What is the important factor that influences the decision-making in a human-robot competitive game?

Hideyuki Takahashi¹, Chinatsu Saitou¹, Atuhiho Toyomaki²
Hiroyuki Okada¹, Takashi Omori¹

¹ Tamagawa University, ² Hokkaido University
E-mail: hideman@lab.tamagawa.ac.jp

Abstract—In our previous studies we have shown that the complexity of the decision sequence in a matching pennies game, (a simple zero-sum game), increases when a participant believes his/her opponent is a human player, even if the opponent is actually a computer program. These findings suggest that mental attribution to a game opponent strongly influences the decision-making in an interpersonal game. However, the critical factors which influence decision-making in a human vs. robot game are still not fully known.

In this study, participants played the matching pennies game with a communication robot, and we investigated the correlation between the entropy of the decision sequence and various other factors included in the human-robot interaction. We found that the mean entropy in each game trial in which the participant’s gaze followed the robot’s head turn was significantly higher than when gaze was not followed, although the apparent humanity of the robot, as measured by a questionnaire, didn’t correlate with the entropy. These findings suggest that one of the key factors that influences decision-making in an interpersonal game is an implicit awareness of the opponent’s gaze.

Keywords—Decision-making, Matching pennies game, Human-Robot Interaction

1. Introduction

Classical learning theories have assumed that animal behavior is mainly governed by principles of reward optimization. However, recent findings in human participants suggest that their behavior often deviates from the reward optimization principle, especially in the context of social interaction. Hence, many researchers have begun to focus on the importance of social interaction, and have shown that decision-making process in this context is influenced by various other factors such as emotion and social norm, rather than the primary reward usually seen in finite experimental environments.[Citations should be included for the last claims.] However, few studies have investigated this influence using actual social interaction, because non-controlled human-human interaction contains numerous extraneous factors, making it difficult to narrow down the key factors that most strongly influence the decision-making process.

Our goal in this study, was to test the value of a factor suspected to influence decision-making in a human-robot interaction (a pseudo, well-controlled social interaction), so as to investigate an aspect of neural information processing in social interaction.

2. The influence of another person in a game decision-making process

The presence of another person is known to strongly influence decision-making [1][2]. In our previous studies, we investigated how decision-making was influenced by an instruction indicating that the opponent was a human player or a computer program, using the matching pennies game, (a simple zero-sum competitive game) [3]. In those investigations, we quantified the complexity of the decision-sequence as entropy $H$ with the following equation:

$$H = -\sum \sum p(d | s) \log p(d | s)$$

The variable $d$ indicates a decision option in the game and $s$ indicates a state that is consistent with prior decisions made by both the participant and his/her opponent in the preceding two trials.

The probability $p(d | s)$ is calculated from the conditional frequency of $d$ for each value of $s$. Entropy $H$ therefore represents the complexity of the decision sequence, and higher values of $H$ indicate higher complexity in the decision sequence.

![Fig.1. Means of entropy and accumulated reward in each session (n=19)](image)

In the experiment, there were two conditions; one the HO condition, and the other the CO condition. In both conditions, the participants’ opponent was actually the computer program, which made a random decision. However, in the HO condition, participants were instructed that their opponent was a human player. Fig.1 shows the means of entropy and accumulated reward in
each session. The mean entropy in the HO condition was significantly higher than in the CO condition, although there was no significant difference in accumulated reward between the two conditions.

The results suggest that the presence of another person strongly influences decision-making in an interpersonal competitive game. However, it is still unclear what key factor related to the presence of another person could most influence decision-making in this game because of the complexity of human-human interaction.

3. Search for a key factor influencing decision-making in a human-robot competitive game

3.1. Overview of the experiment

To overcome the difficulties in investigating human-human interaction, we developed a human-robot competitive game in which participants played the matching pennies game with a communication robot (Fig. 2; Please see Web-based video for more details.). The communication robot was completely controlled by an experimenter. We deemed human-robot interaction to be a more controlled experimental setting than typical human-human interaction.

At first, all participants played the matching pennies game for 20 trials with the robot. Participants were motivated by the instruction that they would get a large reward if they won the game repeatedly. Next, ten participants are asked to imitate the robot's movements for two minutes while the other nine participants were simply asked to observe the robot's movements during the same period. (In this paper, we do not discuss the difference between these two participant groups.) Then, all participants played the matching pennies game again for 20 trials. Before playing each game, participants had a short conversation with the robot and the robot suddenly turned its head during the conversation. In addition, participants were asked to rate the humanity of the robot in a seven-level questionnaire at the beginning and end of the experiment.

3.2. Results

There were two types of the participant behavior in response to the robot’s head turning. In one, the participant followed the robot’s gaze when the robot turned its head, and in the other, the participant didn’t follow the robot’s gaze. There were nineteen participants and each participant played the game twice, for a total of 40 trials. Hence, there were a total of thirty eight games. Numbers don’t match] played. The robot’s gaze was not followed by participants in five games overall, but was followed in the remaining games. The mean entropy in the games with gaze-following was significantly higher than that without gaze-following (Fig. 3, t-test, p<0.01). However, the perceived humanity of the opponent (as measured by the questionnaire), did not differ between the two types of games.

These results suggest that following the robot’s gaze strongly influenced decision-making in this human-robot competitive game, even though this behavior did not correlate with the perceived humanity of the robot.

4. Discussion and conclusion

Our previous studies have suggested that the presence of another other person during decision-making has significantly less influence in autistic participants despite their being able to recognize the presence of the other person explicitly and reported that they changed their behavior depending on this recognition [3]. This discrepancy can be explained within a model in which explicit and implicit information processing for the humanity perception exist separately in the brain and implicit information processing for gaze awareness mainly changes the entropy in the game.

In the future, we would like to explore the neural circuitry corresponding to explicit and implicit information processing for humanity perception and shed more light on the multi-dimensionality of humanity perception in decision-making.

References