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BRIEF REPORT

Loss aversion in the control of attention

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Abstract
Loss aversion is a psychological bias where an increase in loss is perceived as being larger than an equivalent increase in gain. In the present study, two experiments were conducted to explore whether attentional control reflects loss aversion. Participants performed a visual search task. On each trial, a red target and a green target were presented simultaneously, and participants were free to search for either one. Participants always gained points when they searched for a gain color target (e.g., red). However, they gained or lost points when they searched for a gain-loss color target (e.g., green). In Experiment 1, the expected values of the gain color and the gain-loss color were equal. Therefore, for maximizing the reward, participants did not need to preferably search for a particular color. However, results showed that participants searched for the gain color target more than the gain-loss color target, suggesting stronger attentional control for the gain color than the gain-loss color. In Experiment 2, even though the expected value of the gain-loss color was greater than that of the gain color, attention was allocated to the gain color more than to the gain-loss color. The results imply that attentional control can operate in accordance with the loss aversion principle when the boundary conditions for loss aversion in a repeated binary decision-making task were met.

Keywords Loss aversion · Prospect theory · Attentional control

Introduction

Due to limited cognitive capacity, attention can focus only on a small number of items at a time (Kahneman, 1973). It has been suggested that the value of items is a critical factor in determining the amount of attention to various items such that more attention is allocated toward more valued items (Anderson, 2016; Rusz et al., 2020). Therefore, it is critical to understand how the human cognitive system determines value (Camerer et al., 2004). This question has been studied most actively in the economic decision-making literature (Barberis, 2013). Traditional economic theories postulate that because decision-makers are rational, they should behave to maximize their benefits based on mathematical analysis. However, inconsistent with this prediction derived from the economic theories, human decision-making is not fully rational (Simon, 1972). Empirical limitations of the traditional economic theories led Kahneman and Tversky to develop prospect theory, an account of behavioral economics, to explain how decision-makers actually behave. Prospect theory suggests that decision-makers do not objectively evaluate values of alternatives but subjectively distort them (Kahneman & Tversky, 1979). To ascertain how the cognitive system determines value for attentional allocation, the present study investigates whether attentional control operates based on mathematical analyses of gains and losses or a psychological bias suggested by prospect theory where people are more sensitive to losses than gains (Kahneman, 1991).

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Prospect theory

Prospect theory explains how objective value (e.g., money, time) is systematically distorted due to three psychological principles: reference dependence, diminishing sensitivity,

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and loss aversion (Camerer, 2004). According to the reference dependence principle, relative value, rather than absolute value, is critical because value is determined from a reference point. For example, when it is possible to receive \$10 or \$20, receiving \$20 will lead to satisfaction. However, when it is possible to receive \$30 or \$20, receiving \$20 will lead to disappointment. The value of \$20 is different depending on the reference points of \$10 and \$30. According to the diminishing sensitivity principle, the impact of a change in the absolute value decreases with the distance from a reference point of zero. Change from \$10 to \$11 looms larger than change from \$100 to \$101. According to the loss aversion principle, losses loom larger than gains. The pain of losing \$100 is more significant than the pleasure of gaining \$100. Prospect theory has been extensively validated in the decision-making literature (Barberis, 2013), and has had enormous impacts on education, communication, business, marketing, economics, politics, and any situation where someone seeks to influence decision-making of a person or a group of people (Thaler & Sunstein, 2009).

Applicability of prospect theory to attention

To develop prospect theory, Kahneman and Tversky drew from the understanding that basic cognitive principles operate across early (perception) and later (decision-making) cognitive stages, "An essential feature of the present theory is that the carriers of value are changes in wealth or welfare, rather than final states. This assumption is compatible with basic principles of perception and judgement" (Kahneman & Tversky, 1979, p. 277). This suggests that prospect theory may operate in attention, the selection process important in perception (see Carrasco, 2011, for review).

In line with this, previous studies demonstrated that attentional control reflects the reference dependence and diminishing sensitivity principles of prospect theory. Kim and Beck (2020) found evidence of reference dependence in attention. A 50-point item that was compared with a 1-point item attracted more attention than a 50-point item that was compared with a 100-point item, suggesting that relative value (higher or lower), not absolute value (50 points), influences attentional allocation to items. Also, Otto and Vassena (2021) showed reference dependence in attentional control. A reward of 10 cents reduced switching costs by increasing cognitive control more when the other available reward was 1 cent than when it was 19 cents. Kim et al. (2022) demonstrated diminishing sensitivity in attention. The absolute value difference between 1 point and 100 points had more impact on attention than the absolute value difference between 901 points and 1,000 points. The present study investigated whether attentional control reflects the loss aversion principle of prospect theory.

