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Effect of Emotional Congruency and Cognitive Load on Word Processing

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Abstract

Existing research suggests that the modulation of emotional words to cognitive responses is multifaceted. As an important component of cognition, the influence of emotional words on working memory performance has received increasing attention from researchers. Various modalities of emotional stimuli, particularly facial expressions, are typically presented alongside emotional words to elucidate their associations. Previous studies have demonstrated that the congruency effect occurs when emotional words and faces share the same valence. However, the effect of other emotional modalities on emotional word processing in working memory under varying cognitive loads remains understudied. We implemented the delayed emotional conflict task, a dual-task paradigm that comprises a primary lexical recognition task and a secondary facial recognition task. Results reveal that emotional words, especially negative words, can disrupt working memory performance, and this effect strengthens as cognitive load increases. Notably, in the context of low cognitive load, neutral faces are likely to facilitate the processing of positive words. Additionally, in contrast to prior research, this study does not observe the congruency effect in conditions where the words and faces have the same valence (e.g., negative words and angry faces). These results indicate that both intrinsic valence and the valence of other modalities can modulate word processing in working memory tasks, and these modulations display distinct patterns across different cognitive loads. However, due to the features of stimuli and paradigm, no congruency effect is observed here.

1 Introduction

1.1 Research Background

Emotional words are a category of words characterized by affective connotations, and their processing mechanisms differ from those of neutral words (Frijda et al., 1995; Landis, 2006). There are controversial findings on the implications of emotional word processing. Some investigations have indicated that emotional words exert an inhibitory effect on cognitive behaviors when compared to neutral words (Algom et al., 2004; Herbert and Sütterlin, 2011), while most studies reported the reverse findings, pointing out that more rapid processing of emotional words compared to neutral words (Kissler and Herbert, 2013; Kousta et al., 2009). Further comparisons revealed that negative words are subject to superior processing relative to positive words (Dijksterhuis and Aarts, 2003; Nasrallah et al., 2009), thereby substantiating the "negativity bias." Emotional words have been associated with memory (Adelman and Estes, 2013; Ferré et al., 2018; Talmi and Moscovitch, 2004), including implications for working memory.

Working memory (WM) is a cognitive system responsible for the temporary storage and manipulation of information under attentional control, lasting only a few seconds and considered essential for a variety of complex mental activities (Baddeley, 2020; Cowan, 1999; Jonides and Smith, 2013). According to Baddeley's model, four components are delineated in working memory: the central executive, which controls attention; the phonological loop, which handles linguistic information; the visuo-spatial sketchpad, responsible for processing and storing visual and spatial details; and the episodic buffer, which integrates information from various sources into a cohesive presentation (Baddeley, 2000; Baddeley and Hitch, 1974). Within the realm of working memory research, there is a growing concern regarding how emotions affect its underlying mechanisms.

Studies on working memory have similarly debatable discussions as those surrounding the general processing of emotional words. Rączy and Orzechowski (2021) also identified a "negativity bias" in the working memory task, with faster reaction times for negative words compared to both neutral and positive words, while no significant difference exists between neutral and positive words. However, negative words impair working memory performance compared to positive and neutral words have been demonstrated by several studies (Kopf et al., 2013; Weigand et al., 2013), while some studies have suggested that both negative and positive words may similarly disrupt working memory performance (Fairfield et al., 2015; Garrison and Schmeichel, 2019). Some findings, nonetheless, contest the assertion that there is no difference between neutral and positive words. Jin et al. (2013) highlighted that distinct patterns in working memory performance for negative and positive words, revealing that positive words elicit faster reaction times than neutral and negative words, while negative words are associated with slower reaction times relative to neutral and positive words. These polarizing arguments imply that the confirmation of a distinction in the processing of emotional and neutral words, yet the mechanisms by which emotional words are modulated within working memory could be intricate.

