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Valence versus motivation: The different impact of emotion on space- and object-based attention

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Abstract

Numerous studies have indicated that both the broaden-and-build model and the motivational dimensional model emphasize the impact of emotion on spatial attention by altering the attentional scope. However, no prior research has investigated the impact of emotional valence and motivational intensity on spatial attention within the same paradigm. Furthermore, object-based attention, characterized by distinct neural mechanisms from space-based attention and also susceptible to attentional scope, represents a major pattern of selective attention. Nevertheless, it is still unclear whether and how emotional valence and motivation play a role in object-based attentional selection. Therefore, the present study aimed to explore these areas. Using a two-rectangle paradigm, Experiment 1 found that motivational intensity modulated space-based effects, whereas emotional valence modulated object-based effects. Experiment 2 used a traditional spatial cueing paradigm to further study the stability of modulating effect of motivation intensity on space-based attention, yielding results consistent with those of Experiment 1. The present study indicated that the broaden-and-build model and motivational dimensional model were not either one or the other, but both played a role in object- and space-based attention. This study provides crucial empirical evidence for theoretical complementation and integration of emotional attention.

Keywords Emotional valence · Emotional motivation · Space-based attention · Object-based attention

Introduction

In the real world, individuals are continuously bombarded with lots of visual information, yet their cognitive resources are limited, preventing them from processing all information equally. In this scenario, selective attention is crucial for the cognitive process. Furthermore, selective attention is constrained not only by spatial location (space-based attention), but also by object boundaries (object-based attention). Furthermore, we are often experiencing different emotions during the process of attentional selection, implying that people's emotions always interact with their attentional selection. However, whether and how individuals' emotions influence different patterns of attentional selection is an intriguing question that deserves further research.

Notably, researchers have proposed two models to explain how emotions impact attentional scope: the broaden-and-build model and the motivational dimensional model. The early valence-based broaden-and-build model argued that positive emotions broaden attentional scope, while negative emotions narrow it (e.g., Fredrickson, 2001; Rowe et al., 2007; Xie & Zhang, 2016; Zhang et al., 2016). Later, Gable and Harmon Jones (2008) challenged this model and proposed a motivational dimensional model, arguing that emotional motivation represents the strength of the urge to move toward/away from a stimulus and can range from low to high, serving as the third emotional dimension. According to this model, whether emotions are positive or negative,

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high and low motivational intensity narrow and broaden attentional scope, respectively (e.g., Gable & Harmon-Jones, 2008, 2010a, b; Harmon-Jones et al., 2013; Liu & Wang, 2014). Both models emphasize the influence of emotion on attentional scope, yet the debate persists regarding which emotional dimension predominantly influences attentional selection.

A large body of research has suggested that emotions influence spatial attention by altering attentional scope (e.g., Liu et al., 2016; Moriya & Nittono, 2011; Rowe et al., 2007; Vanlessen et al., 2013; Zhang et al., 2016). For example, Zhang et al. (2016) adopted a variant of the spatial cueing paradigm to explore the impact of different emotions on spatial attention with fMRI. In their study, participants were presented with one face (emotional or neutral) and four gratings positioned randomly in the upper and lower visual fields surrounding the face in the left and right hemifields, and participants were asked to identify the gender of the face. Results showed that negative and positive faces decreased and increased V1 responses to flanking gratings, respectively, suggesting that emotional valence modulated the attention field in V1. Additionally, Liu et al. (2016) used the variant of the flanker task to investigate the influence of the approach-motivated positive affect on the spatial attention using the event-related potential (ERP) technique. The results revealed that when the flanker letter and the detection stimuli were presented simultaneously, the P1 amplitude was larger in the low approached-motivated positive affect condition than in the high approached-motivated positive affect condition, and previous studies have linked P1 to spatial attention (Fu et al., 2001). These findings suggest compared with the high approach-motivated positive affect, the low approach-motivated positive affect broadened attentional scope, allowing the distractor to enter the attentional system and receive more attentional processing. However, prior studies have not simultaneously examined the roles of emotional valence and motivational intensity in spatial attention within the same paradigm to determine whether spatial attention is influenced by emotional valence or motivational intensity.

Numerous studies have found that in addition to spatial location, the object itself can also guide attentional allocation, known as object-based attention (e.g., Duncan, 1984; Richard et al., 2008; Watson & Kramer, 1999). Subsequently, Egly et al. (1994) have proposed a two-rectangle paradigm, which allowed space- and object-based attention to be studied simultaneously. In this paradigm, participants were presented with two horizontally or vertically oriented rectangles and a fixation; one of the four ends of the two rectangles was brightened to serve as a cue. After a 200-ms inter-stimulus interval, the target appeared at one of three locations: the cued location (valid condition), the opposite location of the cued rectangle (invalid same-object condition), or an equidistant location of the uncued rectangle. The results showed that participants responded faster in the valid condition than in the invalid same-object and invalid different-object conditions, reflecting space-based effects. Crucially, participants responded faster in the invalid same-object condition than in the invalid different-object condition, yielding object-based effects. Furthermore, previous studies have indicated that space- and object-based attention have different neural mechanisms (e.g., Baldauf & Desimone, 2014; He et al., 2004, 2008; Hou & Liu, 2012). For example, He et al. (2008) used the two-rectangle paradigm to explore the neural mechanisms of space- and object-based attention using an ERP technique. The results revealed enhancement of the anterior and posterior N1 was related to space- and object-based attention, respectively, highlighting that space- and object-based attention have different neural mechanisms.

A large number of studies have indicated that object-based attention is not robust and can also be modulated by numerous factors (e.g., Chen, 2012; Hein et al., 2017; Hu et al., 2020a, b, 2021, Hu & Yang, 2024; Reppa et al., 2012). On the one hand, object properties can modulate object-based attention (e.g., Hein et al., 2017; Hu et al., 2020b, 2021; Zhao et al., 2020). For instance, Hu et al. (2021) have investigated the impact of object emotion on the different patterns of attentional selection using different emotional faces as objects. The results showed no significant difference for space-based effects among positive, neutral, and negative faces, but the object-based effects were larger for negative faces than for neutral and positive faces, and there was no significant difference for object-based effects between neutral and positive faces. On the other hand, a growing body of evidence has shown large inter-individual variability in object-based attention, indicating individual characteristics influenced the object-based attention (e.g., Fischer & Hoellen, 2004; Hu et al., 2020a, 2022; Pilz et al., 2012). For example, Hu et al. (2020a) have explored the role of cognitive style in different patterns of attentional selection by preselecting as holistic or analytic individuals. Their results revealed that no significant differences were obtained for space-based effects between holistic and analytic individuals, whereas object-based effects were obtained for analytic individuals but not for holistic individuals. This was in line with the interpretation that holistic individuals with broadened attentional scope perceived two objects as a larger object unit, and allocated attentional resources equally to the two invalid locations, resulting in the disappearance of object-based effects. This study suggested that cognitive style modulated the object-based attention by altering attentional scope. Moreover, Hu et al. (2022) have also found that different personality traits can modulate attentional scope and further influence object-based attention. As discussed above, individuals' emotions play a crucial role in shaping behavioral responses by altering attentional scope dynamically. Nevertheless, it is still unclear whether and how individuals' emotional valence and motivational intensity modulate object-based attention.

