Evaluative distractors modulate attentional disengagement: People would rather stay longer on rewards

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Attentional disengagement is of great significance to individuals adapting to their environment who can benefit from disregarding the attraction of salient and task-irrelevant objects. Previous studies have suggested that, in addition to causing greater financial loss compared with neutral distractors, reward distractors hold attention longer than neutral distractors. However, few studies have directly compared the attentional disengagement differences between reward-associated and loss- or punishment-associated stimuli. In the current study, we used different color singleton stimuli tied to reward or punishment outcomes; the stimuli were present in the center of the screen. Participants were required to respond to a line within the target at a peripheral location. The results showed that the response to the target was slower when the central distractor was associated with a reward than with punishment. This finding reflects that, although participants understand that reward-associated and punishment-associated stimuli have an equal opportunity for the same economic benefit, they still take longer to disengage from a reward distractor compared with a punishment distractor.

Introduction

Imagine that a yellow butterfly lands on a green lawn. Your attention would be captured by this butterfly because of its physical salience. Visual salience can capture our attention, but the continuous or persistent attentional capture by salient stimuli that are task irrelevant (i.e., distractors) is adverse for the current task. Clearly, disengagement of attention from task-irrelevant stimuli as soon as possible is important for an individual for task completion. Previous studies have suggested that stimuli associated with threats or punishment hold attention longer than neutral stimuli (Koster, Crombez, Verschuere, & De Houwer, 2004; Rudaizky, Basanovic, & MacLeod, 2014; Suarez-Suarez, Rodriguez Holguin, Cadaveira, Nobre, & Doallo, 2019). Similarly, a distractor signaling the availability of a high-reward holds attention longer than low-reward stimuli (Watson, Pearson, Theeuwes, Most, & Le Pelley, 2020). However, few studies have directly compared the effects on attentional disengagements

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of reward and loss distractors presented in equal quantities.

Notably, evidence from previous studies using a modified dot probe task to examine the influence of evaluative stimuli on attention disengagement has been questioned (Müller, Rothermund, & Wentura, 2016; Pool, Brosch, Delplanque, & Sander, 2014). Typically, in modified dot probe task, a target was preceded by two cues, one of which was either associated or not associated with reward stimuli (baseline: two cues were neutral stimuli). If participants' responses are faster when the target appears at the location of a valuable stimulus (valid trials) than when the target randomly appears at the location of a neutral stimulus (baseline), then there should be a facilitation effect and attention should be captured by a reward cue. If participants' responses are slower when the target appears in the opposite location of the reward cue (invalid trials) than when the target randomly appears at the location of a neutral stimulus, then this would genuinely demonstrate an effect of attention disengagement. Notably, a non-facilitation effect (comparing valid and neutral conditions) and a disengagement effect (comparing invalid and neutral conditions) be satisfied simultaneously that can reflect the existence of attentional disengagement (Watson et al., 2020). However, a previous study showed that there was a significant difference in response times (RTs) in valid trials between conditioned and unconditioned stimuli but no significant RT difference between conditioned and unconditioned stimuli in invalid trials (Pool et al., 2014). Accordingly, a facilitation effect existed on a conditioned reward cue, but there was no attention disengagement from a valuable cue. Similarly, other researchers only observed that target discrimination was slower on invalid trials than baseline trials, but there were no facilitation effects between valid and neutral trials (Müller et al., 2016), which may be due to the floor effect (see Watson et al., 2020). Thus, this evidence indicated that a dot probe paradigm has shortcomings requiring investigation regarding attentional disengagement on evaluative stimuli, which should be conducted instead using the attentional disengagement paradigm developed by Watson et al. (2020), which has proved to be an effective direct test for the effect of evaluative stimuli on attention disengagement.

Previous researchers used different evaluative stimuli, such as financial reward and electric shock, to compare differences in the attention mechanism between reward and punishment (Kim, Nanavaty, Ahmed, Mathur, & Anderson, 2021). However, this approach may be problematic in that these reinforcements (financial reward and electric shock) do not belong to the same dimension. In other words, electric shock, as a punishment, is a primary reinforcement, whereas financial reward is a secondary reinforcement. Therefore, we selected reinforcers that belonged to the same dimension (financial loss and financial reward) to compare their effects on attentional disengagement.

