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The influence of the diffusion of responsibility effect on outcome evaluations: Electrophysiological evidence from an ERP study

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ABSTRACT

Previous studies have revealed that personal responsibility has an influence on outcome evaluation, although the way this influence works is still unclear. This study imitated the phenomenon of responsibility diffusion in a laboratory to examine the influence of the effect of responsibility diffusion on the processing of outcome evaluation using the event-related potential (ERP) technique. Participants of the study were required to perform the gambling task individually in the high-responsibility condition and with others in the low-responsibility scenario. Self-rating results showed that the participants felt more responsible for monetary loss and believed that they had more contributions to the monetary gains in the high-responsibility condition than in the low-responsibility situation. Both the feedback-related negativity (FRN) and the P300 were sensitive to the responsibility level, as evidenced by the enhanced amplitudes in the high-responsibility condition for both components. Further correlation analysis showed a negative correlation between FRN amplitudes and subjective rating scores (i.e., the higher the responsibility level, the larger the FRN amplitude). The results probably indicate that the FRN and P300 reflect personal responsibility processing under the social context of diffusion of responsibility.

Introduction

An old Chinese story goes as such: "One boy is a boy, two boys half a boy, three boys no boy."[1] The diffusion of responsibility is a well-known social phenomenon by which the sense of personal responsibility and individual accountability are sharply deemphasized when people work with others compared with when they work individually (Latane and Darley, 1968; Latane and Darley, 1969; Forsyth et al., 2002). In general, people tend to make riskier choices and feel less responsible for the negative consequences of these choices when deciding as a group, as opposed to acting individually (Mynatt and Sherman, 1975). A similar phenomenon is also common in real life. Individuals tend to take on varying degrees of personal responsibility when making decisions by themselves or as part of a group.

During uncertain circumstances, it is necessary for human beings to monitor their responses and evaluate external feedback. Rapid evaluation and the use of outcome information to guide future actions are critical in daily life. Recently, the processing of response monitoring and outcome evaluation has received considerable research attention (Miltner et al., 1997; Gehring and Willoughby, 2002; Holroyd and Coles, 2002; Yeung and Sanfey, 2004; Yeung et al., 2005). Prior studies have revealed that personal responsibility is very important for a decision-maker in evaluating potential outcomes based on available choices. For example, different levels of personal responsibility can lead to different kinds of emotional feelings such as regret or disappointment (Bell, 1982; Loomes and Sugden, 1982; Bell, 1985).

The influence of personal responsibility on outcome evaluation is also evident in a recent study. In a functional Magnetic Resonance Imaging (fMRI) study, Coricelli et al. (2005) studied how personal responsibility modulates outcome evaluation by comparing the brain activity evoked by outcomes in self-choosing and computer-choosing trials in a gambling task and found that outcome processing is significantly influenced by personal responsibility. However, the temporal course linking the influence of personal responsibility to outcome evaluation has seldom been investigated, particularly in a social context.

This study was motivated by the above-mentioned knowledge. To simulate a true gambling game in a social context, we adopted a modified Chuck-A-Luck Dice Game in which the final outcome was determined by the accumulative sum of three dice. In the high-

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[1] This story tells us that there was once a temple with only one monk living there. The monk shouldered two buckets of water to drink everyday. Some days later, another monk came to the temple. Using a stick, the two monks carried one bucket of water every day. What was worse was the arrival of a third monk, which prompted everyone to expect that someone else should take on the chore. Consequently, no one fetched water so they had no water to drink. This story is a typical example of the effect of responsibility diffusion.

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responsibility condition, the participants had the opportunity to "throw" all three dice. However, in the low-responsibility condition, he/she could control only a die as the other two would be controlled by his/her two partners. Past event-related potential (ERP) studies have identified two main components related to the outcome evaluation process: feedback-related negativity (FRN) and P300. Thus, we recorded the electrophysiological activity of the participants' scalp to test how the neural process of outcomes would be influenced by personal responsibility.

The FRN is a negative deflection that mainly distributes on the frontal–central recording sites and peaks approximately 250–300 ms after the onset of feedback. Its amplitude is larger for negative feedback associated with unfavorable outcomes, such as monetary losses or incorrect responses, than for positive feedback. The dipole modeling of the FRN has consistently suggested a neural generator in the anterior cingulate cortex or ACC (Miltner et al., 1997; Gehring and Willoughby, 2002; Luu et al., 2003). A growing body of literature suggests that this ERP component is involved in a general evaluation of action plans. Miltner et al. (1997) reported that FRN is elicited when subjects receive feedback indicating inaccurate performance in a time-estimation task, thus reflecting the neural mechanism of error detection. A reinforcement learning theory was then put forth by Holroyd and Coles, 2002, suggesting that the FRN reflects the impact of phasic decreases in dopamine signals from the basal ganglia to the motor-related areas of the ACC. More specifically, the FRN reflects a fast good–bad evaluation of feedback, with its amplitude depending on the relationship between the actual and the expected outcomes (Holroyd and Coles, 2002; Nieuwenhuis et al., 2004). However, Gehring and Willoughby (2002) argued that the FRN (referring to it as MFN) reflects an evaluation of the affective or motivational significance of errors detected by cognitive monitoring processes.

