The Emotional Stroop Effect Is Modulated by the Biological Salience and Motivational Intensity Inherent in Stimuli

Sixiang Quan1,2, Zhenhong Wang1* and Ya Liu3

1 School of Psychology, Shaanxi Normal University, Xi’an, China, 2 School of Educational Science, Shaanxi Xueqian Normal University, Xi’an, China, 3 Department of Psychology, Chongqing Normal University, Chongqing, China

Prior research has found significant emotional Stroop effects for negative stimuli, but the results have been inconsistent for positive stimuli. Combining an evolutionary perspective of emotion with the motivational dimensional model of affect, we speculated that the emotional Stroop effect of a stimulus may be influenced by the biological salience and inherent motivational intensity of the stimulus. In the present study, we examined this issue with two experiments. The results indicated that both low- and high-withdrawal-motivation negative stimuli produced a robust emotional Stroop effect; however, the high-withdrawal-motivation negative stimuli produced a stronger emotional Stroop effect than the low-withdrawal-motivation negative stimuli. Regarding positive stimuli, only the high-approach-motivated positive stimuli produced the emotional Stroop effect, unlike the low-approach-motivation positive stimuli. These findings suggest that the emotional Stroop effect is modulated by the biological salience of stimuli and by the motivational intensity inherent in the stimuli. Biological salience and motivational intensity play an additive effect in the emotional Stroop effect.

Keywords: emotional Stroop effect, negative stimuli, positive stimuli, biological salience, motivational intensity

INTRODUCTION

The emotional Stroop effect refers to the phenomenon that the emotional information of stimuli will delay the reaction of participants when they are asked to respond to the non-emotional information in a task (Williams et al., 1996; Algom et al., 2004). Since the discovery of the emotional Stroop effect, researchers have examined this effect with different task stimuli, such as emotionally charged words (Algom et al., 2004; Chajut et al., 2010; Ben-Haim et al., 2014; Caparos and Blanchette, 2014), emotional pictures (Hester et al., 2006), facial expressions (Lee et al., 2009), and even sensitive stimuli for clinical populations (Andersson et al., 2006).

Many studies have demonstrated that the emotional Stroop effect of negative stimuli is significant (Williams et al., 1996; Algom et al., 2004; Frings and Wühr, 2012). It is believed that the negative stimuli, regardless of whether the stimuli are emotional words, emotional pictures or other types of stimuli, produce a robust emotional Stroop effect because the negative stimuli provide threat or alert information that is vital to survival (Fox et al., 2001; Schimmack and Derryberry, 2005; Wyble et al., 2008). Researchers have suggested that a dedicated system automatically captures or grasps negative threatening stimuli and prioritizes the processing of such stimuli.
low-approach-motivation positive stimuli. The motivational high-rewarding or high-approach-motivation positive stimuli, stimulus; conversely, positive stimuli such as appetizing food are motivation negative stimulus, and a negative stimulus such as a poisonous snake is a high-threat or high-withdrawal-motivation positive stimuli in terms of the motivational intensity positive stimuli can be divided into low- and high-approach motivational dimensional model of affect proposed by Gable and Kringelbach, 2008; Chajut et al., 2010). According to the value, eliciting approach behaviors (Schultz, 2004; Berridge or withdrawal behaviors, and positive stimuli have a positive motivation negative pictures were used in experiment 1. 

Regarding positive stimuli, the findings of studies on the emotional Stroop effect have been inconsistent. Some studies found the emotional Stroop effect of positive stimuli was significant (e.g., Martin et al., 1991; Constantine et al., 2001), but some other studies have not found this effect (e.g., McKenna and Sharma, 1995; White, 1996; Bertels et al., 2011). However, from an evolutionary perspective of emotion, positive stimuli such as infants and appetizing food or erotic stimuli are positive rewarding stimuli, and acquiring the sources of these stimuli is critical for an organism’s survival or reproduction. Therefore, similar to negative stimuli, these kinds of positive rewarding stimuli may capture attention automatically and have priority processing because such stimuli are particularly important for the acquisition of food, reproduction and social attachment (Gable and Harmon-Jones, 2010; Pool et al., 2016). Thus, these kinds of positive rewarding stimuli are highly biologically salient stimuli (Lykins et al., 2006; Brosch et al., 2007; Nummenmaa et al., 2011) and thus may produce an emotional Stroop effect. Different from positive stimuli such as appetizing food, infants and erotic stimuli, other positive stimuli such as scenery, flowers and sports pictures, which indicate a safe, comfortable environment in which conditions are better than necessary, suggest a low urgency to act and lead to relaxation (Fredrickson and Branigan, 2005; Gable and Harmon-Jones, 2010). That is, those positive stimuli that suggest a safe, comfortable environment in which conditions are better than necessary are stimuli with low biological salience and may not induce the emotional Stroop effect. However, no study to date has examined this issue.