The current study examined the attentional disengagement effect on reward and loss in the case of equal quantity by using the attentional disengagement paradigm developed by Watson et al. (2020). In this paradigm, a distractor was displayed at the center of a picture, and the target and other shapes were presented around the distractor. Participants had to inhibit attention to the central distractor in order to search for the target and make a response to the line orientation within the target. Participants' attention was at the central location after fixation disappeared, and they had to shift their attention from this central location to the target, which could minimize the influence of any effect of an evaluative distractor on spatial attentional capture (Watson et al., 2020). That is to say, this paradigm provided relatively accurate measurements of the speed of disengagement from the central evaluative distractor. Specifically, when a reward distractor was presented, making a response to a target within a limited time would garner 500 points, with no reward (0 points) for an incorrect response or timeout. When a punishment distractor was presented, making a response to a target within a limited time would garner 0 points but a loss of 500 points would result for an incorrect response or timeout. Moreover, a control group was included, which was identical to the experimental group except that all of the distractors were not associated with any value. We speculated that, if participants took longer time on the central distractor that was associated with reward compared to punishment, then this would suggest that an effect of reward on attentional disengagement is larger than punishment in the case of equal quantities.

Experiment 1

Methods

Participants

We recruited 36 college students ranging from 17 to 23 years of age (30 females; age $M = 19.81$ years; $SEM = 0.21$) from Southwest University for the experimental group and 30 students ranging from 18 to 24 years of age (24 females; age $M = 20.47$ years; $SEM = 0.31$) for the control group. None of the students had a history of psychiatric or neurological disorders. The Human Ethics Committee of Southwest University approved the experimental protocol.

Stimuli and design

The experiment was conducted on a computer with an 18.5-inch monitor (1366 × 768-pixel resolution; 60-Hz refresh rate). We used E-Prime 2.0 software to control the stimulus presentation. We used the visual search task that Watson et al.' study had used, which has little difference among the stimuli (Watson et al., 2020). On each trial of this procedure, a white cross (1.0 degree of visual angle) was at the center of the screen throughout the entire duration of the trial except for the search display and a blank screen. After 500 to 700 ms, the white fixation point disappeared. After 150 ms of a blank screen, a search display was presented lasting 2000 ms. The search display consisted of a series of six shapes (five gray circles and a gray diamond), and there was a singleton colored distractor at the center of the screen (each 2.0° × 2.0° visual angle). The six shapes were distributed evenly around the center of the screen. All circles contained a gray line segment oriented at either 45° or 135°, and half of the shapes were 45°. The target contained a gray line oriented either horizontally or vertically. The location of the target was presented randomly in the peripheral location. All stimuli were displayed against a black background.

Participants were instructed to report the orientation of the line segment in the diamond by pressing the F or T key for horizontally and vertically oriented lines, respectively. There were two practice blocks and eight normal blocks in this experiment. Each normal block consisted of 40 trials: 16 with a single reward-related distractor, 16 with a single punishment-related distractor, and eight with no distractor (all shapes were gray). The trials were presented randomly. Before the formal experiment, participants were required to complete two blocks in a practice phase. Each practice block had a half trial of a formal block. Only when accuracy in the practice block exceeded 80% could each participant proceed to perform the formal experiment. We set the threshold for the formal experiment based on the RTs in the practice phase. The threshold equaled the mean reaction time for correct trials in the practice phase.

In the experimental group, one singleton was rendered in blue and associated with reward, whereas another singleton was rendered in orange and associated with punishment. In the no-distractor condition, no distractor was presented. The colored singleton was balanced among the participants. If a participant's correct response time was lower than the threshold in the reward trials, the feedback screen presented "Congratulations, +500 points," which lasted 1500 ms; otherwise, the feedback screen showed "Unfortunately, –0 points" (an incorrect response or the correct response time was higher than the threshold). In the punishment and no-distractor trials, if a participant's correct response time was lower than the threshold, the feedback screen would present "Good job, +0 points"; otherwise, the feedback screen would show "Sorry, –500 points" (an incorrect response or the correct response time was higher than the threshold). Each feedback screen displayed the current total scores of the search task.