Thaler et al. (1997) showed loss aversion in a repeated binary decision-making task where participants repeatedly make decisions between two options. While participants always gained money for one option, they mostly gained money but occasionally lost money for the other option. The expected value of the gain option (i.e., the average amount expected to be gained if the gain option is chosen) was smaller than that of the gain-loss option. Therefore, rational decision-making predicts the gain-loss option should be chosen more often. However, participants chose the gain option more than the gain-loss option because losing money was more significant than its absolute value, indicating loss aversion.

To examine whether the loss aversion principle occurs in attention, the present study applied the Thaler et al. (1997) study to a visual search task. In the present study, participants performed a visual search task. On each trial, two targets were presented simultaneously, one within one of several red circles and the other within one of several green circles. Participants responded to only one of the targets and were free to decide to search for a target in either the red or the green circles. When responding to one color target (e.g., a red target), participants always gained reward points on each trial. When responding to the other color target (e.g., green target), participants gained reward points on some trials or lost reward points on the other trials. The expected values of the gain color and the gain-loss color were equal. Thus, if attentional control operates based on the rational analysis of gains and losses, participants do not need to bias attention to a particular color. In contrast, according to the loss aversion principle, the subjective value associated with the gain color is larger than the subjective value associated with the gain-loss color. Therefore, participants would prefer to attend to the gain color over the gain-loss color.

Experiment 1

Method

Participants Forty participants with normal or corrected-to-normal visual acuity and color vision participated in Experiment 1 for payment of KRW 7,000 (about US\$6). To determine the effect size, we looked to the Kim and Beck (2020) study, which had an effect size of 0.30. The present study was assumed to have a higher effect size than Kim and Beck (2020), given more direct measures in attentional selection in the present study. Therefore, we ran the G-power test with a power of 0.85, an alpha of 0.05, and an effect size of 0.5, and found a minimum sample size of 38.

Apparatus and Stimuli Stimuli were presented on a 24-in. (16:9) LED monitor. The distance between participants and the monitor was approximately 60 cm but was not constrained. Experiments were programmed and administered using MATLAB and Psychophysics Toolbox software. The experiments were conducted individually in a dimly lit, sound-attenuated room.

Each trial consisted of blank, fixation, pre-search, search, post-search, and feedback displays (see Fig. 1). The background of the screen was gray (RGB: 140, 140, 140) for all displays. In the blank display, no stimuli were presented in the gray background for 100 ms. In the fixation display, a black cross bar (0.5° each line, RGB: 0, 0, 0) was presented in the center of the screen for 500 ms. In the pre-search display for 1,500 ms, six red circles (1.2° diameter each, RGB: 140, 0, 0) were presented around an invisible circle (5.2°) in the left or right side of the center fixation, and six green circles (1.2° diameter each, RGB: 0, 100, 0) in the other side. In the search display presented until a response, each circle contained a digit. Two different target numbers among 1, 2, 3, and 4 were randomly chosen. One of the targets was presented in one of the red circles and the other target in one of the green circles. Non-target numbers of 5, 6, 7, 8, and 9 were randomly presented in the remaining red and green circles. In the post-search display presented for 500 ms, all numbers disappeared, and empty circles were presented in display. In the feedback display for 1,200 ms, for a correct response, a gaining point or losing point was presented in the center of the responded color circle. For an incorrect response, a message of "incorrect" was presented in the center of the red circles and in the center of the green circles.

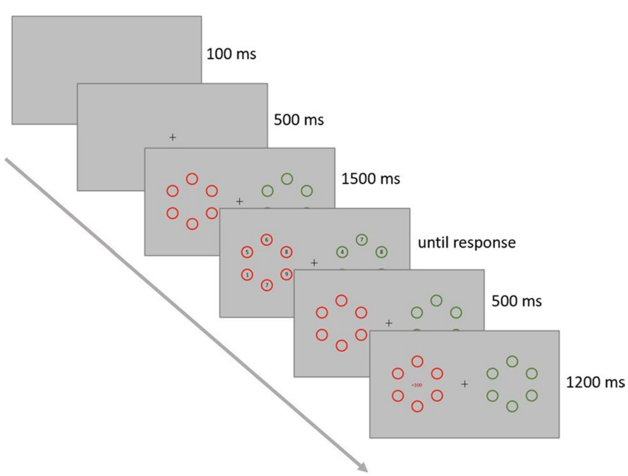

Fig. 1 Sequence of trial events in Experiments 1 and 2. One of the two different targets was in the red circles and the other in the green circles. Participants were free to search for either the red or green target. Whether the red or green target was selected was recorded based on the responded key (Irons & Leber, 2020). Reward feedback was presented in the side of the selected color

