The effects of different reward types on the attention capture of non-target emotional faces

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Abstract. To investigate the impact of different reward types on the attention capture effect of non-target emotional faces, this study recruited 40 healthy college students and used a visual discrimination task to explore the attention capture effect. The results showed that the main effect of reward type was significant ($F[1,39] = 4.352$, $p = 0.044$), with reaction times being significantly longer under monetary rewards compared to social rewards. The main effect of emotion was not significant ($p > 0.05$), and the interaction between reward type and emotion was also not significant ($p > 0.05$). The study indicates that both monetary and social rewards can effectively regulate cognitive resource allocation, but social rewards are more effective in inhibiting the attention capture effect of non-target emotional faces.

Keywords: monetary reward, social reward, emotional face, attention capture.

1. Introduction

Attentional capture (attentional capture) is the phenomenon that stimuli unrelated to the task itself can unconsciously attract attention during visual search (Folk & Remington, 1998; Theeuwes, 1992).

Emotionally significant and highly salient stimuli are more likely to capture attention resources compared to non-emotional stimuli (Barratt & Bundesen, 2012; Batty & Taylor, 2003; Glickman & Lamy, 2018; Phelps & LeDoux, 2005; Pool et al., 2016; Vuilleumier, 2005; Vuilleumier & Driver, 2007). Even when presented as distractors, these stimuli consistently receive priority processing (Awh et al., 2012). Rewards, as salient stimuli, can elicit positive emotional responses in individuals. Research indicates that there is a shared neural basis between rewards and positive emotions, with the amygdala, which plays a crucial role in processing emotional information, also being essential in the reward pathway (Hickey et al., 2011). Furthermore, rewards, as a special type of stimulus, influence an individual's emotional attention processing (Chen & Wei, 2019). Therefore, the interaction between rewards and emotions plays a vital role in attention regulation and cognitive resource allocation.

Currently, researchers generally agree on two mechanisms of attention selection processing: bottom-up stimulus-driven attention capture and top-down stimulus-driven attention capture. Bottom-up stimulus-driven attention capture (Buschman & Miller, 2007; Connor, Egeth & Yantis, 2004) means that irrelevant emotional stimuli receive more attention because individuals' perceptual processing is highly dependent on the salient features of these stimuli. When we are hungry, we search for food; when we are thirsty, we seek water. We consciously choose relevant stimuli and ignore irrelevant ones based on our current needs or task requirements, which is known as top-down goal-directed attention selection (Anderson, 2013; Lien, Ruthruff, & Johnston, 2010). This conscious attention selection effectively reduces the interference from irrelevant stimuli (Wolfe, Butcher, Lee, & Hyle, 2003). Bottom-up stimulus-driven attention capture refers to the ability to capture attention when irrelevant emotional stimuli are relevant to the current task, a process regulated by factors such as thought patterns, cognitive strategies, and goal setting (Glickman & Lamy, 2018). In summary, the capture of attention by irrelevant emotional stimuli is a highly bottom-up but unstable activation process.

Reward (reward) refers to the desired things or stimuli that can bring certain value or results obtained by completing specific tasks (John & Maunsell, 2004). The 'specific tasks' and 'desired things' mentioned in this definition refer to two stages of reward processing: the expectation stage before completing the task and the feedback stage after receiving the reward.

Most reward studies use monetary rewards as feedback. Besides influencing behavior, monetary rewards can also affect individuals' internal psychological processes (Della Libera & Chelazzi, 2006). For instance, in the attention selection process, stimuli associated with monetary rewards, even if unrelated to the task, tend to dominate attention processing (Anderson et al., 2011a; Anderson, Laurent, & Yantis, 2011b; Hickey, Chelazzi, & Theeuwes, 2010a; Della Libera & Chelazzi, 2006). In addition to monetary rewards, social rewards can significantly enhance individual performance in tasks (Kohls, 2009). Smoski et al. developed the Social Incentive Delay Task (SID) by using emotional face images instead of money as reward feedback, based on the Money-Incentivized Delay Task (MID) (Smoski, Rittenberg & Dichter, 2011). Many studies have found that in the feedback stage, ordinary individuals show greater activation of specific reward processing areas by social rewards compared to monetary rewards, and also activate a broader range of brain regions (Ethridge et al., 2017; Belel, Jacqueline & Dan, 2017; Wang, Liu & Shi, 2014). Furthermore, comparative studies have revealed age and gender differences in responses to monetary and social rewards: adolescents and adults tend to focus more on monetary rewards (Altikulac et al., 2019); women are more likely to prioritize social rewards over men (Spreckelmeyer et al., 2019).