Furthermore, negative and positive stimuli can be conceptualized as being diametrically opposed to each other in terms of valence and action tendency (Pool et al., 2016). Negative stimuli have a negative value, eliciting avoidance or withdrawal behaviors, and positive stimuli have a positive value, eliciting approach behaviors (Schultz, 2004; Berridge and Kringelbach, 2008; Chajut et al., 2010). According to the motivational dimensional model of affect proposed by Gable and Harmon-Jones (2010), negative stimuli can be divided into low- and high-withdrawal motivation negative stimuli, and positive stimuli can be divided into low- and high-approach motivation positive stimuli in terms of the motivational intensity inherent in emotional stimuli. Therefore, a negative stimulus such as a poisonous snake is a high-threat or high-withdrawal-motivation negative stimulus, and a negative stimulus such as pollution is a low-threat or low-withdrawal-motivation negative stimulus; conversely, positive stimuli such as appetizing food are high-rewarding or high-approach-motivation positive stimuli, and positive stimuli such as scenery are low-rewarding or low-approach-motivation positive stimuli. The motivational dimensional model of affect advocates that the effects of emotion on cognitive processing are modulated by the motivational intensity inherent in an emotional stimulus, and a large number of studies have provided evidence for this conclusion (Fredrickson and Branigan, 2005; Gable and Harmon-Jones, 2010; Liu and Wang, 2014). In the view of the motivational dimensional model of affect, high-motivation emotional stimuli, regardless of whether they are negative or positive stimuli, occupy more attentional resources or narrow our attention scope, while low-motivation emotional stimuli, regardless of whether they are negative or positive stimuli, occupy less attentional resources or broaden our attention scope (Gable and Harmon-Jones, 2008; Harmon-Jones et al., 2013). Therefore, emotional stimuli with high motivational intensity regardless of whether they are negative or positive stimuli might induce an emotional Stroop effect, while emotional stimuli with low motivational intensity regardless of whether they are negative or positive stimuli may not induce the same effect. However, little is known about whether the emotional Stroop effect could be modulated by the motivational intensity inherent in emotional stimuli.

In summary, the present study was conducted to examine whether the emotional Stroop effect is modulated by the biological salience of emotional stimuli and by the motivational intensity inherent in these stimuli. To examine this issue, two experiments were conducted in the present study. Considering the evolutionary perspective of emotion and the motivational dimensional model of affect, both high- and low-withdrawal-motivation negative stimuli may produce an emotional Stroop effect because an affective evaluation lends such stimuli a high survival value and the stimuli are thus more biologically salient. High-withdrawal-motivation negative stimuli may produce stronger emotional Stroop effects than low-withdrawal-motivation negative stimuli. Regarding positive stimuli, high-approach-motivation positive stimuli, such as appetizing food, are highly biologically salient, suggesting that such stimuli may produce an emotional Stroop effect. Low-approach-motivation positive stimuli that suggest a safe, comfortable environment are stimuli with low biological salience and, therefore, may not produce an emotional Stroop effect.

**EXPERIMENT 1**

To examine how both low- and high-withdrawal-motivation negative stimuli produce a robust emotional Stroop effect and whether high-withdrawal-motivation negative stimuli produce a stronger emotional Stroop effect than low-withdrawal-motivation negative stimuli, both high- and low-withdrawal-motivation negative pictures were used in experiment 1.

**Method**

**Participants**

*A priori* sample size estimation with a large effect size and 95% statistical power was conducted by G*Power to determine the sample size required for this study (Cohen et al., 2003). As the minimum number of participants required for the repeated-measures ANOVA with the large effect size ($f^2 = 0.40$)
and 95% statistical power was 18. Therefore, we recruited
47 undergraduate students (between 18 and 24 years old)
with normal or corrected-to-normal vision participated in this
experiment. None of the participants were color blind or had
color weakness, and the participants could correctly distinguish
all the colors used in our experiments. All of the participants
were unaware of the purpose of this experiment. Each participant
signed an informed consent form prior to the experiment. One
participant decided not to continue with the experiment because
of fear. The data from two other participants were excluded from
the analysis because the accuracy of the data was lower than
90%. Thus, a total of 44 effective participants were included with
a mean age of 21.65 years (SD = 1.44). After completing the
experiment, the participants watched 5-min comedy clips of “Lost
On Journey” to improve their mood. Each participant was fully
debriefed as to the purpose of this experiment and obtained 30
RMB (4.22 $) as a reward.

**Experiment Materials**

The stimuli were chosen from the international affective picture
system (IAPS) (Lang et al., 2005), the Chinese affective picture
system (CAPS) (Lu et al., 2005), and the internet. We selected
112 emotional pictures in total. There were 32 sad and
pollution pictures as the low-withdrawal-motivation stimuli1,
32 mutilation, snake and threat pictures as high-withdrawal-
motivation stimuli2, and 32 household pictures and neutral
daily life scenes pictures as neutral stimuli. The 16 remaining
neutral stimuli were used as test stimuli in the practice session.3
We roughly matched the perceptual features, including color,
brightness, and visual complexity, of the three kinds of pictures.
The size of all the pictures was set to 192 × 144 pixels. We used
Photoshop software to add 10-pixel green and red frames to each
picture. Each picture appeared twice in the experiment: once with
a red frame and once with a green frame.

