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Beneficial Roles of Emotion in Decision Making: Functional Association of Brain and Body

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Abstract

Though traditional microeconomics has supposed that human decisions are based on logical and exact computation of cost-benefit balances or efficacies, studies in behavioral economics have shown that humans sometimes make seemingly irrational decisions driven by emotions. In our everyday situations, factors related to decisions are complex and which alternative will be the most beneficial is uncertain. In such cases, emotions have been thought adaptive because they can quickly reduce negative alternatives and facilitate fast and effective decision making. Some theorists argued that one of important sources of such emotional drives affecting decision making is bodily responses that are represented in brain regions (Craig, 2009; Damasio, 1994). In this article, empirical evidence for the functional associations of the brain and body accompanying decision making will be shown as follows. (1) Heart rate responses and concentration of inflammatory cytokine (IL-6) can predict acceptance or rejection of an unfair offer in an economical negotiation game, the Ultimatum Game. Activation of the anterior insula mediates relationship between bodily states and decision making. (2) Sympathetic responses reflected by secretion of adrenaline are represented in brain regions such as the midbrain, anterior cingulate cortex, and anterior insula, and furthermore can determine exploration of decision making in a situation where an action-outcome contingency is stochastic and unstable. These findings suggest beneficial roles of emotion and bodily responses in decision making.

Keywords: decision making, emotion, somatic marker hypothesis, brain, body

A 17th century philosopher, Benedict de Spinoza wrote:

We may, under the guidance of reason, seek a greater good in the future in preference to a lesser good in the present, and we may seek a lesser evil in the

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present in preference to a greater evil in the future (*Ethics*, part 4, proposition 66)[1].

This statement seems to represent a person who makes a rational decision, as traditional theories in economics have described as *homo economicus* (Persky, 1995). However, Spinoza further remarked:

The knowledge of good and evil is nothing else but the emotions of pleasure or pain, in so far as we are conscious thereof (*Ethics*, part 4, proposition 8).

He saw through whether it is good or evil should be totally relative and we can have conceptions of the good or evil only thorough our experiences of positive or negative emotions. Therefore, our judgment of whether it is good or evil and preferences based on the judgment are inevitably determined by emotions. Then, what are emotions in this sense?

By emotion, I mean the modifications of the body, whereby the active power of the said body is increased or diminished, aided or constrained, and the ideas of such modifications (*Ethics*, part 3, definition 3).

In this meaning, emotions are not so called basic emotions such as happiness, anger, sadness, or surprise, but changes of bodily states caused by external or internal stimuli and awareness of such bodily changes. In Spinoza's thought, we make decisions about what is a good thing, what we should take, and what most will benefit us, based on our own emotions colored by our bodily states.

Such thoughts about emotions and decision making have been succeeded to modern behavioral economics and neuroeconomics. In spite of a long history of microeconomics supposing that our decisions are based on logical and exact computation of cost-benefit balances or efficacies, in the 1990s, decision making models (Loewenstein, Weber, Hsee, & Welch, 2001; Mellers, 1999) where emotional processes play key roles were presented. Indeed, for most encounters in our everyday lives, the precise values of available options and the precise contingencies between the options and outcomes are not known. In this sense, our world is uncertain. We have to decide which option is good or bad, beneficial or threatening, and to approach or to avoid, in such uncertain situations. In such cases, we sometimes rely on fast, intuitive, and impulsive reactions rather than rational deliberation. Here, this type of decision making is called "emotional decision making."

