the affective relationship based on arousal of
502 primes-targets. Moreover, valence, arousal, and emotional priming effects were modulated by
503 valence type, but not by arousal level. These findings are important because they replicate previous
504 studies that suggested that valence and arousal both influence affective priming and extended this
505 literature by systematically manipulating the relationship of primes-targets along the valence and
506 arousal, indicating that the valence information of emotion words tended to be more stable than
507 arousal information within the semantic system, at least in the present lexical decision-priming
508 task.
509   One important limitation of the present study is that only a lexical decision-priming task and
510 behavioral measure were employed, which may limit the generalization of our findings to the
511 affective priming literature. According to a meta-analysis of nearly 30 years of affective priming
512 research (Herring et al., 2013), the relative effects of valence and arousal on affective priming
513 should be further examined by employing other non-evaluative (e.g., pronunciation/naming) or
514 evaluative (e.g., valence/arousal decision) priming tasks and manipulating feature-specific
515 attention allocation. Another limitation is that although the conclusions of the present study were
516 drawn by comparing the priming effects of valence, arousal, and the combination of valence and
517 arousal on subsequent target processing, the U-shaped relationship of valence and arousal ratings
518 (e.g., Yao et al., 2017) may indicate that the arousal difference between high and low arousal words
519 was less than the valence difference between positive and negative words. Therefore, future studies
520 should utilize more direct measurement methods, such as event-related potentials, that can
521 distinguish subtle differences in the affective relationship between primes and targets in terms of
522 valence and arousal to directly explore and compare brain electric activity that is evoked by
523 information about the valence and arousal of emotional words.

Acknowledgements

525   This research was supported by grants from the National Nature Science Foundation of China
526 (31600885) to Zhao Yao, and also was supported by the Fundamental Research Funds for the
527 Central Universities (20101196146, 20101194941, 20106186449) and the Higher Education
528 Reform Project of Xidian university (20901190006) to Zhao Yao.

529

References

531 1. Aguado, L., Martínez-García, N., Solís-Olce, A., Dieguez-Risco, T., & Hinojosa, J. A. (2018).
532   Effects of affective and emotional congruency on facial expression processing under different
533   task demands. *Acta psychologica, 187*, 66–76.
534 2. Citron, F. M. M. (2012). Neural correlates of written emotion word processing: A review of
535   recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language*,
536   122, 211–226.

537   3.   Clore, G. L., & Storbeck, J. (2006). Affect as information about liking, efficacy, and
538   importance. In J. Forgas (Ed.), *Affect in social thinking and behavior* (pp. 123–142). New
539   York: Psychology Press.
540   4.   Delaney-Busch, N., Wilkie, G., & Kuperberg, G. (2016). Vivid: how valence and arousal
541   influence word processing under different task demands. *Cognitive, Affective, & Behavioral
542   Neuroscience*, *16*(3), 415–432.
543   5.   Estes, Z., & Adelman, J. S. (2008). Automatic vigilance for negative words is categorical and
544   general. *Emotion, 8*(4), 453–457.
545   6.   Fazio, R. H. (2001). On the automatic activation of associated evaluations: An overview.
546   *Cognition & Emotion*, *15*(2), 115–141.
547   7.   Gianotti, L. R., Faber, P. L., Schuler, M., Pascual-Marqui, R. D., Kochi, K., & Lehmann, D.
548   (2008). First valence, then arousal: the temporal dynamics of brain electric activity evoked by
549   emotional stimuli. *Brain topography*, *20*(3), 143–156.
550   8.   Herring, D. R., Taylor, J. H., White, K. R., & Crites Jr, S. L. (2011). Electrophysiological
551   responses to evaluative priming: the LPP is sensitive to incongruity. *Emotion, 11(4)*, 794.
552   9.   Herring, D. R., White, K. R., Jabeen, L. N., Hinojos, M., Terrazas, G., Reyes, S. M., … Crites,
553   S. L. (2013). On the automatic activation of attitudes: A quarter century of evaluative priming
554   research. *Psychological Bulletin, 139*(5), 1062–1089.
555   10. Herring, D. R., White, K. R., Jabeen, L. N., Song, I., & Crites, S. L. (2015). Something
556   (important) is out there! Effects of prime arousal and location on evaluative priming.
557   *Motivation and Emotion, 39*(5), 742–752.
558   11. Hinojosa, J. A., Carretié, L., Méndez-Bértolo, C., Míguez, A., & Pozo, M. A. (2009). Arousal
559   contributions to affective priming: electrophysiological correlates. *Emotion*, *9*(2), 164.
560   12. Hinojosa, J. A., Méndez-Bértolo, C., & Pozo, M. A. (2012). High arousal words influence
561   subsequent processing of neutral information: Evidence from event-related potentials.
562   *International Journal of Psychophysiology*, *86*(2), 143–151.
563   13. Kissler, J., & Koessler, S. (2011). Emotionally positive stimuli facilitate lexical decisions—
564   An ERP study. *Biological psychology*, *86*(3), 254–264.
565   14. Klauer, K. C., & Musch, J. (2003). Affective priming: Findings and theories. *The psychology
566   of evaluation: Affective processes in cognition and emotion*, 7–49.
567   15. Koch, A., Alves, H., Krüger, T., & Unkelbach, C. (2016). A general valence asymmetry in
568   similarity: Good is more alike than bad. *Journal of Experimental Psychology: Learning,
569   Memory, and Cognition, 42*(8), 1171.
570   16. Larsen, R. J., Mercer, K. A., Balota, D. A., & Strube, M. J. (2008). Not all negative words
571   slow down lexical decision and naming speed: Response to Estes and Adelman. *Emotion, 8*(4),
572   445–452.
573   17. Nicolle, A., & Goel, V. (2013). Differential impact of beliefs on valence and arousal.
574   *Cognition & emotion*, *27*(2), 263–272.
575   18. Pan, F., Shi, L., Lu, Q., Wu, X., Xue, S., & Li, Q. (2016). The negative priming effect in
576   cognitive conflict processing. *Neuroscience letters, 628*, 35–39.