**Procedure**

There were three experimental blocks (blocks with
low-withdrawal-motivation, neutral, and high-withdrawal-
motivation stimuli) with each block consisting of 64 trials. The
presentation order of these stimuli was random and different
for each participant. There was a 1-min rest break between each
experimental block.

Each trial started with a fixation cross for 500 ms. Afterward,
the emotional pictures appeared and remained at the center
of the screen for 2000 ms or until the participants gave a
response. Participants were instructed to press the “S” key on
the keyboard with the left index finger if the frame of a picture
was red and to press the “K” key on the keyboard with the
right index finger if the frame of a picture was green. They
were asked only to judge the frame color and to ignore the
content and color of the pictures. The participants were asked
to respond as quickly and accurately as possible. The next trial
began after a blank screen lasting 500 ms. To familiarize the
participants with the experimental procedure, each participant
was instructed to complete a practice block with 32 trials before
the experimental block. After completing each experimental
block, the participants were instructed to rate the pleasure
(1 = extremely unpleasant, 9 = extremely pleasant), arousal
(1 = extremely calm, 9 = extremely exciting), and motivational
intensity (1 = especially want to withdrawal, 9 = especially want
to approach) of the pictures that they just saw. An example of a
trial for this experiment is shown in Figure 1.

**Results**

Table 1 presents the means and standard deviations of the
valence, arousal and motivational intensity of the three types
of negative pictures. A repeated-measures ANOVA showed that
there were significant effects on the valence, F(2,86) = 74.12,
*p < 0.001, ηp² = 0.63. Post hoc comparisons demonstrated that
the pleasure ratings of both the high-withdrawal-motivation
(t(43) = 13.92, p < 0.001, d = 2.56, 95% CI [1.91, 3.21]) and low-
withdrawal-motivation negative pictures (t(43) = 6.08, p < 0.001,
d = 1.43, 95% CI [0.87, 1.98]) were significantly lower than those
of the neutral pictures. And the difference between high- and
low-withdrawal-motivation negative pictures was also significant
(t(43) = 5.42, p < 0.001, d = 1.13, 95% CI [0.65, 1.60]). On the
arousal ratings, results suggested a significant effect for picture
type, F(2,86) = 22.61, p < 0.001, ηp² = 0.43. The high-withdrawal-
motivation (t(43) = 5.96, p < 0.001, d = 1.21, 95% CI [0.73, 1.68])
and low-withdrawal-motivation pictures (t(43) = 5.62, p < 0.001,
The biological salience of these stimuli is high. Furthermore, studies have found that negative stimuli produce a robust emotional Stroop effect, and our findings are consistent with those prior findings (McKenna and Sharma, 1995; White, 1996). The biological salience of these stimuli is high. Furthermore, this study also found that the high-withdrawal-motivation negative stimuli produced stronger emotional Stroop effects than the low-withdrawal-motivation negative stimuli. Therefore, we believe that, although negative stimuli can produce the robust emotional Stroop effect, this effect may also be modulated by the motivational intensity inherent in the negative stimuli.

**EXPERIMENT 2**

To examine whether high-approach-motivation positive stimuli produce the emotional Stroop effect but low-approach-motivation positive stimuli do not, high- and low-approach-motivation positive pictures were used in experiment 2.

**Method**

**Participants**

Same as experiment 1, the number of participants required in this experiment was 18. Therefore, we recruited thirty undergraduate students with normal or corrected-to-normal vision (between 19 and 24 years old) participated in this experiment. None of the participants were color blind or had color weakness. The participants could correctly distinguish all the colors used in our experiments. All of them were unaware of the purpose of this experiment. Each participant signed an informed consent form prior to the experiment. After completing the experiment, the participants obtained 30 RMB (4.22 $) as a reward. One participant decided not to continue participation in the experiment for a personal reason. The data from two other participants were excluded from the analysis because the accuracy was lower than ninety percent. Thus, there were 27 effective participants with a mean age of 21.74 years (SD = 1.53).

**Experiment Materials**

The stimuli were chosen from the IAPS (Lang et al., 2005), the CAPS (Lu et al., 2005), and the internet. We selected 112 emotional pictures in total. There were 32 sports/adventure, scenery and happy pictures used as low-approach-motivation stimuli, 32 appetizing dessert, infant, and erotic pictures used as high-approach-motivation stimuli, and 32 household pictures and neutral daily life scenes pictures used as neutral stimuli (Briggs and Martin, 2009). The 16 remaining neutral stimuli were used in the practice session. We roughly matched the perceptual features, including color, brightness and visual complexity, of the three kinds of pictures. The size of all the pictures was set to 192 × 144 pixels. We used Photoshop software to add 10-pixel green and red frames at the margins of each picture. Each picture...

