The Difference in the Manner of Interacting with a Moving Robot Influences Animacy Perception

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Abstract

We experimentally examined whether differences in the manner of interacting with a moving robot (actually operating it vs. only observing its motions) influenced animacy perception and whether the strength of this influence could be changed in relation to the robot’s motions, which exhibited a degree of goal-directedness. We found that perceived animacy was higher for a robot that exhibited more goal-directedness when participants only observed its motion. This was consistent with the results of previous works. On the other hand, perceived animacy was the highest for a robot that moved with 1/f noise (showing moderate goal-directedness) when participants actually operated the robot. This result suggests that the manner of interacting influences animacy perception.

Keywords: animacy perception; human-agent interaction; 1/f noise

Introduction

Previous studies of Animacy perception

We are strongly attached to a tool that we often use and are apt to personify it; talking to it, flattering it, regarding it as animated, etc. Perceiving an object as animated is called animacy perception (Scholl & Tremoulet, 2000).

Animacy perception has been studied in psychology for more than 60 years; Heider & Simmel (1944) first showed that their participants regarded geometric shapes as living things because of their motions. Until recently, many studies have attempted to discover the specific motion cues that mediate animacy perception. In particular, the apparent goal-directedness of an object’s motion was said to be important for animacy perception (Dittrich & Lea, 1994; Tremoulet & Feldman, 2006; Tremoulet & Feldman, 2000). For example, Dittrich & Lea (1994) examined what motion caused animacy perception. They concluded that perceiving animacy depended on how much a target object appeared to be goal-directed. Note that, in these psychological studies, participants just observed an object on display; the manner in which participants interacted with an object was eliminated as much as possible for control.

On the other hand, we intuitively know from experience that animacy perception depends on how we interact with an object; for example, we only observe the object or we actually operate or possess it. In addition to the importance of goal-directedness for animacy perception (Bassili, 1976; Opfer, 2002; Schultz, Friston, O’Doherty, Wolpert & Frith, 2005; Schultz, Imamizu, Kawato & Frith, 2004; Csibra, Gergely, Biro, Koos & Brockbank, 1999), the ability to interact was recently emphasized in cognitive development. Previous studies (Johnson, Slaughter & Carey, 1998; Legerstee, 1997) suggested that infants attributed a mental state to an object that had an ability to interact contingently with other agents. Arita, Hiraki, Kanda and Ishiguro (2005) showed that infants regarded a robot interacting with others as a communicative agent while they regarded a non-interactive robot as just an object. These previous studies suggest that “interaction” is an important factor for animacy. As far as we know, no one in this field has addressed, whether the manner of interaction with an object influences animacy perception although the ability to interact contingently with other agents was a focus of study.

In this experiment, we examined whether differences in the manner of interacting with an object (i.e. actually operating it vs. observing its motion) influenced animacy perception and whether the strength of this influence could be changed in relation to the degree of goal-directedness in the object’s motion.

Experimental design

In this experiment, we prepared two experimental conditions: the operator condition and observer condition. In the operator condition, each participant operated a moving robot by himself/herself to control its direction of motion. In the observer condition, each participant observed the robot that another person operated. Under these conditions, we examined whether the manner of interaction with a robot influences perceived animacy of the robot.

In addition, we prepared three tasks in each condition: a noiseless task, 1/f noise task, and white noise task. In each task, the motion of the robot exhibited specific characteristics. In the noiseless task, the robot moved 10 cm/sec. under normal conditions and exhibited phototaxis in the presence of light. In two other tasks, random numbers were added to the motor output of the robot in the noiseless task; motions of the robot exhibited some fluctuations. In the white noise task, normal random numbers or white noise were added to the motor output in the noiseless task.
1/f noise task, 1/f noise or pink noise (Wagenmakers, Farrell, & Ratcliff, 2005) was added. 1/f noise is a kind of noise that has a special pattern of wavelength. There is neither a monotone nor disorder; a good balance is maintained between regularity and irregularity. Therefore, the robot motion in the 1/f noise task is unpredictable but not completely random. The degree of goal-directedness in the robot’s motion was the highest in the noiseless task, followed by that of the 1/f noise task and white noise task.

In both the observer condition and operator condition, a questionnaire survey regarding these three tasks was carried out to examine how interaction with a robot influences animacy perception in each type of robot motion.

From previous studies, it was expected that higher goal-directedness resulted in a higher degree of animacy perception under the observer condition. If active interaction (actual operating experience) influences animacy perception, on the other hand, the result obtained under the operator condition was expected to be different from that obtained under the observer condition. In this paper, “active interaction” means operating a robot by one’s self.

