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The neural basis of social tactics: An fMRI study

Hiroki Fukui,[a,*] Toshiya Murai,[a] Jun Shinozaki,[b] Toshihiko Aso,[b] Hidenao Fukuyama,[b] Takuji Hayashi,[a] and Takashi Hanakawa[b]

[a]*Department of Neuropsychiatry, Kyoto University Graduate School of Medicine, Shogoin-Kawaharacho 54, Kyoto 606, Japan*
[b]*Human Brain Research Center, Kyoto University Graduate School of Medicine, Shogoin-Kawaharacho 54, Kyoto 606, Japan*

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One of the most powerful ways of succeeding in complex social interactions is to read the minds of companions and stay a step ahead of them. In order to assess neural responses to reciprocal mind reading in socially strained human relationships, we used a 3-T scanner to perform an event-related functional magnetic resonance imaging study in 16 healthy subjects who participated in the game of *Chicken*. Statistical parametric mapping showed that the counterpart effect (human minus computer) exclusively activated the medial frontal area corresponding to the anterior paracingulate cortex (PCC) and the supramarginal gyrus neighboring the posterior superior temporal sulcus (STS). Furthermore, when we analyzed the data to evaluate whether the subjects made risky/aggressive or safe/reconciliatory choices, the posterior STS showed that the counterpart had a reliable effect regardless of risky or safe decisions. In contrast, a significant opponent × selection interaction was revealed in the anterior PCC. Based on our findings, it could be inferred that the posterior STS and the anterior PCC play differential roles in mentalizing; the former serves as a general mechanism for mentalizing, while the latter is exclusively involved in socially risky decisions.

Keywords: Mentalizing; Theory of mind; Game theory; Chicken; fMRI; Prefrontal cortex

Social cognition is the ability to construct representations of the relationships between the self and others and to use these representations flexibly in order to guide social behavior (Adolphs, 2001). Researchers of social cognition have focused on the neural correlates of our ability to attribute intentions to the self and others, calling this ability the "theory of mind" (Premack and Woodruff, 1978), the "intentional stance" (Dennett, 1987), or "mentalizing" (Frith and Frith, 1999).

This cognitive function is said to be impaired in some pathological conditions such as autism (Baron-Cohen et al., 1985), schizophrenia (Frith and Corcoran, 1996), and cerebral lesions (Stone et al., 1998). Functional imaging studies of normal volunteers have revealed the neural substrates underlying the mentalizing mechanism. In several studies, participants were asked to infer the mental states of characters in stories or cartoons (Fletcher et al., 1995; Brunet et al., 2000; Gallagher et al., 2000; Vogeley et al., 2001) and from expressions in photographs (Baron-Cohen et al., 1999) or to attribute mental states to animations of geometric shapes (Castelli et al., 2000). Taken together, these studies have implicated a consistent network of brain areas in mentalizing, including the anterior paracingulate cortex (PCC), the posterior superior temporal sulcus (STS) at the temporoparietal junction, and the temporal pole (Frith and Frith, 2003). While these studies employed "explicit" and "offline" mentalizing tasks involving additional cognitive demands, more recent studies (McCabe et al., 2001; Gallagher et al., 2002; Rilling et al., 2004; Decety et al., 2004) have probed the neural correlates of "implicit" and "online" mentalizing in participants actually immersed in a social interaction with a partner who is outside the scanner. In a functional magnetic resonance imaging (fMRI) study, McCabe et al. (2001) suggested that when participants played an economic trust game against human and computer opponents, a human–computer comparison of brain activation within the group of cooperators showed heightened responses in a number of areas including the medial prefrontal cortex. Gallagher et al. (2002) used positron emission tomography to examine normal subjects while playing the rock–paper–scissors game. The subjects were told that they were playing with either another person or a rule-following, preprogrammed computer. The only region showing significant brain activity associated with the difference in opponent was the bilateral anterior PCC. Rilling et al. (2004) used Prisoner's Dilemma and the Ultimatum Game to scan the brains of players matched with that of another person or a computer. In both games, they observed activation in several areas, including the anterior PCC (in their paper, it is abbreviated as APC) and posterior STS. Finally, Decety et al. (2004) reported that subjects who played an originally designed computer game showed significant activation of the orbitofrontal cortex when they were cooperating with a person, while activation of the medial prefrontal cortex was

* Corresponding author. Fax: +81 75 751 3246.
E-mail address: xhirokix@kuhp.kyoto-u.ac.jp (H. Fukui).
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observed when they were competing with a partner outside the scanner.