In the present study, the overarching goal was to determine whether and how emotional valence and motivational intensity modulated space- and object-based attentional allocation across two experiments. Experiment 1 adopted a two-rectangle paradigm and investigated space- and object-based attention simultaneously to explore the influence of positive and negative emotions with different motivational intensities on space- and object-based attention. However, it is important to note that the two-rectangle paradigm in these experiments involved spatial attention derived from both exogenous cues and high probability expectations, differing from traditional spatial attention. Therefore, Experiment 2 used a classical spatial cue paradigm to further study the impact of positive and negative emotions with different motivational intensities on space-based attention. Hu et al. (2021) have found that objects' emotional valence only modulated object-based attention, and previous studies have found that individual characteristics (e.g., personality traits, cognitive style) can also modulate object-based attentional selection (Hu et al., 2020a, 2022), implying that individuals' emotional valence may only modulate object-based attention. In addition, Liu et al. (2016) have found that compared to high motivational intensity, positive emotions with low motivational intensity broadened attentional scope and caused distractors around the target to enter the attentional system, while weakening the inhibitory capacity to distractors. In their study, the researchers maintained the same emotional valence (positive emotions) and found that different motivational intensities modulated space-based attention, implying that individuals' emotional motivation may only modulate space-based attentional selection. Based on the aforementioned studies, we hypothesized that emotional motivation would mainly modulate space-based attention, whereas emotional valence would mainly modulate object-based attention. Specifically, for the space-based attention, the space-based effects would be larger in low motivational intensity than in neutral and high motivational intensity, and the space-based effects would be larger in a neutral condition than in high motivational intensity. For object-based attention, positive emotion would not produce object-based effects, while neutral and negative emotions would elicit object-based effects, and the object-based effects would be larger for negative emotions than for neutral emotions.

Experiment 1

In Experiment 1a, we used different emotional pictures to elicit high approach-motivated positive, low approach-motivated positive, and neutral emotions to explore the impact of approach-motivated intensity positive emotion on space- and object-based attentional selection. Similarly, in Experiment 1b, we used different emotional pictures to evoke high avoidance-motivated negative, low avoidance-motivated negative, and neutral emotions to explore the impact of avoidance-motivated intensity negative emotions on space- and object-based attentional selection.

Methods

Participants

Sixty undergraduate students were recruited in exchange for monetary compensation, with 30 participants for Experiment 1a, and another 30 participants for Experiment 1b. All the participants had normal or corrected-to-normal vision and were naïve to the purpose of the study. They gave written informed consent in accordance with the Ethics Committee on Human Experimentation of the University.

The sample size for this study was estimated by a priori power analysis using G* Power (Faul et al., 2009). We set the alpha level at .05, and all 28 participants provided .95 power to find a medium-sized effect ($f = 0.25$; Cohen, 1992) for the interaction in a 2 × 3 within-subjects ANOVA. Moreover, the sample size was also based on the number of participants in previous studies of selective attention, ranging from 25 to 30 participants (e.g., Hu et al., 2021; Song et al., 2021; Zhao et al., 2020). Based on these analyses, we recruited 30 students to participate in this experiment.

Apparatus and stimuli

The experiment was programmed by using E-prime 2.0 on a 19-in. monitor (1,280 × 1,024 pixels; 60-Hz refresh rate). Participants were seated in a quiet and equally lit room at a distance of approximately 60 cm from the monitor. Each rectangle subtended 1.3° × 4.5°, and the distance between the two rectangles was 1.8°. The central fixation subtended 0.3° × 0.3°. The target and distractors subtended 0.6° × 0.6°.

All the emotional pictures used in this study were sourced from the research conducted by Liu and Wang (2014), and were originally selected from the International Affective Picture System (IAPS; Lang et al., 2005) and the internet. Moreover, previous studies have used pictures of delicious desserts and beautiful landscapes to evoke high and low approach-motivated positive emotions, while pictures of threatening animals and dirty environment were used to elicit high and low avoidance-motivated negative emotions, and household objects to elicit neutral emotion (e.g., Gable & Harmon-Jones, 2010a; Liu & Wang, 2014). Therefore, in Experiment 1a, 32 pictures of delicious desserts (e.g., cakes), 32 pictures of beautiful landscapes (e.g., flowers), and 32 pictures of household objects (e.g., desks) were selected to elicit high approach-motivated positive, low approach-motivated positive, and neutral emotions, respectively. Previous studies have confirmed that these pictures can effectively induce different approach-motivated positive emotions (e.g., Gable & Harmon-Jones, 2010b; Liu & Wang, 2014). In Experiment 1b, 32 pictures of threatening animals (e.g., snake), 32 pictures of a dirty environment (e.g., garbage dump) and 32 pictures of household objects (e.g., desk) were selected to induce high avoidance-motivated negative, low avoidance-motivated negative, and neutral emotions, respectively. Previous studies have confirmed that these pictures can effectively induce different avoidance-motivated negative emotions (e.g., Gable & Harmon-Jones, 2010a; Harmon-Jones et al., 2013). All the pictures had a pixel size of 640 × 480 and were meticulously processed using photoshop CS6 software to ensure uniformity in terms of size, brightness, and contrast of each picture.

Design and procedure

Experiment 1a used a 3 (approach-motivated intensity: neutral, low, high) × 3 (cue validity: valid, invalid same-object, invalid different-object) within-subjects factorial design. Experiment 1b adopted a 3 (avoidance-motivated intensity: neutral, low, high) × 3 (cue validity: valid, invalid same-object, invalid different-object) within-subjects factorial design. For each of the experiments, there were 192 trials (50%) for the valid condition and 96 trials (25%) for each of the invalid same-object and invalid different-object conditions. There was a total of 400 trials, which took participants about 35 min to complete, with 16 practical trials and 384 experimental trials.

As shown in Fig. 1a, at the beginning of each trial, participants were first presented with emotional pictures for 2,000 ms, and asked to carefully view the emotional pictures. Then, two horizontally or vertically oriented rectangles and a central fixation "+" were presented in the center of the screen for 1,000 ms. Next, a cue appeared equally at each of the four ends of the two rectangles for 100 ms, and then the two rectangles and the fixation were presented again for 200 ms, Finally, the target display with one target letter (T or L) and three distractor letters (a T/L hybrid) was presented until the participants responded as quickly as possible while focusing on the fixation, by pressing a key, and a performance accuracy of approximately 90% was noted. Half of the participants were instructed to press the "Z" key when the target letter was T, and the "M" key when the target letter was L. The other half had the reverse instruction. The next trial started after a blank inter-trial interval of 1,000 ms.

After completing the experimental task, participants were asked to view the emotional pictures again and rate their pleasure (1 = very unpleasant, 9 = very pleasant), arousal (1 = very calm, 9 = very exciting), and motivational intensity (1 = very much want to avoid, 9 = very much want to approach).