A threshold also existed in the control group. The main difference between the experimental and control groups was whether the singleton distractor was tied to a value. The feedback was correct or incorrect according to whether participants responded to the target correctly and the response time was lower than the threshold. Each feedback screen displayed the current accuracy of the search task.

Procedure

Figure 1 illustrates the experimental procedure. The participants were instructed that monetary compensation was dependent on performance (20–30 yuan), and they were instructed that before the formal experiment they should complete practice trials and calculate the mean RTs as the threshold in the practice phase. For the experimental group, participants were informed that the blue circle reliably predicted reward. If a participant's correct response time was lower than the threshold, that participant won 500 points, but 0 points otherwise. The orange circle and gray circle (no distractor) reliably predicted punishment. If a participant's correct response time was lower than the threshold, that participant avoided a loss of 500 points, but lost 500 points otherwise. For half of the participants, the blue distractor was tied to reward, whereas the orange distractor was tied to punishment. The mapping reversed for the other half of the participants. In the control group, participants were told they should make a correct response to the orientation of the line within the targets. and the response time was lower than the threshold; monetary compensation was dependent on accurate performance. To ensure that participants understood the instructions, the researchers asked participants what color was related to the reward or punishment and how to get points before the visual search task began. The participants were allowed to take a break after finishing one block.

Results

Visual search task: Control group

We have excluded errors trials and the RTs more than ±3 *SD* from each subject's mean RTs. Pairwise *t*-tests showed that the RT difference between no-reward distractor and no distractor was not significant, $t(29) = 1.51$, $p = 0.14$, $d_z = 0.28$. No RT difference between no-punishment and no-distractor condition ($M = 720.47$ ms) was observed, $t(29) = 1.55$, $p = 0.13$, and $d_z = 0.28$. Importantly, there was no significant difference in RTs between the no-reward distractor ($M = 727.43$ ms) and the no-punishment distractor ($M = 727.30$ ms), with $t(29) = 0.05$, $p = 0.96$, and $d_z = 0.009$. The

