

Communication Fundamentals within a Triadic Interaction in a Cooperative Play Mediated by INAMO

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ABSTRACT

In this study, we investigated the nature of the triadic interaction between humans within a cooperative play by utilizing a panel-type robot platform, INAMO. INAMO is moved by a joystick that triggers acceleration of the flywheels where the rotations charge the kinetic energy that enables the robot to turn around the electromagnets that are contacting to other INAMOs. An experiment based on a novel cooperative play mediated by the INAMOs was set up to examine the effects of a common task and the social reference on the skills of the subjects, communication between the subjects and interestingness of the game. The evaluations of the subjects' performance and their impressions about the cooperative play were analyzed. The results demonstrated that the existence of a common task and the social reference have significant effects on such triadic interactions.

ACM Classification Keywords

H.5.3 Group and Organization Interfaces: Collaborative computing; D.2.2 Design Tools and Techniques: User interfaces; I.2.9 Robotics: Commercial robots and applications

Author Keywords

Social referencing, Triadic interaction, Swarm Robot, Cooperative Play, Human-robot Interaction

INTRODUCTION

Game playing brings entertainment to our everyday life. Especially, cooperative plays, which is defined as mutual engagement by two or more individuals in a recreational activity, not only lets people to enjoy communicating and compete with other socially, but also lets them observe each other's feelings and to find an unexpected aspects of each other. Therefore, in general, cooperative plays maintain more fun compared to solitary plays.

As it happens in sports, sometimes, even though it is obvious how to use the body during a play, frustration emerges as a result of an inability to move the body in a desired way.

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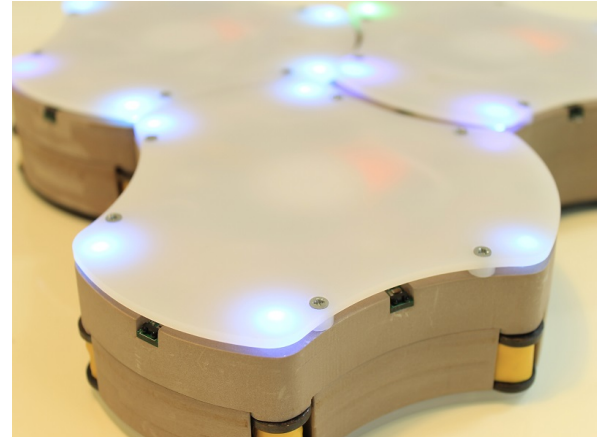


Figure 1. Panel type robot INAMO

However, repeatedly practicing the same movements helps to overcome this frustration and gradually alleviates impatience. Entertainment robots have been studied to provide intimacy and enjoyment to people. Many researches in this area have studied entertainment robots within a dyadic relationship between a human and a robot, and have been elaborated only on the particular unilateral approach of humans (e.g. [1]). On the other hand, attempts have been made to use entertainment robots as a third party to utilize them to draw out cooperative play through collaboration among children who, in normal circumstances are avoiding getting involved (e.g. [3]).

In the previous study, a panel type robot INAMO Fig.1, that needs to cooperate with a human in order to generate its movements based on its operating principle, has been introduced [2]. The operation mode of INAMO cannot be manipulated smoothly, and accordingly, this causes frustration. In this research, we demonstrated the importance of a common task and a social reference within a cooperative play in order to restrain this frustration. Moreover, we examined the effectiveness of the common task and the social reference on subjective evaluations of the participants and explored the fundamental requirements for a cooperative play through INAMO.

TRIADIC INTERACTION AND SOCIAL REFERENCE

We can list two main interaction types in communication within a play. One of them is the dyadic interaction that is person-person, or person-object. Another one is the triadic in-

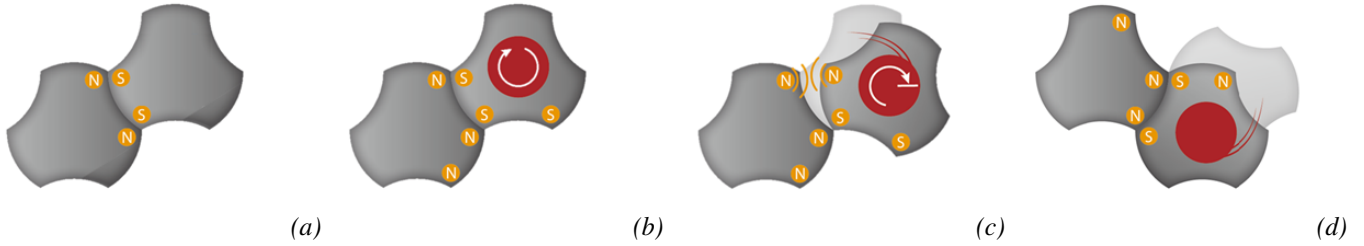


Figure 2. The figure depicts the dynamic locomotion of INAMO: connection state (a), polarity and the direction of the flywheel (b), movement of INAMO (c) and movement completion (d). The red part on the body specifies the flywheels, and the parts labeled as S and N identify the electromagnets.

teraction in a relationship among person-object-person where the object stands as a third party.