Results and discussion

Experiment 1a: Approach-motivated positive emotion

Only reaction times (RTs) for correct responses were analyzed, and RTs more than three standard deviations from the participant's mean for each condition were excluded from the analyses, resulting in the exclusion of 3.99% of the total trials.

Space-based effects We performed a two-way repeated-measures analysis of variance (ANOVA) on mean RTs with approach-motivated intensity (low, neutral, high) and cue validity (valid, invalid) as factors. The results showed that the main effect of cue validity was significant, $F(1, 29)$ =

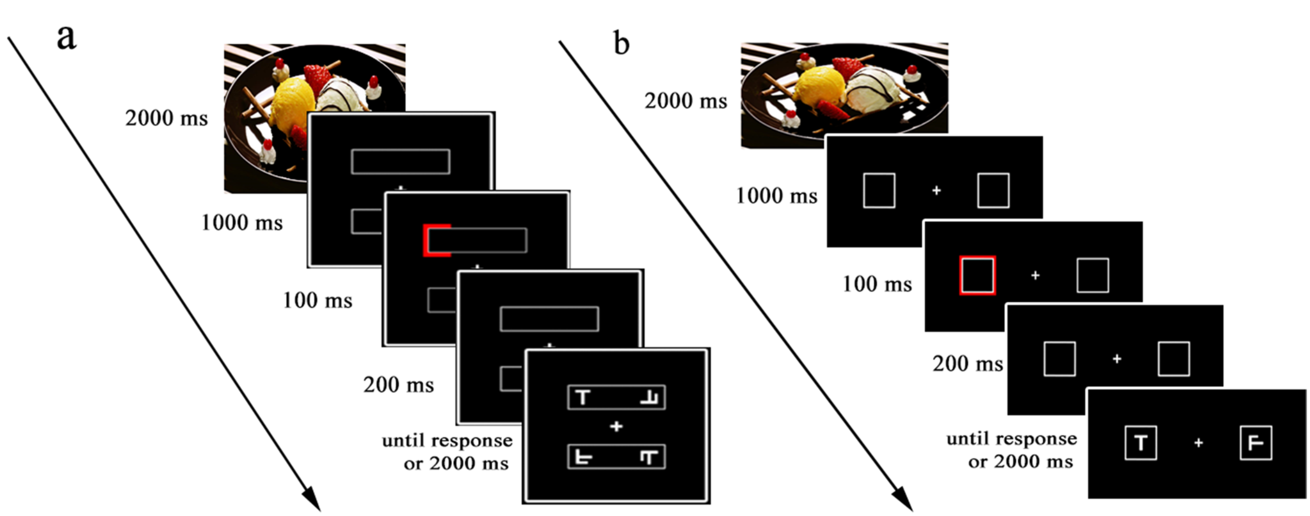

Fig. 1 Sequence of events in Experiment 1 (**a**) and Experiment 2 (**b**)

107.72, $p < .001$, $\eta_p^2 = .79$, participants responded faster for valid trials ($M = 631$ ms, $SE = 18$ ms) than for invalid trials ($M = 732$ ms, $SE = 18$ ms). No other main effect or interaction reached significance, $Fs < 2.88$, $ps > .064$.

ANOVA conducted on the error rates showed that the main effect of cue validity was significant, $F(1, 29) = 13.85$, $p = .001$, $\eta_p^2 = .32$, participants had less error rates for valid trials ($M = 1.61$, $SE = 0.28$) than for invalid trials ($M = 3.02$, $SE = 0.41$). No other main effect or interaction reached significance, $Fs < 0.93$, $ps > .400$.

Object-based effects We performed a two-way repeated-measures ANOVA on RTs with approach-motivated intensity (low, neutral, high) and cue validity (invalid same-object, invalid different-object) as factors (see Fig. 2a). The results showed that the main effect of approach-motivated intensity was not significant, $F(2, 58) = 2.67$, $p = .078$, $\eta_p^2 = .08$. The main effect of cue validity was significant, $F(1, 29) = 72.58$, $p < .001$, $\eta_p^2 = .72$; participants responded faster for invalid same-object trials ($M = 721$ ms, $SE = 18$ ms) than for invalid different-object trials ($M = 742$ ms, $SE = 19$ ms). Importantly, the interaction between approach-motivated intensity and cue validity was significant, $F(2, 58) = 5.52$, $p = .006$, $\eta_p^2 = .16$. The simple-effect analysis revealed that object-based effects reached significance in neutral [$F(1, 29) = 41.52$, $p < .001$], but not in low [$F(1, 29) = 3.81$, $p = .061$] and high [$F(1, 29) = 2.58$, $p = .119$] conditions. To further explore whether the disappearance of object-based effects in the low and high approach-motivated intensity conditions was due to slower RTs in invalid same-object condition and/