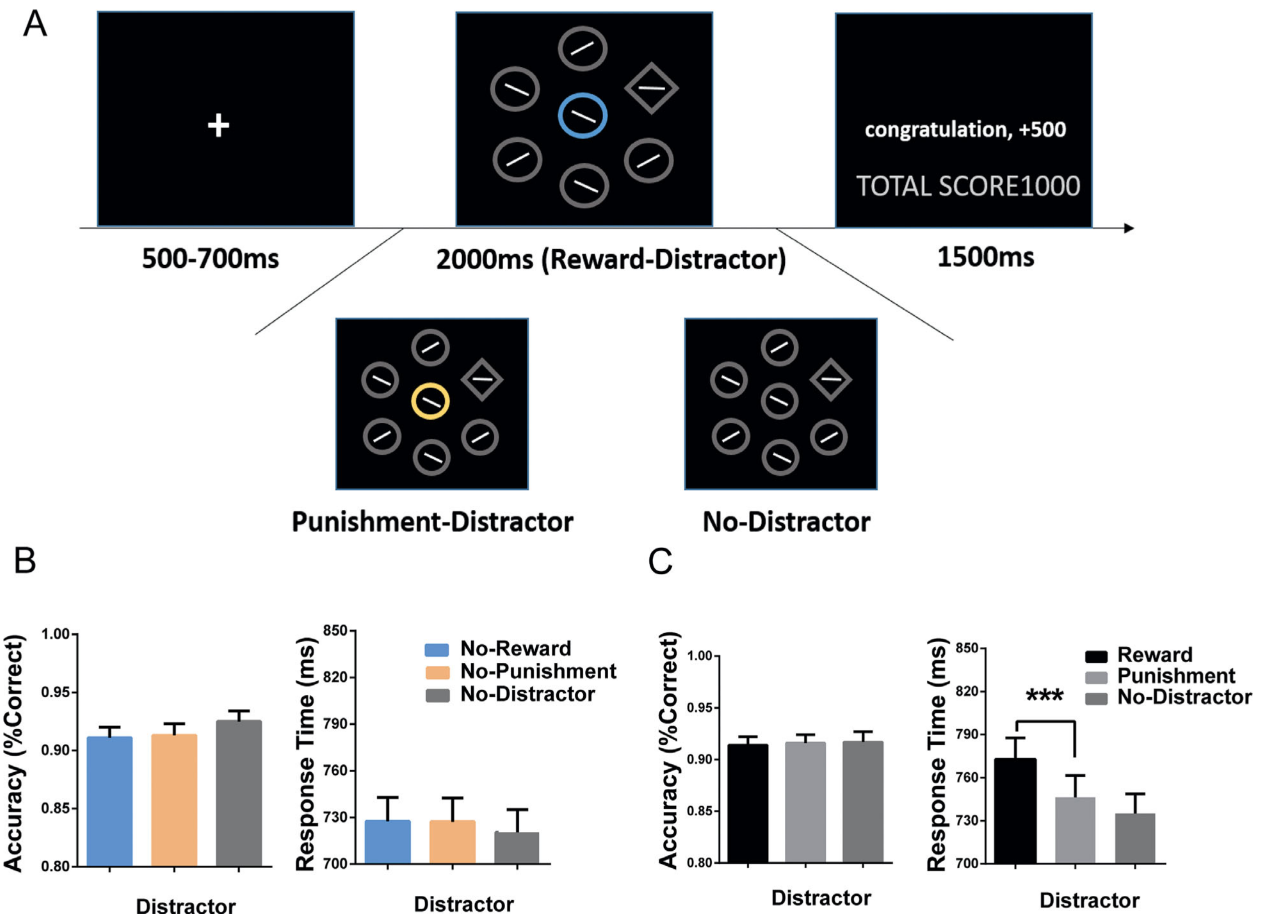

Figure 1. Results from Experiment 1. (A) Sample trial sequences for the visual search. Participants were asked to judge the orientation of the line within the targets. The blue singleton at the central location for the experiment group signaled reward, and the orange singleton signaled punishment. The gray circle at the fixation location represents no-distractor trials. (B) Response accuracy and response times for correct responses in the control group. (C) Response accuracy and response times for correct responses in the experimental group. Error bars represent within-subject standard errors of the mean (***$p < 0.001$).

difference in response accuracy between the no-reward distractor ($M = 91.13\%$) and the no-punishment distractor ($M = 91.33\%$) was not significant, with $t(29) = -0.26$, $p = 0.79$, and $d_z = 0.05$, which indicates that there was no trade-off between speed and accuracy in the reward and punishment conditions.

Visual search task: Experimental group

Pairwise *t*-tests showed that RTs were also slower on reward-associated distractors, with $t(35) = 8.41$, $p < 0.001$, and $d_z = 1.40$, and punishment-associated distractors, with $t(35) = 5.28$, $p = 0.008$, and $d_z = 0.47$, than the no-distractor condition ($M = 735.11$ ms). Importantly, RTs were slower for reward-related distractors ($M = 772.75$ ms) than punishment-related distractors ($M = 746.36$ ms), with $t(35) = 5.99$, $p < 0.001$, and $d_z = 0.99$. The difference in response accuracy between reward distractors ($M = 91.36\%$) and punishment distractors ($M = 91.61\%$) was not significant, with $t(35) = -0.48$, $p = 0.64$, and $d_z = -0.08$), which indicates that there was no trade-off between speed and accuracy in the reward and punishment conditions. Additionally, we used an independent-samples *t*-test to compare the RT difference between no-reward/no-punishment trials from the control group and reward/punishment trials from the experimental group because the physical salience between the control group and the experimental group was identical, and their distinction was whether distractors were associated with value. The results revealed that the RT was slower on reward conditions relative to no-reward conditions, with $t(64) = 2.09$ and $p = 0.04$, and there was no significant difference between the punishment and no-punishment conditions, with $t(64) = 0.89$ and $p = 0.38$.

Discussion

In Experiment 1, we used the attention disengagement paradigm developed by

Watson et al. (2020) to investigate the influence of evaluative stimuli on attentional disengagement processes. First, in the control group we found no differences between trials with colored distractors (no-reward and no-punishment distractors) and distractor-absent trials in attentional disengagement. Moreover, there was no significant difference between no-reward and no-punishment distractors that were associated with no value. This may be due to participants having been informed that all distractors were associated with no value, and they found that it was not necessary to attend to the distractor at the central location, which would lead them to turn their attention rapidly away from the central distractor or control attention at the peripheral area of the target.