577 19. Rossell, S. L., & Nobre, A. C. (2004). Semantic priming of different affective categories.
578   *Emotion*, *4*(4), 354.
579 20. Russell, J. A. (2003). Core affect and the psychological construction of emotion.
580   *Psychological Review, 110*, 145–172.
581 21. Spruyt, A., Hermans, D., De Houwer, J., Vandromme, H., & Eelen, P. (2007). On the nature
582   of the affective priming effect: Effects of stimulus onset asynchrony and congruency
583   proportion in naming and evaluative categorization. *Memory & cognition*, *35*(1), 95–106.
584 22. Spruyt, A., De Houwer, J., Everaert, T., & Hermans, D. (2012). Unconscious semantic
585   activation depends on feature-specific attention allocation. *Cognition, 122*, 91–95.
586 23. Steinbeis, N., & Koelsch, S. (2009). Affective priming effects of musical sounds on the
587   processing of word meaning. *Journal of Cognitive Neuroscience, 23*(3), 604–621.
588 24. Unkelbach, C., Fiedler, K., Bayer, M., Stegmüller, M., & Danner, D. (2008). Why positive
589   information is processed faster: The density hypothesis. *Journal of Personality and Social
590   Psychology, 95*, 36–49.
591 25. Yao, Z., & Wang, Z. (2013). The effects of the concreteness of differently valenced words on
592   affective priming. *Acta Psychologica, 143*, 269–276.
593 26. Yao, Z., &Wang, Z. (2014). Concreteness of positive word contributions to affective priming:
594   An ERP study. *International Journal of Psychophysiology, 93*, 275–282.
595 27. Yao, Z., Wu, J., Zhang, Y., & Wang, Z. (2017). Norms of valence, arousal, concreteness,
596   familiarity, imageability, and context availability for 1,100 Chinese words. *Behavior research
597   methods*, *49*(4), 1374–1385.
598 28. Zhang, Q., Lawson, A., Guo, C., & Jiang, Y. (2006). Electrophysiological correlates of visual
599   affective priming. *Brain research bulletin*, *71*(1), 316-323.
600 29. Zhang, Q., Kong, L., & Jiang, Y. (2012). The interaction of arousal and valence in affective
601   priming: Behavioral and electrophysiological evidence. *Brain research, 1474*, 60–72.

Showing a summary of the descriptive statistics(means and SDs) for five variables of word.

1   **Table.1.** Means of Valence (1, Negative to 9, Positive), Arousal (1, Calming to 9, Arousing), Concreteness (1, Abstract to 9,

2   Concrete), word frequency and strokes.

	valence	arousal	concreteness	word frequency	strokes
High-arousal positive words (PH)	7.30 (.48)	6.92 (.28)	5.39 (1.63)	32.76 (27.04)	18.27 (4.70)
High-arousal negative words (NH)	2.41 (.36)	6.96 (.50)	5.13 (1.64)	25.45 (24.45)	16.27(3.30)
Low-arousal positive words (PL)	6.61 (.25)	5.81 (.29)	5.22 (1.49)	22.28 (12.98)	17.20 (4.88)
Low-arousal negative words (NL)	3.07 (.44)	5.62 (.41)	5.18 (1.51)	27.39 (16.01)	17.30 (4.28)
Neutral target words (in Experiment 3)	4.90 (.40)	4.44 (.68)	5.19 (1.60)	38.17 (43.27)	16.91 (4.22)

4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33

34
35

Paired sample t-tests(2-tailed) comparing the four types of experimental words.