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**TABLE 1** | Means and standard deviations of the negative pictures in valence, arousal, and motivational intensity ratings.

| Block               | Valence     | Arousal     | Motivational intensity |
|---------------------|-------------|-------------|------------------------|
| High-withdrawal     | 2.32 (1.38) | 5.80 (2.11) | 2.50 (1.85)            |
| Low-withdrawal      | 3.82 (1.28) | 5.11 (1.39) | 3.77 (1.18)            |
| Neutral             | 5.55 (1.13) | 3.59 (1.47) | 5.27 (1.30)            |

Smaller rating number represents higher withdrawal-motivated intensity.

d = 1.07, 95% CI [0.63, 1.50] had significantly higher ratings than the neutral pictures. And the difference between high- and low-withdrawal-motivation negative pictures was not significant (t(43) = 1.91, p = 0.06, d = 0.38, 95% CI [−0.02, 0.78]). On the motivational intensity ratings, the effect of picture type of also significant, F(2,86) = 33.98, p < 0.001, η²p = 0.44, with high-withdrawal-motivation (t(43) = 7.66, p < 0.01, d = 1.74, 95% CI [1.15, 2.30]) and low-withdrawal-motivation (t(43) = 5.53, p < 0.01, d = 1.21, 95% CI [0.71, 1.70]) pictures being higher than neutral pictures, and high-withdrawal-motivation pictures being higher than low-withdrawal-motivation pictures (t(43) = 3.46, p = 0.001, d = 0.81, 95% CI [0.32, 1.31]).

Figure 2 presents the mean response times and accuracy for naming the color. Incorrect responses and responses with the response time more than three standard deviations from the mean were excluded. A repeated-measures ANOVA with picture type as a within-subject factor was conducted on the RT and accuracy data. The results indicated that the main effect of picture type on the response time was significant, F(2,86) = 14.71, p < 0.001, η²p = 0.26. Post hoc comparisons revealed that response times were significantly longer under the block of high-withdrawal-motivation pictures than under the block of the low-withdrawal-motivation pictures (t(43) = 2.96, p < 0.01, d = 0.31, 95% CI [0.09, 0.53]) and the neutral pictures (t(43) = 4.73, p < 0.001, d = 0.54, 95% CI [0.29, 0.79]). There was also a significant difference in the response time between the low-withdrawal-motivation picture block and the neutral picture block (t(43) = 3.04, p < 0.01, d = 0.27, 95% CI [0.08, 0.45]).

The main effect of picture type on accuracy was significant, F(2,86) = 19.10, p < 0.001, η²p = 0.31. Post hoc comparisons revealed that the accuracy under the block of the high-withdrawal-motivation pictures was significantly lower than that under the block of the low-withdrawal-motivation pictures (t(43) = 4.93, p < 0.001, d = 0.80, 95% CI [0.44, 1.16]) and the neutral pictures (t(43) = 4.81, p < 0.001, d = 0.82, 95% CI [0.44, 1.19]). There was no difference in accuracy between the block of low-withdrawal-motivation pictures and neutral pictures (t(43) = 0.59, p = 0.56, d = 0.09, 95% CI [−0.22, 0.40]).

**Discussion**

The results of experiment 1 revealed that, compared with the neutral stimuli, both the high- and low-withdrawal-motivation negative stimuli produced significant interference. Existing studies have found that negative stimuli produce a robust emotional Stroop effect, and our findings are consistent with those prior findings (McKenna and Sharma, 1995; White, 1996). The biological salience of these stimuli is high. Furthermore, the high-withdrawal-motivation negative stimuli produced stronger emotional Stroop effects than the low-withdrawal-motivation negative stimuli. Therefore, we believe that, although negative stimuli can produce the robust emotional Stroop effect, this effect may also be modulated by the motivational intensity inherent in the negative stimuli.

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4 Twenty-two pictures were chosen from IAPS. The picture numbers were 2000, 2010, 2020, 5010, 5200, 5201, 5220, 5711, 8160, 8370, 8179, 8186, 8120, 8250, 8320, 8330, 8350, 8380, 8461, 8490, 8497, and 8540. Seven pictures were chosen from CAPS. The picture numbers were 1098, 1018, 1049, 1063, 1098, 1233, and 1244. Other three stimuli which were similar to the pictures selected in IAPS or CAPS were chosen from the internet.

5 Ten pictures were chosen from IAPS. The picture numbers were 2070, 4660, 4689, 4694, 4695, 4800, 7270, 7250, 7330, and 7430. Other twenty-four pictures which were similar to the pictures selected in IAPS or CAPS were chosen from the internet.

6 The neutral pictures of experiment 1 and experiment 2 were the same.
appeared twice in the experiment: once with a red frame and once with a green frame.

**Procedure**
The procedure of experiment 2 was identical to that of experiment 1. An example of a trial for this experiment is shown in Figure 3.