Recently, studies in cognitive neuroscience and neuropsychology are elucidating neural mechanisms underlying such emotional decision making. Especially, the somatic marker hypothesis proposed by Damasio (1994) asserted

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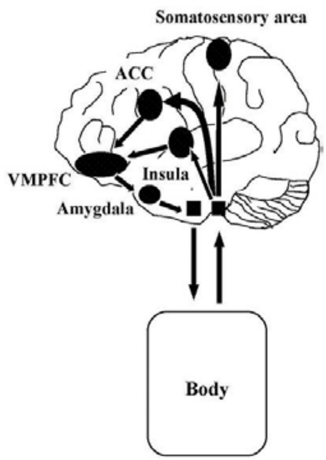
[1] Spinoza, B. (1677). *Ethics: Demonstrated in geometric order and divided into five parts, which treat*. The original text is written in Latin and translated into English by R.H.M. Elwes (1883). The text is in *MTSU Philosophy WebWorks Hypertext Edition* (http://frank.mtsu.edu/~rbombard/RB/Spinoza/ethica-front.html).

that somatic and visceral states, which are initially produced by the amygdale and then mapped in the insula and anterior cingulate cortex of the brain, are critical in guidance of decision making by quickly reducing negative alternatives labeled by bodily states and unpleasant feelings associated with risk. This model can be seen as modern *Spinozism.* Indeed, Damasio (2003) paid homage for Spinoza in his book, and regarded Spinoza as a proto-biologist of emotions. Recently, Craig (2009), who argued importance of the anterior insula (particularly right side) and anterior cingulate cortex where integrated bodily physiological states are represented, has extended this notion. Furthermore, he suggested that such bodily signals might be conveyed to the prefrontal cortex, especially its ventromedial portion, which is involved in decision making. Such neuroanatomy is considered as the rationale of the intuitional bias of decision making by bodily states.

Figure 1. *Schematic Interactions between the Brain and Body in Decision Making*



The amygdala, which is modulated by the ventromedial prefrontal cortex, initiates cascades of emotional responses, including bodily responses. Signals of the bodily responses are conveyed to the brain via afferent neural routes and projected to the somatosensory areas and to emotional areas such as the insula and anterior cingulate cortex. These emotional areas have neural connections with the prefrontal cortex and thus can affect decision making. ACC: anterior cingulate cortex, VMPFC: ventromedial prefrontal cortex (Figure 1).

This model suggests an important aspect on beneficial roles of emotions in decision making. Namely, emotions should have been developed in processes of evolution for survival of animals, and significant functions of emotions should be to make quick and efficient decision making possible for complex environments with uncertainty. Some theorists (Cabanac, 1999; Cabanac, Cabanac, & Parent, 2009) have argued that emotions might have emerged when animals advanced to terrestrial environments where were more complex and more unstable compared to water environments. To adapt to such environments, animals developed a property to evaluate goods and things in a single mental dimension of physical pleasant/unpleasant, instead of simple combinations of stimuli and responses. Thus, a prototype of emotions was somatic and physiological hedonic states and its significant function was to make a decision for a behavior based on the hedonic value. Humans should have inherited such a property. Our bodily states associated with pleasant/unpleasant feelings should work as cues for adaptive decision making. In this sense, emotions can work a kind of "emotional intelligence" to solve difficult problems of decision making in uncertain situations, which computations only in the pure intelligence system cannot solve.

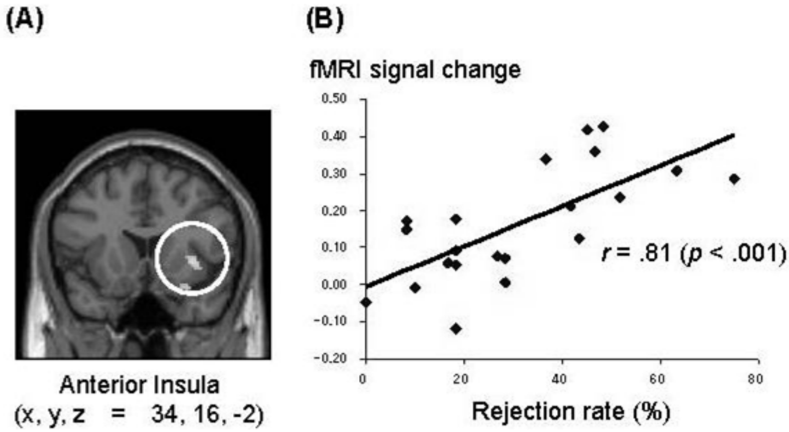
One of the problems of the somatic marker hypothesis is that it remains unclear what causal roles emotions and/or physiological bodily states would play in decision making, and how emotions and/or bodily states would change decision making, especially under uncertainty. Indeed, empirical evidence about physiological responses accompanying decision making is still little and restricted to findings through skin conductance responses (Dunn, Dalgleish, & Lawrence, 2006). Furthermore, though this model argues that unpleasant feelings and somatic markers can reduce negative alternatives linked with risk and can contribute to quick decision making, generally the speed of sympathetic responses reflected by skin conductance responses and their afferent feedback to the brain are too slow to influence decision making on line. Therefore, we are conducting several lines of studies to expand understanding about beneficial roles of emotions and accompanying bodily signals in decision making.