The limited capacity of working memory inevitably possesses competition among semantic information from multiple words in memory. As emotional words convey emotional and semantic information simultaneously, their processing may also be influenced by emotional information from other modalities, such as facial expressions (Ekman, 1992). Facial expressions convey basic emotions, including anger, sadness, fear, disgust, surprise, happiness, and neutrality, enabling us to discern individuals' emotional state during social interactions (Ekman, 1992; Huerta-Chavez and Ramos-Loyo, 2024). Likewise, facial expression is regarded as a powerful factor influencing cognitive processing and behavior (Van Kleef and Côté, 2022). While the patterns affecting working memory are distinct between negative and positive faces, both generally exhibit a facilitation effect due to their bias in requiring attentional resources (Lee and Cho, 2019; Xu et al., 2021). In working memory studies, facial expressions, in addition to serving as task components, are typically employed as an intervention to investigate whether they produce interference or facilitation effects (Jackson et al., 2012). However, when acting as a "distractor," the effects become more nuanced. For instance, it has been found that angry faces interfere with task performance under low cognitive load, while this interference will be diminished under high cognitive load (Van Dillen and Derks, 2012).

The congruence of valence between emotional words and facial expressions affects cognitive mechanisms. This congruent effect is primarily identified through the utilization of a face-word Stroop paradigm (e.g., Fan et al.2016), which indicates that these stimuli are displayed simultaneously. These investigations reveal that responses to incongruent trials are slower than those to congruent trials, with distinct neural activation patterns observed between these two conditions (Chang et al., 2024; Ovaysikia et al., 2011). The encounter with incongruent face-word pairs in terms of valence activates brain regions associated with monitoring and generating emotional conflicts, such as the dorsomedial prefrontal cortex, the dorsolateral prefrontal cortex, and the rostral anterior cingulate cortex, ultimately resulting in slower reaction times during incongruent trials (Egner et al., 2008; Etkin et al., 2006; Fan et al., 2018; Zhu et al., 2010).

1.2 Research Gaps and Aims

Despite the increasing number of studies on emotional word processing, the complex interplay between semantic emotional content and facial expressions across varying levels of working memory loads remains underexplored. This study seeks to 1)examine the interplay between different word valences and face valences within a working memory task, 2)explore how attentional resources are allocated under varying cognitive loads associated with emotional word-face pairs.This study posits three research questions: First, as cognitive load increases, does it lead to a modification of the advantages (or disadvantages) of working memory for emotional words, and can this change be inhibited by emotional facial expressions? Second, under varying cognitive loads, how do emotional faces modulate working memory performance for words with different valences? Third, does an incongruent valence between words and facial expressions lead to a decrement in word processing in working memory, relative to congruent conditions? If so, how does the effect of this valence incongruence interact with varying levels of cognitive load?

1.3 Hypotheses

Building on prior studies, this research proposes three hypotheses. First, emotional words are anticipated to exert a specific effect on working memory relative to neutral words, while increasing cognitive load will diminish this influence and lead to a more pronounced interference effect from emotional facial expressions. Second, the presence of emotional faces is likely to boost working memory for words that have a similar valence, while concurrently disrupting the processing of words with incongruent valence. Furthermore, it is proposed that this modulation will be affected by different levels of cognitive load. Third, a mismatch in valence between words and emotional facial expressions is expected to disrupt the word processing, and as cognitive load rises, this inhibitory effect will be amplified.

2 Method

2.1 Participants

We recruited a sample of 70 college students, with ages ranging from 18 to 30 years (Mean Age = 23.57, SD = 2.97), including 34 males and 36 females. All participants were native Chinese speakers who could read simplified Chinese fluently and were identified as right-handed. They had normal vision or vision corrected to normal and reported no history of psychiatric or neurological disorders. Before the experiment, each participant provided informed consent by signing a consent form.

2.2 Materials

A total of 698 two-character Chinese words (227 negative, 235 neutral, and 231 positive) were meticulously selected from the Chinese Affective Words System (CAWS; Wang et al., 2008), with 23 designated for the practice component, and the remaining 675 words (225 negative, 225 neutral, and 225 positive) employed in the formal part. Of the words utilized in the formal part, 540 words were presented in the memory sets, while an additional 135, which were not included in the memory sets, served as probes. The Chinese Affective Words System (CAWS) assesses the ratings of valence, arousal, and dominance using a 9-point scale (Wang et al., 2008). The selected words for the formal experiment were controlled for valence, with a significant difference observed among negative, neutral, and positive words ($F(2, 672) = 10352$, $p < 0.001$). Additionally, a significant difference in arousal was found between emotional words (negative and positive) and neutral words ($t(673) = 48.135$, $p < 0.001$), according to CAWS norms (Table 1).