Research has shown that in the process of selective attention, when target stimuli are linked to monetary rewards, this can facilitate the attention selection process, leading individuals to more quickly allocate their attention to target stimuli associated with rewards (Hickey, Chelazzi, & Theeuwes, 2010a,2010b; Krebs, Boehler, Egner, & Woldorff, 2011). Studies indicate that when targets are linked to high rewards, these rewards enhance the attention selection process, suggesting that stimuli linked to rewards can attract attention resources (Fan Lingxia et al., 2014). This leads to Hypothesis H1: Rewards can reduce the interference of facial emotions on task goal completion. Hypothesis H2: Different types of rewards have significant differences in their impact on the attention capture of non-target emotional faces. Compared to social rewards, monetary rewards are more effective at reducing the interference of facial emotions on task goal completion.

Emotional stimuli can significantly impact an individual's cognition (Cohen & Henik, 2012; Dolcos, Wang, & Mather, 2014). Even when emotional stimuli are not directly related to the task, they can still influence individuals (Gainotti, 2012; Jessen & Grossmann, 2015; Stefanics, Csukly, Komlosi, Czobor, & Czigler, 2012). Current research on reward-related phenomena primarily focuses on the attentional processing of physical stimuli with low visual features, such as stimulus color (Anderson, 2013; Gong et al., 2016), shape (Anderson et al., 2011a; Failing & Theeuwes, 2014), spatial position (Wang et al., 2014), and neutral faces (Padmala et al., 2017; Yokoyama et al., 2015). Emotional faces are more prominent compared to the aforementioned stimuli, and their top-down perceptual processing is faster. Previous studies have shown that fear and anger evoke attention (Bertels, Kolinsky, Coucke, & Morais, 2013). Therefore, this study selected angry and fearful negative emotional faces, as well as positive (happy) and neutral (calm) emotional faces as irrelevant stimuli

In previous visual search tasks, it has been observed that angry faces attract more attention compared to other facial expressions, a phenomenon known as the anger superiority effect (Hansen & Hansen, 1998). Various theories have been proposed to explain the processing mechanism of the anger superiority effect (Xu Zhan, Li Canju, 2014): The perceptual feature theory suggests that the anger superiority effect is due to the prominent perceptual features of angry faces, such as eyebrows (Becker, Horstmann, & Remington, 2011; Larson, Aronoff, & Stearns, 2007; LoBue, 2013). In contrast, the holistic processing theory posits that when processing emotional faces, the brain does not simply sum up multiple features but integrates them into a meaningful and coherent representation, which is then used to assess the emotional state (Hodsoll, Viding, & Lavie, 2011; Schmidt-Daffy, 2011; Towler, Kelly, & Eimer, 2016). In previous experimental studies, emotional faces have typically

been used as both target stimuli and distractors. The target stimulus often differs from the distractor only in perceptual features. However, due to the coexistence of emotional information, the anger priming effect may result in a higher attentional selection for the target stimulus (i.e., faster search for the angry face as the target) or a higher level of attention capture by the distractor (i.e., the angry face as the distractor interferes with the target search, leading to slower reaction times). However, the anger priming effect is relatively stable and does not change with the degree of processing of the target stimulus (Wu Xia, Xu Jingzhou, Chen Ying, 2020). Therefore, Hypothesis H3 is proposed: fear and anger face information are more likely to attract attention.

