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Psychophysiological correlates of interpersonal cooperation and aggression

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ABSTRACT

Mimicking real world situations, the Chicken Game allows scientists to examine human decision-making when the outcome is not entirely within one person's control. In this social dilemma task, two players independently choose either to safely cooperate with, or riskily aggress against, the other player, and the unique combination of their choices specifies the outcome for each. Coupling the Chicken Game with psychophysiological measures, we confirmed our two hypotheses: that an individual perceives an outcome as most negative when she chooses to cooperate and the other player violates that trust and aggresses, and that motivational salience of an outcome is greater when an individual chooses to aggress and when she gains money. Collectively, the data demonstrate the utility of pairing true social dilemma tasks like the Chicken Game with psychophysiological measures to better understand decision-making.

1. Introduction

The issue of reducing national debt plagues countries internationally and is governed by a unique webbing of risk-taking by, and payoffs for, independent parties. In the 2012 Greek elections, for instance, the political faction elected determined whether or not Greece would accept the austere bailout terms of European Union. Electing a left-wing party would have led Greece to renounce her debts, refuse the bailout plan, and leave the euro zone; instead, the election of a right-wing party has caused Greece to acquiesce with the bailout plan, maintaining her place in the euro zone. Independent of Greece's decisions, the European Union had the choice to alter the bailout plan in favor of Greece's financial welfare, but instead chose to maintain the strict terms to benefit its own financial state. As both Greece and the European Union were faced with choices, it was the combination of their independent decisions that collectively determined the financial outcomes for each.

Like governments faced with economic crises, individuals regularly confront decisions involving various degrees of risk and reward. Whether deciding how to merge into oncoming traffic or if there is time to zip quickly across a one-lane bridge before an approaching car, the final outcomes of many decisions are not determined solely by your choice but instead by the unique combination of your choice and that of someone else. Do you select the safer, more cooperative option in which you risk being taken advantage of? Or, rather, do you choose to aggress and dare the other person to let you come out ahead, despite the risk that you both might end up with a bad outcome? Social psychologists and economics refer to this dilemma as the Chicken Game (Rapoport & Chammah, 1966).

Social decision-making games such as the Chicken Game mimic real world situations by allowing us to examine human decision-making in situations where the outcome is not entirely within one's control. The Chicken Game presents players with a *true* social dilemma, as two players independently choose to either cooperate with, or aggress against, the other player. Choosing to aggress permits maximal personal gains if the other player cooperates; however, both players choosing to aggress earn each the worst outcome. For the player who cooperates when the other aggresses, her reward is slightly better than when both choose to aggress. In contrast, if both players cooperate, they each have moderate gains, which if consistently chosen by both players, would result in the best overall outcomes for each (Fukui et al., 2006). Table 1 provides the relative payoffs of the different social interactions and hence depicts the tension that the game facilitates between cooperative and competitive impulses.

Pairing social-dilemma tasks like the Chicken Game with psychophysiological measures permits insight into human decision-making. Although the current study examines event-related potential (ERP) correlates of cooperation and aggression, functional magnetic resonance imaging (fMRI) literature informs this

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Table 1
Payoff matrix in the Chicken Game. The outcome (in Yuan) for the participant (Player 1) is displayed outside parentheses, and the outcome of the opponent (Player 2) is displayed within parentheses.

		Player 2	
		Cooperate (C)	Aggress (A)
Player 1	Cooperate (C)	10 (10)	−10 (30)
	Aggress (A)	30 (−10)	−30 (−30)

work. Research on the neuroscience of cooperation and aggression has employed social decision-making tasks like the Trust Game (TG), Prisoner's Dilemma Game (PDG), and Ultimatum Game (UG). This literature suggests that decisions to cooperate or compete are guided by both bottom-up and top-down cognitive processes. For example, the caudate nucleus appears to function in learning reward values of stimuli (Montague, Dayan, & Sejnowski, 1996) and tracking an opponent's decision to reciprocate or not reciprocate cooperation in the TG and PDG (King-Casas et al., 2005; Rilling et al., 2002; Rilling, Sanfey, Aronson, Nystrom, & Cohen, 2004). In these ways, the caudate indexes social prediction errors and guides decisions about one's own reciprocity (Rilling, King-Casas, & Sanfey, 2008). Unreciprocated cooperation in particular is associated with activation of the insula, which alongside evidence that the insula is implicated in aversive conditioning, suggests that it may mark negative social interactions in an effort to learn to avoid them in the future (Rilling et al., 2008; Seymour et al., 2004).

However, cognitive control processes may also override the networks implicating these structures and exert a top-down influence on decision-making (Rilling et al., 2008). For example, the dorsolateral prefrontal cortex, involved in goal maintenance and executive functions (Miller & Cohen, 2001; Wagner, Maril, Bjork, & Schacter, 2001), appears to also be involved in the inhibition of the emotionally driven response of the insula, in an effort to rationally accept unfair offers and increase monetary gains (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). Similarly, individual differences in decisions to trust others captured by the amygdala, motivation to voluntarily donate money is represented in the ventral striatum, and norm-driven responses to punishment observed in the lateral orbitofrontal cortex have also been demonstrated to exert top-down influence (Rilling et al., 2008).