The triadic interaction in play has been mainly investigated in the field of the developmental psychology [4]. Besides, there are researches to examine communication models in order to improve the enjoyment of computer based games in a triadic interaction (e.g. [5]). However, these researches do not consider the social reference that could be an important factor of a play. Within a triadic interaction, the attempt to find out how a person interprets a third party by the behavior of the other person's gazing behaviors is called as a social reference [6]. We believe that the social reference is fundamental to transmit and receive intentions and feelings towards and from the other person, which in turn, arranges the communication between the persons and increases pleasure of the play which will help to alleviate frustration. Likewise, a common task in a cooperative play will play a role of enhancing communication and the pleasure of the play through the movements of INAMO as the third party the play.

In this paper, we examined the presence and absence of a common task and the social reference in a cooperative play in order to clarify the fundamentals for communication and the pleasure of play.

DESIGN CONCEPT OF INAMO

The platform of INAMO is designed as swarm robots. It forms a flock with multiple robot bodies and exposes swarm characteristics, such as moving as a crowd and changing the shape of the flock.

The metal disks (also known as flywheels) and electromagnets are mounted inside INAMO. Using the inertial moment by the rotation of the flywheel, it generates rotating movements which serves to connect with or disconnect from another INAMO through the electromagnets mounted at each apex. INAMO will rotate centered on itself if it is alone. On the other hand, if there is more than one INAMO, they can form a swarm together, in which the robots can generate their movements by utilizing each other's support. Below is an example of a basic operation of the swarm behaviors.

- Connection state: Two INAMOs are connected by electromagnets (Fig.2(a)).
- Polarity and direction of the flywheel: The person uses a joystick to choose the direction of the INAMO movement which occurs by rotating and switching the electromagnets

through the signal gained from the joystick. In this state, the flywheel starts to rotate (Fig.2(b)).

- Movement of the INAMO: INAMO generates its movement in a reverse direction by the inertial rotation of the flywheel (Fig.2(c)).
- Movement completion: Repeating this operation alternately between the players drives INAMOs to the target direction Fig.2(d).

EXPERIMENTAL PROTOCOL

In order to observe the communication between the players and to clarify the importance of social referencing within a cooperative play with INAMO, we set up an experiment with four conditions: existence and absence of the social reference (Fig.3(a), (b)); existence and absence of the common task (Fig.3(c), (d)).

Procedure

The experiment was conducted as a within-subject-study. In total, 20 participants (Mean = 26.5, 9 men, 11 women) took part in the evaluation within a counterbalanced measure design. However, one male left the fields blank in the subjective impression questionnaire, therefore we used the data from 19 subjects. During the experiment, the participants tried each condition twice (8 times in total).

The subjective impression questionnaire shown in Table 1 was given to the participants at the end of the each experimental condition. The responses were scored on a 5-point Likert Scale (5: very agree, 4: slightly agree, 3: neither, 2: not so likely, 1: not at all). A statistical significance difference test (t-test) has been applied to compare the ratings of each question for each condition. In addition, the comments of the participants were also taken into consideration.

RESULTS

In this experiment, our aim was to understand the importance of a common task and social reference during a cooperative play with INAMOs by evaluating the participant's subjective impressions about three categories: Skill, Communication and Interestingness. The significance levels of the t-test are *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$.

The mean score of subjective ratings on the presence and absence of a common task in the cooperative play in the case of having the social reference and not having the social reference are shown in (Fig. 4) and (Fig. 5) respectively.

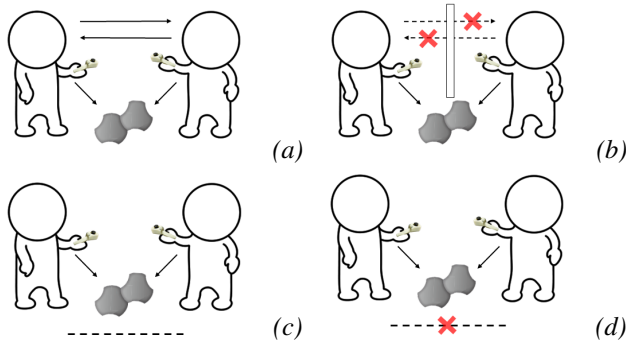


Figure 3. Figures depicts an image about the experimental conditions with social reference (a), without social reference (b), with a common task (c), without a common task (d).

Table 1. The content of the subjective impression questionnaire.

Code	Questions	Category
Q1	I understood the operation method	Skills
Q2	I could control INAMO as I want	
Q3	I understood my partner's intention	Communication
Q4	My partner understood my intention	
Q5	It was easy to understand my partner's thoughts	
Q6	I enjoyed the play	Interestingness
Q7	My partner enjoyed the play	

Concerning the Skills, despite of the operation method being understandable (Q1) regardless of the existence of the common task and the social reference, the subjects could not control INAMO as they wanted (Q2). Based on these results, we considered that the subjects felt frustration.