In summary, this study hypothesizes: 1. Rewards can mitigate the interference of facial emotions on task completion; 2. Different types of rewards significantly affect the attention capture of non-target emotional faces, with social rewards being more effective than monetary rewards in reducing the interference of facial emotions on task completion; 3. Fear and anger faces are more likely to attract attention

2. Methodology

2.1. Participants

Fifty college students participated in the experiment, including 3 males and 47 females, aged between 18 and 21. All participants were right-handed, had normal or corrected vision, and signed an informed consent form before the experiment. The pre-test analysis was conducted using G*Power 3.1.92 (Faul et al., 2009). The study achieved statistical significance at a medium effect size (f =.25), with a minimum sample size of 40 participants.

2.2. Experimental design

The study employed a visual discrimination task (Padmala & Pessoa, 2014), with a within-subject design involving 2 reward types (money and social rewards) and 4 emotional faces (happy, angry, fearful, and neutral). Both reward type and emotion were considered within-subject variables. The reaction time and accuracy rate for judging the direction consistency of line segments were used as dependent variables.

2.3. Experimental materials

2.3.1 Social feedback materials

Social feedback materials are categorized into two types based on the type of feedback: social reward and social neutral. For the pre-experiment, 100 reward statements, each no longer than 15 characters, were collected online, and 6 college students were recruited to rate these statements on their emotional valence (1=very unpleasant, 5=very pleasant) and familiarity (1=very unfamiliar, 5=very familiar). Ultimately, 60 statements with the most pleasant emotional valence (M=3.66~4.23) were selected for the social reward feedback. The social neutral feedback statement was "You are currently performing an experimental task."

2.3.2 Monetary feedback materials

The monetary equivalent of social feedback materials is the monetary equivalent statement of social feedback. Additionally, six college students were recruited to evaluate the monetary equivalent of the rewards in the social feedback materials, asking them how much they would be willing to pay for each sentence, with a range of 1 to 10 yuan. The average monetary equivalent score for each sentence was used as the corresponding monetary feedback value. Specifically, the monetary reward feedback is: "You have received XX yuan in cash"; the neutral monetary feedback is: "You have not received any cash."

2.3.3 Face material

Gong Xu et al. (2011) selected 15 happy, fearful, angry and neutral emotional faces from the Chinese Emotional Face Image Library, with half male and half female, and a unified gray background (RGB: 128,128,128). The same group of emotional faces were used in both practice and formal tests.

Table 1 Ratings of intensity and Identity of Emotional Face MaterialsM(SD)

	Fury	Dread	Neutral	Happy
Intensity	7.24(9.56)	10.46(0.56)	7.96(0.09)	7.23(0.47)
Identity	84.99(0.56)	74.99(7.09)	88.91(6.04)	99.86(0.37)

2.4. Experimental procedure

The experiment was conducted in a quiet room, and the task program was written by E prime3.0. The experiment was completed in a closed behavioral laboratory with soft lighting. A 17-inch CRT screen with a resolution of 1280 x 1024 and a white background were used. Participants were instructed to press the corresponding keys according to the instructions.

Participants first complete a set of line direction discrimination exercises (20 trials). The purpose of these exercises is to familiarize participants with the experimental procedures. No reward feedback is provided during the practice, and the rest of the process for both practice and formal trials is the same. After completing the practice, participants proceed to the formal experiment. Participants complete one set of monetary rewards and one set of social rewards, each consisting of 20 practice trials and 60 formal trials, totaling 160 trials. The two types of tasks are tested in a balanced AB-BA design.

The trial process is as follows: First, a 500ms fixation point is presented; then, a 200ms stimulus screen appears, with a face (4° by 5°) in the center of the field of view. On either side of the face (5°), there are two line segments (0.1° by 1.5°). A 1000ms blank screen follows, during which participants must determine whether the line segments on either side of the face are aligned. Participants press F if the lines are aligned and J if they are not. The key presses are balanced throughout the experiment.

When the reward type was tested, when the subject made a key response, the reward feedback and cumulative amount would appear if the response was correct; otherwise, the subject would receive neutral feedback. The experimental procedure is shown in Figure 1.

When the social reward type was tested, when the participant made a key response, the social support statement feedback appeared (depending on the reaction time of the participant, different levels of statements were presented); if the reaction was wrong, the neutral statement appeared. The experimental process is shown in Figure 2.

