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Brain potentials in outcome evaluation: When social comparison takes effect

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ABSTRACT

Social comparison, in which people evaluate their opinions and abilities by comparing them with the opinions and abilities of others, is a central feature of human social life. Previous work has highlighted the importance of social comparison in reward processing. However, the time-course of the social comparison effect in outcome evaluation remains largely unknown. The purpose of this study was to explore to what extent brain activity is modulated by social comparison between an individual and their anonymous partner. Event-related potentials (ERPs) were measured while the participants viewed their own and their partner's gain and loss outcomes based on their performance in a dot estimation task. Analysis of ERPs revealed that the feedback-related negativity (FRN) amplitude differences between gains and losses were not modulated by social comparison. In contrast, the P300 was larger for gains and showed an effect of social comparison independent of feedback valence. A late component, the late positive potential (LPP), was also modulated by social comparison, but it was insensitive to feedback valence. The data suggest that social comparison modulates outcome evaluation at several points in the information processing stream. Social comparison has no effect on the early coarse evaluation stage, but modulates the late cognitive/affective appraisal and re-appraisal processes. These findings provide neurophysiological evidence for the importance of social comparisons in outcome evaluations by the human brain.

1. Introduction

Social comparison is the process through which people come to know themselves by evaluating their own attitudes, abilities, outcomes, and beliefs in comparison with others (Wood, 1996). Since Festinger's first proposal of social comparison theory (Festinger, 1954), work on social comparison has been growing. Research on social comparison has developed into a complex area encompassing cognitive mechanisms and applications (Buunk and Gibbons, 2007; Fazio, 1979; Fishbein et al., 1963; Gibbons, 1999; Greenberg et al., 2007; Kumar, 2004; McCreary and Saucier, 2009; Poeschl, 2001; Ruble et al., 1980; Stapel and Marx, 2006; Zell and Alicke, 2009). Social comparison has been recognized as an important social psychological phenomenon, and extensive effort has been devoted to understanding its causes and their cognitive and emotional consequences. However, very little is known about the neural mechanisms underlying social comparison and how it affects and illuminates outcome evaluation.

Recent studies in social neuroscience have begun to identify brain networks involved in social comparison. Evidence from imaging research suggests that brain activity in reward-related regions is affected by contextual information about the other person's payment. Specifically, the activation in the bilateral ventral striatum, a region known to be critically involved in reward processing, was lowest for when less money was earned when compared to the other player, followed by the condition of equal payment. Activation was highest when a participant earned more money than the other player. The effect of relative comparisons is independent of the level of payment (high or low) (Fliessbach et al., 2007). Social comparison has also been shown to be related to activation of the dorsal striatum, midbrain/thalamus, anterior insula and medial prefrontal cortex (MPFC) in an interactive, simulated social context (Zink et al., 2008), suggesting a role of social comparison in reward processing. A study using electroencephalographic (EEG) recordings identified event-related brain potential (ERP) correlates with this social comparison effect. Both disadvantageous and advantageous unequal payoff elicited a larger late negative component (LNC), between 550 and 750 ms, when compared to equal payoff conditions (Qiu et al., 2010). Source analysis revealed that the generators of the LNC were localized near the caudate nucleus. This result is consistent with imaging studies that showed the influence of social comparison on outcome evaluation when monetary reward was involved.

Most research on social comparison has focused on the neural mechanisms of reward processing, especially positive rewards (e.g., gains). Only recently have researchers begun to address the fact that social comparison usually arises when people are facing adversity or unfortunate

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circumstances (e.g., losses or punishment). In an fMRI study, for example, researchers investigated the emotional and neural responses associated with upward social comparison (comparison with those who have more) and downward social comparison (comparison with those who have less) (Dvash et al., 2010). Interestingly, even when participants lost money, they expressed joy and schadenfreude (gloating) if the other player had lost more money. On the other hand, when they actually won money, but the other player had won more, they expressed envy. This pattern was reflected in the activities of the ventral striatum. These results highlight the emotional consequences of social comparison in the loss domain. Less clarity, however, exists about the time course of brain responses to the social comparison effect of losses.

To address this question, the present study used EEG recordings aimed at exploring the time-course of the social comparison effect on outcome evaluation when both positive and negative rewards were involved. We were interested in how social comparison affects different stages in the process of outcome evaluation. According to previous neurophysiological studies, two ERP components are particularly sensitive to the aspects of reward and performance outcome. The first component is called feedback-related negativity (FRN) or medial-frontal negativity (MFN), which is a negative deflection in the frontocentral recording sites that reaches maximum amplitude between 250 and 300 ms following the onset of feedback stimulus (Gehring and Willoughby, 2002; Heldmann et al., 2008; Holroyd and Coles, 2002; Holroyd et al., 2004; Miltner et al., 1997; Nieuwenhuis et al., 2004a; Yu and Zhou, 2006a, 2006b, 2009). FRN is more pronounced when there are errors, conflicts, unexpected punishments, and negative feedback. One of the most influential theories proposed that FRN reflects a reinforcement learning signal associated with prediction errors, especially when outcomes are worse than expected (Holroyd and Coles, 2002). It has also been proposed that FRN reflects motivational/affective responses to negative feedback (Gehring and Willoughby, 2002).