**Results**
Table 2 presents the means and standard deviations of the valence, arousal, and motivational intensity for the three types of positive stimuli. A repeated-measures ANOVA showed that there were significant effects on the valence, $F(2,52) = 11.85, p < 0.001, \eta_p^2 = 0.31$. Post hoc comparisons demonstrated that the pleasure ratings of both the high-approach-motivation ($t(26) = 8.23, p < 0.001, d = 1.46, 95\% \text{ CI} [0.93, 2.00]$) and low-approach-motivation pictures ($t(26) = 2.65, p = 0.01, d = 0.81, 95\% \text{ CI} [0.17, 1.45]$) were significantly higher than those of the neutral pictures. And the difference between high- and low-approach-motivation pictures was not significant ($t(26) = 1.52, p = 0.14, d = 0.45, 95\% \text{ CI} [-0.15, 1.05]$). On the arousal ratings, results suggested a significant effect for picture type, $F(2,52) = 10.33, p < 0.001, \eta_p^2 = 0.28$. The high-approach-motivation ($t(26) = 4.27, p < 0.001, d = 1.21, 95\% \text{ CI} [0.56, 1.85]$) and low-approach-motivation pictures ($t(26) = 3.59, p = 0.001, d = 0.77, 95\% \text{ CI} [0.29, 1.23]$) had significantly higher ratings than the neutral pictures. And the difference between high- and low-approach-motivation pictures was not significant ($t(26) = 1.28, p = 0.21, d = 0.39, 95\% \text{ CI} [-0.22, 0.98]$). On the motivational intensity ratings, the effect of picture type was also significant, $F(2,52) = 11.71, p < 0.001, \eta_p^2 = 0.31$. High-approach-motivation pictures had higher motivational intensity ratings than low-approach-motivation pictures ($t(26) = 2.39, p = 0.02, d = 0.66, 95\% \text{ CI} [0.09, 1.22]$) and neutral pictures ($t(26) = 5.60, p < 0.01, d = 1.40, 95\% \text{ CI} [0.77, 2.01]$), and the difference between low-approach-motivation pictures and neutral pictures was also significant ($t(26) = 2.14, p = 0.04, d = 0.54, 95\% \text{ CI} [0.02, 1.04]$).

The means and standard deviations of the response times and accuracy under the three blocks of high-approach-motivation stimuli, low-approach-motivation stimuli, and neutral stimuli are presented in Figure 4. Incorrect responses and response with the response time more than three standard deviations from the mean were excluded. A repeated-measures ANOVA with picture type as a within-subject factor was conducted on the RT and accuracy data. The results indicated that the main effect of the picture type on the response time was significant, $F(2,52) = 47.27, p < 0.001, \eta_p^2 = 0.65$. Post hoc comparisons revealed that the response time was significantly longer under the high-approach-motivation picture block than under the low-approach-motivation picture block ($t(26) = 8.58, p < 0.001$, $d = 1.52$, $95\% \text{ CI} [0.93, 2.00]$).
FIGURE 4 | Results of experiment 2. RTs (A) and accuracy (B) of the emotional Stroop effect task as a function of block. Error bars represent standard errors.

\[d = 1.47, 95\% \text{ CI} [0.95, 1.99]\] and the neutral picture block \((t(26) = 6.65, p < 0.001, d = 1.29, 95\% \text{ CI} [0.77, 1.80])\). There was no difference between the low-approach-motivation picture block and the neutral picture block \((t(26) = 1.22, p = 0.24, d = 0.20, 95\% \text{ CI} [-0.13, 0.52])\).

The main effect of the picture type on accuracy was significant, \(F(2,52) = 23.68, p < 0.001, \eta^2_p = 0.48\). Post hoc comparisons revealed that the accuracy under the high-approach-motivation picture block was significantly lower than that under the low-approach-motivation pictures block \((t(26) = 5.77, p < 0.001, d = 1.38, 95\% \text{ CI} [0.77, 1.97])\) and neutral pictures block \((t(26) = 4.92, p < 0.001, d = 1.03, 95\% \text{ CI} [0.53, 1.51])\). There was no difference between the low-approach-motivation picture block and the neutral picture block \((t(26) = 1.68, p = 0.11, d = 0.38, 95\% \text{ CI} [-0.06, 0.67])\).

**Discussion**

Experiment 2 revealed that the high-approach-motivation positive stimuli produced a significant emotional Stroop effect, while the low-approach-motivation positive stimuli caused no effect. These results supported our hypothesis that high-approach-motivation positive stimuli could produce the emotional Stroop effect, whereas the low-approach-motivation positive stimuli could not.

**GENERAL DISCUSSION**

Results of current study indicate that both the high- and low-withdrawal-motivation negative stimuli produced a robust emotional Stroop effect, and the high-withdrawal-motivation negative stimuli produced a stronger emotional Stroop effect than the low-withdrawal-motivation negative stimuli. Regarding positive stimuli, only the high-approach-motivation positive stimuli produced an emotional Stroop effect, while the low-approach-motivation positive stimuli were ineffective at producing such an effect. These results may suggest that the emotional Stroop effect of stimuli is modulated by the biological salience and motivational intensity inherent in the stimuli.