In the case of absence of the social reference, the mean scores tend to be low (Fig. 4). Particularly, when there is not any common task in the play, the intention of the subject's partner has not been transmitted to the subject (Q5). It can be said that this situation is most likely the same as playing alone. Also, we observed that the sense of transmitting the subject's own intention to their partner was significantly low (Q4). However, in the case of the absence of the social reference, when there is a common task, the subject could somehow transmit their intention to their partner by only the movements of INAMO. In addition, the score of Q6 also exhibits a significant difference which means that in the case of having a common task, even though the participants cannot see each other (no social reference), they can transmit and receive the feeling of sharing the frustration through the third party (INAMO).

In the conditions that the social reference exists (Fig. 5), when there is a common task, the subjects were not only feeling their partners' intention but also felt that their own intentions were transmitted to their partners. In the comparison between

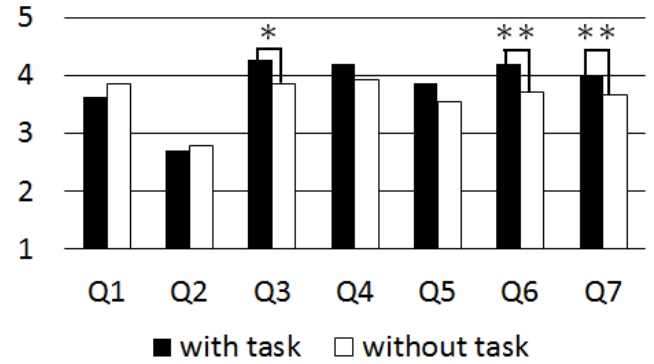


Figure 4. The figure demonstrates the results of the comparison between the conditions of existence and absence of the common task without including the social reference.

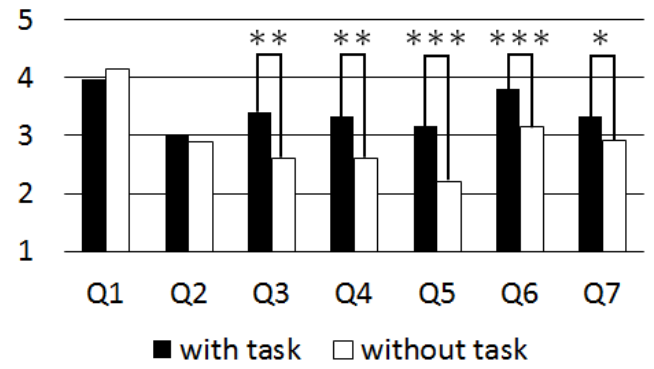


Figure 5. The figure demonstrates the results of the comparison between the conditions of existence and absence of the common task including the social reference.

the existence and absence of the common task, the scores under the Communication and Interestingness categories were both higher and the differences between these cases were statistically significant (Q3: $t=2.10$, $p<.05$, Q6: $t=2.69$, $p<.01$, Q7: $t=2.01$, $p<.05$). In the light of these verifications, we can infer that the subjects could share their frustration with their partners and cooperate towards their common goal together.

We also obtained comments from the participants about their impressions on this cooperative play with INAMO. Their comments were mainly divided into two groups. One is about the difficulty of the operation of INAMO (e.g. "I gradually became accustomed to the operation, but it was difficult to accomplish the task.", "It was getting more difficult.", etc.,). The other group of comments were about the frustration that emerged from their inability to operate INAMO (e.g. "I was frustrated.", "I was feeling that I could almost do it, however I couldn't, I'm frustrated!", etc.,).

As an important factor of a play, if it can be easily played, most likely people will tend to get bored quickly. On the other hand, if it starts as too difficult, people would give up quickly as they would think that it is impossible. This balance is very important. In our study the experimental conditions were set up appropriately to address this issue.

Finally, no groups could achieve to the target by operating INAMO robots cooperatively. However, a few groups could cross the target line with only one INAMO in the case of the existence of the social reference. From this situation, we infer that the shared frustration could attract players to discover the abilities of INAMO.

CONCLUSION AND FUTURE WORK

In this research, we conducted a cooperative play by using INAMO robots as a research platform in order to investigate the important factors in a cooperative play between humans and robots.

We set up an experiment consisting of four conditions: existence and absence of a common task and social reference within a cooperative play with INAMO. The results showed that the existence of a common goal has significant importance in establishing a cooperative play.

The state of targeting to the goal point while cooperating together does not only mean sharing the target but also sharing the each other's frustration of each other. In addition, they could share their sense of accomplishment. In the case where the social reference was restricted, the communication with the other party became difficult, and this situation affected the Interestingness of the play and was evaluated lower.

Taking into consideration the results from Skill category, the comments in the questionnaire about frustration and the difficulty of the operation of INAMO confirmed that frustration leads people to keep playing when they can communicate with the other player.

In the future, we will conduct a cooperative play study between humans and a panel type robot that performs autonomous

movements. We will investigate how to create a feeling of sharing frustration and mutual sharing towards achieving to a common goal.

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