PH = High-arousal positive words, PL = Low-arousal positive words, NH = High-arousal negative words, NL = Low-arousal negative words.

1   **Table.2. Paired sample t-tests (2-tailed) comparing the four types of experimental words.**

	PH	PL	NH	NL
Valence				
PH	——			
PL	$t = 1.87$, $p = .08$	——		
NH	$t = 54.24$, $p < .001$	$t = 57.21$, $p < .001$	——	
NL	$t = 31.47$, $p < .001$	$t = 33.35$, $p < .001$	$t = 1.66$, $p = .11$	——
Arousal				
PH	——			
PL	$t = 12.03$, $p < .001$	——		
NH	$t = -0.32$, $p = .75$	$t = -10.09$, $p < .001$	——	
NL	$t = 11.99$, $p < .001$	$t = 1.34$, $p = .19$	$t = 10.32$, $p < .001$	——

2   Note: PH = High-arousal positive words, PL = Low-arousal positive words, NH = High-arousal negative words, NL = Low-

3   arousal negative words.

Figure 1

Response times of high- and low- arousal positive/negative primes in valence congruenceand incongruence conditions.

The gray column indicates the respose times of prime-target valence congruence condition and the gray slash indicates the respose times of prime-target valence incongruence condition.
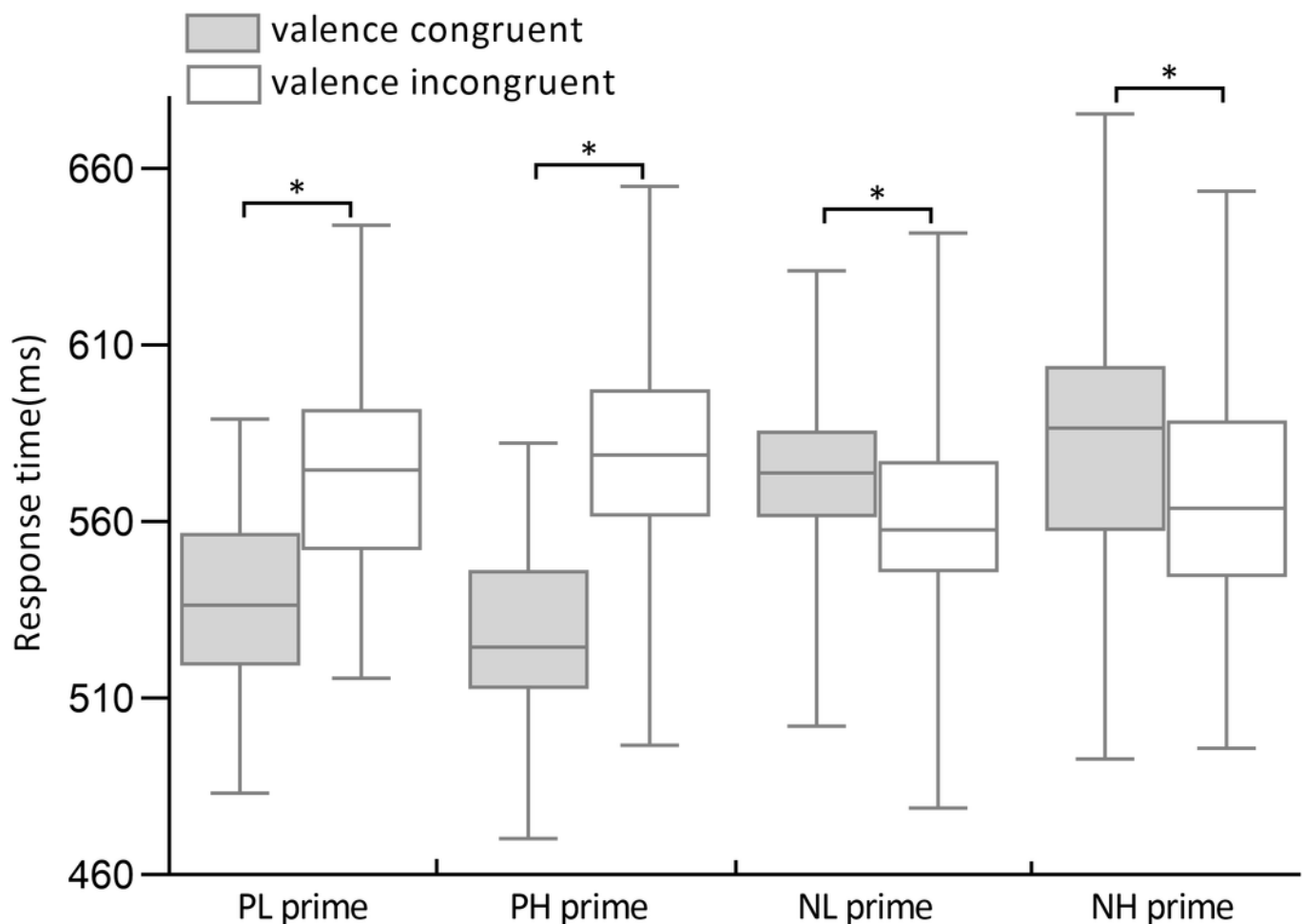
Figure 2

Response times of positive primes and negative primes in arousal congruence and incongruence conditions.