Interestingly, in the experimental group, even when participants knew that delayed disengagement from a distractor would result in missing a reward (correct RT being lower than the threshold would obtain a reward or avoid loss), they had difficulty controlling their attention, and it was held longer by reward-related distractors relative to punishment-related distractors. The results of the experimental group showed that participants were slower to respond to targets when the central distractor was associated with reward compared to punishment, even when the monetary quantity was the same. Clearly, the paradigm controlled the attentional capture process. In other words, this paradigm minimized the influence of any effect of evaluative distractors on spatial capture (Watson et al., 2020) because each participant's attention was at the central location after fixation disappeared. When a reward or punishment distractor was at the center of the picture, participants had to shift their attention away from the central distractor. Thus, the difference between reward and punishment was due to their delayed attentional disengagement.

Recently, Zhuang, Tu, Wang, Ren, and Abrams (2021) questioned that the target never appeared at a fixation location, which may lead participants to inspect the peripheral shapes to find the target without any attending to the distractor at the central location of screen. Furthermore, they pointed out that the study by Watson et al. (2020) showed that a slower response to the targets on the central distractor when the distractor was associated with high reward than when it was associated with low reward was due to attentional capture rather than attentional disengagement. Such conjecture should be undertaken with great care. In the control group, participants may inspect the peripheral shapes in order to find the target because it is not necessary to attend to a no-value distractor at the central location. However, it is different for the experimental group because the distractor is rendered in reward and punishment, and the results actually demonstrate a RT difference between reward and punishment distractors. In order to further investigate whether or not the difference between reward and punishment distractors was indeed due to attentional disengagement, we designed Experiment 2.

Experiment 2

In Experiment 1, all of the distractors associated with reward or punishment were at a central location when the visual search display was presented, which may have kept participants' attention at a central fixation. The results showed that the effect of reward on attentional disengagement was larger than that of punishment in the case of equal quantities. However, there is a potential mechanism called "behavioral freezing" (Müller et al., 2016), which can slow down animal behavior and pause any ongoing actions (Clarke, MacLeod, & Guastella, 2013; Johansen, Cain, Ostroff, & LeDoux, 2011). According to this explanation, participants may have had longer RTs in the reward condition, not as a result of attentional disengagement but because of the central reward distractor, which froze their behavior for a short time. Watson et al., (2020) considered that manipulation of experimental design could overcome this problem—half of the trials to be central-target trials and the remainder to be central-distractors. Therefore, to illustrate the existence of true attentional disengagement for reward distractors rather than freezing, we manipulated half of the trials to be central-target trials and the remainder to be central-distractor trials (Watson et al., 2020). Specifically, half of the central-target trials were reward, punishment, or neutral conditions, and they were presented randomly; the same applied to the central-distractor trials. We speculated that, if there is behavior freezing on the reward trials, then the presence of a central reward target would slow down the response to the target relative to the presence of a central punishment target. The presence of a central reward distractor slowed the participants' responses to the target relative to the central punishment distractor. Certainly, if freezing did not exist, participants would recognize the central reward target more quickly than the central reward distractor. Moreover, the central reward target was faster than the central punishment target, and the central reward distractor was slower than the central punishment distractor.

The aim of Experiment 2 was to further investigate whether there is a true delayed attentional disengagement for central reward distractors compared with punishment distractors. Additionally, we did not establish a control group in Experiment 2 because when all the stimuli were neutral or imbued with no value they would have no effect on attentional disengagement shown in the results of Experiment 1.

Methods

Participants

We recruited 34 college students ranging in age from 17 to 23 years (28 females; age $M = 19.85$ years; $SEM = 0.24$) from Southwest University. None of the students had a history of psychiatric or neurological disorders. The Human Ethics Committee of Southwest University approved of the experimental protocol.