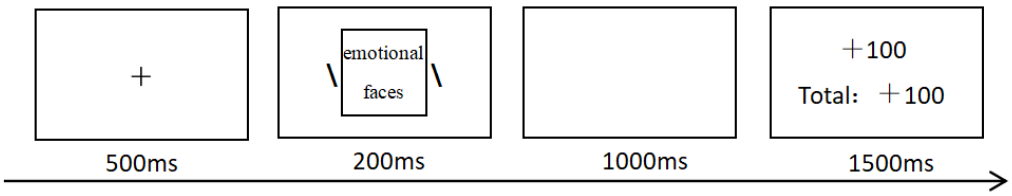

Fig.1: monetary rewards experimental procedure

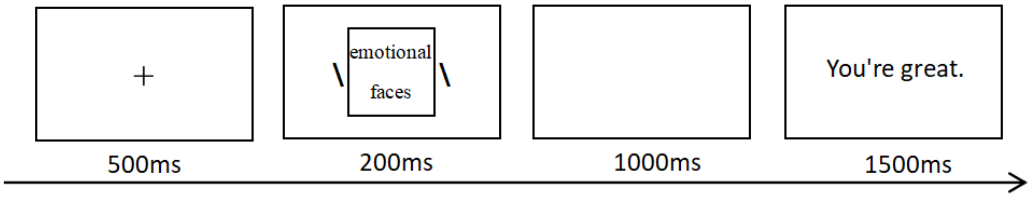

Fig.2: social rewards experimental procedure

3. Results

A total of 50 experimental data sets were collected, and errors in trials, responses outside ±3 standard deviations under each condition, and data with a total accuracy rate below 0.8 were removed, leaving 40 valid data points. A repeated measures ANOVA was conducted on the response times under each condition. The results indicated that the main effect of reward was significant ($F[1,39] = 4.352$, $p = 0.044$), with reaction times being longer under monetary reward conditions compared to social reward conditions ($p < 0.05$). The main effect of emotion was not significant ($p > 0.05$), and the interaction between reward and emotion was also not significant ($p > 0.05$). A repeated measures ANOVA was also performed on the accuracy rates under each condition, revealing no significant differences in accuracy rates across all conditions ($p > 0.05$). The response times and accuracy rates for participants under each condition are detailed in Table 2.

Table 2 Response time and correct rate with different reward types (SD)

Reward Emotional Matching	social rewards				monetary rewards			
	neutral	happy	dread	fury	neutral	happy	dread	fury
Response time（ms）	466.20(55.35)	462.04(52.60)	453.76(49.74)	463.37(44.39)	478.83(47.59)	467.94(41.76)	475.39(42.07)	469.57(47.93)
correct rate（%）	90.63(8.18)	91.33(7.47)	90.07(10.86)	91.25(6.35)	94.55(6.58)	91.25(9.65)	91.18(7.45)	92.95(7.04)