Cognitive and affective theories surrounding the FRN are still matters of debate (Yeung, 2004). Therefore, we tried to discuss the processing reflected by the FRN under a new perspective. In this study, we controlled the responsibility level of the subjects in two Chuck-A-Luck Dice Games to investigate whether the amplitude of the FRN would be affected by the sense of responsibility. Furthermore, this study aims to reexamine the existing theories of the FRN.

In addition to the FRN effect, the P300 is also closely related to the outcome evaluation process. It is reported to be a positive, large-amplitude potential with typical peak latency of between 300 and 400 ms after the onset of stimuli and generally peaks at central–parietal midline electrodes (Sutton et al., 1965; Johnson, 1993). Through a simple gambling task, Yeung and Sanfey (2004) reported the functional dissociations of the FRN and P300; the FRN is sensitive to reward valence but unaffected by reward magnitude, while the P300 has an opposite pattern. The findings have been supported by other researchers (Sato et al., 2005). These results suggest that reward valence and magnitude may be processed separately in the brain. However, another study has yielded inconsistent results on the functional significance of the P300, demonstrating that its amplitude is larger for positive outcomes than for negative ones (Hajcak et al., 2005). Due to the inconsistency of the findings, this study reexamined whether the P300 amplitude was sensitive to the valence of outcome in the present context. In addition, it is still of interest whether the P300 is related to other information on the outcome process, such as the degree of responsibility in the task.

This study employed a modified Chuck-A-Luck Dice Game in which the level of responsibility of the subjects was controlled. Scalp potential responses to different levels of responsibility were recorded, and self-rating results of the participants' subjective feelings after the formal experiment were gathered. The correlations between the self-rating and the ERP data were analyzed to investigate how the effects of responsibility diffusion influence outcome evaluation. This study may help us further understand the functional significance of the FRN and P300.

Materials and methods

Participants

Sixteen undergraduate students (eight females and eight males) aged 18–24 ($M = 20.9$) voluntarily participated in the experiment. All participants were right-handed with normal or corrected-to-normal vision and had no neurological or psychological disorders. Participants received 25 yuan (about US$3.66) as the reward for their participation. We expected that they could have sufficient motivation as the rewards. The study was approved by the local Ethics Committee.

Experimental tasks and procedure

Before the experiment, all the participants were told that they would participate in a Chuck-A-Luck Dice Game together with two strangers. If the numbers on the three dice totaled greater than 10, he/she would win 0.5 yuan in the trial; if not, he/she would lose 0.5 yuan. Each participant took part under two conditions: a self-execution condition in which he/she chucks all three dice one by one by himself/herself and a cooperating condition in which he/she completes the task with two partners. All the participants reported that they never met the two people partnered to them. In the cooperating condition, each of the three individuals chucked one of the three dice sequentially and randomly. These two conditions were set to run randomly trial by trial. Before every trial, a three-person-face cue would appear to indicate the cooperating trial, and a one-person-face cue would appear to indicate the self-execution trial. Rewards for both conditions were the same. The entire game was simulated by a computer program.

In an electromagnetically shielded room, the participants and their partners were seated comfortably about 1 m from a computer screen, with the horizontal and vertical visual angles at below 6°. Fig. 1 shows the seating arrangement: the participants knew that their two partners were seated behind the baffle, although they could not see each other. They were also told that their computers were connected together. In the self-execution condition, as shown in Fig. 2, each trial was initiated by a 1000 ms presentation of a small black asterisk on the gray screen, signaling the participants to fix their gaze on the screen's center. Afterwards, a downward pointing hand symbol was revealed on the screen for 1000 ms, which is the signal for action. Afterwards, a moving yellow bar was shown, and the participants must press the "G" key to stop the yellow bar. The distance of the moving yellow bar indicated the "strength" of the toss. After the participants' response, a blank die (bearing no number on it) was presented for 1000 ms to represent that the participants had tossed a die. This process was repeated for the second and third dice. After all the dice had been tossed, a blank screen was presented randomly for 1500–2000 ms. Afterwards, the participants were informed by a red "+" or "−" on the screen if they won or lost. After this feedback, another blank screen was presented lasting between 600 and 1000 ms randomly. Finally, a screen with the numerical information of the three dice was shown as the detailed feedback. Both kinds of feedback lasted for 1000 ms, but only the first was considered in the final statistical analyses. We did not choose the second feedback for electroencephalogram (EEG) analysis as results from a previous study show that the amplitude of the FRN is reduced as the feedback loses its informational value in a probabilistic learning task (Holroyd and Coles, 2002). In this study, the second feedback was used to enhance ecological validity, enabling the participants to believe that the final reward was truly related to their performance in the entire experiment.

The procedure for the cooperating condition was generally the same, except that a palm gesture appeared on the screen to signal the participant to wait for his/her partners' response. While the partners responded, a blank screen was shown for 1000–1500 ms randomly.