Physiological and neural correlates of economical decision making

We explored possible roles of physiological bodily signals in economical decision making by using a well-known experimental paradigm; the Ultimatum Game. This task is a simple negotiation game where two players are given the opportunity to split a sum of money. One player takes a role of the proposer, and the other, the responder. The proposer makes an offer as to how this money should be split between the two. The responder can either accept or reject this offer. If it is accepted, the money is split as proposed, but if it is rejected, neither player receives anything. The standard economic solution to the Ultimatum Game for the responder is to accept any offer, even the smallest sum of money, on the reasonable grounds that any monetary amount is preferable to zero. However, as easily imagined, unfair low offers are sometimes rejected. Rejection is considered as an emotional decision (cf. aversion to unfairness) contrary to a rational decision of acceptance. Participants in this task should be faced with a conflict between the two options and have to overcome such a conflict to make a decision.

As an index of physiological responses in this situation, we measured responders' heart rate during a task of the Ultimatum Game, time-locked to presentation of offers (Osumi & Ohira, 2009). Transient cardiac deceleration was used as an index of the orienting response. The orienting response, which usually happens within a few seconds after the onset of stimulus presentation, has been thought to reflect perception of significance of the stimulus and capture of attention. The typical cardiac orienting response was observed 1 second after an unfair offer, only when the offer was rejected. The merit of this physiological index is that it is sensitive because this response is governed by the vagus nerve system thus can happen with a short latency, compared to sympathetic activities such as the skin conductance response which has been often used. In this task, it usually takes several seconds to make a decision. Specifically when an offer is unfair, the decision latency is sometimes over 5 seconds because of a conflict between a reasonable acceptance and an emotional rejection (Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006). Our results showed that the bodily response precedes conscious decision making. Thus, in this sense, the body knows which alternative will be chosen probably before consciousness knows that. Consistently with a previous study (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003), another study of ours using functional magnetic resonance imaging (fMRI) confirmed involvement of the anterior insula in emotional rejection in the Ultimatum Game (Ohira & Osumi, 2009). In this study, we made contrasts of brain activity between in the Ultimatum Game and in the Dictator Game where participants could not decide acceptance and rejection of an offer but money was automatically split as proposed. This comparison enables us to draw brain activation reflecting pure decision making processes by subtracting other processes such as evaluation about fairness of the offer and initial emotional reactions to the offer, which might be contained in both games. The results showed that activation of the right anterior insula robustly predicted the rejection rate of unfair offers, suggesting that the insula is indeed involved in decision making (Figure 2).