Stimuli, design, and procedure

The apparatus was the same as that of Experiment 1. The main difference between Experiment 1 and Experiment 2 is that we added a colored target condition at the center of screen. We used the visual search task in Experiment 2 that a previous study had used (Watson et al., 2020), where there is little difference among the stimuli. The search display consisted of a series of six shapes and they all were gray, with either a singleton colored distractor at the central fixation (central distractor) or a colored target at the center of the screen (central target).

Participants were instructed to report the orientation of the line segment in the diamond by pressing the F or T key for horizontally and vertically oriented lines, respectively. There were two practice blocks and eight normal blocks in this experiment. Each block consisted of 40 trials: half of the trials were central-target trials, and the other half were central-distractor trials. Eight trials were associated with reward-related stimuli (blue target), eight trials were associated with punishment-related stimuli (orange target), and four trials were associated with neutral-related stimuli (all stimuli were gray; gray target) for each central-target condition. The same rule was also applied to the central-distractor condition. Before the formal experiment, participants were required to complete two blocks in a practice phase. Only when accuracy in the practice block exceeded 80% could participants proceed to perform the formal experiment. We set the threshold for the formal experiment based on the RTs in the practice phase. The threshold equaled the mean reaction time for correct trials in the practice phase.

Before the experiment started, the participants were informed that they needed to respond to the line orientation within the target. The blue color reliably predicted reward, irrespective of whether the blue color was associated with a central target or distractor. If a participant's correct response time was lower than the threshold, that participant won 500 points, but 0 points otherwise. The orange and gray colors (no distractor) reliably predicted punishment, irrespective of whether the orange color was associated with a central target or a distractor. If a participant's correct response time was lower than the threshold, that participant avoided a loss of 500 points, but lost 500 points otherwise. For half of the participants, the blue color was tied to a reward, whereas the orange color was tied to punishment. To ensure that participants understood the instructions, the researchers asked participants what colors were related to the reward or punishment and how they could get points before the visual search task began. The participants were allowed to take a break after finishing one block.

Results

Visual search task

We have excluded errors trials and the RTs more than ±3 *SD* from each subject's mean RTs and used two (central stimuli: target and distractor) by three (value: reward, punishment, and no-distractor) repeated-measures ANOVAs to examine mean RTs for correct response and accuracy. The results revealed a main effect of central stimuli, with $F(1,33) = 422.11$, $p < 0.001$, and $\eta^2 = 0.93$. Also, the RTs on central-target trials ($M = 548$ ms) were faster than for the central-distractor trials ($M = 677$ ms). A main effect of value type, with $F(2,66) = 35.84$, $p < 0.001$, $\eta^2 = 0.52$, was observed (reward, $M = 624$ ms; punishment, $M = 613$ ms; neutral, $M = 599$ ms). Moreover, a significant interaction was observed, with $F(2,66) = 77.58$, $p < 0.001$, and $\eta^2 = 0.70$ (Figure 2). Pairwise *t*-tests showed that the RTs on rewards for central distractors were significantly slower than those on punishments for central distractors, with $t(33) = -6.24$, $p < 0.001$, and $d_z = -1.07$ (reward, $M = 710$ ms; punishment, $M = 669$ ms; neutral, $M = 649$ ms). However, the RTs on reward-related stimuli for the central-target trials were significantly faster than punishment for central-target trials, with $t(33) = 8.09$, $p < 0.001$, and $d_z = 1.39$ (reward, $M = 537$ ms; punishment, $M = 557$ ms; neutral, $M = 548$ ms).

The accuracy results revealed a main effect of central stimuli, with $F(1,33) = 48.77$, $p < 0.001$, and $\eta^2 = 0.59$, and the accuracy on central-target trials ($M = 0.95$) was higher than for the central-distractor trials ($M = 0.88$). A main effect of value type, with $F(2,66) = 7.87$, $p = 0.001$, and $\eta^2 = 0.19$, was observed (reward, $M = 0.892$; punishment, $M = 0.918$; neutral, $M = 0.920$). No significant interaction was observed between two factors: $F(2,66) = 0.60$, $p = 0.55$, and $\eta^2 = 0.02$.