Design Unbeknownst to the participants, they always gained points when they searched for a target among the gain color (e.g., red circles) and either gained or lost points when searching for the target among the gain-loss color (e.g., green circles). The gain color equiprobably produced +100, +200, +600, or +1,500. The gain-loss color equiprobably produced -100, +100, +900, or +1,500. The color (red and green) and value (the gain and the gain-loss) associations were counterbalanced across participants. The expected values (i.e., the average gain) of the gain color (600) and the gain-loss color (600) were equal. The locations (left or right) of the gain color and the gain-loss color were random across trials. The experiment consisted of 32 practice trials and 288 experimental trials, four blocks of 72 trials each.

Procedure Participants were informed that their search targets were 1, 2, 3, and 4. Two different targets were presented on each trial. One target was presented in one of the six red circles and the other in one of the six green circles. Participants were told that they were free to search for either one. Participants were asked to press the 'V' key with their left middle finger for 1, the 'B' key with their left index finger for 2, the 'N' key with their right index finger for 3, and the 'M' key with their right middle finger for 4. Whether participants searched for the gain color or gain-loss color target was recorded based on the responded key (Irons & Leber, 2020). Participants were told that as earned points increase, the amount of participation payment would increase, and the experiment would finish earlier. Unbeknownst to participants, regardless of the amount of earned points, all participants had 288 trials and received KRW 7,000 (about US$6).

Results

The average points participants earned were similar to the expected values: 599 for the gain color, 598 for the gain-loss color. The dependent variable was the proportion of the responses to the gain color target, which is the number of the responses to the gain color target over the sum of the numbers of the responses to the gain color target and the gain-loss color target. Only correct responses (i.e., either of the targets presented was reported) were included in analyses (98.17% of trials).

The proportion of responses to the gain color (55% for the gain color, 45% for the gain-loss color) was higher than an unbiased response rate (a chance level of 50%,), $t(39) = 2.67$, $p = .011$, $d = .42$, indicating loss aversion (see Fig. 2). To investigate the trend of this attentional bias (subtracting a chance level of 50% from the gain color proportion), a one-way analysis of variance (ANOVA) was conducted on block (blocks 1–4, 72 trials for each block). The effect of block was not significant, $F(3, 117) = 1.21$, $p = .31$, $\eta_p^2 = .03$ (see Fig. 3).

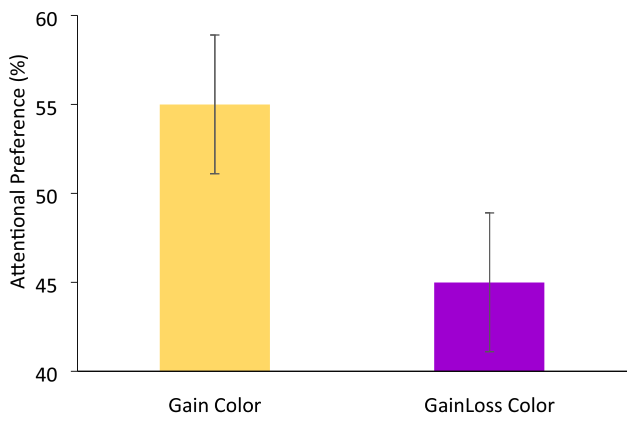

Fig. 2 Results of Experiment 1. Error bars represent 95% confidence intervals

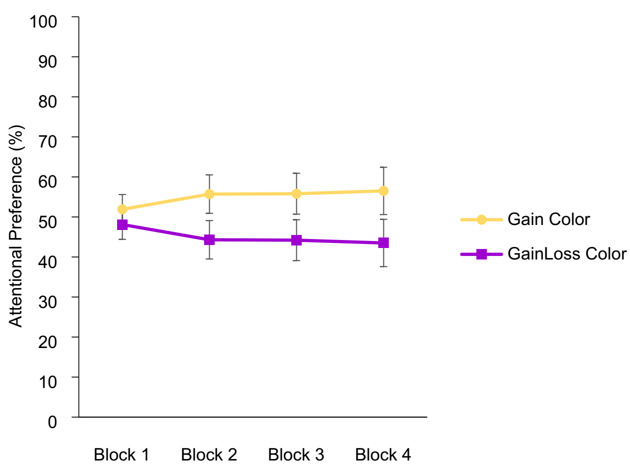

Fig. 3 Attentional preference to the gain color and the gain-loss color across blocks in Experiment 1. Error bars represent 95% confidence intervals