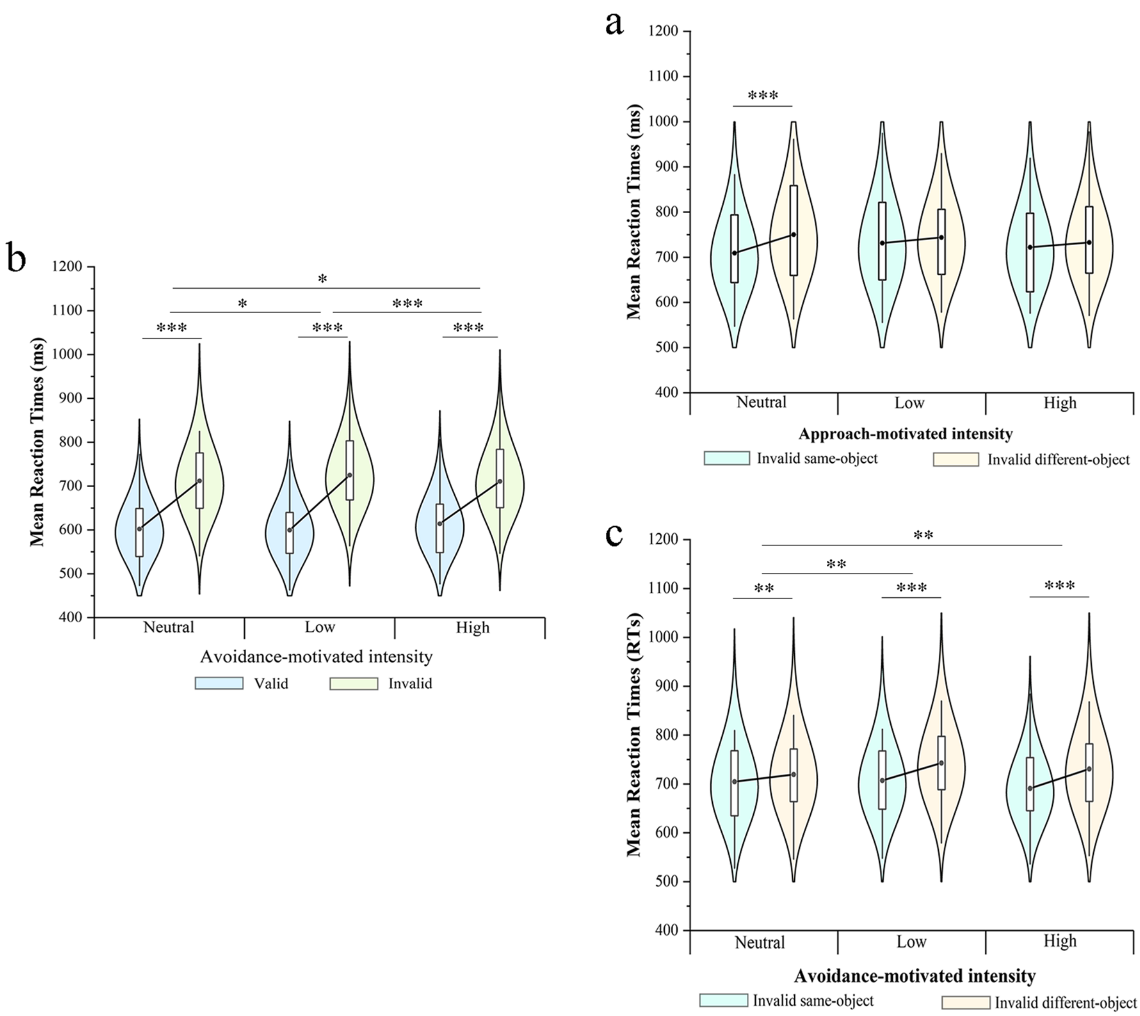

Fig. 2 Results of Experiment 1. (**a**) Mean reaction times (RTs) observed for invalid same-object and invalid different-object trials as a function of approach-motivated intensity, showing the object-based effects in different approach-motivated positive emotions. (**b**) Mean RTs observed for valid and invalid trials as a function of avoidance-motivated intensity, showing the space-based effects in different avoidance-motivated negative emotions. (**c**) Mean RTs observed for invalid same-object and invalid different-object trials as a function of avoidance-motivated intensity, showing the object-based effects in different avoidance-motivated negative emotions. * $p < .05$, ** $p < .01$, *** $p < .001$. The box plots mark the mean, upper and lower quartiles, and 1.5× interquartile range (whiskers)

or faster RTs in invalid different-object condition, a planned test showed that RTs were slower in the low condition (M = 731 ms, SE = 20 ms) than in the neutral condition (M = 709 ms, SE = 18 ms) for invalid same-object trials, $t(29) = 3.21$, $p = .003$, Cohen's $d = 0.22$, 95% confidence interval (CI) = [8, 36], and RTs were faster in the high condition (M = 733 ms, SE = 18 ms) than in the neutral condition (M = 750 ms, SE = 20 ms) for invalid different-object trials, $t(29) = -2.18$, $p = .038$, Cohen's $d = 0.17$, 95% CI = [-34, -1].

An ANOVA conducted on the error rates revealed that none of the main effects or interaction reached significance, $Fs < 1.32$, $ps > .259$.

Affective picture ratings The three-dimensional ratings were submitted to a separate repeated-measures ANOVA with picture type as a within-subject factor (see Table 1). For the valence ratings, the main effect of picture type was significant, $F(2, 58) = 86.66$, $p < .001$, $\eta_p^2 = .75$; post hoc tests showed that both dessert and landscape pictures had higher ratings than neutral pictures, $ps < .001$, and there was no significant difference between beautiful landscape and dessert pictures, $p = .180$. For the arousal ratings, the main effect of picture type was significant, $F(2, 58) = 58.32$, $p < .001$, $\eta_p^2 = .67$; post hoc tests showed that both delicious dessert and beautiful landscape pictures had higher ratings than neutral pictures, $ps < .001$, and there was no significant difference between beautiful landscape and delicious dessert pictures, $p = .286$. For the motivational intensity ratings, the main effect of picture type was significant, $F(2, 58) = 103.40$, $p < .001$, $\eta_p^2 = .78$; post hoc tests showed that both delicious dessert and beautiful landscape pictures had higher ratings than neutral pictures, $ps < .001$, and delicious dessert pictures had higher ratings than beautiful landscape pictures, $p < .001$.

Experiment 1b: Avoidance-motivated negative emotion

Only RTs for correct responses were analyzed, and RTs more than three standard deviations from the participant's mean for each condition were excluded from the analyses, resulting in the exclusion of 3.44% of the total trials.

Space-based effects We performed a two-way repeated-measures ANOVA on RTs with avoidance-motivated intensity (low, neutral, high) and cue validity (valid, invalid) as factors (see Fig. 2b). The results showed that the main effect of avoidance-motivated intensity was not significant, $F(2, 58) = 2.47$, $p = .094$, $\eta_p^2 = .08$. The main effect of cue validity was significant, $F(1, 29) = 118.25$, $p < .001$, $\eta_p^2 = .80$; participants responded faster for valid trials (M = 605 ms, SE = 13 ms) than for invalid trials (M = 716 ms, SE = 16 ms). Importantly, the interaction between avoidance-motivated intensity and cue validity was significant, $F(2, 58) = 13.72$, $p < .001$, $\eta_p^2 = .32$. The simple-effect analysis showed that space-based effects reached significance in neutral [$F(1, 29) = 105.63$, $p < .001$], low [$F(1, 29) = 135.31$, $p < .001$], and high [$F(1, 29) = 84.55$, $p < .001$] conditions, and a planned test showed that the space-based effects were larger in the low condition (M = 125 ms, SE = 11 ms) than in the neutral condition (M = 110 ms, SE = 11 ms), $t(29) = 2.41$, $p = .022$, Cohen's $d = .27$, 95% CI = [2, 29], and high condition (M = 97 ms, SE = 11 ms), $t(29) = 6.99$, $p < .001$, Cohen's $d = .49$, 95% CI = [20, 37]. Moreover, space-based effects were smaller in the high condition (M = 97 ms, SE = 11 ms) than in the neutral condition (M = 110 ms, SE = 11 ms), $t(29) = -2.33$, $p = .027$, Cohen's $d = .23$, 95% CI = [-25, -2]. To further explore whether the smaller space-based effects in high-avoidance-motivated intensity were due to slower RTs in the valid condition and/or faster RTs in the invalid condition, a planned test showed that RTs were slower in the high condition (M = 614 ms, SE = 14 ms) than in the neutral (M = 602 ms, SE = 13 ms; $t(29) = 3.21$, $p = .003$, Cohen's $d = 0.16$, 95% CI = [4, 20]) and low (M = 600 ms, SE = 13 ms; $t(29) = 4.16$, $p < .001$, Cohen's $d = 0.20$, 95% CI = [7, 22]) conditions for valid trials, and RTs were faster in the high condition (M = 711 ms, SE = 16 ms) than in the low condition (M = 725 ms, SE = 16 ms; $t(29) = -5.25$, $p < .001$, Cohen's $d = 0.16$, 95% CI = [-20, -9]) for invalid trials.

