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HOW THE WIN–LOSE BALANCE SITUATION AFFECTS SUBSEQUENT DECISION-MAKING: FUNCTIONAL MAGNETIC RESONANCE IMAGING EVIDENCE FROM A GAMBLING TASK

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Abstract—Humans have been consistently shown to be bad at making decisions, especially in disadvantageous situations. In this study, we designed a task that simulates real-life non-strategic gambling to examine the effect of win–lose balance situations (WIN, LOSS, TIE) on decision-making. In behavioral performances, participants showed shorter response time (RT) in LOSS than in WIN and TIE conditions. Imaging results revealed that decisions in WIN are associated with increased brain activations in the posterior cingulate cortex; decisions in LOSS are associated with increased brain activations in the insula and decreased activations in the inferior frontal gyrus (IFG). Positive correlation was found between brain activation in IFG and RT in LOSS. Overall, we concluded that, in disadvantageous conditions, participants are frustrated by their negative results and tend to make a random selection without full consideration. In advantageous conditions, participants' motivations to gamble are elicited and they tend to engage in more endeavors in making decisions.

Key words: decision-making, balance situation.

INTRODUCTION

Decision making under risk is a complex mental process. The avoidance of risky behaviors, particularly the ones related to experience of loss, is a central feature of decision-making (Rothman and Salovey, 1997). However, plenty of studies have shown that human decision-making is affected by environmental variables (Ernst and Paulus, 2005; Xue et al., 2011; Drugowitsch et al., 2012), even when subjects are told that trials are independent and the outcomes are random (Cohen and Aston-Jones, 2005; Hecht et al., 2010). This issue is quite general since decisions are rarely made in temporal isolation. Current choices are often evaluated with the knowledge of the outcomes which have preceded them.

In recent years, a host of neuroscience approaches have been used to identify the neural mechanisms of risky decision-making. Most of the decision-making studies paid attention to the direct influence from prior results to subsequent decision (Shiv et al., 2005). For example, Xue's study showed that participants were more risk seeking after losing a gamble than after winning one (Xue et al., 2011). Few studies focus on the indirect influence from the win–lose balance situation (they have won or lost some money) to subsequent decision-making. According to the Cumulative Prospect Theory, people tend to think of possible outcomes usually relative to a certain reference point (the status) rather than to the final status. In addition, they have different risk attitudes toward gains (i.e. outcomes above the reference point) and losses (i.e. outcomes below the reference point) and care generally more about potential losses than potential gains (Tversky and Kahneman, 1992; Schmidt and Zank, 2009). There are some idioms that describe people's behavioral tendency under both disadvantages and advantages. For example, in disadvantageous situations, people usually say 'throw the handle after the blade' (distressed by the negative situation) or, on the contrary, 'do all to catch up' (the negative situation thrived their will to struggle). In advantageous situations, people might say 'lost in exhilaration' (get lost in too much excitement) or 'make still further progress' (the positive situation inspired to pursue more successes). Although these phrases tell us our decision-making is affected by our current balance situation, however, what kind of effects should that be and the mechanisms of how the brain works under different situations remain unclear.

The aim of the current study is to assess whether and how the win–lose balance situation affects subsequent decision-making by measuring both neural activities and behavioral responses. In order to create the different win–lose balance situations, we designed a guessing task with a purported win/loss rate of 50% for each trial. Although participants were told the outcomes are 'random', however, the outcomes were organized into some specific conditions, such as participants double their start amount (WIN), or they lose all they have at their start (LOSS), or tie situation (TIE). The WIN and LOSS series are included with the

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Abbreviations: ACC, anterior cingulate cortex; BOLD, blood oxygen level dependence; GLM, general linear model; IFG, inferior frontal gyrus; PCC, posterior cingulate cortex; RT, response time.

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aim to create different situations and the TIE is used as baseline.

Researchers have found that some brain regions, such as the inferior frontal gyrus (IFG) and anterior cingulate cortex (ACC), are involved in decision making (Cazzell et al., 2012; Fukunaga et al., 2012; Rushworth et al., 2012; Sheth et al., 2012). The activation in IFG is thought to signal subjective risk and believed to be crucial in the formation of subjective feelings during decision-making (Christopoulos et al., 2009; Craig, 2009; Fukunaga et al., 2012; Cazzell et al., 2012). The ACC has been associated with error monitoring, conflict detection and performance monitoring in decision-making (Holroyd and Coles, 2002; van Veen et al., 2004; Platt and Huettel, 2008), and was found that could signal anticipated risks, especially potential loss (Krawitz et al., 2010). Other works have identified risk-related brain regions, such as lateral orbitofrontal cortex (OFC), and insula, all of which are also responsive to monetary gains and/or losses (Critchley et al., 2001; Kuhnen and Knutson, 2005). The posterior parietal cortex, dorsolateral prefrontal cortex and anterior insula were found to be more active during choice of risky versus safe options (Paulus et al., 2003; Kuhnen and Knutson, 2005; Schonberg et al., 2011).

