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The Influence of Guilt Emotion on Cognitive Flexibility

Yun Tao* Danna Luo[1] Ting Deng[1]- Xie Ma[2]

[1,1]-, [2,*]*Department of Education, Yunnan Normal University Key Laboratory of Educational Information for Nationalities，Yunnan Normal University*

[1,1]-*These authors contributed equally to this work and should be considered co-first authors*

[*]*Corresponding author. Email: taoyun2011@126.com*

ABSTRACT
Cognitive flexibility is one of the three dimensions of executive function, and the influence of emotion on it has always been a hot topic in international research in recent years. A review of previous studies shows that predecessors focus on influence of basic emotions, while there is no research on higher moral emotions. Guilt emotion, as a special emotion, is a negative emotion, but it has a prosocial function. This study aims to explore the influence of guilt emotion on cognitive flexibility. We induced subjects' guilt emotion by the point estimation task, and then selected switching task paradigm (digital switching and odd-even switching) to compare the differences in accuracy, response time and switch cost of switching task between guilt group and neutral group. The results showed that switching task had longer response times and lower accuracy than task repetition. Secondly, guilt group showed lower RT switch costs, indicating that guilt emotion promote task switching and cognitive flexibility. This study preliminarily explored the influence mechanism of guilt emotion on cognitive flexibility and some supporting evidence for the prosocial function of guilt.

Keywords: *Guilt emotion, Cognitive flexibility, Switching task paradigm*

1. INTRODUCTION

Cognitive flexibility is one of the three dimensions of executive function, which refers to realizing that the current behavior is inappropriate, changing the current cognitive orientation and adopting a new behavior style to adapt to the new needs of the environment [1]. As one of the cognitive abilities commonly used in people's daily life, besides problem solving, it also affects the individual's physical health, mental health and the environment adapting, such as, people with lower cognitive flexibility is easy to suffer from eating disorders [2], cognitive flexibility is internal psychological factors affecting self-acceptance [3], cognitive flexibility and adaptability of promote each other between benign relationship [4]. In addition, life is full of emotional experiences, so it is necessary to explore the influence of emotions on cognitive flexibility.

TX.T. Huang believed that emotion have an organizational effect on cognitive function, which is manifested as the coordination effect of positive emotions and the destruction and disintegration effect of negative emotions. A large number of studies have found that positive emotions promote cognitive flexibility, while negative emotions inhibit cognitive flexibility [1,5,6,7]. In non-clinical samples, positive emotion-induction procedures have been demonstrated to improve performance on some types of cognitive tasks, such cognitive flexibility [5]. Rebecca et al. found that subjects with low positive emotions had slower transition speed from one attentional point to another than subjects with high positive emotions, which they believed proved that the level of positive emotions was low and cognitive flexibility was poor [6]. Y.M. Wang used emotional pictures to induce emotions, and L.Y. Qiu used video to induce emotions, both found that positive emotions significantly improved individuals' cognitive flexibility, while negative emotions inhibited cognitive flexibility [1,7]. According to the broaden-build theory, individuals have a wider range of attention and a more flexible of thinking in positive emotional state, negative emotions narrow the individual's attention [8]. All of the above studies focused on the influence of basic emotions. However, as a kind of advanced organism, human beings also have moral

emotions in addition to basic emotions. Does moral emotions affect cognitive flexibility as well?

Guilt emotion is a typical moral emotion, which is a negative emotional experience of being responsible for the victim when an individual reflects on his conscience after doing harm to others or violating the moral code [9]. Maybe in line with basic negative emotions, guilt narrow an individual's attention span and thus inhibit cognitive flexibility. However, as a special emotion, guilt is a negative emotion, it has a prosocial function, when individuals with guilt emotions, they often have prosocial behaviors to make up for others [10,11,12,13]. A recent EEG study found that the alpha oscillations in the parietal region increases in guilt emotion state[14]. Alpha oscillations have been associated with basic cognitive processes such as attention, a study on attention found that the alpha oscillations over parietal regions is larger for tasks with external attention focus (e.g. tasks that require processing of external information from surroundings) than for tasks with internal attention focus [15]. Individuals with guilt are more likely to perform prosocial behaviors due to attention is directed outward. So, there may be more external attentional resources in guilt emotion that promote cognitive flexibility.

This study attempted to explore the influence of guilt emotion on cognitive flexibility. We use the switching task paradigm, which is one of the most extensive studies of cognitive flexibility, it involves switching between two or more simple cognitive tasks and then comparing the performance of repetitive and switching tasks. The difference between the two is called "switch cost", and the smaller the switch cost, the more flexible the cognitive switch is.

2. EXPERIMENTAL METHODS

2.1. Selecting Subjects

30 healthy Chinese college students come form Yunnan Normal University participated in this experiment. Delete the data inducing failure guilt emotion and accuracy rate of switching task is less than 70%, 27 valid data were obtained (guilt group:14, control group:13), average age 19.29, 11 boys and 16 girls among them. All subjects were healthy, right-handed, with normal or corrected to normal vision, and have no history of brain trauma, sleep disorders, etc.