Our study indicated that both high- and low-motivation negative stimuli produced a robust emotional Stroop effect. From the perspective of evolutionary theory, evolutionary pressure has led the nervous system (“negative brain”) to guarantee rapid and intense responses to negative stimuli (Carretié et al., 2009). Negative stimuli require processing and response resources to be more intensely and urgently mobilized. This urgency would have obvious adaptive and evolutionary advantages (Ekman, 1992; Ohman et al., 2000). Specifically, through evolution, when we encounter dangers or threat stimuli, which are referred to as high-withdrawal-motivation negative stimuli, our biological system acts as fast as possible to escape from the disadvantageous situations in order to survive or allow the continuation of the species. In other words, when we encounter unexpected threat stimuli while we are completing a task, the life-critical information must interrupt the current goal-directed processing. There is a balance between maintaining goal-directed processing and ensuring that the life-critical information interrupts the ongoing processing (Allport, 1989). The processing of this kind of stimuli is automatic and prioritized (Algol et al., 2004; Reynolds and Langerak, 2015; Yamaguchi and Harwood, 2015). The low-withdrawal-motivation negative stimuli indicate that there are unpleasant or dislike things around us. This state is also detrimental to our survival and well-being. Our attention should prioritize these stimuli in contrast to neutral stimuli. In a word, negative stimuli, regardless of whether the stimuli inherently high or low motivational intensity have, convey crucial information meaning that the organism should escape from the current environment or adjust actions. Thus, both high- and
low-withdrawal motivation negative stimuli require attentional resources for the prioritized processing of these stimuli and thus delay the processing of a goal task (Augst et al., 2014). Once a stimulus captures one’s attention, we should then disengage from this stimulus and begin to process the next stimulus. Especially under the condition in which a stimulus contains a negative emotional task-irrelevant dimension, attentional disengagement from this dimension is difficult, hindering the processing of the task-relevant dimension of the next stimulus (Bertels et al., 2011). Taken together, due to the negative stimulus involved, both the high- and low-withdrawal-motivation negative stimuli were biologically salient, and the emotional Stroop effect was observed under both the high- and low-withdrawal-motivation negative stimuli blocks in the present study.

It seems that a failure to respond to negative information may lead to injury or even death, while a failure to respond to positive information may lead to missed opportunities (Hilgard et al., 2014). Generally, an insufficient response to positive stimuli seems to have less serious results. However, from an evolutionary point of view, focusing our attention on positive stimuli such as appetizing food or erotic stimuli is also critical to species survival. Positive stimuli such as appetizing food or erotic stimuli are more biologically salient stimuli and have high inherent approach motivation intensity. Both appetizing food and erotic stimuli are tightly connected to survival, choosing a mate and reproduction. An individual’s survival crucially depends not only on the ability to avoid disadvantageous situations but also on the ability to detect and acquire nourishment (Nummenmaa et al., 2011). Regardless of whether the attentional resources are sufficient, the positive stimuli with high motivational intensity that have high biological salience or convey survival information will be prioritized and processed automatically. Specifically, when we encounter things representing energy intake that can sustain our life, such as appetizing food, our brain is intrinsically prepared to process these stimuli. This brain mechanism is highly biologically plausible, as it makes the food-relevant information “pop out” from the multidimensional stimuli (Nummenmaa et al., 2011). Moreover, erotic and infant stimuli can also effectively capture our attention (Lykins et al., 2006; Brosch et al., 2007). Hence, when these kinds of information are task-irrelevant, such stimuli will produce interference in the current task. In addition, when we encounter low-approach-motivation positive stimuli, there is no emotional Stroop effect. In our daily life, the average resting mood of most people is quite positive rather than absolutely neutral (Gasper and Clore, 2002). This state made the participants have no significantly different reaction when they encountered the low-approach-motivation positive stimuli and the neutral stimuli. Low-approach-motivation positive stimuli are not very urgent for an organism’s survival. Our attention will still be allocated to the current task to complete goal-directed actions under this condition. Therefore, while high-approach-motivation positive stimuli produced a significant emotional Stroop effect, low-approach-motivation positive stimuli did not.

Moreover, although the present study found that both the high- and low-withdrawal-motivation negative stimuli produced a robust emotional Stroop effect, the high-withdrawal-motivation negative stimuli produced a stronger emotional Stroop effect than the low-withdrawal-motivation negative stimuli. This means that negative stimuli, regardless of having a high or low motivational intensity, produced a robust emotional Stroop effect; however, the negative stimuli with a higher inherent motivational intensity produced a stronger emotional Stroop effect. Therefore, this result suggests that the emotional Stroop effect of negative stimuli is also modulated by the inherent motivational intensity of such stimuli. Furthermore, as mentioned above, high-approach-motivation positive stimuli produced a significant emotional Stroop effect, but low-approach-motivation positive stimuli did not. That is, the biological salience and motivational intensity inherent in no matter negative or positive stimuli are additive factors which may contribute to the emotional Stroop effect. Therefore, the emotional Stroop effect might be modulated not only by the biological salience of emotional stimuli but also may be modulated by the inherent motivational intensity of such stimuli.

This study took an experiment approach to the emotional Stroop effect by investigating the biological salience and motivational intensity inherent in the stimuli. And these two factors have not received much attention in the emotional Stroop literatures. The findings provide the first evidence that biological salience and motivational intensity have additive effect for the emotional Stroop effect. These findings provide a new perspective and more comprehensive interpretation for this effect, and provide supports for the motivational dimensional model of affect.

Several limitations of our study should be considered. First, our study only adopted affective pictures as the stimuli, therefore, diverse stimuli should be used in future research to explore whether these findings can be generalized to emotional words or other conditioned emotional stimuli. Second, all the participants recruited in the present study were normal undergraduates, and thus, the results might not be generalized to clinical participants, such as people with anxiety, anorexia, post-traumatic stress disorder and so on.

