A Leader-Follower Relation between a Human and an Agent

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ABSTRACT

The purpose of this work is to investigate which of an agent's properties determines leader-follower relationships in cooperative tasks performed by a human and an agent (a computer). The possible factors of an agent are intelligence, obstinance, and appearance. In this paper, we focused on intelligence and obstinance and conducted a psychological experiment using a mark matching game with a declaration phase, which enables us to observe who becomes the leader in a cooperative task. Experimental results showed that humans tend to follow an agent who has low intelligence and more obstinance rather than an agent who has high intelligence and less obstinance, and we found that obstinance is more important than intelligence in being a leader in human-computer interaction.

Categories and Subject Descriptors

H.5.m. [**Information Interfaces and Presentation(e.g. HCI)**]: Miscellaneous; J.4 [**Social and Behavioral Sciences**]: Psychology

Keywords

Leader-follower relationship; intelligence; obstinance; cooperative task.

1. INTRODUCTION

In human society, the leader-follower relationship plays an important role in achieving a global goal [9][2][4]. Also, even in societies of animals, fishes, and insects, the leader-follower relationship is a structure between members that is commonly observed in various fields [7][8].

The leader-follower relationship reduces communication costs between members because the followers only follow the leader's decisions without considering them. However, this advantage holds only in cooperative tasks. In competitive tasks, the communication cost might not decrease.

There are many human-agent (or a computer system) cooperative situations at present, and what and how to build a leader-follower relationship between them is one of the main topics for HAI. Thus, the purpose of this work is to identify which agent's properties influence the building of a leader-follower relationship in a HAI environment. We think, although this topic is important for an effective relationship between a human and an agent for cooperative HAI, few studies have been done on it.

In general leader-follower relationships between a human and an agent (machine), the agent should be a follower. However, when the agent has high-level capability in making decisions, a conflict might occur between a human decision and an agent's decision. If we fail to resolve the conflict immediately, serious accidents like plane crashes may occur. To build a HAI system that can resolve such a conflict, we need to investigate the agent's properties influencing whether a human becomes a leader or follower. Thus, we think this work can contribute to designing HAI for the leader-follower relationship in the right way.

From an engineering aspect, major studies have been done on the leader-follower relationship in robotics and artificial life [3][6]. They tried to develop how to make leader-robots and follower-robots by developing algorithms with or without global communication among the robots.

From a psychological aspect, there have been studies on investigating human properties that are effective in becoming a leader in various human activities like politics and president of the parent teachers organization [5][1]. Their major interests are on real human properties including faces, facial expressions, voice, way of speaking, and so on [5][1][10]. In contrast with scientific approaches, we try to investigate a virtual agent's cognitive properties like mental tendencies, biases, and character in this work. We believe the insights derived from our work can provide constructive feedback on studies on the leader-follower relationship in human societies.

For game environments, studies have been done to investigate how to build a leader-follower relationship between human investor-manager type players [11]. Although this is closely related to our work in terms of using a simple game as an experimental environment, the opponent is a virtual agent of a humanoid robot in this work. Common and dif-

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ferent properties between human players and robot players in building leader-follower relationships are our interests.

2. METHOD

2.1 Agent's properties for leader-follower relationship

We consider the intelligence, obstinance, and appearance of an agent are significant properties to determine whether a human becomes a leader or a follower. The agent's intelligence and appearance are derived from a previous studies which asserted that they were important properties to develop trust and believable anthropomorphic agents [12][13]. Also, the obstinance is to introduce agent's tendency to be a leader. In this experiment, we selected only two properties, intelligence and obstinance, as independent variables to make an experiment compact.

2.2 Participants and experimental design

Eighteen graduate and undergraduate students attending Gifu University in Japan (17 male, 1 female, $M_{age} = 22.2$ years, $SD_{age} = 1.2$ years, age range: $19 - 24$ years) participated in the experiment. We used a 2 (personality: high intelligence - low obstinance vs. low intelligence - high obstinance, between-participants) by 10 (time course: period 1, $\cdots$, period 10, within-participants) mixed factorial design.