Discussion

Attentional preference for the gain over gain-loss color suggests that the subjective value of the gain color is larger than the gain-loss color despite equal expected values, indicating loss aversion. Furthermore, the loss aversion effect across blocks suggests that the learning was rapid as in Thaler et al. (1997). According to the traditional economic theories, attention should have been evenly allocated to the colors.

Experiment 2

In decision-making, loss aversion was demonstrated even if the expected value of gain-loss-related choice was larger than that of gain-related choice (Thaler et al., 1997). In line with this, Experiment 2 tested loss aversion in attention when the expected value associated with the gain-loss color was larger than the expected value associated with the gain color. Therefore, the rational attentional control predicts the attentional bias to the gain-loss color over the gain color. In contrast, the loss aversion principle predicts the attentional bias to the gain color over the gain-loss color.

Method

The methods were identical to those of Experiment 1 except for the following changes. First, 40 new participants participated. Second, the expected value of the gain-loss color (625) was greater than that of the gain color (575). The gain color equiprobably produced +100, +200, +500, or +1,500. The gain-loss color equiprobably produced -100, +400, +700, or +1,500.

Results

As in Experiment 1, only correct responses were included in analyses (98.10% of trials). The average earned points were similar to the expected values, 578 for the gain color, 621 for the gain-loss color.

The proportion of responses to the gain color target (55.7% for the gain color, 44.3% for the gain-loss color) was higher than an unbiased response (a chance level of 50%), $t(39) = 3.45$, $p < .001$, $d = .54$, indicating loss aversion (see Fig. 4). A one-way ANOVA revealed that the effect of block was not significant, $F(3, 117) = .57$, $p = .63$, $\eta_p^2 = .015$ (see Fig. 5).

Discussion

The expected value of the gain color was less than the expected value of the gain-loss color. However, attentional control was prioritized to the gain color over the gain-loss

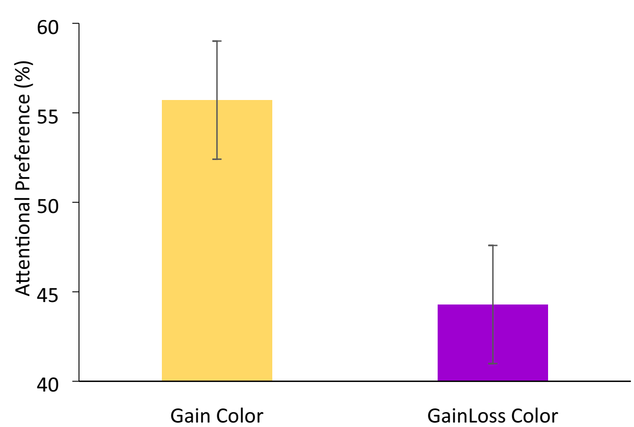

Fig. 4 Results of Experiment 2. Error bars represent 95% confidence intervals

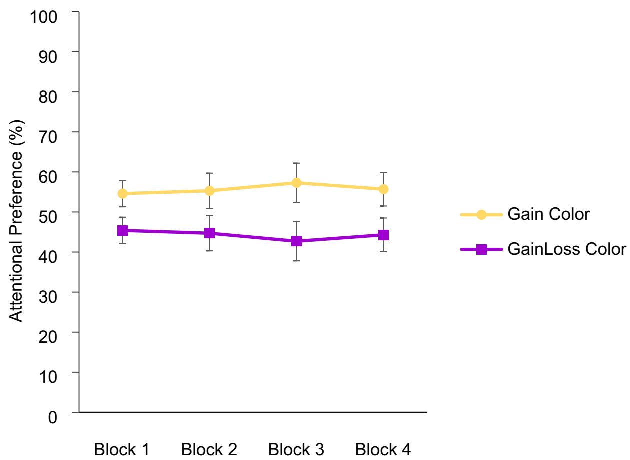

Fig. 5 Attentional preference to the gain color and the gain-loss color across blocks in Experiment 2. Error bars represent 95% confidence intervals

color. The finding suggests that attentional control operated according to loss aversion rather than mathematical analyses.

