Model of Agency Identificatio through Subconscious Embodied Interaction

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ABSTRACT
Humans can communicate because they adapt and adjust their behavior to each other. Developing a relationship with an unknown artifact, on the other hand, is difficult To address this problem, some robots utilize the context of the interaction between humans. However, there has been little investigation on interaction when no information about the interaction partner has been provided and where there has been no experimental task. Clarificatio of how people perceive unknown objects as agents is required. We believe that a stage of subconscious interaction plays a role in this process. We created an experimental environment to observe the interaction between a human and a robot whose behavior was actually mapped by another human. The participants were required to verbalize what they were thinking or feeling while interacting with the robot. The results of our experiment suggest that the timing of movement was used as the cue for interaction development. We need to verify the effects of other interaction patterns and inspect what kind of action and reaction are regarded as signals that enhance interpersonal interaction.

Author Keywords
Interaction; agency; communication relationship;

ACM Classificatio Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Artifacts, such as robots, can perform complicated tasks and have become closely involved in our everyday life. Such artifacts are therefore expected to cooperate with us and to assume social roles in human society. However, it is difficul to communicate with an unknown artifact because whether it can respond to us and how it will behave are unknown. To resolve this problem, some artifacts are designed so that their physical appearance promotes interaction with humans [9, 10], although, when human action is induced from previous knowledge, it is possible that this adaptation gap [8] may negatively influenc continued interaction. Humans can perceive an agent's properties, such as animacy and intention, by observing a moving geometric figur [4]. These perceptions are influence by the difference between only observing a target and actual interaction [3]. Therefore, we focus on how people realize, through interaction, that an abstract-shaped object is an agent.

Research on minimum interaction indicates that people recognize other people without cues provided beforehand because of our ability to form extemporaneous joint action or turn-taking with each other [1, 5]. However, little research has been done on interaction when the participants have no prior knowledge of or context for, such as experimental tasks, the interaction partner. When interaction is directed toward a goal, such as a judgment of whether the partner is a human or a computer, it becomes easy to converge in a certain pattern. In this study, we focus on interaction that is undirected by experimental task. In this interaction, the participants are not motivated to compose joint actions with the partner beforehand and the interaction easily diverges from a certain pattern (Figure 1).

In order to clarify how people behave and trace this stage through the interaction, we conducted an experiment in which the participants interact with an ostensibly unknown artifact whose behavior is actually mirroring another participant's movement. By modeling this process, we can design artifacts that are able to form relationships with humans, thus promoting communication and interaction between humans and robots.

STAGE OF SUBCONSCIOUS INTERACTION
In this section, we describe our concept (Figure 2) and research method of subconscious interaction. In human communication, we can immediately recognize a partner as human. The human brain possesses an area that is specificall designed to detect the human body [2]. In addition, as the phenomenon of "biological motion" illustrates, [6] we have a specifi perception for recognizing human body movement. On the basis of these abilities, other people are regarded as agents with which we can communicate. On the other hand, artifacts, especially non-humanoid, non-animal, or abstract-shaped robots, must build a social relationship beyond just

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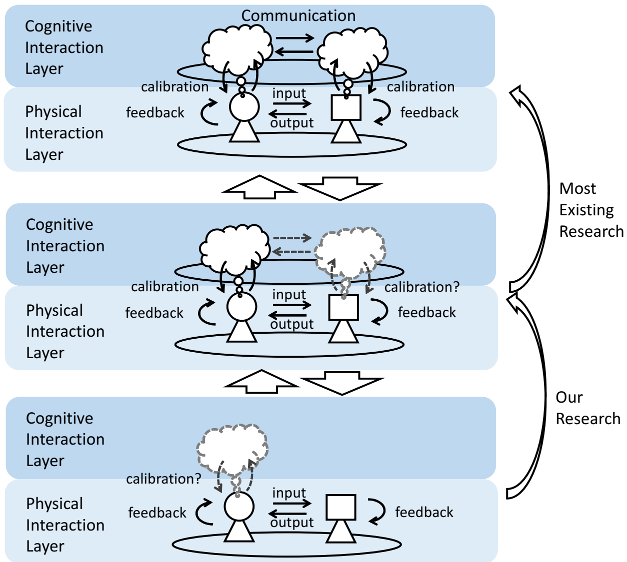

Figure 1. Interaction with unknown artifacts.

being objects. The artifacts' behavior must convey to human abstract thinking that their motions contain some intention or meaning.