Particularly relevant for the current study, previous studies have shown that the processing of performance feedback in an observation situation, in which feedback does not refer to the participant's own performance but to the performance of another player, yields similar FRN amplitudes as in active conditions (Kobza et al., 2011; Leng and Zhou, 2010; Yu and Zhou, 2006b). However, other studies reported reduced FRN amplitudes in observation conditions (Bellebaum et al., 2010a; Fukushima and Hiraki, 2009; Itagaki and Katayama, 2008). It should be noted that in all previous studies examining feedback processing in an observation condition, the positive (e.g., gains or correct) or negative (e.g., losses or incorrect) feedback for the choice made on each trial represented only one player's outcome, either the participant's outcome or the observer's. Social comparison was, therefore, unavailable during the outcome evaluation stage in such cases. Whether FRN is modulated by social comparison remains unclear.

Another ERP component that has been related to outcome evaluation is the P300, which is the most positive peak in the 200–600-ms period after feedback onset. The P300 typically increases in magnitude from the frontal to parietal sites (Goyer et al., 2008; Hajcak et al., 2007; Sato et al., 2005; Wu and Zhou, 2009; Yeung and Sanfey, 2004). The P300 is sensitive to reward valence as well as reward magnitude in monetary gambling tasks, with more positive amplitude for positive feedback than for negative feedback, suggesting a role in differentiating good from bad outcomes (Hajcak et al., 2005, 2007; Holroyd et al., 2006; Leng and Zhou, 2010; Wu and Zhou, 2009). These studies led to the hypothesis that outcome evaluation can be divided roughly into two related processes: an early evaluation of the motivational/affective significance of the feedback stimuli, followed by a more elaborative evaluation, in which factors that affect the allocation of attentional resources come into play in a top-down controlled manner (Goyer et al., 2008; Leng and Zhou, 2010; Wu and Zhou, 2009).

To examine the social comparison effect on outcome evaluation, possibly indexed by the magnitude of FRN and P300, we employed a modified dots-estimation task similar to the one used in the Fliessbach et al. (2007) study. However, in this study, negative as well as positive rewards were used. For the task, the participant and his/her partner estimated the number of dots presented on the screen simultaneously. Monetary gains or losses were given for correct or incorrect answers. We increased the task difficulty such that a sufficient number of trials generating negative feedback were obtained. The participant's outcome could be the same (1:1), less (1:2) or more (2:1) than his/her partner's. ERP was extracted when participants viewed the feedback about the conjoint payoffs of their own and their partners.

Behavioral studies suggest that social comparison may be a relatively spontaneous, effortless, and unintentional reaction to the performances of others (Gilbert et al., 1995). If social comparison arises spontaneously, it would take effect very early in outcome evaluation, and we would expect to see its impact upon both FRN and the P300. Specifically, if social comparison takes effect as early as at the FRN stage, we would find the least favorable outcomes (e.g., a personal loss greater than that experienced by one's partner) eliciting the largest FRN; if social comparison takes effect at the P300 stage, we would find the most favorable outcomes (e.g., a gain greater than one's partner's) eliciting the largest P300. If, on the other hand, outcome evaluation entails both semi-automatic (reflexive) and intentional (attentional) processes, the social comparison may affect the later, attention-sensitive process of outcome evaluation of the associated neural activity, as indexed by the P300. However, in this case, the resultant FRN should not be different. Furthermore, social comparison theory suggests that social comparison plays an important role in self-constructing when self-regulation and adaptation are involved (Festinger, 1954). A reasonable prediction is that social comparison may have a lasting effect on outcome evaluation beyond the early FRN and P300 stages. Therefore, we might expect to uncover a social comparison effect in the late reappraisal stage, as indexed by the LPP, which is often reported in emotional processing and the amplitude thereof is usually the largest for the most arousing stimuli, i.e., those with the greatest motivational relevance (Schupp et al., 2000).

2. Methods

2.1. Participants

Seventeen undergraduate and graduate students (nine males and eight females) at Peking University participated in the current experiment. All participants were right-handed. All participants received a pay of ￥40 for their involvement and a bonus up to￥10 based on their performance on the task. Data from one participant were excluded due to excessive artifacts in the EEG recording. The study was approved by the local research ethics committee.

2.2. Stimuli and task

Stimuli were presented in white color against a black background on a 17 in. computer screen. The stimulus set included 20 dot images, with a varying number of 19 to 48 white dots. The Chinese words "多" ('more') and "少" ('less') under a digit number triggered the participants to make a response. The presentation of the Chinese words "你:" ('you') and "他:" ('he') and sign of "+" or "−" plus a digit number served as feedback stimuli (see Fig. 1).

A variant of a previously administered dot estimation task was used (Fliessbach et al., 2007). We asked participants to make a binary decision based on their estimation of the number of dots and to press one of two response keys. The response key and the corresponding button-press were counterbalanced between participants. They were instructed to respond as accurately and quickly as possible. At the end of each testing block, they received feedback about the amount of money they had earned during the block. This monetary feedback strictly depended on their performance.