CONCLUSION

In conclusion, the present study found that both high- and low-withdrawal-motivation negative stimuli produced a robust emotional Stroop effect, and high-withdrawal-motivation negative stimuli produced a stronger emotional Stroop effect than low-withdrawal-motivation negative stimuli. High-approach-motivation positive stimuli produced an emotional Stroop effect, but low-approach-motivation positive stimuli did not. These findings provide the first evidence that the emotional Stroop effect is modulated by the biological salience of stimuli and by the motivational intensity inherent in the stimuli. Biological salience and motivational intensity play an additive effect in the emotional Stroop effect.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.
ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of the Psychology School of Shaanxi Normal University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ZW developed the study concept. SQ and YL contributed to the study design. SQ conducted the experiments and interpreted the data under the supervision of ZW. SQ drafted the manuscript.

REFERENCES

Algom, D., Chajut, E., and Lev, S. (2004). A rational look at the emotional stroop phenomenon: a generic slowdown, not a stroop effect. J. Exp. Psychol. 133, 323–338. doi: 10.1037/0096-3445.133.3.323

Allport, A. (1989). “Visual attention,” in Foundations of Cognitive Science, ed. M. Posner (Cambridge, MA: MIT Press), 631–681.

Andersson, G., Westöö, J., Johansson, L., and Carlbring, P. (2006). Cognitive bias via the Internet: a comparison of Web-based and standard emotional Stroop tasks in social phobia. Cogn. Behav. Ther. 35, 55–62. doi: 10.1080/16506070500372469

Augst, S., Kleinsorge, T., and Kunde, W. (2014). Can we shield ourselves from task disturbance by emotion-laden stimulation? Cogn. Affect. Behav. Neurosci. 14, 1009–1025. doi: 10.3758/s13415-013-0243-x

Ben-Haim, M. S., Mama, Y., Icht, M., and Algom, D. (2014). Is the emotional Stroop task a special case of mood induction? Evidence from sustained effects of attention under emotion. Attent. Percept. Psychophys. 76, 81–97. doi: 10.3758/s13414-013-0545-7

Berridge, K. C., and Kringelbach, M. L. (2008). Affective neurocueses of pleasure: reward in humans and animals. Psychopharmacology 199, 457–480. doi: 10.1007/s00213-008-0999-6

Bertels, J., Kolinsky, R., Pietrons, E., and Morais, J. (2011). Long-lasting attentional influence of negative and taboo words in an auditory variant of the emotional Stroop task. Emotion 11, 29–37. doi: 10.1037/a0022017

Briggs, K. E., and Martin, F. H. (2009). Affective picture processing and motivational relevance: arousal and valence effects on ERPs in an oddball task. Int. J. Psychophysiol. 72, 299–306. doi: 10.1016/j.ijspsycho.2009.01.009

Brosch, T., Pourtois, G., Sander, D., and Vuilleumier, P. (2011). Additive effects of emotional, endogenous, and exogenous attention: behavioral and electrophysiological evidence. Neuropsychologia 49, 1779–1787. doi: 10.1016/j.neuropsychologia.2011.02.056

Brosch, T., Sander, D., and Scherer, K. R. (2007). That baby caught my eye. Emotion 7, 685–689. doi: 10.1016/j.1528-3542.7.3.685

Caparos, S., and Blanchette, I. (2014). Emotional Stroop interference in trauma-exposed individuals: a contrast between two accounts. Conscious. Cogn. 28, 104–112. doi: 10.1016/j.concog.2014.06.009

Carretié, L., Albert, J., López-Martín, S., and Tapia, M. (2009). Negative brain: an emotional global versus local processing of visual information. Psychol. Sci. 13, 34–40. doi: 10.1111/j.1467-9280.2008.02112.x

Ekman, P. (1992). An argument for basic emotions. Psychol. Rev. 99, 14–32. doi: 10.1037/0096-0262.99.1.14

Ekman, P., Russo, R., Bowles, R., and Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? J. Exp. Psychol. 130, 681–700. doi: 10.1037/0096-3445.130.4.681

Ekman, P. W., and Corrigan, M. (2014). Positive emotions broaden the scope of attention and thought-action repertoires. Cogn. Emot. 19, 313–332. doi: 10.1080/0269993041000238

Ekman, P., and Wühr, P. (2012). Don’t be afraid of irrelevant words: the emotional Stroop effect is confined to attended words. Cogn. Emot. 26, 1056–1068. doi: 10.1080/02699931.2011.638908

Ekman, P. A., and Harmon-Jones, E. (2008). Approach-activated positive affect reduces breadth of attention. Psychol. Sci. 19, 476–482. doi: 10.1111/j.1467-9280.2008.02112.x

Ekman, P. A., and Harmon-Jones, E. (2010). The motivational dimensional model of affect: implications for breadth of attention, memory, and cognitive categorisation. Cogn. Emot. 24, 322–337. doi: 10.1080/02699309303378305

Ekman, P., and Clore, G. L. (2002). Attending to the big picture: mood and global versus local processing of visual information. Psychol. Sci. 13, 34–40. doi: 10.1111/j.1467-9280.2004.00406