Method

Participants and Tasks

Ten students (6 men and 4 women, from 20 to 26 years old) participated in this experiment. All of them were asked to carry out the three tasks under the operator condition as well as the observer condition. Under the operator condition, participants operated a moving robot, which exhibited positive phototaxis, by using a flashlight to make the robot push as many marbles as possible out of the specified field (80 * 80 cm) in 5 minutes (Figure 1b). After each task was finished, participants answered a questionnaire that was intended to measure the degree of their perception of animacy, intentionality, and reactivity of the robot. Under the observer condition, each participant observed another person performing the task of pushing marbles under the operator condition and answered the same questionnaire as that under the operator condition.

Each condition had three types of task. In each task, the robot exhibited different types of motion, as explained in Section 1.2. Therefore, two-way (conditions (2) * tasks (3)) factorial design was used. In addition, to determine stress levels induced by the tasks, the amount of amylase in the saliva of participants was measured after each task was finished under the operator condition. That was carried out because the amount of amylase in saliva is known to increase under psychological stress.

All the participants were naïve to the purpose of the experiment and participated in this type of experiment for the first time.

Apparatus

A compact mobile robot named e-puck (Ecole Polytechnique Fédérale de Lausanne, 2006) was used. E-puck was round and 70 mm across. Each participant could use a flashlight to move e-puck. The sampling rate of each light sensor was 0.4 Hz. A 15 * 80 mm plastic plate was attached in front of e-puck (Figure 1a).

The experiment was performed on a desk (100 * 100 cm). The field (80 * 80 cm) where each participant was permitted to move e-puck was specified on the desktop. Thirty marbles (15 mm in diameter) were scattered in the field. A COCORO METER (made by NIPRO) was used to measure the amount of amylase in saliva.

Figure 1: a: e-puck robot and marble used in this experiment, b: experimental scene.

Questionnaire

The questionnaire used in this experiment consisted of three categories of questions about perception of animacy, intentionality, and reactivity (Table 1). Each category had 2 or 3 questions. The questions were elicited from Opfer (2002) and Richards and Siegler (1986). Participants were asked to answer each question on a 6-point scale (0 was the worst and 5 was the best).

<table>
<thead>
<tr>
<th>Categories</th>
<th>Items of the questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animacy</td>
<td>Do you feel the robot was alive?</td>
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<tr>
<td></td>
<td>Do you feel the robot had the ability of vision?</td>
</tr>
<tr>
<td></td>
<td>Do you feel the robot was capable of thinking?</td>
</tr>
<tr>
<td>Intentionality</td>
<td>Do you feel the robot behaved as if it had a purpose?</td>
</tr>
<tr>
<td></td>
<td>Do you feel the robot had planning ability?</td>
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<tr>
<td></td>
<td>Do you feel the robot had emotion?</td>
</tr>
<tr>
<td>Reactivity</td>
<td>Do you feel the robot had good reactivity?</td>
</tr>
<tr>
<td></td>
<td>Do you feel the robot moved toward its goal?</td>
</tr>
</tbody>
</table>

Table 1: Questionnaire used in the experiment
Motion of robot

In the noiseless task, the robot moved 10 cm/sec. under normal conditions and exhibited phototaxis in the presence of light; the robot moved according to Braitenberg’s algorithm (Braitenberg, 1984). In the other two tasks, two types of randomness or fluctuations were added: normal random to white noise task and 1/f noise to 1/f noise task. The ranges of random numbers in normal random and 1/f noise were from –10 cm/sec. to 10 cm/sec. Normal random numbers were generated from this equation: (normal random number) = (the sum of 12 regular random numbers) – 6. Intermittent chaos was used to generate 1/f noise; when x(t) < 0.5, x(t + 1) = x(t) + 2 * x(t) * x(t), when x(t) > 0.5, x(t + 1) = x(t) + 2 * (1 - x(t)) * (1 - x(t)), where x(t) denotes the intensity of noise at time t.

Procedure

The amount of amylase in saliva was measured using the COCORO METER. The measured amount was used as the reference value of each participant. Before the experimental tasks, participants practiced operating the robot using a flashlight for 1 minute. Then, participants performed the experimental tasks under the operator condition and observer condition alternately. Half of the participants started with the operator condition and the other half started with the observer condition. The experimental order of the three tasks was randomized for each participant. Each participant performed all the tasks (2 conditions * 3 tasks; 6 types of tasks). After each task was finished, participants answered the questionnaire and the amount of amylase in saliva was measured.