We hypothesize the decision-making-related brain regions, such as IFG (Craig, 2009; Christopoulos et al., 2009; Fukunaga et al., 2012; Cazzell et al., 2012) and ACC (Holroyd and Coles, 2002; van Veen et al., 2004; Platt and Huettel, 2008) would show differences which reflect different situations. Previous studies have suggested that emotion and task processing engage overlapping executive resources (Buhle and Wager, 2010; Gu et al., 2012), and the disadvantages will elicit negative emotion experience, which may affect the executive function process. Thus, we also hypothesize that brain regions that involve in emotion processing (e.g., the amygdala or insula, LeDoux, 2000; Gu et al., 2012) would be also involved in this process.

EXPERIMENTAL PROCEDURES

Participant selection

Seventeen healthy young adults (age: 21.3 ± 1.7 years; female: 5) participated in this study. They provided written informed consent, which was approved by The Human Investigations Committee at Zhejiang Normal University. None of them reported current Axis I disorders as assessed using structured psychiatric interviews (M.I.N.I.) (Lecrubier et al., 1997) by an experienced psychiatrist. In addition, depression was assessed using the Beck Depression Inventory (Beck et al., 1961) with an exclusionary cut-off of $\geqslant 5$. All subjects are right handed and do not suffer head injury with lost consciousness during their lifetime.

Task and procedure

A reality-simulated guessing task was designed to create win or loss context (Dong et al., 2011). This task used an event-related design. Fig. 1 shows the event sequence of each trial during the task. A white cross was presented at the center of a black screen for 500 ms to cue the beginning of a new trial. Then the back of two cards was shown side by side and participants were asked to choose either the right or the left one with a button-press response as fast as possible. The selected card would be turned over after it was presented for 1500 ms and displayed for another 2000 ms. Participants would win 10 Chinese Yuan (≈$1.6) if the selected card was red or lose the same amount if it was black. The word "win" or "loss" appeared between the two cards for 2000 ms immediately after the turnover of the selected card. The accumulated balance was presented beneath the word. The win or loss trials were presented randomly throughout the task. A black screen was presented randomly between 500 and 1500 ms as inter-trial-interval (Fig. 1) (Dong et al., 2011). The experiment consisted of two blocks and 245 trials in total. One block consisted of 120 trials and the other consisted of 125 trials with an inter-block-interval of 1 min. The whole experiment was for 1260 s (21 min) in total and presented using E-prime software (Psychology Software Tools, Inc.).

Each participant was provided 50 Yuan as the initial balance before the task, and was explicitly informed that he or she would receive the entire balance in cash at the end of the task. We defined three different task conditions based on the balance (1) WIN, the balance is over 100 Yuan (participants doubled their balance). (2) LOSS, the balance is less than 0 Yuan (participant lost all they have); and (3) TIE: the balance is between 40 and 60 Yuan (participants win or lose no more than 10 Yuan). Participants who choose the same card for more than 75% of all trials (they might have selective bias) or choose the same card for more than 10 continuous trials (they might lack motivation to perform properly) were excluded from further analysis.

Although participants were told the results were totally randomized, in fact, the results of all trials were predetermined. This is to create the WIN/LOSS situation in the present study. In addition to this, the whole win–lose amount was waived in one of the four situations (WIN–LOSS–WIN–LOSS; WIN–LOSS–WIN; LOSS–WIN–LOSS–WIN; LOSS–WIN–LOSS) (Fig. 2), which is to avoid the effect of changing (WIN after LOSS; LOSS after WIN). Every condition (WIN, LOSS, TIE) consisted of 40 valid trials in this study. In the situation where participants usually miss some trials, the missed trials were set as 'lose' in our program. Thus, the number of WIN trials was usually less than 40 (32–39), and the number of LOSS trials was usually more than 40 (40–46). In this study, we only focus on how the overall situation affects the decision-making process. Other aspects of decision making, e.g., results of the decision will be presented in other studies.

Image acquisition and pre-processing

Structural images covering the whole brain were collected using a T1-weighted three-dimensional spoiled gradient-recalled sequence (176 slices, TR = 1700 ms, TE = 3.93 ms, slice thickness = 1.0 mm, skip = 0 mm, flip angle = 15°, inversion time 1100 ms, field of