Figure 2. *Activation of the Right Anterior Insula During a Task of the Ultimatum Game (A) predicted the rate of rejection of unfair offers (B), suggesting that the anterior insula, especially its right side, might be involved in emotional biasing of decision making*



Another line of evidence comes from our studies on roles of an inflammatory cytokine, interleukin (IL)-6 in decision making in the Ultimatum Game. Cytokines are proteins mainly secreted by immune cells and work for communication between immune cells. Some kinds of inflammatory cytokines including IL-6 can affect brain functions partly by afferent vagus routes and partly by breaking leaky sites of the blood-brain barrier. Typical effects of the inflammatory cytokines on the brain are known as "sickness responses" (Dantzer, O'Connor, Freund, Johnson, & Kelley, 2008) which are characterized by symptoms of depression-like unpleasant feelings, fatigue, pain, helplessness, impaired motivation and cognitive abilities, fever, and facilitated tones of sympathetic and endocrine activities. An fMRI study using vaccination to increase peripheral inflammatory cytokines revealed that functional neural mechanisms of the "sickness responses" are the afferent neural route including the midbrain, thalamus, amygdala, and finally mid/anterior insula (Harrison et al., 2009). Based on these previous findings, we predicted that levels of IL-6 could influence decision making by affecting activity of the insula. This prediction was confirmed by our finding that baseline levels of IL-6 negatively and significantly correlated with rejection rates for unfair offers in the Ultimatum Game (r = -.72, unpublished data): the higher concentration of IL-6 in peripheral blood, the lower rate of rejection for unfair offers. Furthermore, our preliminary fMRI data clarified that this relationship between IL-6 levels and rejection rates for unfair offers was mediated by activation of the insula. This study also provides further evidence that bodily states colored by inflammatory cytokines can modulate brain functions and in turn, affect decision making. It should be noted that participants did not precisely recognize their heart rate orienting response, cytokine levels, and the degrees of activation in their insula cortex. Furthermore, participants' rating of their subjective affective states (cf. pleasant-unpleasant) did not predict their decision making. Thus, the somatic marker can work implicitly and almost unconsciously.

Specific responses of psychopathic individuals in the Ultimatum Game also provide an insight about roles of emotions in decision making (Osumi et al., 2009). Psychopathic individuals often involve antisocial behaviors with no regard for social norms or relationships with other people. The hallmark of psychopathy is an affective impairment. Psychopathic individuals fail to elicit electrodermal responses and reduced activation of the affective neural circuit in responses to aversive stimuli (Benning, Patrick, & Iacono, 2005; Birbaumer et al., 2005; Osumi, Shimazaki, Imai, Sugiura, & Ohira, 2007). In line with that notion, we inferred that psychopathic individuals would show less involvement of their emotions and thus rather show more rationality in decision making. Our results supported this prediction. Normal adults with high tendency of psychopathy who played the Ultimatum Game as the responders indicated lack of the cardiac orienting responses and insular activation, and less rejection to unfair offers, compared to their counterpart with low tendency of psychopathy. Psychopathic individuals show more rational decision making like *homo economicus* as traditional economics models described (Persky, 1995) or *utilitarian*, probably because of their impairment of emotions and accompanying bodily responses[2].

Sympathetic bodily responses mediates exploration-exploitation trade-off in uncertain decision making

Two typical strategies of decision making are known: exploration and exploitation. Exploration is a strategy characterized by trying new options and actions to seeking for reward and resource usually in trial-and-error manners. On the other hand, exploitation is a strategy characterized by sticking to currently appropriate options and actions to maintain reward and resource. For survival of animals, the balance of exploration and exploitation is critical in choices of meals and mates. The balance of the two strategies is observed in relatively primitive animals such as fungi that is faced against a conflict between growth at local site or sending out hyphae to distant site, or ants who are wondering whether they should settle at the current site or build a new nest (Cohen, McClure, & Yu, 2007). Generally, exploitation is a better policy when environments are stable because such a policy can provide promising reward with minimum costs. However, when environments are instable, animals including humans have to adopt exploration to find changes of environment, to get possible reward, and to avoid possible risks. However, because the total amount of resource is limited, relationship between exploration and exploitation should be trade-off. We must decide at how much rates we should take exploration and at how much rates we should take exploitation. The most difficult problem is, as our situations are usually uncertain, it is not clear how much rate of mixing of the two strategies is the most adaptive. How can we solve this problem and decide rates of the two options in a specific situation? Especially, how can animals and humans overcome temptation of exploitative sticking to previously acquired rewarding options and drive themselves into potentially risky exploration, even when environments are instable? We speculate that emotions and accompanying bodily states forcibly determine it and make us to choose an option at a specific moment. This might be one of beneficial roles of emotions in decision making.