An ANOVA conducted on the error rates revealed that the main effect of cue validity was significant, $F(1, 29) = 28.48$, $p < .001$, $\eta_p^2 = .40$; participants had less error rates for valid trials (M = 1.30, SE = 0.27) than for invalid trials (M = 2.64, SE = 0.27). No other main effect or interaction reached significance, $Fs < 1.65$, $ps > .201$.

Object-based effects We performed a two-way repeated-measures ANOVA on RTs with avoidance-motivated intensity (low, neutral, high) and cue validity (invalid same-object, invalid different-object) as factors (see Fig. 2c). The results showed that the main effect of avoidance-motivated intensity was significant, $F(2, 58) = 8.42$, $p = .001$, $\eta_p^2 = .23$; post hoc tests showed that participants responded slower in the low condition (M = 725 ms, SE = 16 ms) than the neutral (M = 712 ms, SE = 17 ms, $p = .017$) and the high (M = 711 ms, SE = 16 ms, $p < .001$) conditions. The main effect of cue validity was also significant, $F(1, 29) = 63.19$, $p < .001$, η_p^2

Table 1 Means and standard errors of affective picture ratings in Experiment 1a

Picture type	Valence	Arousal	Motivational intensity
Neutral	4.87 ± 0.05	4.51 ± 0.13	4.69 ± 0.08
Beautiful landscape	6.22 ± 0.11	5.97 ± 0.18	6.07 ± 0.14
Delicious dessert	6.42 ± 0.11	6.16 ± 0.14	7.09 ± 0.16

= .69; participants responded faster on invalid same-object (M = 701 ms, SE = 15 ms) than invalid different-object trials (M = 731 ms, SE = 17 ms). Importantly, the interaction between cue validity and avoidance-motivated intensity was significant, $F(2, 58) = 6.84$, $p = .002$, $\eta_p^2 = .19$. The simple-effect analysis revealed that object-based effects reached significance in neutral [$F(1, 29) = 8.31$, $p = .007$], low [$F(1, 29) = 44.77$, $p < .001$], and high [$F(1, 29) = 38.83$, $p < .001$] conditions, a planned test showed that the object-based effects were smaller in the neutral condition (M = 15 ms, SE = 5 ms) than in the low condition (M = 35 ms, SE = 5 ms; $t(29) = -3.23$, $p = .003$, Cohen's $d = .73$, 95% CI = [-34, -8]) and high condition (M = 40 ms, SE = 6 ms), $t(29) = -3.15$, $p = .004$, Cohen's $d = .79$, 95% CI = [-41, -9]; there was no significant difference between the low and high conditions, $t(29) = -0.54$, $p = .590$, *Cohen's* $d = .12$, 95% CI = [-19, 11]. To further explore whether the larger object-based effects in the low and high avoidance-motivated intensity conditions were due to faster RTs in invalid same-object condition and/or slower RTs in invalid different-object condition, a planned test showed that RTs were faster in the high condition (M = 691 ms, SE = 14 ms) than in the neutral condition (M = 705 ms, SE = 17 ms) for invalid same-object trials, $t(29) = -2.56$, $p = .016$, Cohen's $d = 0.16$, 95% CI = [-25, -3], and RTs were slower in the low condition (M = 743 ms, SE = 17 ms) than in the neutral condition (M = 719 ms, SE = 17 ms) for invalid different-object trials, $t(29) = 4.05$, $p < .001$, Cohen's $d = 0.25$, 95% CI = [12, 36].

An ANOVA conducted on the error rates revealed that none of the main effects or interactions reached significance, $Fs < 1.51$, $ps > .229$.

Affective picture ratings The three-dimensional ratings were submitted to separate repeated-measures ANOVA with picture type as a within-subject factor (see Table 2). For the valence ratings, the main effect of picture type was significant, $F(2, 58) = 182.51$, $p < .001$, $\eta_p^2 = .86$; post hoc tests showed that both threatening animals and dirty environment pictures had lower ratings than neutral pictures, $ps < .001$, and there was no significant difference between threatening animals and dirty environment pictures, $p = .158$. For the arousal ratings, the main effect of picture type was significant, $F(2, 58) = 75.81$, $p < .001$, $\eta_p^2 = .72$; post hoc tests showed that both threatening animals and dirty environment pictures had higher ratings than neutral pictures, $ps < .001$, and there was no significant difference between threatening animals and dirty environment pictures, $p = .060$. For the motivational intensity ratings, the main effect of picture type was significant, $F(2, 58) = 287.06$, $p < .001$, $\eta_p^2 = .91$; post hoc tests showed that both threatening animals and dirty environment pictures had lower ratings than neutral pictures, $ps < .001$, and threatening animal pictures had lower ratings than dirty environment pictures, $ps < .001$.

Table 2 Means and standard errors of affective picture ratings in Experiment 1b

Picture type	Valence	Arousal	Motivational intensity
Neutral	4.92 ± 0.06	4.29 ± 0.18	4.94 ± 0.07
Threatening animals	2.87 ± 0.12	6.38 ± 0.15	2.80 ± 0.11
Dirty environment	2.73 ± 0.12	6.61 ± 0.15	1.93 ± 0.09

Comparison of object-based effects between Experiment 1a and Experiment 1b

Experiment 1a and Experiment 1b jointly found that object-based effects may be modulated by emotional valence, not motivational intensity. However, positive and negative emotions were manipulated in the two experiments. Therefore, we further directly compared the object-based effects for the positive and negative emotions via cross-experiment analysis. Because different participants were used in Experiment 1a and Experiment 1b, we first conducted an independent-samples t-test to compare the RTs for neutral condition between Experiment 1a and Experiment 1b; the results showed that no significant difference were obtained between Experiment 1a and Experiment 1b for the neutral condition, $t(58) = 0.71$, $p = .482$, Cohen's $d = 0.18$, 95% CI = [-68, 32]. We performed a two-way mixed-measures ANOVA on object-based effects with motivated intensity (low, high) as within-factor and Experiments (Experiment 1a, Experiment 1b) as between-factor. The results showed a significant main effect of Experiment, $F(1, 58) = 20.06$, $p < .001$, $\eta_p^2 = .26$, the object-based effects were larger in Experiment 1b (M = 38 ms, SE = 4 ms) than those in Experiment 1a (M = 11 ms, SE = 4 ms). No other main effect or interaction reached significance, $Fs < 0.19$, $ps > .667$.

The results of Experiment 1 revealed that space-based effects were smaller in the high avoidance-motivated intensity compared to the neutral and low avoidance-motivated intensity, and space-based effects were smaller in the neutral condition compared to the low avoidance-motivated intensity. However, object-based effects were obtained in the neutral condition, not in the low and high approach-motivated intensity, and object-based effects were larger in the low and high avoidance-motivated intensity compared to the neutral condition. Therefore, the results of both Experiment 1a and 1b suggested that motivational intensity modulated space-based attention, whereas emotional valence modulated object-based attention. These results indicated that the impact of positive and negative emotions with different motivational intensity on attentional selection have a universal mechanism.