For facial stimuli, 80 facial expressions were selected from the Chinese Facial Affective Picture System (CFAPS; Gong et al.2011). According to previous studies, there was a detection advantage associated with angry faces. For instance, faster responses were observed for angry faces than for happy faces, a phenomenon called the "angry superiority effect"(Hansen and Hansen, 1988), and thus angry faces incorporated as representative negative facial stimuli. Specifically, there were 26 angry (14 male and 12 female), 28 neutral (14 male and 14 female), and 26 happy faces (14 male and 12 female). Among the total, 8 faces were designated as practice components, while an additional 72 faces (24 each for the expressions of angry, neutral, and happy, with balanced gender representation) were utilized in the formal part. Furthermore, we ensured that each face was presented fewer than five times throughout the entire procedure. We selected facial expressions based on identification rate in a experiment on face identification reported by Gong et al. (2011) in their study on the CFAPS (participant number = 100, 51 females, mean age = 23 ± 1; identification rate of angry face = 88.55% ± 4.61%; neutral face: 96.44% ± 1.09%; happy face: 100%), choosing the most recognized expressions for each emotion from both male and female faces.

The experiment consisted of 27 conditions: word valence (negative/neutral/positive) × cognitive load (low/moderate/high) × face valence (angry/neutral/happy). All the stimuli were presented on a black background, maintaining the same contrast and brightness. The characters were displayed in white using the PingFang SC font with 57 point font size, and the images were resized to 260 × 300 pixels.

2.3 Procedure

The study employs a delayed emotional conflict task, which is a dual-task paradigm, to address our research questions, encompassing a primary lexical recognition task and a secondary facial recognition task. It inserts a facial expression during the maintenance to evoke effects of congruence or incongruence in valence. In detail, several two-character Chinese words are displayed on the screen simultaneously, and cognitive load is manipulated by adjusting the number of words presented. Specifically, the low cognitive load involves the presentation of two words, while the moderate cognitive load includes four words, and six words are displayed in the high cognitive load condition. Following a string of words, a facial expression-either angry, neutral, or happy-is presented in the center

	Sample	Mean Valence	Mean Arousal
Negative Words	残忍 (cruel)	2.71 ± 0.34	6.37 ± 0.55
Neutral Words	平常 (ordinary)	5.37 ± 0.42	4.20 ± 0.61
Positive Words	美丽 (beautiful)	7.22 ± 0.22	6.32 ± 0.47

Table 1: Sample, mean valence, and mean arousal of negative, neutral, and positive words selected from the Chinese Affective Words System (CAWS).

of the screen. The whole procedure was divided into practice and formal parts. The formal experiment comprised 135 trials, with a overall duration ranging from about 22 to 30 minutes. Each condition was presented five times, and the sequence of trials was randomized for each participant.

As noted by Schwering and MacDonald (2020), digit span reflects the verbal working memory within the specific context of recalling sequences of numbers, rather than serving as a general measure of language-dependent criteria. Therefore, before the formal experiment, participants were required to complete a digit span task to assess their working memory capacity. The digit span task was conducted using a program that included two subtasks: forward recall and backward recall. Participants listened to an audio sequence and, after it ended, entered the numbers in either the same order or the reverse order of presentation. For both subtasks, the program plays two sequences of numbers, starting with two digits and advancing to longer sequences if at least one is answered correctly, while terminating the test if both sequences are answered incorrectly. The mean forward sequence was 10.22 ± 1.78, while the mean backward sequence was 8.89 ± 1.87. We utilized the Reliable Digit Span (RDS; Greiffenstein et al., 1994) to assess overall performance, which is defined as the sum of the longest strings of digits recalled both forward and backward, with completion of both of them required. The scores from the digit span were not analyzed in the current study, as they pertain to a separate research question, while these data were retained for future research.