General discussion

The present study demonstrated that the impact of losses on attentional control is larger than the impact of gains. The gain color target was more likely to be reported than the gain-loss color target when the expected values of the gain and gain-loss colors were equal (Experiment 1) and even when the expected value was greater for the gain-loss color than the gain color (Experiment 2), consistent with loss aversion (Kahneman & Tversky, 1979; Thaler et al., 1997). This is the first evidence for attentional control reflecting loss aversion.

Loss aversion in voluntary attention and involuntary attention

Previous studies did not find evidence to support the loss-aversion principle in attention (Becker et al., 2020; Wentura et al., 2014). Previous studies used an attention capture paradigm in which the valued colors were presented as to-be-ignored items, whereas in the current study these items were always the targets. Therefore, the lack of evidence for loss aversion is possibly due to the previous studies measuring involuntary attention rather than voluntary attention.

Voluntary attention and involuntary attention are the two types of attention that are commonly distinguished in the attention literature (Kahneman, 1973; Theeuwes, 1991; Wolfe, 1994). Voluntary attention refers to the intentional allocation of attention that includes an exertion of effort in attention allocation toward stimuli relevant to current plans and intentions (Kahneman, 1973). For instance, observers can decide to attend to red objects and then intentionally direct effort toward this goal. On the other hand, involuntary attention refers to the unintentional allocation of attention. For instance, physically or emotionally salient items can automatically attract attention independent of an observer's intention. Critically, voluntary attention and involuntary attention operate in different cognitive systems (Katsuki & Constantinidis, 2014). While involuntary attention is automatic bottom-up processing, voluntary attention and decision-making are volitional top-down processing (Kahneman, 1973, 1991). Accordingly, a common neural apparatus, the frontal lobe network, is essential in voluntary attention and decision-making (Buschman & Miller, 2007; Duncan, 1995; Padoa-Schioppa & Conen, 2017). Furthermore, the two attentional systems are influenced differently by emotion factors (Mohanty & Sussman, 2013; Wright et al., 2008). The dopaminergic activities in the midbrain and striatum play a key role in the involuntary attention to the reward-associated stimuli (Anderson et al., 2016, 2017). The dopaminergic activities in these areas are influenced by gains more than losses (Yacubian et al., 2006). These findings suggest that involuntary attention is influenced more by gains than losses. Accordingly, voluntary attention may reflect loss aversion even though involuntary attention does not.

Uncertainty and loss aversion

Another possibility for the effect of loss aversion in this study, but not in the previous study (Wentura et al., 2014), is the different types of the loss conditions. The experience-based decision-making research showing loss aversion typically used a mixed condition, gain or loss randomly occurs on each trial, for the loss condition (Barron & Erev, 2003; Gneezy & Potters, 1997; Thaler et al., 1997). The present study used the mixed condition for loss condition, which was not used in the previous attention study (Wentura et al., 2014).

In repeated binary decision-making, the likelihood of the behavior predicted by loss aversion is increased when the expected value is difficult to compute so that uncertainty of the outcomes increases (Ert & Erev, 2013; Van Dijk & Van Knippenberg, 1996). In a pilot experiment in which computation of the expected value was easier because one color was associated with +100, and the other color was associated with +300 and -100, loss aversion was not found. The proportion of responses to the gain color (51.39%) was not higher than chance, $t(20) = .21$, $p = .84$, $d = .05$. A potential reason for this lack of the effect was that unlike one-shot decision-making tasks, in repeated decision-making tasks (experience-driven loss aversion), computation of the expected value needs to be difficult to produce loss aversion because loss aversion can be more evident when uncertainty on the outcomes increases (Ert & Erev, 2013; Thaler et al., 1997; Van Dijk & Van Knippenberg, 1996). Therefore, in the current study we used more payouts for each color as suggested. Given that loss aversion is not universal (Ert & Erev, 2013; Kahneman & Tversky, 1982; Novemsky & Kahneman, 2005), the current findings demonstrate a context of loss aversion in attentional control but do not imply that loss aversion operates in any context. Future research should further investigate the boundary conditions of loss aversion (Novemsky & Kahneman, 2005).