Discussion

The results of Experiment 2 showed that participants' responses were faster in the reward-associated target trials than punishment trials when a target was present at a central location of the search display. In

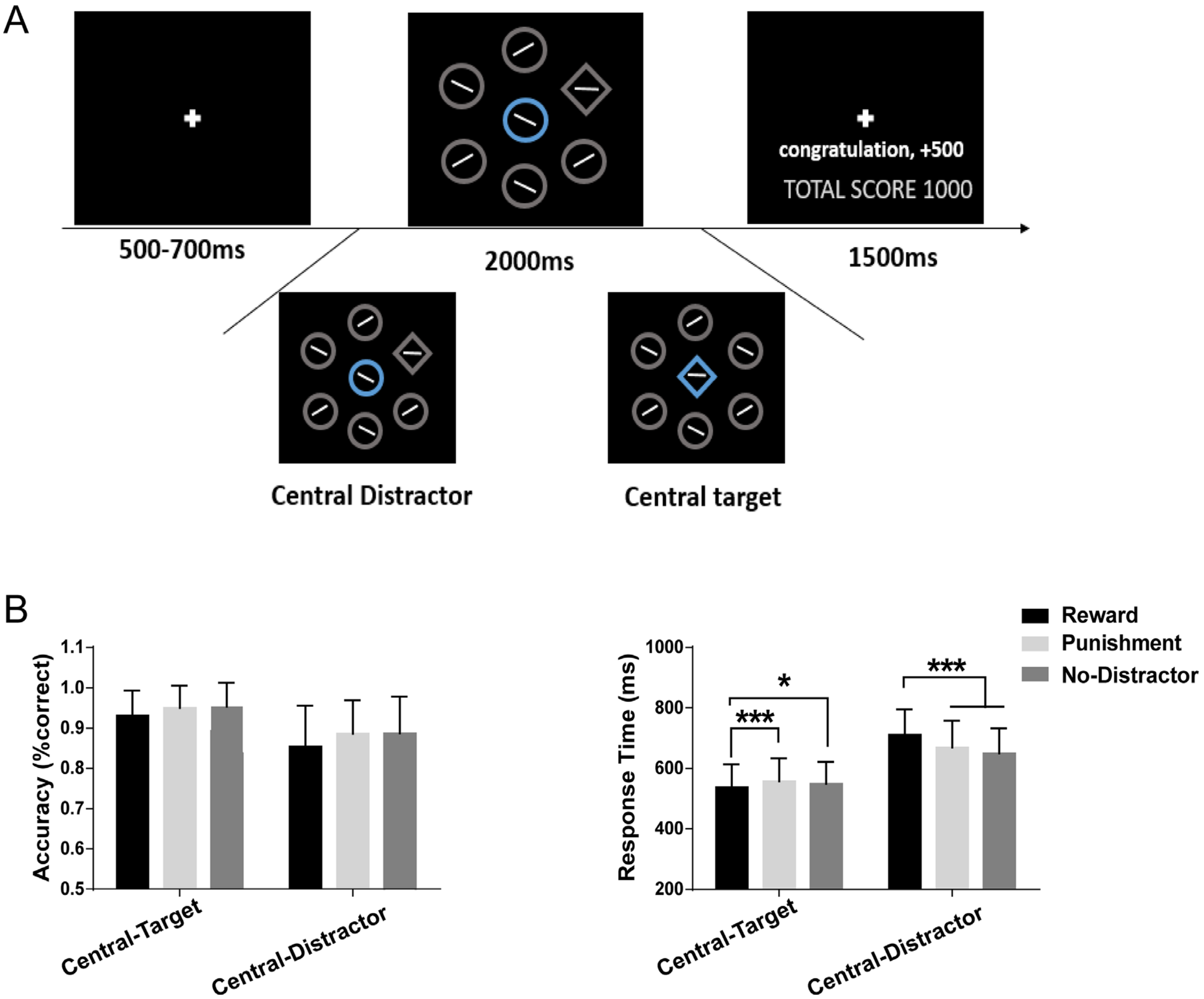

Figure 2. Results from Experiment 2. (A) Sample trial sequences for the visual search. Participants were asked to judge the orientation of the lines within the targets. Half of the trials were central-target trials, and the other half of the trials were central-distractor trials. The blue singleton at the central location signaled reward, and the orange singleton signaled punishment. The gray circle at the fixation location represents no-distractor trials. (B) Response accuracy and response times for correct responses. Error bars represent within-subject standard errors of the mean (*$p < 0.05$; ***$p < 0.001$).