After finishing the digit span task, participants were seated in a soundproof room to minimize distractions for the formal experiment. Once the experimental process was introduced by the experimenter, they commenced the entire experiment. Each trial began with a fixation cross displayed for 500 ms, followed by a memory set consisting of words categorized into three conditions: low cognitive load (2 words), moderate cognitive load (4 words), and high cognitive load (6 words). An inter-stimulus interval (ISI) of 500 ms followed. Subsequently, a facial expression (angry, neutral, or happy) was presented in the maintenance phase, requiring participants to memorize this face. Another ISI of 500 ms preceded the probe, during which two words were displayed. Participants were instructed to identify which word was presented in the previous memory set by pressing either the left or right key. Following another 500 ms ISI, two facial expressions were shown, and participants were required to identify which facial expression was presented earlier during the maintenance phase by pressing the corresponding key (Figure 1). Participants were provided two rest periods throughout the procedure to minimize the effects of fatigue.

2.4 Analysis

Reaction times (RTs) and accuracy (ACC) for emotional words and facial expressions were recorded during the experiment. Considering the secondary facial recognition task serves to introduce an interfering factor that affects RTs, these data were excluded from the analysis. Additionally, given their working memory capacity superior to the three different cognitive loads, the accuracy of the lexical recognition task was exceptionally high (low cognitive load: 95.27% ± 2.12%, moderate cognitive load: 98.41% ± 1.25%, high cognitive load: 98.38% ± 1.26%), prompting us to concentrate on its RTs. Furthermore, only correct trials from both lexical and facial memory tasks were incorporated into the analysis, ensuring a robust evaluation of the data.

Before analysis, data were pre-processed by removing practice and incomplete trials, and reaction times lower than 200 ms or higher than 2500 ms were considered outliers and excluded. We removed 16 trials (0.5%) from low cognitive load conditions, 36 trials (1.0%) from moderate cognitive load conditions, and 57 (1.9%) trials from high cognitive load conditions. Mean RT for each condition (word valence × cognitive load × face

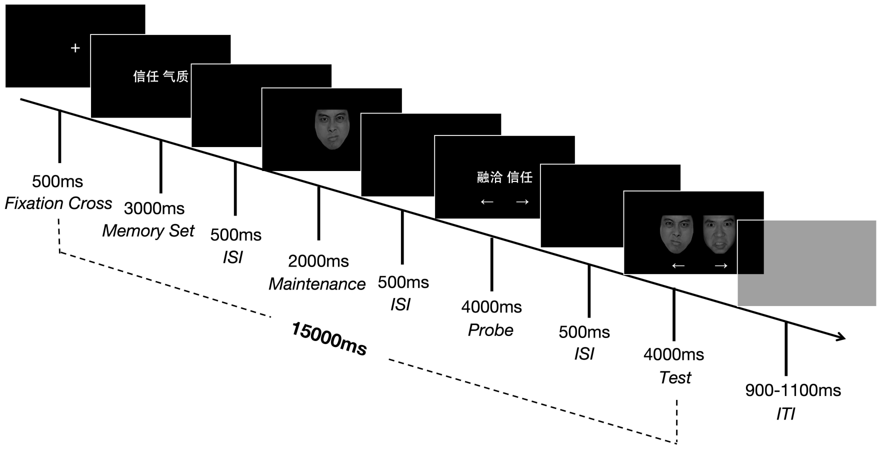

Figure 1: Experimental stimuli and example timeline used in the delayed emotional conflict task. Maintenance is a core component of WM, characterized by active rehearsal of information to prevent decay over time. The probe and test in WM tasks serve a similar function, which are to assess during the retrieval phase whether participants can accurately recall the information that was encoded and maintained in WM.

valence) is calculated based on correct trials. To analyze the RTs associated with the working memory task for emotional words, the mean RTs were subjected to a 3 (word valence: negative, neutral, positive) × 3 (cognitive load: low, moderate, high) × 3 (face valence: angry, neutral, happy) repeated-measures ANOVA. Significant effects were further analyzed using post hoc tests with Tukey's HSD and Bonferroni corrections.