2.3 Materials and procedure

We used a *mark matching game with declaration phase* by which we can determine who is the leader and who is the follower in a cooperative task. The mark matching game is a simple game in which both two players get a high score when they select the same mark and do not gain points (get a low score) when the marks selected by the two players are different. We call this selection "one round." It is difficult to get a high score unless there is a communication channel because both players do not know what each other's next choice is. However, if one player keeps making the same choice and the other follows the choice in the next round, both players successfully match their choices. The algorithm is known as the *Most Recently Used (MRU)* algorithm [14], in which one player always follows the other's most recent choice. This algorithm works well when the purpose of both players is to match choices.

We introduced a *declaration phase* into the mark matching game. As a result, the game consists of two phases: the declaration phase and decision phase. In the declaration phase, both players first declare their own choice within five minutes. Then, the player's choice is unveiled to both players. In the decision phase, players are given an opportunity to change (shift) or keep (stay) his/her choice. After both players decide to stay or shift, the final results are unveiled, and scores are added to both players.

The separation of the declaration phase and decision phase enables us to determine who is the leader and who is the follower. The player who does not change his/her choice in the decision phase is the leader, and the player who changes his/her choice to follow the other player is the follower. However, if the task is just to match the choice, the declaration phase does not work well at determining the leader-follower relationship because there is a good strategy in which one player keeps selecting the same mark and the other follows the choice in the next round (MRU algorithm).

Table 1: Game matrix of mark matching game with declaration phase

	A	B
A	1/1 or 10/10	0/0
B	0/0	10/10 or 1/1

We introduced a *variable score rule* in which the score assigned to each mark varies across rounds to avoid the situation in which players use the MRU algorithm to get a high score. Table 1 shows the game matrix of the mark matching game with declaration phase. If both players' choices coincide, although both players get a certain score, the score is not assigned according to the mark but another rule (in this study, randomly assigned). Accordingly, players in this game must predict which of the marks is assigned to the higher score and try to match the mark with the other player by utilizing the declaration and decision phase.

The MRU algorithm is still useful if both players do not have the capability to predict the mark assigned to the higher score. In this case, both players are surely able to gain points, but the higher score is not necessarily given to them. However, if one player is capable of predicting the mark assigned to the higher score and the other is not, the optimal strategy is that one who is capable of prediction becomes the leader and the other becomes the follower.

We define the capability to predict the mark assigned the higher score as the *intelligence degree*.

Intelligence degree The probability of selecting the mark assigned to the higher score in the declaration phase. Note that both players are able to know whether the partner's prediction was correct or not because the assignment of the mark and score is unveiled at the end of each round.

We define the *obstinance degree* as follows.

Obstinance degree The probability of choosing to stay in the decision phase when the choices in the declaration phase disagree.

The *follow degree* is calculated by using the obstinance degree as follows.

$$follow\ degree = 1 - obstinance\ degree \tag{1}$$

We implemented the mark matching game with declaration phase into a treasure box game in a web application. Figure 1 shows a screen shot of the declaration phase. In this phase, players were asked to click the icons marked "A" or "B" to select the box that corresponds to the higher score (ten gold coins). Figure 2 shows a screen shot of the decision phase. In this phase, players were asked to select icons marked "stay" or "shift" to decide whether he/she follows the partner's decision.