To examine this hypothesis, we recently conducted a combined neuroimaging study using ^{15}O-positron emission tomography (PET) and measurement of sympathetic activities (heart rate, heart rate variability, blood pressure, and concentrations of adrenaline and noradrenaline) during a stochastic reversal learning task, which can simulate instable contingencies between options, and outcomes (unpublished data). In this task, participants chose one of two stimuli to gain monetary reward. One advantageous stimulus was associated with reward at a probability of 70% whereas another disadvantageous stimulus was associated with

[2] Of course, behaviors of psychopathic individuals should highly depend on situations and game contexts. We indicated that they less rejected unfair offer in a single trial Ultimatum Game where rejection cannot affect the proposer. However, it is predicted that they might more reject unfair offers in a repeated trial Ultimatum Game where rejection can work as a threat to the proposer and result in increase of gain.

reward at a probability of 30%. Participants did not know this contingency and thus they have to find it though trials and errors. In an initial learning stage, they conducted 120 trials of this task. After that, in a reversal learning stage with another 120 trials, the contingency between options and outcomes was suddenly reversed without any explicit instructions; the previously advantageous stimulus became disadvantageous (30% reward) and the previously disadvantageous stimulus became advantageous (70% reward), respectively. In this stage, participants had to suppress the dominant tendency to choose the previous advantageous option and to learn new contingency. Probably another important thing for them is that they learnt that contingencies between options and outcomes are not stable but variable in their experimental situation.

To evaluate the degree of exploration, we calculated Shanon's conditional entropy (*H*) as an index of the amount of randomness of choices (Advantageous stimulus vs. Disadvantageous stimulus) under states of outcomes in the previous trial (Reward vs. Non-reward). A conditional probability (a probability of a behavior *a* under a state *S*) is determined as follows,

$$P(a \mid S) = \frac{Num(a \mid S) + c}{\sum_k \{Num(k \mid S) + c\}}$$

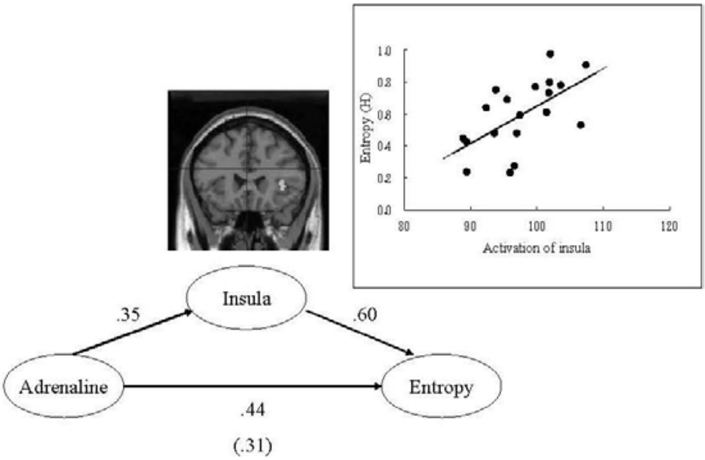
where $Num(a|S)$ is a number of selection of a behavior *a* under a state *S*. $Num(k|S)$ is a number of total behaviors *k* under a state *S*. A constant *c* is fixed to 1 here. Then, the entropy *H* is calculated as follows,

$$H = -\frac{1}{N}\sum_S \sum_a P(a \mid S)\log_2 P(a \mid S)$$

where *N* is a number of states *S*. $H = 0$ means null randomness and $H = 1$ means complete randomness.

