



Heart-rate deceleration predicting the determination of costly punishment: Implications for its involvement in cognitive effort expended in overriding self-interest



Takahiro Osumi ^{a,b,*}, Hideki Ohira ^a

^a Department of Psychology, Nagoya University, Nagoya 464-8601, Japan

^b Japan Society for the Promotion of Science (JSPS), Tokyo 102-8472, Japan

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ABSTRACT

Previous studies have investigated which biological markers predict the decision to reject unfair monetary offers, termed costly punishment, in the ultimatum game (UG). One study showed that a phasic deceleratory response in heart rate (HR) is evoked in the responder more readily by offers that will be rejected than by offers that will be accepted. However, owing to the paucity of supporting evidence, it remains unclear whether and why HR deceleration can predict the decisions of UG responders. In this paper, we report two separate studies (Study 1 and Study 2) using modified versions of the UG to explore factors modulating HR deceleration. In Study 1, as well as unfair offers, fair offers induced greater HR deceleration when responders were forced to reject offers compared to when they were forced to accept offers. In Study 2, a high rejection rate for very unfair offers was sustained, regardless of the size of the offers, but HR deceleration was increased for unfair but large offers, relative to unfair, small offers. Moreover, HR deceleration was associated with the rejection of large offers. However, across the two studies, HR deceleration did not simply vary depending on unfairness. These findings support the possibility that HR decelerates as a function of cognitive load in determining costly punishment.

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1. Introduction

Punishment is widely used in societies to correct or prevent unfair, selfish behaviors. In some cases, people are willing or compelled to incur personal cost in giving punishment. This behavioral tendency is well demonstrated in laboratory studies using the ultimatum game (UG). In this game, two players (a proposer and a responder) must divide a sum of money in a single trial. If the responder accepts the proposer's offer, the deal goes ahead. If the responder rejects the offer, neither player receives any money. Despite the economic rationality of accepting offers, empirical studies have demonstrated that responders are more likely to reject offers of 20% or less (Camerer, 2003; Güth et al., 1982). Examining the psychological mechanisms underpinning the determination of such costly punishment, namely the rejection of unfair offers in the UG, increases our understanding of how people resolve the conflict of economic self-interest and social motives related to fairness.

Psychophysiological approaches help elucidate latent information processing or psychological responses, such as emotion or attention to

stimuli or situations. The somatic marker hypothesis (Damasio, 1994) proposes that salient bodily responses indicate whether a situation is good or bad, and shape directions for decision-making. Thus, peripheral body responses have come into focus, not only as indices of psychological activity during decision-making, but also as a potential predictor for decisions (e.g., Bechara et al., 1996). Regarding decision-making for responders in the UG, several studies have demonstrated that skin conductance response (SCR), often used as an index of emotional arousal, is higher for unfair offers than for fair offers and is positively correlated to the rejection rate for unfair offers (Dunn et al., 2012; Hewig et al., 2011; van 't Wout et al., 2006). Such findings support the theoretical viewpoint that the rejection of ultimatum offers is an irrational, impulsive behavior attributable to emotions such as anger (e.g., Sanfey et al., 2003).

However, some studies have indicated inconsistent findings for the association between SCR and the rejection of UG offers (Brevers et al., 2015; Civai et al., 2010; Osumi and Ohira, 2009), which implies that physiological arousal does not fully predict the rejection of ultimatum offers. Rather, an orienting response might better predict the rejection decision for ultimatum offers. An orienting response, as exemplified by phasic deceleration in heart rate (HR), is caused by significant information, including a target for approach or avoidance (Lang et al., 1997; Sokolov et al., 2002). Accordingly, it has been hypothesized that HR

* Corresponding author at: Department of Psychology, Faculty of Humanities and Human Sciences, Hiroshima Shudo University, 1-1-1 Ozukahigashi, Asaminami-ku, Hiroshima 731-3195, Japan.

E-mail address: toosumi@shudo-u.ac.jp (T. Osumi).

deceleration will mark receiving unfair treatment significant enough for responders to decide on costly punishment. Consistent with this hypothesis, Osumi and Ohira (2009) showed that offers that will be rejected induce greater deceleration in HR than offers that will be accepted, despite no electrodermal difference.

Thus, HR deceleration appears useful as a biological marker for processing the information crucial for the costly punishment decision. Nevertheless, supporting evidence has been insufficient. Several studies have failed to replicate the association between HR deceleration and the rejection of ultimatum offers (Dunn et al., 2012; Van der Veen and Sahibdin, 2011), indicating the need to reconsider whether and why HR deceleration can predict the decision of costly punishment. We therefore report here two separate studies (Study 1 and Study 2) using modified versions of the UG to explore factors modulating HR deceleration.

A considerable factor modulating HR deceleration is unfairness. However, in the standard experimental task for UG decision-making, whether responders do or do not reject ultimatum offers happens according to responders' voluntary decisions depending on fairness norms. For this reason, unfairness and the rejection decision are likely confounded, making it difficult to determine whether cardiac response is elicited by the affective significance of unfair offers or another factor linked to performing rejection. Therefore, first, we evaluated the effect of unfairness independently of performing rejection or acceptance. To this end, in Study 1, we applied a rule that forced responders to choose irrational rejection or rational acceptance for each offer.