2.2. Experimental Design

The mixed design of 2 (emotion type: guilt group, neutral group) ×2 (task type: repetitive task, switch task) was adopted, in which the empathy type was the between-subject variable, the task type was within-subject variable, and the dependent variables included the accuracy , response time and switch cost.

2.3. Experimental Material

2.3.1. Guilt emotion inducing materials.

In this study, interpersonal situations were selected to induce guilt, it involves point estimation task [14], with a total of 25 point figure (800*400) as stimulus materials. The subjects were asked to determine if the number of points is greater than 20.

2.3.2. Subjective evaluation materials of guilt

Participants were asked to rate guilt on a nine-point scale. On a scale of 1 to 9, the emotion gets stronger, with a higher score indicating a stronger sense of guilt emotion.

2.3.3. Switching task materials.

Cognitive flexibility uses the digital switch task paradigm, Eight numbers, 1, 2, 3, 4, 6, 7, 8 and 9, were used as stimulus materials, and the colors were divided into red or green. There were 16 stimuli in total. The subjects were asked to respond to the keys of numbers and colors.

2.4. Experimental Procedures

All the subjects performed the experiment together. Firstly, the subjects were subjective evaluation guilt emotion rating. Secondly, we induced subjects' guilt emotion by the point estimation task. All subjects were told that be automatically matched in pair to completion point estimation tasks, if the number of points is greater than 20, press “F” key, less than “J” key. In addition, subjects was informed that (1) Among them, one is the helper, the other is the decision maker, task of the helper is to look at the point figure 1.5s, then inform his thinking to the decision-maker by button, the decision-maker can only look at the point figure 0.75s, and then make the final judgment combination with the helper’ suggestion. (2) Reward of the helper is fixed (RMB 20), reward of decision-maker related to final result. At beginning，decision makers have 20 yuan as the foundation, each correct judgment adds 1 yuan, and each wrong judgment deducts 1 yuan, a total of 20 times. (3) Every time there will be feedback correctly or not (guilty group feedback auxiliary error 16 times, control group feedback helper error 8 times). (4) At the end of tasks, both the helpers and the decision makers were given feedback about each other compensation. Decision makers of guilt group were feedbacked that only got 5 yuan, and decision-makers of neutral group got 22 yuan. The program set all the subjects as helpers (the subjects did not know), the difference between the number of mistakes and the payoff was used to induce the subjects' guilt. After completing the point estimation tasks, subjects were tested again with the subjective

guilt emotion rating material. Finally, all subjects were required to completed the repetition and switch tirals. Tasks are divided into three types: (1) digit value judgment: display the number as red, the number is less than 5, press "F" key, more than 5, press "J" key; (2) digit parity judgment: the number is shown as green. Press "F" for odd numbers and "J" for even numbers; (3) more/small -- odd/even switch judgment: render the number as red, make more/small judgment, render the number as green, make odd/even judgment. The first two judgments belong to the repetition condition, and the third judgment belongs to the switch condition, whose task sequence is ABAB.

E-Prime 1.1 software was used to write the computer experiment program. The stimulus presentation and related reactions were automatically recorded by the computer. Both the point estimation task and the switching task have practice phases. After all the subjects completed the experiment, they were informed of the real purpose of the experiment and given 15 yuan as a reward.

3. RESULT

3.1. Operational inspection

Excluding invalid and extremely datas. paired-samples t test was used to test the effectiveness of emotion induction, and the results showed that: in guilt-induced group, guilt after posttest (M = 6.00, SD = 1.46) was significantly higher than that pretest (M = 4.42, SD = 1.60); t (25)=2.80, p = 0.015, Cohen's d =1.08, there was no significant difference in the neutral induction group. It was proved that the guilt-induced operation was effective and the point estimation task could effectively induce the guilt of the subjects.

3.2. Accuracy

In order to investigate whether there are differences in accuracy between in two groups, we conducted a 2×2 two-factor analysis of variance. Result is that the main effect of task type was significant, F(1,25) = 22.12, p < 0.001, η_p^2 = 0.47, and the accuracy of repetitive task（M = 91.54, SD =1.43） is significantly higher than that of switch task（M = 83.08, SD =2.66), both the main effect of emotion group and the interaction between emotion type and task type were not significant.

3.3. Response time and Switch cost

On response time, result is that the main effect of emotion type was not significant. But the main effect of task type was significant, F(1, 25)=151.08, p < 0.001, η_p^2 = 0.86. The response time of switch task (M = 1062.94, SD =38.18) was significantly longer than that of repeatitive task (M = 635.00, SD= 17.53). The interaction between emotion type and task type was significant, F(1,25)=6.54, p =0.017, η_p^2 =0.21. Further simple effect analysis showed that the response time of the guilt group was no different from that of the neutral group in the repeatitive task, while the response time of the guilt group was significantly longer than that of the neutral group in the switch task.