A regression analysis revealed that increase of peripheral adrenaline was associated with increase of entropy of decision making during the reversal learning stage (β=.43, p<.05). Thus, increased sympathetic activity leads to facilitation of exploration in decision making. Analyses of PET images showed that increase of peripheral adrenaline during reversal learning correlated activation in the anterior insula, dorsal anterior cingulate cortex, and dorsal pons, which are main sites of afferent routes from the body to the brain. In addition, increase of entropy of decision making during reversal learning correlated activation in the anterior insula and ventromedial prefrontal cortex. Finally, a statistical mediation analysis revealed that activation of the insula mediated association between sympathetic activity reflected by increase of adrenaline and entropy of decision making during reversal learning (Figure 3). Taken together, bodily states reflected by sympathetic activity can work as a source of judgment about the trade-off between exploration and exploitation. Briefly, animals and humans might become more explorative when they are more excited.

Figure 3. *Activation of the right insula during a stochastic reversal learning task mediates a correlation between levels of adrenaline and entropy (exploration) in decision making*



However, on the other hand, we should also notice that bodily states could be modulated based on evaluation of contingencies between options and outcomes. We previously showed that suppression of cardiovascular responses happened within few minutes after onset of the decision making task under uncertainty (Kimura, Ohira, Isowa, Matsunaga, & Murashima, 2007). Probably, this phenomenon might be interpreted as an energy-saving coping to an uncertain situation. Allocation of much biological energy in such a situation might be dangerous. We further indicated that neural basis of this phenomenon is the top-down control by the anterior cingulate cortex of the brain over cardiovascular activities via modulation of sympathetic and parasympathetic activities (Ohira et al., 2010). Thus, a bi-directional circuit between the brain and body is continuously working to evaluate contingencies between available options and possible outcomes, to modulate decision making and behaviors optimally, and to adapt to given environments. Bodily signals represented the somatic marker can be recognized as a manifestation of one aspect of such a circuit.

Conclusion

As described above, cumulating evidence has clarified that emotions and accompanying bodily states are substantially associated with decision making. This phenomenon should be a key to explore roles of emotions as a manifestation of implicit emotional intelligence, which makes beneficial contributions for our adaptation to environments. However, it should be considered whether emotions are always beneficial and adaptive in decision making.

Rational decisions without emotional responses in the Ultimatum Game typically observed in psychopaths or *homo economicus* can provide monetary reward. Thus, at least in a short-term range, rational acceptance is more adaptive compared to emotional rejection. However, such rational decision might be harmful in a long-term range, probably by reducing reputation of the person in his/her group ("He/She is a chicken"), and then by increased risk of intimidation or betrayal. In this sense, by emotions, we can overcome the short-term utilitarianism and chose more long-term beneficial options (e.g. altruistic punishment, reputation). However, too strong emotional responses might make negotiation impossible and harm social adaptation. On the other hand, a cool-headed exploitation strategy can promise constant reward at least in a short-term range. However, it might be harmful to stick to the currently and locally most optimal option, because such policy can miss potential larger reward. However, again in this case, too strong emotions might lead to too instable and mostly random decisions, which are apparently maladaptive. Taken together, influences of emotions on decision making are linked both merits and demerits. Therefore, appropriate regulation of emotions and optimal tuning of emotional influences on decision making is critical for adaptation. Detailed mechanisms of such regulation and tuning of emotions which might be embedded in our biological systems are very open for future research.

Finally, I would like to close this article by Spinoza' words:

... a mental decision and a bodily appetite, or determined state, are simultaneous, or rather are one and the same thing, which we call decision ... (*Ethics*, part 3, proposition 2, note).

References

Benning, S.D., Patrick, C.J., & Iacono, W.G. (2005). Psychopathy, startle blink modulation, and electrodermal reactivity in twin men. *Psychophysiology, 42,* 753-762.

Birbaumer, N., Veit, R., Lotze, M., Erb, M., Hermann, C., Grodd, W., & Flor, H. (2005). Deficient fear conditioning in psychopathy. *Archives of General Psychiatry, 62,* 799-805.