We hypothesize that some interaction pattern or joint action formed subconsciously on the physical level is performed as signals. Because the interaction partner has been already recognized as an agent, this does not continue. When interaction collapses, the partner seems to be regarded as an object. We assume that a social relationship can repeatedly form and collapse through interaction. We attempt herein to specify and model this process.

A think-aloud method is useful for investigating change in inner states against an object. Without a clue, it is difficul to segment physical interaction. By getting participants to speak about their thinking or feelings during interaction, we can put a mark on the interaction and the development of recognition of the interaction partner is observed. We also attempt to detect any cues indicating that the object is being perceived as an agent with an inner state.

We focus on interaction based in the real world rather than in a virtual environment. Many studies on interaction have used upper limb motion. Entire body movements, such as gait, differ from upper limb action [7]. While walking, humans unconsciously adjust direction and automatically avoid obstacles. Therefore, unconscious motions occur at a higher frequency than interaction using only the upper limbs. By using an abstract-shaped robot whose function is only to move a fl wer, we can observe lower-limb-driven interaction.

EXPERIMENT

Purpose

In this section, we describe the details of our experiment for investigating the process of how people realize that an interaction partner has the ability to construct a communication relationship. We observed interaction between humans and

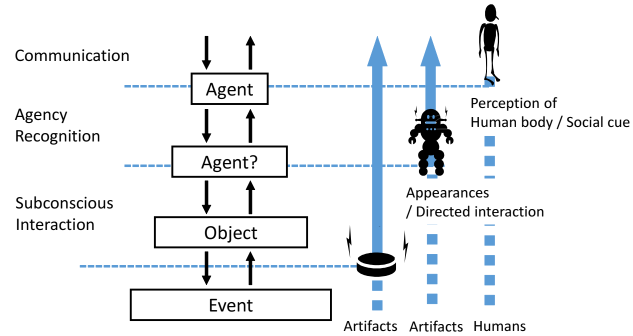

Figure 2. Stages of subconscious interaction

robots. It is difficul for participants to notice that a robot's motion corresponds with another participant's motion without interaction. However, the robot's behavior is certainly capable of building an interpersonal relationship through interaction. Therefore, we observed the interaction between a human and a robot that was not previously perceived as an agency, but that behaves as an agent. We acquired the participants' inner state data using a think-aloud method. Our aim was to model the process of creating a relationship from the utterance data and behavioral data.

Method

Apparatus

As shown in Figure 3, two rooms were used as the experimental environment. Both rooms were constructed with similar equipment. A three meters in diameter circle constituted the delimited fiel of the participants' movement. In both rooms, the positions of the participants were mirrored by robots in another room. That is, the position of the robot located in one room mapped the position of the participant in the other room (Figure 4). In this way, each participant was able to interact with the other participant without being aware of each other. We used a robot with three omni wheels that is able to move in any direction (Figure 5). We controlled the robot via Bluetooth. The robot's position was calculated by encoders and corrected by image processing through a video camera. The robot was covered with an outer case. The participants put on a headset and voice recorder for utterance data gathering. The participant's position was measured with a laser rangefinde (URG-04LX, Hokuyo Automatic Co.).