Experiment 2

The results of Experiment 1 indicated that motivational intensity modulated space-based attention, whereas emotional valence modulated object-based attention. However, it should be noted that space-based attention in a two-rectangle paradigm was driven by both exogenous cues and high probability expectations, which differed from classical spatial attention. Therefore, Experiment 2 used the classic spatial cueing paradigm to further test the stability of the effects of positive (Experiment 2a) and negative (Experiment 2b) emotions of different motivational intensity on space-based attention.

Methods

Participants

Thirty undergraduates participated in Experiment 2 in exchange for monetary compensation. All the participants had normal or corrected-to-normal vision and were naïve to the purpose of the study.

Apparatus and stimuli

The apparatus and stimuli for Experiment 2 were similar to those of Experiment 1. In addition, the square box in Experiment 2 subtended 2° × 2°. Experiment 2 was divided into Experiment 2a and Experiment 2b and the emotion induction materials of Experiments 2a and 2b were same as in Experiment 1a and Experiment 1b, respectively.

Design and procedure

Experiment 2a used a 3 (approach-motivated intensity: neutral, low, high) × 2 (cue validity: valid, invalid) within-subjects factorial design. Experiment 2b adopted a 3 (avoidance-motivated intensity: neutral, low, high) × 2 (cue validity: valid, invalid) within-subjects factorial design.

The experimental procedure of Experiment 2 was similar to that of Experiment 1, except that for the affective picture ratings, in consideration of time limitations and to mitigate the fatigue effects, half of the participants were asked to rate 16 pictures of each type, while the other half were asked to rate additional set of 16 pictures for each type.

Results and discussion

Only RTs for correct responses were analyzed, and RTs more than three standard deviations from the participant's mean for each condition were excluded from the analyses, resulting in the exclusion of 4.40% of the total trials.

Experiment 2a: Approach-motivated positive emotion

We performed a two-way repeated-measures ANOVA on RTs with approach-motivated intensity (low, neutral, high) and cue validity (valid, invalid) as factors (see Fig. 3a). The results showed that the main effect of approach-motivated intensity was not significant, $F(2, 58) = 2{,}12$, $p = .129$, $\eta_p^2 = .07$. The main effect of cue validity was significant, $F(1, 29) = 26{,}11$, $p < .001$, $\eta_p^2 = .47$; participants responded faster for valid trials ($M = 670$ ms, $SE = 21$ ms) than for invalid trials ($M = 713$ ms, $SE = 22$ ms). Importantly, the interaction between approach-motivated intensity and cue validity was significant, $F(2, 58) = 8.29$, $p = .001$, $\eta_p^2 = .22$. The simple-effect analysis showed that space-based effects reached significance in the neutral [$F(1, 29) = 24.58$, $p < .001$], low [$F(1, 29) = 32.44$, $p < .001$], and high [$F(1, 29) = 8.97$, $p = .006$] conditions; a planned test showed that the space-based effects were smaller in the high condition ($M = 27$ ms, $SE = 9$ ms) than in the neutral condition ($M = 46$ ms, $SE = 9$ ms), $t(29) = -2.73$, $p = .011$, Cohen's $d = .39$, 95% CI = [-34, -5], and the low condition ($M = 55$ ms, $SE = 10$ ms), $t(29) = -4.12$, $p < .001$, Cohen's $d = .56$, 95% CI = [-43, -14]. There was no significant difference between the low and neutral conditions, $t(29) = -1.22$, $p = .233$, Cohen's $d = .17$, 95% CI = [-24, 6]. To further explore whether the smaller space-based effects in high approach-motivated intensity was due to slower RTs in valid condition and/or faster RTs in invalid condition, a planned test showed that RTs were slower in the high condition ($M = 677$ ms, $SE = 21$ ms) than in the low condition ($M = 659$ ms, $SE = 21$ ms; $t(29) = 3.07$, $p = .005$, Cohen's $d = 0.15$, 95% CI = [9, 15]) for valid trials, and RTs were faster in the high condition ($M = 703$ ms, $SE = 22$ ms) than in the neutral condition ($M = 720$ ms, $SE = 22$ ms; $t(29) = -2.93$, $p = .007$, Cohen's $d = 0.13$, 95% CI = [-28, -5]) for invalid trials.

An ANOVA conducted on the error rates revealed that the main effect of approach-motivated intensity was significant, $F(2, 58) = 4.45$, $p = .016$, $\eta_p^2 = .13$; post hoc comparisons showed that participants had higher error rates in the neutral condition ($M = 3.07$, $SE = 0.46$) than in the low condition ($M = 2.08$, $SE = 0.34$; $t(29) = 2.32$, $p = .028$, Cohen's $d = .45$, 95% CI = [0.1, 1.9]) and high condition ($M = 1.92$, $SE = 0.36$), $t(29) = 2.42$, $p = .022$, Cohen's $d = .51$, 95% CI = [0.2, 2.1]; there was no significant difference between low and high conditions, $t(29) = 0.47$, $p = .645$, *Cohen's* $d = .08$, 95% CI = [-0.5, 0.8]. No other main effect or interaction reached significance, $Fs < 2.48$, $ps > .126$.

Experiment 2b: Avoidance-motivated negative emotion

We performed a two-way repeated-measures ANOVA on RTs with avoidance-motivated intensity (low, neutral, high) and cue validity (valid, invalid) as factors (see Fig. 3b). The

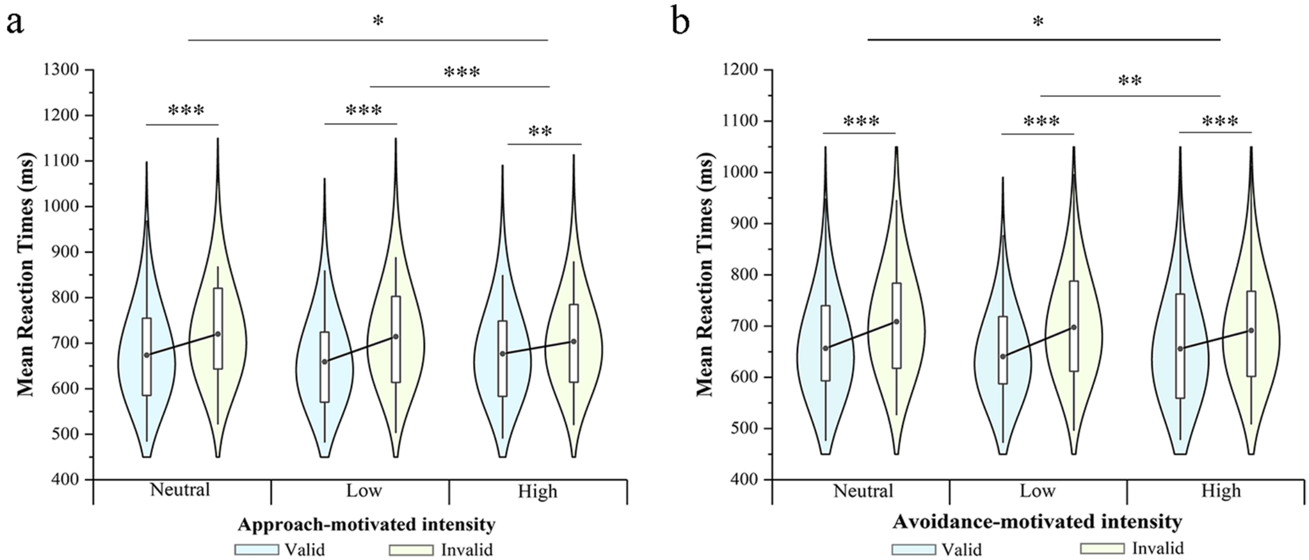

Fig. 3 Results of Experiment 2. (**a**) Mean reaction times (RTs) observed for valid and invalid trials as a function of approach-motivated intensity, showing the space-based effects in different approach-motivated positive emotions. (**b**) Mean RTs observed for valid and invalid trials as a function of avoidance-motivated intensity, showing the space-based effects in different avoidance-motivated negative emotions. * $p < .05$, ** $p < .01$, *** $p < .001$. The box plots mark the mean, upper and lower quartiles, and 1.5× interquartile range (whiskers)