The anterior cingulate cortex (ACC) is also critically involved in the processes of cooperation and competition. In addition to increased DLPFC and insula activity following unfair offers in the UG, individuals also had increased ACC activation (Sanfey et al., 2003). With a cognitively oriented dorsal region (dACC) and an affectively oriented rostral region (rACC), Sanfey and colleagues interpreted the ACC as representing the conflict between rational and emotional responses to unfair offers, such that increased ACC activation to unfair offers reflects augmented negative emotional responses. Additional research provides support of the ACC's sensitivity to the affective properties of social pain. For example, Eisenberger and Lieberman (2004) found increased activation of the ACC following social exclusion by peers, and Burklund, Eisenberger, and Lieberman (2007) found that individuals with heightened sensitivity to rejection had increased ACC activation in response to disapproving facial expressions.

In the same way that offers in the UG elicit cognitive and emotional responses, the Chicken Game provides outcomes that research purports are evaluated similarly by the ACC. Numerous studies provide evidence that the ACC is associated with outcome evaluation, such that there is greater ACC activity for more negative outcomes (Behrens, Woolrich, Walton, & Rushworth, 2007; Quilodran, Rothe, & Procyk, 2008; Walton, Devlin, & Rushworth, 2004). Outcome evaluation is, in fact, an important step in adaptive decision-making (Paulus, 2005), as encoding the outcomes of previous actions helps an individual to determine how future decision-making behavior should be altered (Platt, 2002). In support, it appears that the evaluation of outcomes in the ACC is critical in the process of selecting motor actions to guide future behavior (Quilodran et al., 2008; Shima & Tanji, 1998).

As cooperative and competitive tendencies are woven in with the complex social environments addressed in the Chicken Game, exploring how outcomes are evaluated provides the opportunity to understand how decisions are made. Psychophysiological research purports that the brain has developed special mechanisms to quickly assess the valence and magnitude of outcomes, as well as their subjective, motivational significance (Leng & Zhou, 2010). Two event-related potentials (ERP) components index such aspects of outcome evaluation: the feedback-related negativity (FRN) and the P300.

The FRN is a negative-going component that is maximal over fronto-central recording sites between 200 and 300 ms after feedback presentation, and whose neural generator is evidenced to be the ACC (Gehring & Willoughby, 2002; Holroyd & Coles, 2002). It is consistently larger for more unfavorable outcomes, which alongside evidence of the ACC's role in representing affective pain, suggests that the FRN reflects whether the individual achieved the desired feedback (Holroyd, Hajcak, & Larsen, 2006; Sanfey et al., 2003). A second ERP component indexing evaluations of decision-making is the P300, a positive-going component that peaks at parietal electrodes between 200 and 600 ms after feedback presentation. The generation of the P300 appears more widely distributed, although evidence converges across methodologies to suggest that the ACC and parietal cortex may play critical roles in its generation (for review, see Linden, 2005). The P300 is most consistently thought to reflect the processes of attentional allocation and motivational salience (Gu, Ge, Jiang, & Luo, 2010; Hajcak, Holroyd, Moser, & Simons, 2005; Wu & Zhou, 2009; Yeung, Holroyd, & Cohen, 2005; Zhou, Yu, & Zhou, 2010). Consistently, Leng and Zhou (2010) found that rewarding monetary feedback elicited greater P300, as did observing a friend's, rather than a stranger's, outcomes.

While there is evidence that the ACC is related to social psychological constructs like social exclusion, rejection, and unfairness, evidence is only now forthcoming that the FRN component in particular may reflect these constructs. Recently, investigators have used the UG to examine outcome evaluation during decision-making in social contexts. In this social dilemma task, participants typically reject such unfair offers even if the alternative is no monetary gain (Bolton & Zwick, 1995). Unfair offers are characterized by a larger FRN relative to fair offers (e.g., Boksem & De Cremer, 2010; Polezzi et al., 2008). Boksem and De Cremer (2010) found that the effect was most pronounced in individuals for whom fairness was important. In the context of a social situation, Polezzi et al. (2008) also found that mid-value offers, which could not easily be classified as fair or unfair, also produced larger FRNs relative to fair offers, suggesting that both unfair and mid-value offers may be perceived as undesirable relative to fair offers.

The UG and TG, however, do not allow for an understanding of social situations in which mutual cooperation or conflict may occur. The PDG and Chicken Game address this issue, but unlike the well-studied PDG, in which the worst outcome is when the participant cooperates and the competitor aggresses, the Chicken Game has no dominating decision strategy. Because the worst outcome in Chicken Game is when both players compete, there is no clearly advantageous choice.

In the present study, participants therefore completed the Chicken Game as their EEG were recorded. Based on the conflict monitoring theory of the FRN, in which outcomes that violate expectancy produce greater FRN amplitudes (Carter et al., 1998; Gehring & Fencsik, 2001; Jia et al., 2007; van Veen & Carter, 2002),