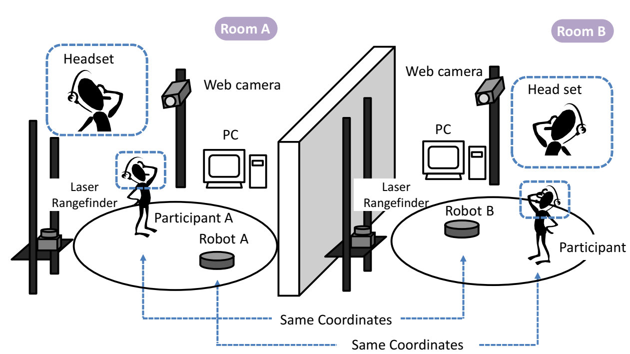

Figure 3. Experimental setup

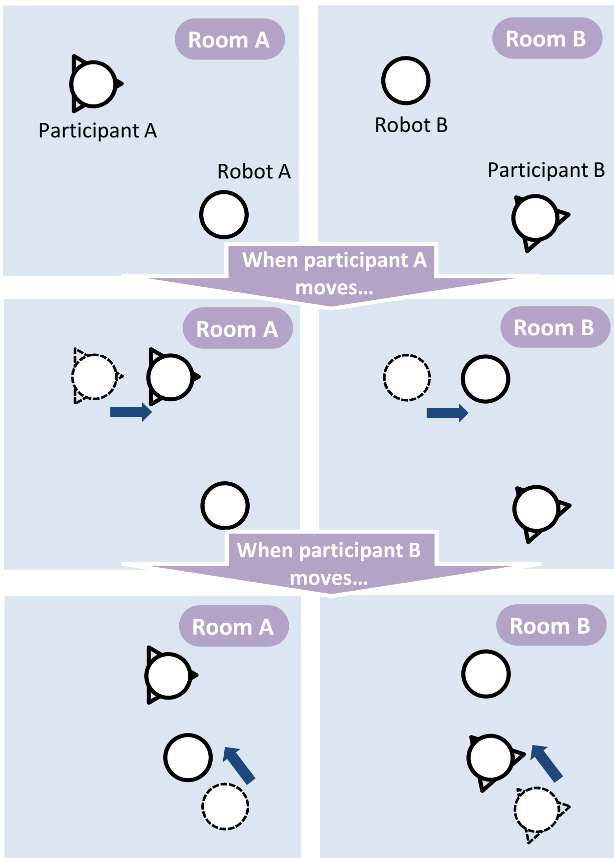

Figure 4. Feature of robots

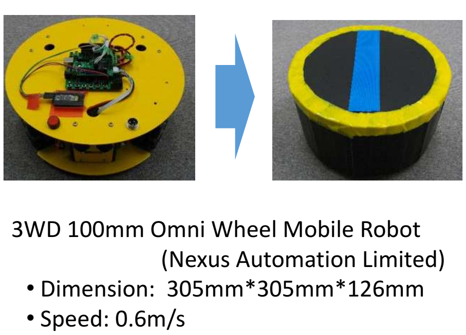

Figure 5. Appearance of robots

Task

The participant pairs were guided into the rooms separately without knowledge of their respective partners. Before interacting with the robot, the participants practiced thinking aloud. They were required to speak about anything they felt or thought while working on a puzzle called a tangram. The participants were then instructed to move freely within the delimited fiel circle and to speak about what they were feeling or thinking. At this phase, different instructions were given to the participant pairs. One of the pair was not told about the robot's behavior. The other participant was told that the robot's movement mirrored the other participant's position. They were also told that their position was conveyed to the partner through a robot in another room in the same manner. Additionally, they were instructed to act in such a way as to make their partner aware of their existence. Every participant was left alone in the room, and the interaction between the participants and the robot was observed for seven minutes (Figure 6). The participants then responded to questionnaires.

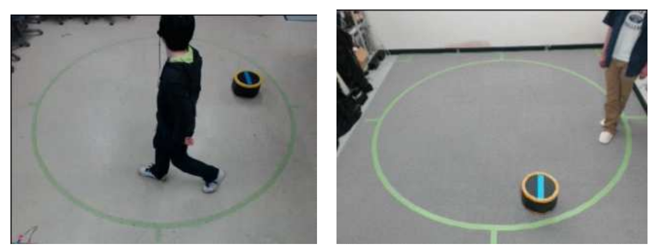

Figure 6. An interaction scene

Observed Data

We observed and analyzed the following data:

- Behavioral data
  - Log data of participant position (every 125 ms)
  - Log data of robot position (every 125 ms)
  - Interaction video
- Speaking data
- Questionnaires
  - Free descriptions about behavior of participant and robot

Results and Discussion

At present, we do not have a sufficien number of participants, and more experiments and data analysis is ongoing. In this article, we describe and discuss some distinctive, observed interaction and considerations. The speaking data was utilized to detect the point at which the participants' internal state changed. We investigated how this change was carried out by behavioral data analysis.