3 Results

3.1 Main Effect

A repeated-measures ANOVA suggests main effects of word valence ($F(1.95, 134.41) = 67.71$, $p < 0.001$, partial $\eta^2 = 0.496$), cognitive load ($F(1.82, 125.50) = 199.12$, $p < 0.001$, partial $\eta^2 = 0.743$), and face valence ($F(1.98, 136.76) = 3.60$, $p = 0.009$, partial $\eta^2 = 0.067$) are significant (Table 2).

Regarding the valence of words, negative words elicit significantly longer reaction times compared to neutral words ($t(69) = 10.772$, $P < 0.001$) and positive words ($t(69) = 3.886$, $p = 0.001$), while positive words show significantly longer reaction times than neutral words ($t(69) = 8.165$, $p < 0.001$). This indicates that the recognition of neutral words is faster than that of emotional words, with negative words showing a notable interference effect within the emotional category. Furthermore, RTs under low cognitive loads are significantly faster than those experienced under moderate ($t(69) = -15.722$, $p < 0.001$) and high cognitive load ($t(69) = -17.652$, $p < 0.001$). Moreover, reaction times for the angry faces condition are significantly slower than for the neutral face condition ($t(69) = -3.016$, $p = 0.010$). However, the differences between angry and happy face conditions ($t(69) = -1.783$, $p = 0.183$) and between neutral and happy face conditions ($t(69) = 1.412$, $p = 0.341$) are not significant.

3.2 Two-Way Interaction Effect

Word Valence × Cognitive Load As can be seen from Figure 2(a), the interaction between word valence and cognitive load reaches a significant level ($F(3.57, 246.03) = 11.81$, $p < 0.001$, partial $\eta^2 = 0.146$). In the context of low cognitive load, the RTs for negative words are significantly longer than positive words ($t(69) = 6.246$, $p < 0.001$) and neutral words ($t(69) = 6.054$, $p < 0.001$). However, there is no significant difference in RTs between neutral words and positive words. Under the moderate cognitive load, negative words require longer times to be processed than neutral words ($t(69) = 5.773$, $p < 0.001$), while no significant difference is observed between negative and positive words. Meanwhile, RTs for neutral words are significantly faster than positive words ($t(69) = -6.877$, $p < 0.001$). When cognitive load is high, emotional words demonstrate notable interference effects compared to neutral words, which is reflected in extended reaction times (negative words: $t(69) = 8.133$, $p < 0.001$; positive words: $t(69) = 5.154$, $p < 0.001$). Within the category of emotional words, there is a significant difference between negative words and positive words, with negative words demanding more time for recognition than positive words ($t(69) = 3.216$, $p = 0.006$).

Face Valence × Cognitive Load The interaction between face valence and cognitive load is also observed ($F(3.54, 243.99) = 12.97$, $p < 0.001$, partial $\eta^2 = 0.158$), as depicted in Figure 2(b). Angry faces can facilitate the lexical recognition under low cognitive loads compared to the influence of neutral faces ($t(69) = -3.562$, $p = 0.002$), while there is no difference between the angry faces and happy faces. As cognitive load increases, the facilitation effect of angry faces is further demonstrated, with significantly faster RTs for the conditions with angry faces in comparison to neutral ($t(69) = -6.777$, $p < 0.001$) and happy faces ($t(69) = -3.971$, $p = 0.001$). However, when cognitive load is high, angry faces instead bring an inhibitory effect. When faced with angry faces, the RTs for the lexical recognition task are significantly slower than when faced with neutral faces ($t(69) = 3.043$, $p = 0.010$).

Word Valence × Face Valence Figure 2(c) illustrates that a pronounced interaction effect is observed between the word valence and the face valence ($F(3.82, 263.68) = 2.94$, $p = 0.023$, partial $\eta^2 = 0.041$). Regardless, under the influence of what face valences, RTs for negative words did not significantly differ. As opposed to neutral faces, emotional faces can enhance the working memory performance for neutral words (angry faces: $t(69) = -2.441$, $p = 0.052$; happy faces: $t(69) = -3.422$, $p = 0.003$), but there is no significant difference between the angry and happy faces. Moreover, angry faces produce a significant facilitation effect on positive words compared to happy and ($t(69) = -3.194$, $p = 0.006$) neutral faces ($t(69) = -2.934$, $p = 0.014$).