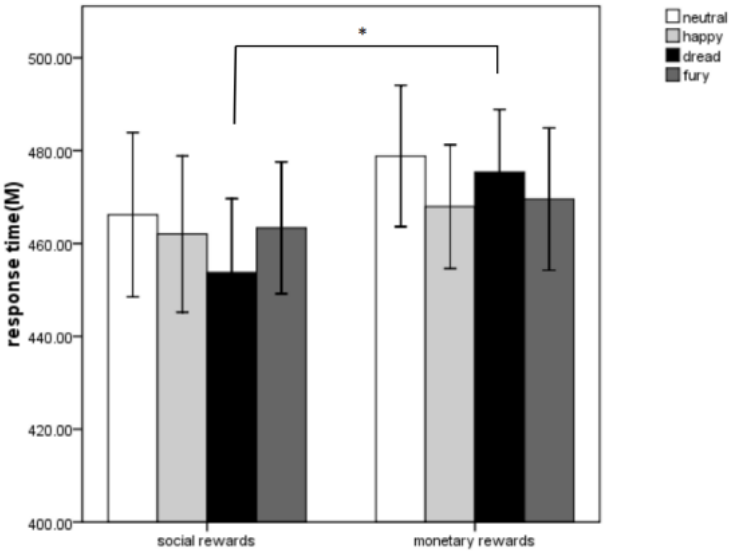

Fig.3: Response time under different reward types

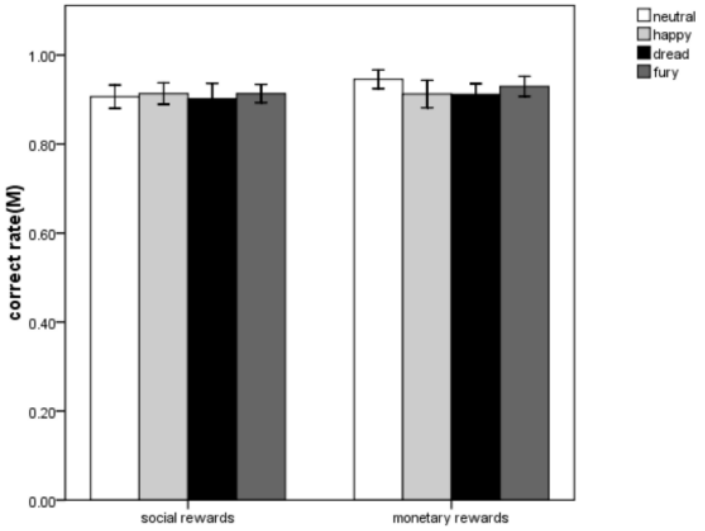

Fig.4: Correct rate under ifferet reward types

4. Discuss

In this study, we found that the main effect of reward was significant ($F[1,39] = 4.352$, $p = 0.044$), with reaction times being longer under monetary reward conditions compared to social reward conditions ($p < 0.05$). The main effect of emotion was not significant ($p > 0.05$), and the interaction between reward and emotion was also not significant. These results align with our expectations and are consistent with the findings from Zhou Xing's (2019) study on attention capture by non-target emotional faces in reward learning. However, some results deviated from our expectations. These deviations may be due to a small sample size, which made the differences between groups insignificant; an imbalanced gender ratio in the sample; and a limited number of practice trials, which led participants to not fully understand the experimental tasks. To better understand these deviations, further exploration of these factors is needed in future studies.

The findings of this study are of significant theoretical and practical importance. Theoretically, our research demonstrates that in reward conditions, the reaction time for social rewards is shorter than that for monetary rewards, indicating that social rewards are more effective in reducing the attention capture of emotional faces compared to monetary rewards. Practically, reward training can enhance cognitive control over negative emotions, improve the perception of negative emotions, effectively control the bias in emotional attention processing, and promote prosocial behavior. Additionally, the response patterns of social rewards can be applied to artificial intelligence and human-computer interaction, helping to design more user-friendly interfaces and reward mechanisms that align with human cognitive characteristics, thereby enhancing user experience and satisfaction. Furthermore, elements of emotional faces can be incorporated into screen advertisements to attract users' attention.

Compared to existing studies, this study employs a fully within-subjects design, which eliminates the influence of individual differences among participants on the experiment. This approach also allows for the examination of interactions between multiple variables, making the results more broadly applicable. However, we have observed that some findings conflict with the anger advantage effect. This discrepancy may be due to sample differences. To gain a more comprehensive understanding of these differences, it is necessary to further investigate how these factors impact the research outcomes.

Although this study has achieved certain results, it still faces some limitations. For example, the sample is imbalanced in terms of gender ratio and the experimental conditions are not strictly controlled. These limitations may affect the accuracy and reliability of the research findings. Therefore, future studies should aim to balance the gender differences in the sample, optimize the

experimental design, and improve the experimental conditions to enhance the scientific rigor and practical value of the research.

Looking ahead, we believe the attention capture field has vast potential for development. To explore this area more deeply, future research could further utilize neuroimaging techniques, such as fMRI. Additionally, cross-cultural and cross-group comparative studies could be conducted. We are confident that with ongoing research, we can make significant contributions to the development of the attention capture field.

5. Conclusion

This study investigated the effects of emotional faces as distractors on target task attention processing under monetary rewards and social rewards. Both monetary rewards and social rewards effectively regulated cognitive resources and weakened the interference effect of emotional faces on target task completion, with social rewards being more effective than monetary rewards.

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