Figure 7 shows the speaking data and behavioral data analysis of participant P_1, who was not informed of the robot's behavior before interaction. The upper line chart is the velocity of the participant's movement. The lower chart shows the cross-correlation function (CCF) between the participant's and the robot's velocity, which is calculated by 15 seconds of data. The CCF are given by

$$f(k) = \frac{Cov(A_t, B_{t+k})}{\sigma_{A_t}\sigma_{B_{t+k}}} \quad (1)$$

where $Cov(A_t, B_{t+k})$, σ_{A_t} and $\sigma_{B_{t+k}}$ denotes the covariance and standard deviation. The range of time delay is plus/minus 5 seconds ($-5 \le k \le 5$). When peaks of the CCF value (displayed in red) appeared in minus-time dilation, the robot moved earlier than the participants. When the peaks appeared in plus-time dilation, the participants moved earlier than the robot. When the peaks appeared near zero, the participant and robot moved simultaneously.

P_1 declared his intention to follow the robot in Figure 7a. In the beginning phase of the experiment, before Figure 7a, the CCF peak gradually converged to around zero. It seems that P_1's reaction to the robot's movement occurred earlier. P_1 and the robot's motion began to synchronize, although P_1 gently moved in this phase, as shown by the velocity. After Figure 7a, P_1 actually chased the robot and said, "Does the robot continue to move while I am moving?" To verify the hypothesis, P_1 suspended and resumed chasing the robot repeatedly. In Figure 7b, P_1 suspected that the robot was controlled by someone. In this phase, it is possible that P_1 realized that the robot had an inner state. For P_1, the timing of the movement was used as the cue for interaction development. Another participant, who did know about the robot beforehand, likewise used the timing cue (Figure 8).

We believe that other cues exist because the participants who were told about the robot and tried to make their partner aware of them undertook several strategies. According to their speaking data, each of them executed trials, such as following the partner, moving around the field and tracing their partner's movement. We need to verify the effects of these steps and uncover what type of action and reaction are regarded as signals that enhance the interpersonal interaction.

CONCLUSION

In this study, we believe that a stage of subconscious interaction is the process in which participants perceive objects as agents. Through this process, humans appear to progress in establishing relationships with artifacts. In order to extract the subconscious interaction, we observed the interactions with an unknown robot whose positions were mapped by other participants. As a result, some participants used timing of movement as a cue for interaction development. We also investigated other cues during our progress. Modeling of this interaction process must await further, ongoing investigation.

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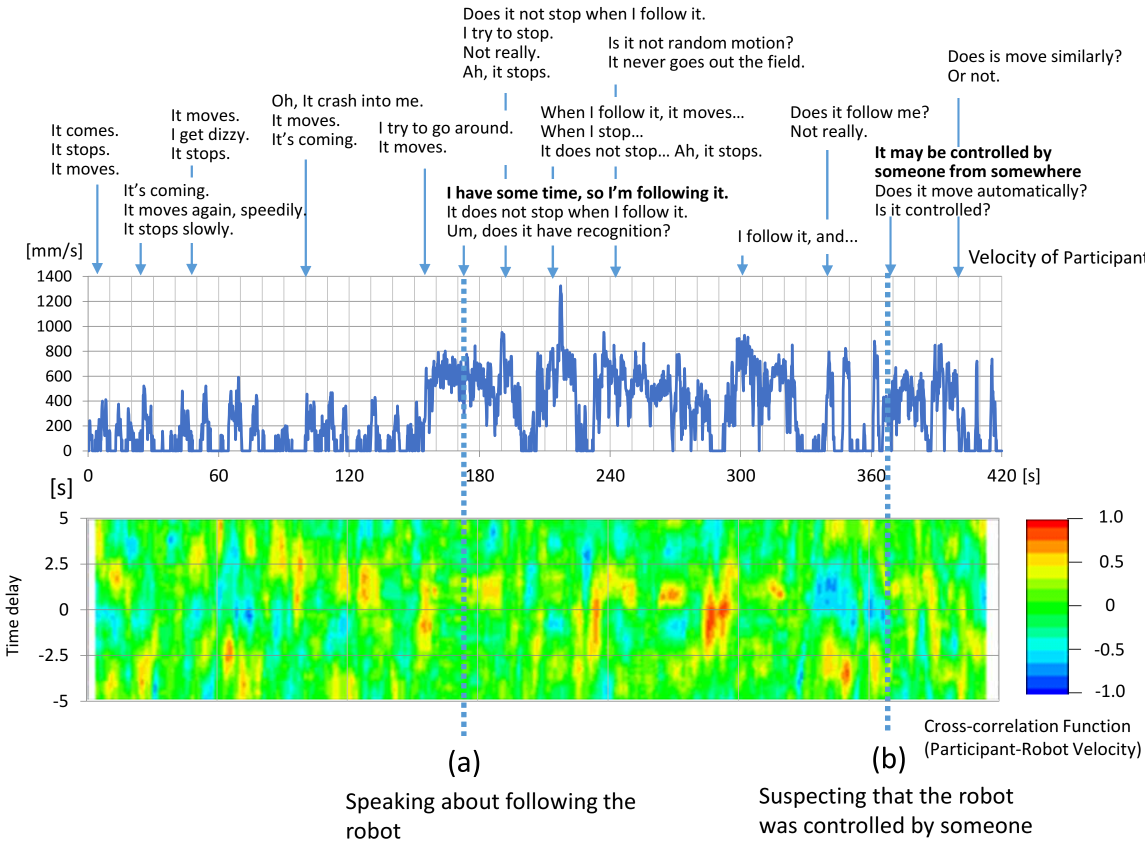