Harmon-Jones, E., Gable, P. A., and Price, T. F. (2013). Does negative affect always narrow and positive affect always broaden the mind? Considering the influence of motivational intensity on cognitive scope. Curr. Direct. Psychol. Sci. 22, 301–307. doi: 10.1177/0967119813481533

Hester, K., Dixon, V., and Garavan, H. (2006). A consistent attentional bias for drug-related material in active cocaine users across word and picture versions of the emotional Stroop task. Drug Alcohol Depend. 81, 251–257. doi: 10.1016/j.drugalcdep.2005.07.002

Hilgard, J., Weinberg, A., Hajcak Proudfit, G., and Bartholow, B. D. (2014). The negativity bias in affective picture processing depends on top-down and bottom-up motivational significance. Emotion 14, 940–949. doi: 10.1037/a0036791

Lang, P. J., Bradley, M. M., and Cuthbert, B. N. (2005). International Affective Picture System (IAPS): Instruction Manual and Affective Ratings. Technical Report A-6. Florida: University of Florida.

Lee, T. H., Lim, S. L., Lee, K., Kim, H. T., and Choi, J. S. (2009). Conditioning-induced attentional bias for face stimuli measured with the emotional Stroop task. Emotion 9, 134–139. doi: 10.1037/a0014590

Liu, Y., and Wang, Z. (2014). Positive affect and cognitive control: the approach motivational intensity influences the balance between cognitive flexibility and stability. Psychol. Sci. 25, 1116–1123. doi: 10.1177/09567976145213

Lykins, A. D., Meana, M., and Kambe, G. (2006). Detection of differential viewing patterns to erotic and non-erotic stimuli using eye-tracking methodology. Arch. Sex. Behav. 35, 569–575. doi: 10.1007/s10508-006-9065-z
Martin, M., Williams, R. M., and Clark, D. M. (1991). Does anxiety lead to selective processing of threat-related information? *Behav. Res. Ther.* 29, 147–160. doi: 10.1016/0005-7967(91)90043-3

McKenna, F. P., and Sharma, D. (1995). Intrusive cognitions: an investigation of the emotional Stroop task. *J. Exp. Psychol.* 21, 1595–1607. doi: 10.1037/0278-7393.21.6.1595

Nummenmaa, L., Hietanen, J. K., Calvo, M. G., and Hyona, J. (2011). Food catches the eye but not for everyone: a BMI-contingent attentional bias in rapid detection of nutrients. *PLoS One* 6:e19215. doi: 10.1371/journal.pone.0019215

Ohman, A., Hamm, A., and Hugdahl, K. (2000). "Cognition et al. and the autonomic nervous system: orienting, anticipation, and conditioning," in *Handbook of Psychophysiology*, 2nd Edn, eds J. T. Cacioppo, L. G. Tassinary, and G. G. Bernston, (Cambridge, MA: Cambridge University Press), 533–575.

Pool, E., Brosch, T., Delplanque, S., and Sander, D. (2016). Attentional bias for positive emotional stimuli: a meta-analytic investigation. *Psychol. Bull.* 142, 79–106. doi: 10.1037/bul0000026

Pratto, F. (1994). "Consciousness and automatic evaluation," in *The heart’s eye: Emotional Influences in Perception and Attention*, eds P. M. Niedenthal, and S. Kitayama, (New York, NY: Academic Press), 116–140.

Reynolds, M. G., and Langerak, R. M. (2015). Emotional Stroop Dilution: the boundary conditions of attentional capture by threat words. *Acta Psychol.* 159, 108–115. doi: 10.1016/j.actpsy.2015.05.008

Schimmack, U., and Derryberry, D. (2005). Attentional interference effects of emotional pictures: threat, negativity, or arousal? *Emotion* 5, 55–66. doi: 10.1037/1528-3542.5.1.55

Schultz, W. (2004). Neural coding of basic reward terms of animal learning theory, game theory, microeconomics and behavioural ecology. *Curr. Opin. Neurobiol.* 14, 139–147. doi: 10.1016/j.conb.2004.03.017

Wentura, D., Rothermund, K., and Bak, P. (2000). Automatic vigilance: the attention-grabbing power of approach-and avoidance-related social information. *J. Pers. Soc. Psychol.* 78, 1024–1037. doi: 10.1037//0022-3514.78.6.1024

White, M. (1996). Automatic affective appraisal of words. *Cogn. Emot.* 10, 199–212. doi: 10.1080/026999396380330

Williams, J. M. G., Mathews, A., and MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychol. Bull.* 120, 3–24. doi: 10.1037//0033-2909.120.1.3

Wyble, B., Sharma, D., and Bowman, H. (2008). Strategic regulation of cognitive control by emotional salience: a neural network model. *Cogn. Emot.* 22, 1019–1051. doi: 10.1080/02699930701597627

Yamaguchi, M., and Harwood, S. L. (2015). Threat captures attention but does not affect learning of contextual regularities. *Cogn. Emot.* 9931, 1–8. doi: 10.1080/02699931.2015.1115752

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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