Like affective significance, the factor of cognitive demands or cognitive control has been noted as a factor modulating HR deceleration. For example, HR deceleration is pronounced owing to the processing of complex stimuli (Fredrikson and Öhman, 1979). Moreover, HR deceleration is attenuated during the upregulation of positive affect in response to positive pictures (Pavlov et al., 2014), but pronounced during cognitive rumination on a negative aspect of unfair UG offers (Vögele et al., 2010). During a cognitive task, a pronounced HR deceleration in response to error signals was associated with appropriate behavioral adjustment (Van der Veen et al., 2004). Such findings give rise to another possibility, that HR deceleration is modulated by cognitive reasons for performing rejection in the UG.

In theory, executive function is involved not only in the rational choice of acceptance, but also in choosing rejection of unfair offers. Consistent with this, neural activity in the right dorsolateral prefrontal cortex, believed to be involved in goal maintenance and executive control (Miller and Cohen, 2001), is involved with rejection but not acceptance of unfair offers (Knoch et al., 2006, 2010). Moreover, the rejection of unfair offers is predicted by the self-rated need for cognition (Mussel et al., 2013), performance on a motor response inhibition task (Sütterlin et al., 2011), and the vagal component of heart rate variability, a marker of inhibitory control or emotion regulation (Sütterlin et al., 2011; although see Dunn et al., 2012). These findings support the notion that executive function serves to override self-interest and maintain norm orientation.

Accordingly, in Study 2, we examined the possibility that HR deceleration during rejection decision-making is involved in overriding self-interest. To this end, we assessed HR deceleration for offers in which the monetary amount of the offers was manipulated independently of the unfairness level. Larger monetary offers would motivate responders to accept and would thereby be more difficult to reject. In support of this prediction, responders exhibited slower responses for large than for small offers (Van der Veen and Sahibdin, 2011). Thus, monetary size of offers is a key factor in the manipulation of cognitive effort for executing rejection.

2. Study 1

First, we studied phasic HR deceleration in response to ultimatum monetary offers when responders were forced to choose rejection or acceptance regardless of unfairness. If HR deceleration represents

processing affective significance related to unfairness, HR will be decelerated more by unfair than by fair offers, even if responders are forced to choose rejection or acceptance. Conversely, if HR deceleration reflects a factor involved in executing costly rejection, such as cognitive effort, greater magnitudes of HR deceleration will be elicited by offers that responders must reject than by offers they must accept, regardless of whether the offers are fair or unfair.

In addition, physiological arousal in HR acceleration and SCR is measured to understand emotional and motivational states. As shown in previous studies (e.g., van 't Wout et al., 2006), unfair offers may elicit greater SCR than fair offers. However, it should be noted that physiological arousal reflects non-specific emotional arousal (Civai et al., 2010; Osumi and Ohira, 2009). Accordingly, physiological arousal may not vary with either the unfairness of offers or with the gain/loss resulting from choices. Instead, rules governing choice (voluntary vs. forced) might affect arousal, because responders control the emotional and motivational responses to execute forced choices. If this is the case, responders will be less likely to exhibit physiological arousal for the forced rejection of fair offers. Such forced rejection is never true for punishing a norm violator or for gaining a monetary reward.

2.1. Methods

2.1.1. Participants

Participants in Study 1 were 39 Japanese undergraduate students (21 males). Their mean age was 20.15 ($SD = 1.70$) years. None of them had been exposed to the UG or other economic game theories. All participants were informed of the procedure of Study 1 and signed a consent form.

2.1.2. Experimental task and procedure

Participants were required to choose acceptance or rejection for UG offers under rules of voluntary and forced choices. The voluntary-choice condition left participants to themselves during decision making to accept or reject each offer. However, in the forced-choice conditions, participants were required to accept or reject each offer according to instructions, independent of monetary distribution amounts. For each offer, a monetary stake of 1000 yen (approximately 10 US dollars) was divided between a proposer and a responder, and the monetary amounts distributed to responders were 500, 400, 300, 200, or 100 yen. Each offer amount was proposed four times in each forced-acceptance, forced-rejection, or voluntary-choice condition. Before the task started, participants were told they would receive 60 offers from four proposers. However, there was no actual proposer; offers were made by the experimenter. To improve the credibility of the current task, participants were told that the offers had been made by students who had played UG proposer roles in a previous study and that they would not meet proposers face-to-face at the time of the experiment. In addition, participants were informed that they and the proposers would be paid according to their choices.

The experimental task was begun following a 3 min rest period. Once the task began, participants performed four sessions, each including 15 offers from a proposer. At the beginning of each session, a picture of "the proposer" was presented. Offers were displayed on a monitor and varied randomly, trial-by-trial. At the beginning of each trial, a red, cross-shaped fixation point was presented for 1 s, and a sentence explaining the rule was shown for 1 s. In the voluntary-choice condition, the sentence "You can choose as you like" was displayed. On the other hand, in the forced-choice conditions, either "You must choose ACCEPTANCE" or "You must choose REJECTION" was displayed. These rules were randomly ordered. Before the presentation of an offer, a black cross was presented for 4–6 s to allow each autonomic activity to recover to baseline. An offer (e.g., "I get 700 yen; you get 300 yen") was presented for 6 s and followed by the cue to respond, "ACCEPTANCE or REJECTION." Once the response cue was displayed, participants chose acceptance or rejection according to rules by pressing the left

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