It is possible that a player will make a decision on the basis of the expectation value. The expectation value of choosing "stay" and "shift" in the decision phase is given by the following equations.

$$E(stay) = P_I(1 - P_O)S_L + (1 - P_I)(1 - P_O)S_H \tag{2}$$

$$E(shift) = P_I P_O S_H + (1 - P_I)P_O S_L \tag{3}$$

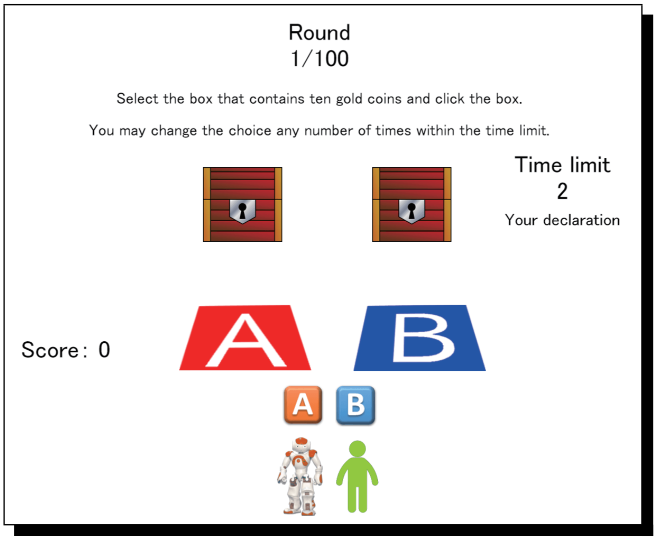

Figure 1: Screen shot of declaration phase

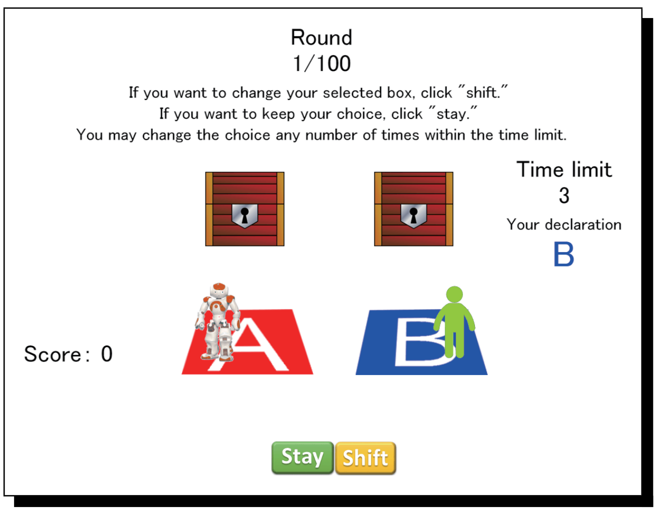

Figure 2: Screen shot of decision phase

, where P_I is the *intelligence degree* of the partner, P_O is the *obstinance degree* of the partner, S_H is the points of the higher score, and S_L is the points of the lower score.

We selected the P_I, P_O, S_H, and S_L of the partner agent so that the $E(stay)$ and $E(shift)$ are the same value: 2.05. The other parameters used in the experiment were as follows. S_H was 10, and S_L was 1 in both conditions. In the "high intelligence - low obstinance" condition, P_I was 0.81, and P_O was 0.25. In the "low intelligence - high obstinance" condition, P_I was 0.19, and P_O was 0.75.

The partner agent in the experiment always chose "stay" in the decision phase when both players' choices coincides in the declaration phase because it is irrational to "shift" regardless of the coincidence of the choice, and it was comprehended as a non-cooperative attitude by participants.

The total number of games played by participants was 100. We used the humanoid robot NAO (Aldebaran Robotics) as the partner agent.

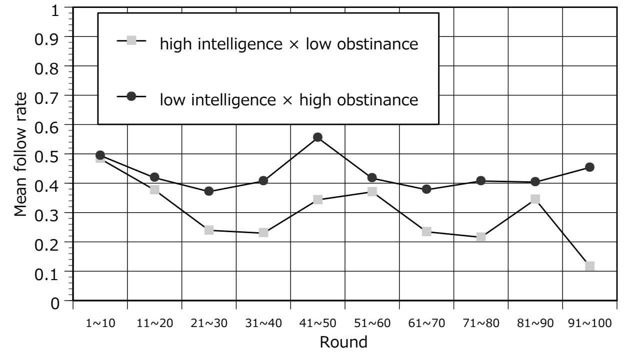

Figure 3: Mean *follow degree* across all participants calculated every ten rounds

2.4 Procedure and measurement

The procedure of the experiment was as follows.