RT switch cost was obtained by subtracting response time of switch task from response time of repeatitive task. We conducted an independent-samples t test, it is found that RT switch cost in guilt group was significantly greater than that in neutral group, t (25)=2.56，p=0.017, Cohen's d =0.07.

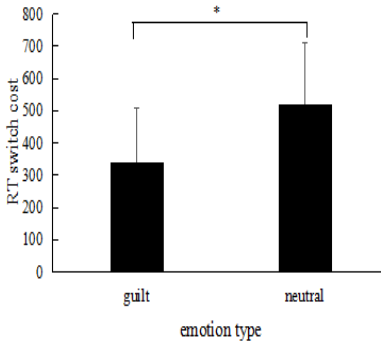

Figure 1 Switch cost effect in different emotion groups.

Table 1. Response time (ms), accuracy (%) and cost of different emotions in switching task paradigm.

Emotion group	Response	Type Styles		Switch Cost
		Repetitive task	Switch task	
Guilt group	Accuracy	91.50±2.05	83.59±3.82	7.90±7.70
	Response time	631.94±24.33	970.86±53.00	338.92±170.79
Neutral group	Accuracy	91.59±1.98	83.57±3.69	14.01±18.34
	Response time	638.06±25.25	1155.02±55.00	516.96±190.03

4. DISCUSSION

This study explored the influence of guilt emotion on cognitive flexibility. In line with previous findings, compared with the switch task, the repeatitive task had higher accuracy and shorter response time. In addition, the RT switch cost of guilt group was lower than that of neutral group, indicating that guilt emotion accelerates switching tasks and promote cognitive flexibility.

Contrary to previous studies on basic emotions [1,7], guilt as a negative emotion does not inhibit cognitive switch, but makes individual more flexible. From an evolutionary perspective, negative emotions function as a reminder that an individual is in danger [16]. Guilt is often a negative emotion caused by hurting them or having the idea of hurting others, guilt will make people afraid of being alienated from others in interpersonal relationship. As an alert, guilt can mobilize cognitive resources and make cognition more flexible.

In addition, cognitive and attention resources are correlation that guilt promotes cognitive flexibility. According to the broaden and build theory, individuals with positive emotion have a wider range of attention and more flexible thinking, they are more likely to pay attention to new cognitive system information, and the switch task involves new information processing. We believe that the influence of emotion on cognitive flexibility is not the effect of valence, but the attention and cognitive resources. Previous studies have shown that guilt can reduce self-depletion [17], meaning that guilty individuals reduce cognitive depletion. According to attentional resource theory, which makes individuals more quickly engage in new information processing, so guilt emotion promotes cognitive flexibility.

It is not only related to the amount of attention and cognitive resources, but also related to the directivity of attention. Individuals are more likely to complete the task at hand when their attention is directed outward rather than inward. Guilt emotion focuses on the harm that the event has done to others, tends to compensate, when individuals are looking for opportunities to make up for their behaviors, their attention is more directed to the outside world. In previous studies, guilt induced significantly greater alpha oscillations than shame and happiness [14], alpha oscillations represent attention pointing outward. Therefore, guilt emotion is more conducive to completing tasks and accelerating cognitive switch.

In order to further understand the specific reasons for the promotion of guilt emotion on cognitive flexibility, in the follow-up research, we can further study from the following five aspects. Firstly, in the same way to induce other negative emotions, such as sadness, anger, etc., if the same promotion effect, it is explained as the warning effect of guilt emotion. Secondly, to explore whether guilt individual's attention resources are more. Induing other increase attention resources emotions, such as pride. Thirdly, to explore whether guilt individual's attention is directed to the outside world .Subsequent studies can compare the effect of shame on cognitive flexibility because shame is an emotion that directs attention to the self. Fourthly, the follow-up research can also increase the research on inhibitory and refreshing functions in executive function. If the increase of individual's attention resources and attention is directed to the outside world, the inhibitory and refreshing functions will also be increased. Or use EEG means to explore the change of attention resources from a technical perspective. Finally, we found emotional valence is not the influence of cognitive flexibility, so whether emotional intensity will affect cognitive flexibility? In subsequent studies, we can distinguish the effects of different levels of guilt on cognitive flexibility in more detail. such as self-directed guilt and others-directed guilt, to test the influence of different intensity of guilt on cognitive flexibility. This study enriched the effect of emotion on cognitive flexibility, preliminarily explored the influence mechanism of guilt emotion on cognitive flexibility and some supporting evidence for the prosocial function of guilt.

5. CONCLUSION

The study expanded the influence of emotion on cognitive flexibility, and guilt emotion promotes cognitive flexibility.

AUTHORS' CONTRIBUTIONS

This research was completed with the joint efforts of four authors: D.N. Luo, X. Ma and Y Tao conducted the research; and D.N. Luo analyzed the data; D.N. Luo and T. Deng wrote the paper; all authors had approved the final version.

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