results showed that the main effect of avoidance-motivated intensity was significant, $F(2, 58) = 3.54$, $p = .036$, $\eta_p^2 = .11$; post hoc tests showed that participants responded slower in the neutral condition ($M = 683$ ms, $SE = 21$ ms) than in the low condition ($M = 669$ ms, $SE = 19$ ms), $t(29) = 2.49$, $p = .019$, Cohen's $d = .12$, 95% CI = [2, 25], and high condition ($M = 674$ ms, $SE = 22$ ms), $t(29) = 2.26$, $p = .031$, Cohen's $d = .08$, 95% CI = [1, 17], but there was no significant difference between the low and high conditions, $t(29) = 0.76$, $p = .455$, Cohen's $d = .04$, 95% CI = [-8, 17]. The main effect of cue validity was significant, $F(1, 29) = 34.45$, $p < .001$, $\eta_p^2 = .54$, participants responded faster for valid trials ($M = 651$ ms, $SE = 20$ ms) than for invalid trials ($M = 699$ ms, $SE = 21$ ms). Importantly, the interaction between avoidance-motivated intensity and cue validity was significant, $F(2, 58) = 4.73$, $p = .013$, $\eta_p^2 = .14$. The simple-effect analysis showed that space-based effects reached significance in the neutral [$F(1, 29) = 30/88$, $p < .001$], low [$F(1, 29) = 39.07$, $p < .001$], and high [$F(1, 29) = 15.00$, $p = .001$] conditions; a planned test showed that the space-based effects were smaller in the high condition ($M = 36$ ms, $SE = 9$ ms) than in the neutral condition ($M = 52$ ms, $SE = 9$ ms), $t(29) = -2.11$, $p = .043$, Cohen's $d = .32$, 95% CI = [-32, -1], and the low condition ($M = 57$ ms, $SE = 9$ ms), $t(29) = -3.71$, $p = .001$, Cohen's $d = .43$, 95% CI = [-33, -10]. There was no significant difference between the low and high conditions, $t(29) = -0.61$, $p = .544$, Cohen's $d = .10$, 95% CI = [-12, 21]. To further explore whether the smaller space-based effects in high avoidance-motivated intensity condition was due to slower RTs in valid condition and/or faster RTs in invalid condition, a planned test showed that RTs were slower in the high condition ($M = 656$ ms, $SE = 22$ ms) than in the low condition ($M = 640$ ms, $SE = 18$ ms; $t(29) = 1.96$, $p = .006$, Cohen's $d = 0.14$, 95% CI = [1, 31]) for valid trials, and RTs were faster in the high condition ($M = 691$ ms, $SE = 22$ ms) than in the neutral condition ($M = 709$ ms, $SE = 22$ ms; $t(29) = -3.25$, $p = .003$, Cohen's $d = 0.14$, 95% CI = [-28, -6]) for invalid trials.

An ANOVA conducted on the error rates revealed that none of the main effects or interactions reached significance, $Fs < 1.46$, $ps > .237$.

Affective picture ratings The three-dimensional ratings were submitted to separate repeated-measures ANOVAs with picture type as a within-subject factor (see Table 3). For the valence ratings, the main effect of picture type was significant, $F(4, 116) = 291.07$, $p < .001$, $\eta_p^2 = .91$; post hoc tests showed that both threatening animals and dirty environment pictures had lower ratings than neutral pictures, $ps < .001$, and both delicious dessert and beautiful landscape pictures had higher ratings than neutral pictures, $ps < .001$; there was no significant difference between threatening animals and dirty environment pictures ($p = .802$), delicious dessert and beautiful landscape pictures ($p = .931$). For the arousal ratings, the main effect of picture type was significant, $F(4, 116) = 35.07$, $p < .001$, $\eta_p^2 = .55$; post hoc tests showed that both threatening animals and dirty environment pictures had higher ratings than neutral pictures, $ps < .001$, and both delicious dessert and beautiful landscape pictures had higher ratings than neutral pictures, *ps* < .001; there was no significant difference between threatening animals and dirty environment pictures ($p = .309$), delicious dessert and beautiful landscape pictures ($p = .171$). For the motivational intensity ratings, the main effect of picture type was significant, $F(4, 116) = 344.79$, $p < .001$, $\eta_p^2 = .92$; post hoc tests showed that both threatening animals and dirty environment pictures had lower ratings than neutral pictures, *ps* < .001, and both delicious dessert and beautiful landscape pictures had higher ratings than neutral pictures, *ps* < .001. Moreover, threatening animal pictures had lower ratings than dirty environment pictures, $p < .001$, delicious dessert pictures had higher ratings than beautiful landscape pictures, $p < .001$.

Comparison of space-based effects between Experiment 2a and Experiment 2b

Experiment 2a and Experiment 2b jointly found that space-based effects may be modulated by motivational intensity, not emotional valence. Therefore, we further directly compared the space-based effects for different motivated intensity via cross-experiment analysis. We performed a two-way repeated-measures ANOVA on space-based effects with motivated intensity (neutral, low, high) and Experiment (Experiment 2a, Experiment 2b) as within-factors. The results showed a significant main effect of motivated intensity, $F(2, 58) = 13.48$, $p < .001$, $\eta_p^2 = .32$; post hoc tests showed that space-based effects were smaller in the high condition ($M = 31$ ms, $SE = 7$ ms) than in the neutral ($M = 49$ ms, $SE = 7$ ms; $p = .003$) and low ($M = 56$ ms, $SE = 7$ ms; $p < .001$) conditions. There was no significant difference between the low and high conditions, $p = .139$. No other main effect or interaction reached significance, *Fs* < 0.33, *ps* > .571.

The results of Experiment 2 showed that both approach and avoidance motivation, space-based effects were smaller in the high-motivated intensity than in the neutral and low-motivated intensity. This was in line with the interpretation that relative to the high-motivated intensity, the low-motivated intensity broadened individuals' attentional scope and allowed the distractors to enter the attentional system, resulting in larger space-based effects (Liu et al., 2016). These findings were consistent with Experiment 1 and Experiment 2. Based on the results of three experiments, the different intensities of approach and avoidance motivation did indeed modulate space-based attention.