3.3 Three-Way Interaction Effect

As shown in Figure 3, the interaction among word valence, cognitive load, and face valence is significant ($F(6.45, 445.11) = 2.78$, $p = 0.010$, partial $\eta^2 = 0.039$). Simple effects analyses of cognitive load at the interaction of word valence and face valence indicate significant differences across most conditions. For instance, the combination of angry faces and negative words under high cognitive load results in slower RTs compared to low cognitive load ($t(69) = 8.695$, $p < 0.001$) and moderate load ($t(69) = 6.863$, $p < 0.001$). Additionally, slower RTs are observed in the pairing of angry faces and positive words when the cognitive load is high than when it is low ($t(69) = 10.825$, $p < 0.001$) and moderate ($t(69) = 3.237$, $p = 0.006$). Further analyses of the word valence effect, specifically within the context of angry faces and high cognitive load, suggest that negative words elicit significantly longer RTs than neutral words ($t(69) = 4.671$, $p < 0.001$) and positive words ($t(69) = 3.110$, $p = 0.008$) when paired with angry faces.

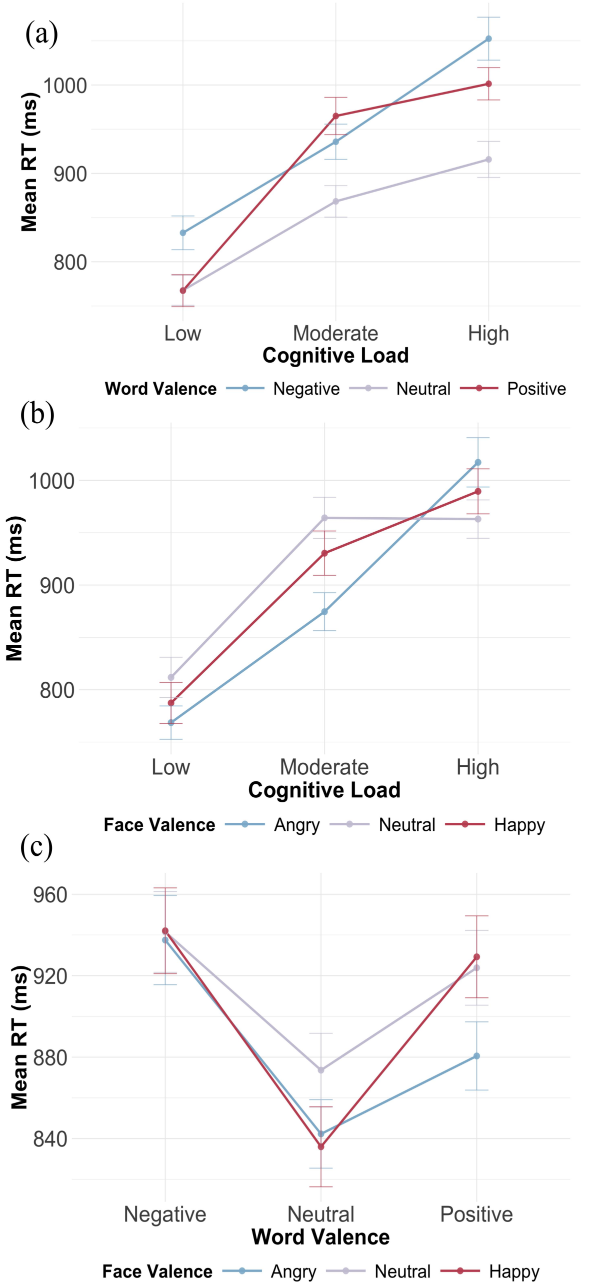

Figure 2: (a) Interaction effect of word valence and cognitive load on mean reaction time. (b) Interaction effect of face valence and cognitive load on mean reaction time. (c) Interaction effect of word valence and face valence on mean reaction time.

4 Discussion

Controversial findings emerge in previous studies in relation to the influence of word valence on cognitive behavior. Some research demonstrates that emotional words can facilitate cognitive processing (Kousta et al., 2009), while other studies reveal that they may interfere with cognitive tasks, leading to extended reaction times (Fox et al., 2001; Maratos et al., 2000). This study supports the findings that emotional words induce longer RTs than neutral words, which may be attributed to the ability of high-arousal emotional words to capture much attention, resulting in processing delays (Kuperman et al., 2014).