The gray column indicates the respose times of prime-target arousal congruence condition and the gray slash indicates the respose times of prime-target arousal incongruence condition.
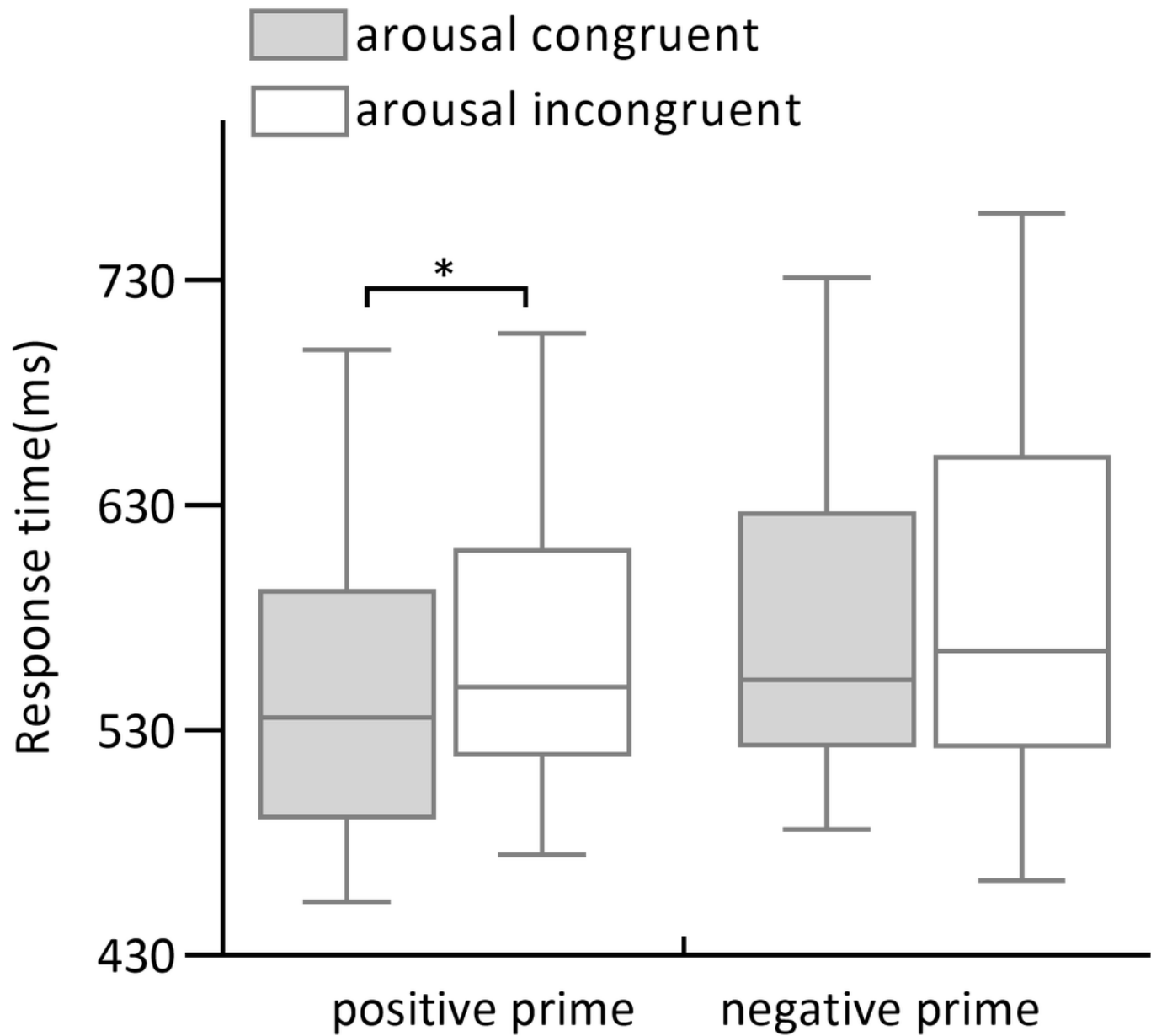
Figure 3

Response times of positive primes and negative primes in emotional congruence and incongruence conditions.

The gray column indicates the respose times of prime-target emotional congruence condition and the gray slash indicates the respose times of prime-target emotional incongruence condition.