Table 3 Means and standard errors of affective picture ratings in Experiment 2

Picture type	Valence	Arousal	Motivational intensity
Threatening animals	2.96 ± 0.12	6.05 ± 0.15	1.84 ± 0.13
Dirty environment	2.97 ± 0.13	5.93 ± 0.10	2.74 ± 0.13
Neutral	5.06 ± 0.07	4.53 ± 0.10	5.01 ± 0.06
Beautiful landscape	6.39 ± 0.09	5.87 ± 0.07	6.29 ± 0.10
Delicious dessert	6.42 ± 0.09	5.99 ± 0.08	7.30 ± 0.16

General discussion

In the present study, we manipulated positive and negative emotions with different motivational intensities and cue validity to investigate whether and how emotional valence and motivation modulated space- and object-based attentional selection. Experiment 1 adopted two-rectangle paradigm to investigate the impact of positive and negative emotions with different motivational intensities on space- and object-based attentional selection. The results showed that motivational intensity mainly modulated space-based effects, whereas emotional valence mainly modulated object-based effects, suggesting that emotional valence and motivational intensity influenced object- and space-based attention, respectively. However, unlike classical spatial attention, space-based attention originated from both exogenous cues and high probability expectations in the two-rectangle paradigm. Therefore, Experiment 2 used the traditional spatial cueing paradigm to further investigate the stability of the effects of positive and negative emotions of different motivational intensities on space-based attention. The results demonstrated that the space-based effects were indeed modulated by different motivational intensities.

The findings of the present study suggest that emotional valence and motivational intensity modulate object- and space-based attentional selection, respectively. On the one hand, object-based attention was mainly modulated by emotional valence. According to the broaden-and-build model, positive and negative emotions broadened and narrowed attentional scope, respectively (e.g., Fredrickson, 2001; Fredrickson & Branigan, 2005), and a large number of empirical studies have confirmed the validity of the broaden-and-build model (e.g., Peng et al., 2022; Xie & Zhang, 2016; Zhang et al., 2016). More importantly, previous studies have indicated that individuals' attentional scope modulated object-based attention (e.g., Hu et al., 2020a, 2022). Accordingly, compared with neutral emotion, positive emotion broadened individuals' attentional scope, thus individuals perceived the two objects as one larger object unit and allocated attentional resources equally to the two invalid locations, resulting in the disappearance of object-based effects. In contrast, negative emotion narrowed individuals' attentional scope, so individuals perceived the two objects as two distinct objects and allocated more attentional resources to the invalid same-object location, leading to larger object-based effects.

On the other hand, space-based attention was mainly modulated motivational intensity. According to the motivational dimensional model, both positive and negative emotions, high motivational intensity narrowed attentional scope, whereas low motivational intensity broadened it (e.g., Gable & Harmon-Jones, 2008, 2010a, b; Liu & Wang, 2014). More importantly, Rowe et al. (2007) have found that broadened attentional scope can reduce people's ability for attentional selection and distractors' inhibitory ability while allowing distractors to penetrate the attentional system. Moreover, similar findings have also been confirmed in other cognitive tasks (e.g., global-local tasks) (Fredrickson & Braningan, 2005; Gable & Harmon Jones, 2010a; Liu et al., 2016). Accordingly, compared to high motivational intensity, low motivational intensity broadened individuals' attentional scope, allowing distractors to enter the attentional system for further processing, thereby reducing the individuals' attentional selection ability and inhibitory ability to distractors, resulting in larger space-based effects.

The present study can also further incorporate the broaden-and-build model and the motivational dimensional model, both of which have been widely used in emotional attention. Despite the fact that both the broaden-and-build model and the motivational dimensional model emphasized the role of emotion on the attentional scope, suggesting that the two models were either one or the other. However, the current study challenged previous findings by claiming that the two models were indeed not either one or the other, but rather played a role in different patterns of attentional selection. This was consistent with Campbell et al.'s (2021) findings that emotional valence and motivation were not two independent and contradictory emotional dimensions. The present study may also provide a novel perspective for the future emotional attention research, namely that whether emotional valence or motivational intensity modulated attentional selection depended on whether the focus of attentional selection was spatial location or object itself. However, in the various emotional attention paradigms used in previous studies (e.g., spatial cueing paradigm, Flanker task, etc.), it was difficult to distinguish between space- and object-based attention (e.g., Hu et al., 2021), which may be the main reason for the inconsistent results. Therefore, for future studies, researchers should specify whether the research focus is on the spatial location (space-based attention) or the object itself (object-based attention), and then further examine the two theoretical models of emotional attention.

The current study was the first attempt to demonstrate that as the subject of attentional selection, individuals' emotions can modulate object-based attentional selection, namely that positive emotions caused the disappearance of object-based effects, whereas negative emotions elicited larger object-based effects. Furthermore, as pointed out by the "positive starting point effect," individuals were often in positive or negative emotions, rather than truly neutral emotions in everyday life (Fredrickson & Cohn, 2008), resulting in large individual differences in object-based attention, and individuals' emotional state may be an important factor in modulating object-based attention. Therefore, controlling participants' emotional state and minimizing the influence of emotional state on object-based attention is important for future research on object-based attention. However, individuals' emotions include not just state emotions, but also trait emotions. Trait emotion refer to people's dispositions to experience certain emotions and moods across situations and over time (e.g., Polk et al., 2005; Hur et al., 2015). Thus, future studies can further investigate whether individuals' state and trait emotions have the same mechanism for object-based attention. In addition, Hu et al. (2021) found that objects' emotions can also modulate object-based attention, and previous studies have indicated that a mood-congruent effect between individuals and objects played an important role in attentional selection (e.g., Becker & Leinenger, 2011; Sanchez et al., 2014). Thus, future research can also examine the interactive mechanism of emotional information between individuals and objects in object-based attention.

In conclusion, emotional valence and motivational intensity played different roles in different forms of attentional selection, namely space-based attention was mainly modulated by motivational intensity, whereas object-based attention was mainly modulated by emotional valence. This means that the valence-based broaden-and-build model and the motivation-based motivational dimensional model were not either one or the other, but rather contributed to object- and space-based attentional selection, respectively.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.3758/s13414-024-02958-8.

Authors' contributions S. Hu and T. Yang conceived and designed the experiments. Testing and data collection were performed by S. Hu and T. Yang. S. Hu and T. Yang performed the data analysis and interpretation under the supervision of Y. Wang. S. Hu drafted the manuscript, and Y. Wang and J. Zhao provided critical revisions. All authors approved the final version of the manuscript for submission.

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Data availability All the data and materials for the experiments reported here is available as electronic supplementary files.

Code availability Not applicable.

Declarations

The authors have no financial or proprietary interests in any material discussed in this article.

Conflicts of interest The authors declare that they have no conflicts of interest with respect to their authorship or the publication of this article.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to participate Informed consent to participate was obtained from all individual participants included in this study.

Consent for publication Participants gave consent for their data to be published.

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