Negative stimuli also engage attentional allocation earlier than positive stimuli, while demanding greater cognitive resources (Smith et al., 2003). Besides, their threat-related salience brings about rapid attentional capture, thereby engendering the interference effects (Algom et al., 2004; Anticevic et al., 2010). Positive stimuli are detected later and lack threat connotations, allowing sufficient cognitive resources to inhibit the influence of valence. These help explain why negative words require longer processing time compared to neutral and positive words. However, under conditions of high cognitive load, both negative and positive words elicit longer reaction times relative to neutral words. Previous studies using the emotional Stroop task have discovered that the ink color naming of emotional words is slower than that of neutral words, indicating that emotional content can interfere with cognition (Ben-Haim et al., 2016; Kahan and Hely, 2008). When faced with high cognitive load, cognitive resources approach saturation, with the majority allocated to process the task, so the interference effects from emotional valence become difficult to inhibit. At the neural level, the cognitive control network in the prefrontal cortex becomes occupied by the task, rendering it unable to effectively suppress emotional interference (Pessoa, 2009). This accounts for the observation that negative and positive words elicit longer reaction times under high cognitive load in the current working memory task. Additionally, negative words show a stronger interference effect across all cognitive loads, stemming from the competition among semantics, valence, and attention for limited cognitive resources, which amplifies their disruptive impact (Gross, 1998; Volokhov and Demaree, 2010).

Although negative words show a stronger effect in the presence of angry, neutral, or happy faces, no significant differences in patterns are explored. This may be explained by the fact that the dominance of high arousal in negative words masks the role of facial valence in the reaction. Furthermore, positive words are also affected by increasing cognitive loads. Specifically, as cognitive load increases from low to moderate and from low to high, we observe a prolongation of reaction times, but there is no significant effect when the load shifts from moderate to high. This suggests that positive words remain stable after reaching a moderate load, possibly due to the lower arousal effect of positive words compared to negative words (Ito et al., 1998). These results partially verify our first hypothesis: emotional words indeed exert specific effects on the working memory task. However, increasing cognitive load amplifies the impact of emotional words instead of diminishing the effects of word valence.

When faced with high cognitive load, participants show extended reaction times for negative words influenced by angry and happy faces, as opposed to neutral and positive words. Nonetheless, neutral faces facilitate the processing of positive words when cognitive load is low, yielding shorter reaction times compared in comparison to neutral words. However, this facilitation effect disappears with greater cognitive load. One plausible explanation is that positive words facilitate efficient processing (Fredrickson, 2001; Niedenthal et al., 1997), and neutral faces do not exert additional emotional responses that influence recognition processing, and the low cognitive load provides sufficient resources for the effective processing of positive information. With the rise in cognitive load, the processing of positive words requires more semantic engagement and additional cognitive resources, causing the disappearance of their superiority, in contrast to neutral words that do not necessitate simultaneous emotional processing and thus maintain an advantage.

We also hypothesize that when negative words are paired with angry faces and positive words are paired with positive words, a facilitation effect will be detected, resulting in faster reaction times. However, in the current paradigm, no facilitation effect was observed in these pairs. Negative words paired with angry faces elicit the longest reaction times, while positive words with happy faces are not the fastest. Conversely, their effects still follow a sim-

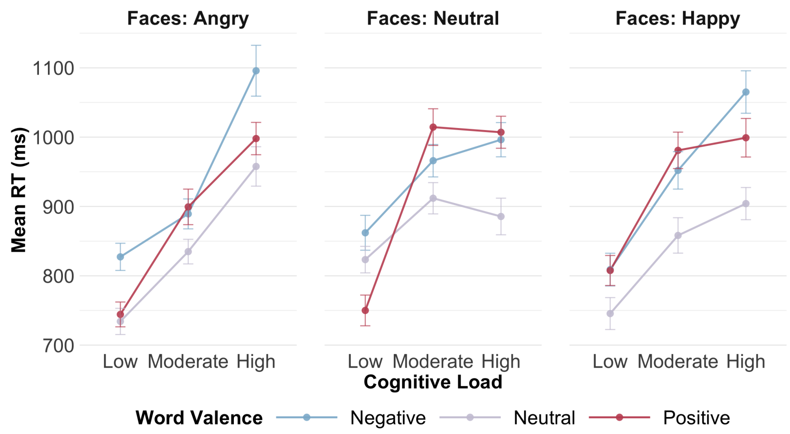

Figure 3: Interaction of word valence, cognitive load, and face valence on reaction time.