Results

In Figure 2, mean numbers of marbles that were pushed out by the robot under the operator condition were plotted. No participant could push out all thirty marbles in 5 minutes. These results suggest that when a robot had a stronger tendency to follow a light, more marbles could be pushed out. Mean differences between the amounts of amylase in saliva measured after each task and the reference value under the operator condition are shown in Figure 3. The amount in the 1/f noise task was much less than that in the other tasks, which means that psychological stress in the 1/f noise task was the least of all the tasks under the operator condition. We had expected that if the robot exhibited smaller goal-directedness, the psychological stress of participants was larger. However, the psychological stress of participants had no relationship with the goal-directedness of the robot. Participants’ stress in the 1/f noise task was significantly smaller (F (2,21) = 9.61, p < .01) than that in other tasks, which suggests that the noiseless task was not stress-free in spite of its high controllability.

Animacy

Average animacy ratings are shown in Figure 4. Under the observer condition, when a robot exhibited higher goal-directedness, the animacy rating was higher. Under the operator condition, on the other hand, the animacy rating in the 1/f noise task was higher than that in the noiseless task. A two-way ANOVA revealed that the interaction between the rating in the noiseless task and that in the 1/f noise task was significant (F (1,9) = 15.1, p < .01). This result suggests that, only under the operator condition, the animacy rating in the 1/f noise task was higher than that in the noiseless task.
The mean ratings of animacy in three tasks are plotted. The rating of animacy was calculated as the average of the scores of the three items in the animacy category of the questionnaire.

Intentionality

Averages of intentionality ratings are shown in Figure 5. This result was similar to that of the animacy ratings although the between the rating in the noiseless task and that in the 1/f noise task was marginally significant ($F(1,9) = 4.65, p = .06$).

Reactivity

Averages of reactivity ratings are shown in Figure 6. This result exhibits a different trend than that of the results of animacy and intentionality ratings. No significant difference was found between the operator and observer conditions. Under both conditions, higher goal-directedness resulted in higher reactivity ratings. This result indicates that participants understood the actual reactivity.

Discussion

It was expected that higher goal-directedness leads to higher ratings of animacy and intentionality because animacy was known to depend on goal-directedness (Dittrich & Lea, 1994, Csibra, 2003). Although the result in under the observer condition was as expected, the result under the operator condition was not. The ratings of animacy and intentionality in the 1/f noise task were higher than those in the noiseless task only when participants operated with a moving robot by themselves. The rating of reactivity in the noiseless task was higher than that in the 1/f noise task, which seemed to follow the degree of goal-directedness.

Two hypotheses seem possible for explaining why the animacy rating in the 1/f noise task was the highest under the operator condition. One hypothesis is that we perceive an object whose motion exhibits 1/f noise as more animated because 1/f noise can be seen in the motions of many living things. Miyashita & Ishiguro (2004) indicated that a humanoid robot exhibiting natural involuntary motion like oscillation looked more human-like. Another hypothesis is that, by interacting with an object with the motion exhibiting a good balance between regularity and irregularity in the 1/f noise task, we considered the object as an agent that had an internal state, which is based on “Theory of Mind” (Scholl & Leslie, 2001; Baron-Cohen, 1995).

We carried out an additional experiment whose setting was the same as the one explained, except that participants were allowed to carry out the tasks in only one minute. If the former hypothesis were true, the result in this additional experiment would be similar to the result in the experiment explained because the motion of the robot is the same. If the
latter were true, the result in the additional experiment would be different from that in the experiment explained because one minute is not enough time for interacting with the robot. As a result, we could not find any significant difference in animacy rating between the operator and observer conditions \((F(5,12) = 3.11, p = .40)\). Animacy rating in additional experiment is shown in Figure 7). This suggests that whether participants had an active interaction or not influenced animacy perception in the 1/f noise task and noiseless tasks. Active interaction with a robot might provide the participants with a chance to know the property of the robot’s motions better. It can be considered that the participants repeated trial and error operation of the robot so that they recognized a good balance between regularity and irregularity exhibited by 1/f noise and came to realize that the robot had an internal state. As a result, they perceived animacy in the robot.

Psychological stress was lower in the 1/f noise task than in other tasks although performance in the 1/f noise task was lower than that in the noiseless task. Therefore, psychological stress that resulted from unsuccessful operation of an artificial object may be suppressed when we perceive animacy of the object.

Our results suggest that “active interaction” influences animacy perception.

Figure 7. The mean ratings of animacy in three tasks are plotted. There is no difference between operator condition and observer condition.

References