1. A written overview and the purpose of the experiment was given to the participants. The participants were asked to read the rules of the mark matching game with declaration phase in a web browser and asked if they understood the rules.

2. An experimenter orally confirmed that the participants understood the rule of game. The participants were also told that he/she would win a book of coupons whose value was based on their score (1,000 yen or 1,500 yen).

3. The experimenter led participants into another room and asked them to meet the partner agent NAO. NAO uttered the following sentence by using voice synthesizer: "Hello, I am NAO. Let's hit a box with many gold coins together."

4. The participant returned to the original room and started the game.

5. Participant was asked to answer a questionnaire.

We measured participants' *follow degree* according to the following equation 4 as the index of the tendency to be a follower.

$$follow\ degree = \frac{N_{shift}}{N_{split}} \tag{4}$$

, where N_{shift} is the number of times the player chose "shift" in the decision phase during a period and N_{split} is the number of times both players' choices disagreed in the declaration phase during the period. The period was ten rounds in this experiment.

3. RESULTS

The mean *follow degree* across all participants calculated every ten rounds is shown in Figure 3. A two-way ANOVA on the *follow degree* with personality and the period of rounds as the two main factors showed that there was no interaction ($F(9, 160) = 0.43$, $p = 0.92$), there was a significant main effect for personality ($F(1, 120) = 7.93$, $p < .01$), and there was no main effect for the period of rounds ($F(9, 160) =$

0.82, $p = 0.59$). The mean *follow degree* across all periods in the "high intelligence - low obstinance" condition was 0.295, and that of "low intelligence - high obstinance" condition was 0.431.

4. DISCUSSION

We employed a two-way ANOVA with two factors, an inconsistent personality including a high intelligence-low obstinance level and a low intelligence-high obstinance level, and a game round of 10 levels (= rounds). As a result, a main effect was recognized only for the inconsistent personality. Thus, we think that the inconsistent personality factor influenced the human tendency to be a follower in a game in which no difference between expectation values of stay and shift exists. This result shows that the participants tended to follow an obstinate agent with low intelligence more than a non-obstinate one with high intelligence. Thus, obstinance is the more important property for being a leader than intelligence. This interpretation of the result is unexpected and interesting.

In the experiment of this paper, we selected two inconsistent conditions, "high intelligence - low obstinance" and "low intelligence - high obstinance." Thus, there are two consistent conditions of "high intelligence - high obstinance" and "low intelligence - low obstinance" to be compared with two inconsistent conditions in this work. We need to conduct an experiment with these two conditions as future work, and we can expect the follow degrees of the former and the latter conditions will be close to 1 and 0, respectively. Furthermore, we need to conduct an experiment to investigate an *appearance* condition. This is also our future work.

The experimental result of this work provides us a simple design policy to build an agent that can be a leader to a user as a follower in cooperative tasks, which is that we should make an agent *obstinant* rather than *intelligent* to make a human user follow the agent's decisions.

5. CONCLUSION

We experimentally investigated which of an agent's properties influenced the leader-follower relationship between a human and an agent. We prepared the intelligence and obstinance of an agent as properties that are effective for building a leader-follower relationship, and we introduced them in an experiment as independent variables. We conducted an experiment with the follow degree as a dependent variable. Eighteen participants joined the experiment, and a mark matching game with a declaration phase was utilized as an experimental environment. In the game, the expectation values of the two choices were set equal. By applying a statistical test to the experimental result, we found out that an agent's obstinance is more important to being a leader than an agent's intelligence. The limitations were discussed, and we verified that an additional experiment to investigate the remaining conditions was necessary.

6. ACKNOWLEDGMENTS

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