Cabanac, M. (1999). Emotion and phylogeny. *The Japanese Journal of Physiology*, *49*, 1-10.

Cabanac, M., Cabanac, A.J., & Parent, A. (2009). The emergence of consciousness in phylogeny. *Behavioral Brain Research, 198*, 267-272.

Cohen, J.D., McClure, S.M., & Yu, A.J. (2007). Should I stay or should I go? How the human brain manages the trade-off between exploitation and exploration. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 362,* 933-942.

Craig, A.D. (2009). How do you feel-now? The anterior insula and human awareness. *Nature Review Neuroscience*, *10*, 59-70.

Damasio, A.R. (1994). *Descartes error: Emotion, reason, and the human brain*. Avon.

Damasio, A.R. (2003). *Looking for Spinoza: Joy, sorrow, and the feeling brain*. Mariner Books.

Dantzer, R., O'Connor, J.C., Freund, G.G., Johnson, R.W., & Kelley, K.W. (2008). From inflammation to sickness and depression: When the immune system subjugates the brain. *Nature Review Neuroscience, 9*, 46-56.

Dunn, B.D., Dalgleish, T., & Lawrence, A.D. (2006). The somatic marker hypothesis: A critical evaluation. *Neuroscience and Biobehavioral Reviews, 30*, 239-271.

Harrison, N.A., Brydon, L., Walker, C., Gray, M.A., Steptoe, A., Dolan, R.J., & Critchley, H.D. (2009). Neural origins of human sickness in interoceptive responses to inflammation. *Biological Psychiatry*, *66*(5), 415-422.

Kimura, K., Ohira, H., Isowa, T., Matsunaga, M., & Murashima, S. (2007). Regulation of lymphocytes redistribution via autonomic nervous activity during stochastic learning. *Brain, Behavior, and Immunity*, *21*, 921-934.

Knoch, D., Pascual-Leone, A., Meyer, K., Treyer, V., & Fehr, E. (2006). Diminishing reciprocal fairness by disrupting the right prefrontal cortex. *Science*, *314*, 829-832.

Loewenstein, G.F., Weber, E.U., Hsee, C.K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin*, *127*, 267-286.

Mellers, B. (1999). Emotion-based choice. *Journal of Experimental Psychology: General, 128*, 332-345.

Ohira, H., Ichikawa, N., Nomura, M., Isowa, T., Kimura, K., Kanayama, M., ... Yamada, J. (2010). Brain and autonomic association accompanying stochastic decision-making. *Neuroimage*, *49*, 1024-1037.

Ohira, H., & Osumi, T. (2009, August). *Body knows decision: Neural and physiological bases of emotional decision-making in the Ultimatum Game.* Paper presented at the annual meeting of International Society for Research on Emotion, Leuven, Belgium.

Osumi, T., Nakao, T., Ohira, H., Kasuya, Y., Shinoda, J., & Yamada, J. (2009, October). *Dual deficit in psychopathy: Neural correlates of psychopathic traits within social exchange*. Paper presented at the 49th annual meeting of Society for Psychophysiological Research, Berlin, Germany.

Osumi, T., & Ohira, H. (2009). Cardiac responses predict decisions: An investigation of the relation between orienting response and decisions in the ultimatum game. *International Journal of Psychophysiology, 74*, 74-79.

Osumi, T., Shimazaki, H., Imai, A., Sugiura, Y., & Ohira, H. (2007). Psychopathic traits and cardiovascular responses to emotional stimuli. *Personality and Individual Differences, 42*, 1391-1402.

Persky, J. (1995). Retrospectives: The Ethology of Homo Economicus. *The Journal of Economic Perspectives*, *9*, 221-231.

Sanfey, A.G., Rilling, J.K., Aronson, J.A., Nystrom, L.E., & Cohen, J.D. (2003). The neural basis of economic decision making in the Ultimatum game. *Science, 300*, 1755-1758.

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