contrast, participants' responses were slower in reward-associated distractor trials than punishment trials when a distractor was present at the fixation location. That is to say, there was a different pattern of behavior between the central-target and central-distractor conditions. Reward could speed up recognition when it was tied to the target, but reward could impair performance when it was associated with distractor. These findings reliably demonstrate the existence of a true delayed attentional disengagement on central reward distractors rather than behavioral freezing. Our results indicate delayed attentional disengagement in reward distractors compared with punishment distractors when a distractor was present at the fixation location, which is consistent with the results of Experiment 1. This result is consistent with a previous study that found that participants' responses to a target were faster when a reward was tied to a target rather than when a reward was tied to a distractor (Watson et al., 2020).

General discussion

In the current study, we demonstrated that a reward distractor held attention longer than a punishment distractor when the quantities of rewards and punishments were equal. In Experiment 1, when participants were informed that they had to respond to targets and ignore the central distractors (control group; distractors were associated with no value), participants could ignore all of the central distractors and respond to the peripheral targets rapidly (the difference between distractor and no-distractor condition was not significant). However, when participants were informed that the central location of the distractor predicted the reward or punishment, participants had difficulty disengaging from the central reward distractor compared to the punishment distractor. Additionally, we compared the mean RT differences between no-reward/no-punishment trials of the control group and reward/punishment trials of the experimental group. We found that the RTs were slower for reward conditions in comparison with no-reward conditions, and there were no significant differences between the punishment and no-punishment conditions. These results suggest that attention was focused longer on central reward distractors relative to punishment distractors.

In Experiment 2, we further investigated whether the slower responses to the targets on central distractors when the distractor was associated with reward than when it was associated with punishment was due to attentional disengagement rather than behavioral freezing. We observed that delayed attentional disengagement existed for reward distractors compared with punishment distractors when the distractor was present at a fixation location, which is consistent with the results of Experiment 1.

One interpretation of these results is that they could be due to subjects' previous experiences. Reward is related to a positive experience, whereas punishment is associated with a negative experience, and thus participants are more likely to stay longer on a reward distractor (Barbaro, Peelen, & Hickey, 2017). In other words, although the participants knew that reward-associated and loss-associated stimuli were equally useful and that longer response times would result in the omission of a reward, they were slower to locate targets when the central distractor was associated with a reward. Another interpretation is that reward distractors were contrasted with punishment distractors, which may readily activate the avoidance response and defensive motivational system, which could in turn mediate the rapid disengagement of attention from the central-punishment distractor.

Notably, numerous previous studies have demonstrated that individuals with anxiety disorders or depression had difficulty in disengaging from punishment or threatening stimuli, which appears to contrast with our findings (Kircanski, Joormann, & Gotlib, 2012; Rudaizky et al., 2014). However, there are some differences between our study and the cited studies. First, our study is based on participants who did not have a history of psychiatric or neurological disorders, which is quite different from these previous studies. Second, we used financial loss as a punishment reinforcement, which differs from the use of threating stimuli such as pain and electric shock in terms of behavioral and neural mechanisms (Barbaro et al., 2017; Zimmer, Keppel, Poglitsch, & Ischebeck, 2015).

At first glance, we have an absence of a genuine neutral condition that should be a color singleton and associated with a neutral value rather than a non-salient distractor. However, the control group was not associated with reward and punishment, which is similar to a neutral condition. Thus, we did compare differences between evaluative and neutral stimuli, although this may still be considered a limitation of the current study.

Conclusions

In this study, different color singleton stimuli were tied to reward and punishment outcomes, which were counterproductive to the participants' goals, as they were required to respond to the target rather than the reward or punishment distractor. The results showed that participants' responses were slower for reward-associated distractors than for punishment-associated distractors when a distractor was present at a central location of the search display, even though they understood that reward-associated and punishment-associated stimuli offered an equal opportunity to provide the same economic benefit.

Keywords: attentional disengagement, reward, punishment

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