Figure 7. Velocity and CCF (P1)

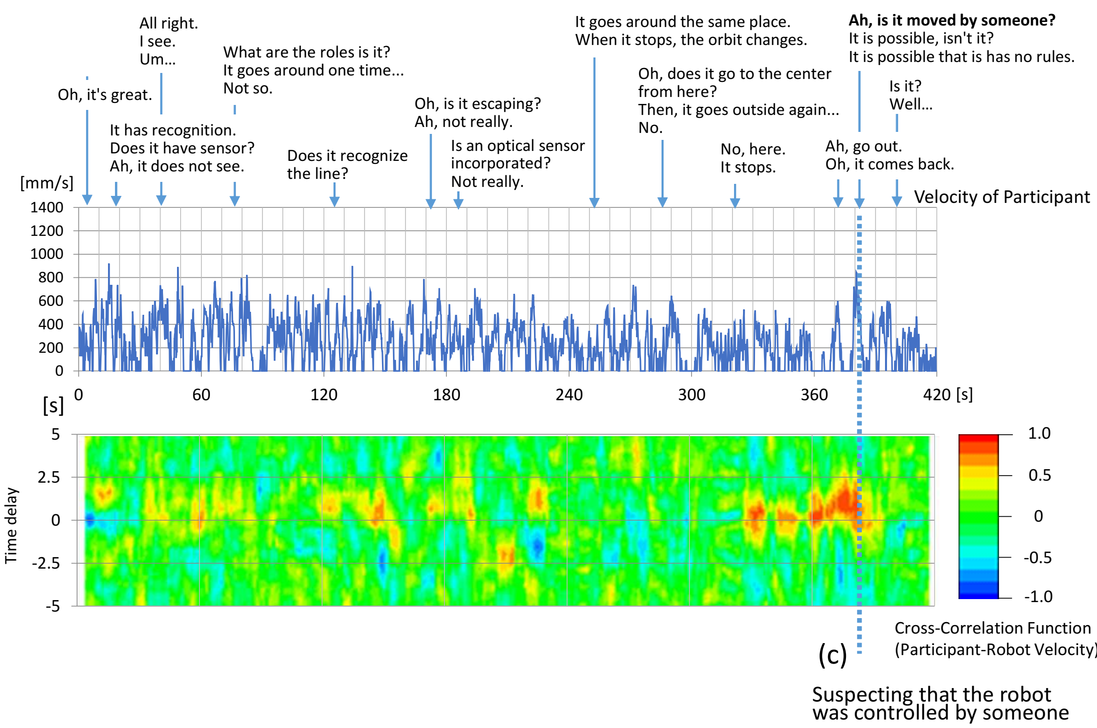

Figure 8. Velocity and CCF (P2)