In this study, we used the game of *Chicken* as an implicit mentalizing task. This game of *Chicken*, which was highlighted in the film "Rebel without a Cause," is an extremely risky game in which two players drive vehicles toward each other; the first to swerve loses and is given the humiliating title "chicken." The underlying principle is an important method of tight negotiation; thus, Bertrand Russell famously compared the game of *Chicken* to nuclear brinkmanship. In our study, we have not used the real game of *Chicken* in which players drive cars. Instead, we have used a game theoretical version of the game of *Chicken*. In this version, two players play a kind of gambling game, in which their gains or losses are determined by their respective behaviors. Therefore, each player should constantly anticipate the opponent's decisions while making his own decisions. The Prisoner's Dilemma is another famous game with game theoretical conceptualization that has been applied by Rilling et al. (2002, 2004) in their fMRI studies. It has a similar setting; two players attempt to maximize their profit while predicting the opponent's imminent behavior. In the Prisoner's Dilemma, a player would benefit by defecting irrespective of the other's move. However, in the Prisoner's Dilemma, despite the fact that the noncooperative state is evolutionarily stable, many natural species show altruism, with individuals bearing costs for the benefit of others (Wilkinson, 1984; Clutton-Brock et al., 1999). This conundrum has led to a considerable gap between theory and

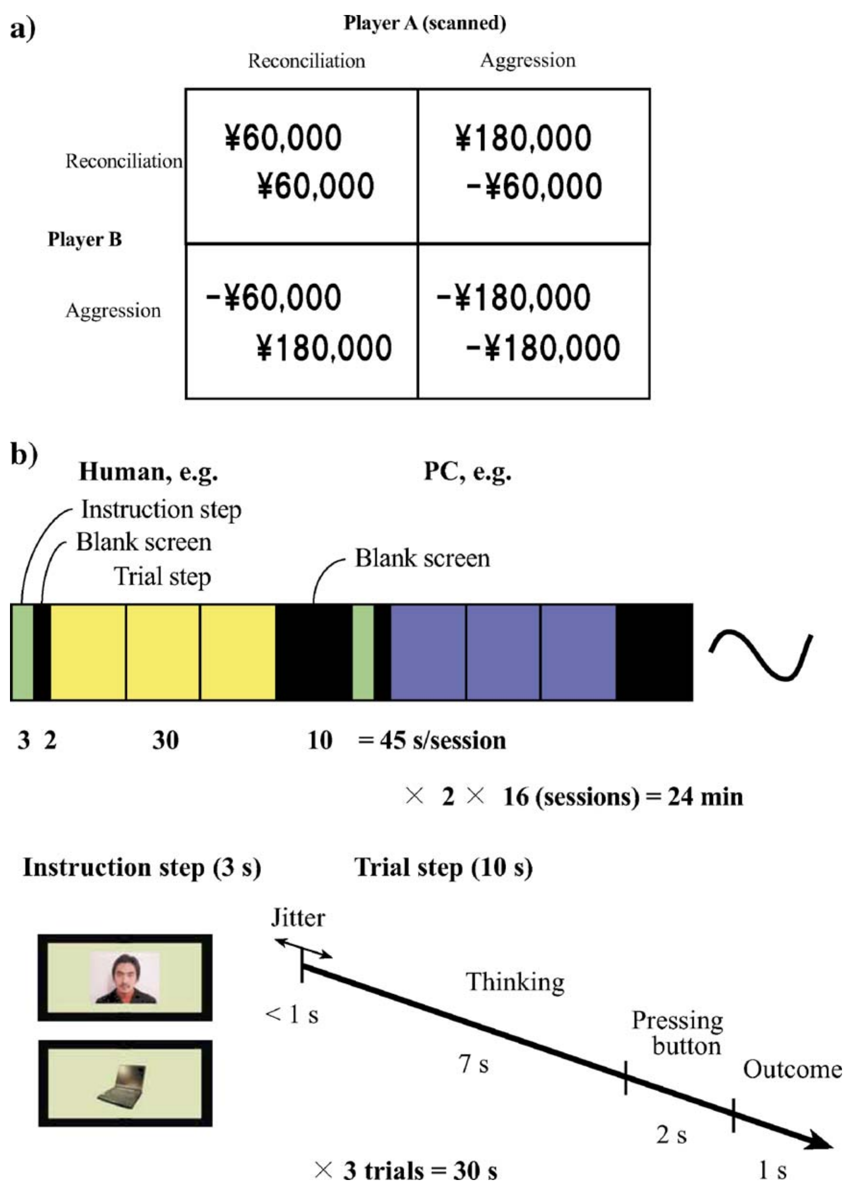

Fig. 1. Experimental design. (a) Payoff matrix for the "game of Chicken." (b) Time course of an fMRI study. All sessions were separated by a 10-s display of a blank screen and each session began with a 3-s display of a photograph of the opponent (human or computer). This prompt was followed by 3 consecutive trials of the same type, with each trial lasting 10 s. Every session (16 sessions in all) comprised 3 trials of 2 types each (human–human and human–computer). Each trial began with a 7-s preparation interval (with a jitter of ±0.5 s). During the next 2-s epoch, subjects chose to aggress or reconcile, and the trial outcomes were then displayed for 1 s.