Selection history and loss aversion

The present study added new evidence for the impact of selection history on attention. Selection history includes learning from past experiences to guide attention (Anderson et al., 2021; Awh et al., 2012). For example, learned associations between stimulus features and rewards (Anderson et al., 2011; Anderson & Yantis, 2013) or punishment (Anderson & Kim, 2018; Grégoire et al., 2021; Le Pelley et al., 2019) are used to guide attention. Likewise, in the present study, attentional bias was formed by associative learning between colors and positive and negative outcomes, leading to the attentional control based on the experience-based loss aversion (Thaler et al., 1997).

As a related point, the approach in this study assumed that participants integrate the gains and losses over trials to learn the subjective values of the gain and gain-loss colors. However, it is possible that the attentional bias to the gain color might have been due to a short-lived bias after loss-experiences. To check this possibility, it was examined whether participants attended more often to the gain color or the gain-loss color after a loss trial in the two experiments. The immediate impact of the loss experience appears rather reversed. After loss trials (N trials), participants attended to the gain color on 49.99% of N+1 trials, 50.76% of N+2 trials, 50.92% of N+3 trials, 51.21% of N+4 trials, and 52.87% of N+5 trials. In decision-making literature, this pattern of behaviors related to loss-experiences has been commonly observed, such as the gambler's fallacy (Tversky & Kahneman, 1971). For example, participants might wrongly believe that losses would occur rarely between consecutive or immediate trials. Assuming that this wrong belief is true, attention to the gain-loss color immediately after loss-trials could be a good strategy to earn more rewards; in Experiment 1, for example, the gain color's expected value is 600 (+100, +200, +600, +1500), and the gain-loss color's expected value is 833 (+100, +900, +1500; wrongly believing that there will be no loss of -100). Therefore, the immediate impact of the loss experience might be insignificant.

Given that the present study utilized the methods in Irons and Leber (2016) where participants were instructed to search intentionally between the colors to measure dynamic changes in voluntary attentional control (i.e., the exertion of effort in attention allocation toward stimuli relevant to current plans and intentions, Kahneman, 1973), it was assumed that the current experiments measured voluntary attention rather than involuntary attention. The assumption was further supported by the search strategy reflecting the gambler's fallacy, which is volitional/strategic behavior (Tversky & Kahneman, 1971). But given the lack of direct evidence of volitional attentional control, awareness checks for search strategies at the end of experiment could be used in future research to address this issue.

Suboptimal attentional control strategy

In line with the previous research (Anderson, 2016; Kim & Beck, 2020; Kim et al., 2022; Otto & Vassena, 2021), the present study showed that value-driven attentional control may not operate to maximize benefits; instead, it is based on subjective value. These findings are in line with research (Irons & Leber, 2016) showing the relationships between attentional control and cognitive efforts. Irons and Leber (2016) found that many people did not use optimal attentional control strategies to reduce cognitive efforts regardless of attentional control abilities. The key factor that could predict strategy choice was subjective cognitive efforts, which refers to the experience of mental demands incurred by a task (Irons & Leber, 2020). Together with the present and previous studies in value-driven attention, Irons and Leber's research suggests that attentional control may not operate to maximize benefits and/or minimize costs.

Conclusion

Findings in behavioral economics and cognitive science have consistently hinted at the idea that prospect theory underlies the selection processes in decision-making and selective attention. Basic perception principles are the foundation of prospect theory (Kahneman & Tversky, 1979; Thaler, 1980). Decision-making and attentional control not only share a core concept of selection but interact functionally (Armel et al., 2008; Kahneman & Treisman, 1984). Also, the selection processes share a critical factor affecting selection – value. More valuable items are more likely to be selected in decision-making (Loewenstein et al., 2008) and perception (Anderson, 2016). Furthermore, a common neural apparatus, the frontal lobe network, is essential in both selection processes (Buschman & Miller, 2007; Duncan, 1995; Padoa-Schioppa & Conen, 2017). In line with this, the present and previous studies demonstrated that attention operates based on the reference dependence principle (Kim & Beck, 2020), the diminishing sensitivity principle (Kim et al., 2022), and the loss aversion principle of prospect theory. Thus, prospect theory is applied to the selection in the decision-making stage and the attentional selection in the perceptual stage.

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Open Practices Statement

The experiments were not preregistered. The data from both experiments are available via the Open Science Framework at: https://osf.io/semc6/.