Effect	df	MSE	*F*	pes	*p*-value
Word Valence	1.95, 134.41	20548.10	67.71	.495	<.001***
Cognitive Load	1.82, 125.50	35589.70	199.12	.743	<.001***
Face Valence	1.98, 136.76	21619.65	4.95	.067	.009**
Word Valence: Cognitive Load	3.57, 246.03	21980.38	11.81	.146	<.001***
Word Valence: Face Valence	3.82, 263.68	19280.93	2.94	.041	.023*
Cognitive Load: Face Valence	3.54, 243.99	26261.53	12.97	.158	<.001***
Word Valence: Cognitive Load: Face Valence	6.45, 445.11	27084.21	2.78	.039	.010**

Table 2: Results of the three-way ANOVA on spectrum power analysis. Note: df = degrees of freedom; MSE = Mean Square Error; *F* = *F*-statistic; pes = Partial Eta Squared.

ilar pattern to that of word valence, with negative words showing the greatest impact, followed by positive words, and then neutral words. These results indicate that facial expressions influence encoding rather than maintenance. The combination of word valence and face valence seems to evoke an additive effect instead of a facilitation effect, as evidenced by the stronger inhibitory effect produced when negative words are paired with angry faces as cognitive load increases. In accordance with Baddeley's model, it can be inferred that participants process words through the phonological loop and facial expressions through visuo-sketchpad, with both managed within their respective components. (Baddeley, 2000). Although information regarding words and faces can be integrated within the episodic buffer (Baddeley and Hitch, 1974), the allocated durations are insufficient, with only 3000 ms designated for each memory set and 2000 ms for each facial expression, which hampers the effective integration of valence information. Additionally, the lexical and facial recognition tasks do not necessitate participants to integrate the valence from words and faces, which positions them as valence-irrelevant tasks. Therefore, they must allocate a large portion of their limited cognitive resources to complete the tasks, which consequently reduces the modulation of cognitive processing by valence, ultimately leading to a reduced influence from valence. These factors may elucidate why the absence of a congruency effect was observed in the present paradigm. In other words, facial expressions are likely to be considered distractors when they are presented during maintenance. This surmise can be substantiated by the previous findings from Dolcos and McCarthy (2006), which demonstrate that emotional distractors impair working memory performance, aligning with the current result showing that the fastest reaction times for neutral words occur under the influence of varying face valences. There are two further potential explanations account for this phenomenon: first, the valences of words and facial expressions are not entirely congruent, as positivity does not always correspond to happiness and negativity does not entirely equate to anger, which may lead to incongruent combinations; second, previous studies that detected the congruence effect consistently employed a paradigm that presented words and faces simultaneously (Egner et al., 2008; Etkin et al., 2006; Fan et al., 2018, 2016), while this study chooses to present them sequentially.

5 Conclusion

This study examines the impact of the interaction among the valence of words, cognitive load, and valence of faces on working memory, emphasizing the significant effect of the combination of negative stimuli with high cognitive load. Negative stimuli can elicit a stronger inhibitory effect, and when multiple negative stimuli are presented in a trial, this effect persists, leading to an exacerbated impact on performance. In any case, negative words exert a profound dominance, which requires a substantial allocation of limited resources to regulate emotions, thereby adversely affecting working memory performance. Positive words manifest their superiority exclusively under conditions of low cognitive load and in the absence of competing emotional stimuli. Once cognitive demands increase or emotional faces are introduced, this advantage diminishes rapidly. The congruency effect between word and face valence fails to be demonstrated by this study, which may be attributed to the characteristics of the stimuli and the experimental paradigm employed. Future studies can apply EEG or fNIRS techniques to explore the neural activation patterns elicited by different combinations of emotional stimuli and cognitive loads.

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