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Do Synchronized Multiple Robots Exert Peer Pressure?

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ABSTRACT
In human-human interaction, peer pressure is a major social influence on people's thoughts, feelings, and behaviors. The larger the group of people, the more social influence it exerts. In this paper, we investigate whether multiple robots and their synchronized behaviors exert peer pressure on people, as in human groups. We developed a multiple robot controller system that enables robots to perform precise synchronization. In the experiment, we prepared a setting that resembled previous experiments that investigated peer pressure between people and robots. The participants answered questions after hearing the robots' answers, only some of which were incorrect. Our experiment results showed that the influence of the synchronized multiple robots increased the error rates of the participants, but we found no significant effects toward conformity.

Author Keywords
Human-robot interaction; group interaction; peer pressure

ACM Classification Keywords
H.5.2. User Interfaces – *Interaction styles*

INTRODUCTION
Human decision making is strongly influenced by others. In particular, the power of the many is one famous social influence from others. For example, Sherif investigated a conformity effect in an ambiguous situation and showed that participants willingly followed the opinions of others, even though they admitted objections to them [1]. Asch experimentally investigated the impact of the majority's influence and concluded that participants conformed to other people's incorrect choices [2][3]. Asch also investigated how peer pressure is strengthened by an increase in the number of the sources of such influence. Other literature identified the social influences of relationships among people's thoughts, feelings and behaviors [4, 5].

Can robots exert a social influence, like peer pressure, on people? Even though people regard a robot as a different being from humans, they do view it as a social being [6, 7]. This attitude is helpful for understanding how people are influenced by robots. Several researchers investigated the effects of answering this question in the human-robot interaction research field and showed that robots influence people's decisions [8, 9]. Even though these research works showed that people's decision making is influenced by robots, the power of such influence is relatively weak compared to the effect from humans.

Another question must be confronted. Do multiple robots exert more social influence? Since the practice of installing groups of robots like Pepper in real shops continues to advance worldwide, understanding their social influence is critical. However, the answer to that question remains unknown because how multiple social robots exert social influence hasn't been extensively addressed by the human-robot interaction research field. Do people change their decisions if a number of robots oppose them? Are people more likely to follow the opinions of unanimous robots?

This paper addressed these questions by investigating the effects of peer pressure from multiple robots with a relatively large number of robots (Fig. 1). The power of influence from robots is probably weaker than from humans, and past research reported that the size of the group is important to increase conformity [2]. We also investigated the effects of the synchronized behaviors of multiple robots, which are designed to increase conformity by showing unanimity because past research work reported that it increases the power of social influence [2].

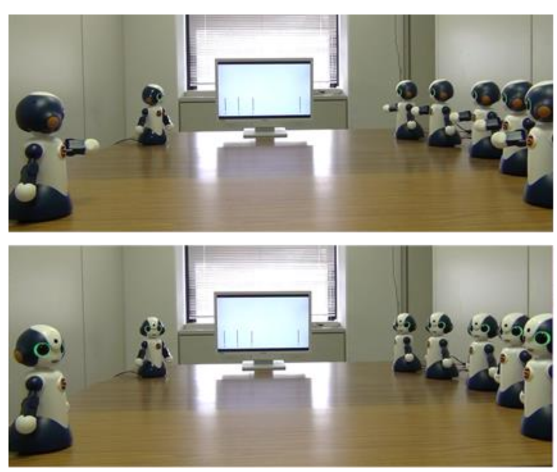

Fig. 1 Synchronized behaviors of multiple robots

RELATED WORKS

Social influence from a single robot

Many robotics researchers have investigated the social influence from a single robot in the human-robot interaction research field with an approach that resembles human-computer interaction research works [10] [11]. For example, researchers unveiled the effects of a robot's social facilitation, which is the tendency for people to perform differently in the presence of others (i.e., a robot) than when they are alone. The existence of physical robots influenced the performances of people in simple tasks, similar to human existence [12] [13].

Nagakawa et al. focused on social influence due to the unique feature of physical robots in the physical interaction between a robot and people and reported that a robot's physical interaction motivates people during simple and monotonous tasks [8, 9]. Shinozawa et al. clarified that physical presence affects human decision making more greatly than a screen-agent in the real world [14]. These social influences of robots can be exploited for commercial purposes, and real robots have already been installed for advertisements in daily environments like shopping malls [15] [16].

Even though these research works provided rich knowledge about the social influences of robots on people, they mainly focused on a single robot effect, not a multiple robot effect. It remains unknown whether using multiple robots increases the social influence from robots to people. In this paper, we unveil the effects of multiple robots under the context of social influence.

Interaction with a group of robots

Some research works focus on using multiple robots in human-robot interaction contexts. Sakamoto et al. developed a passive social medium using two robots and investigated its effectiveness for information-providing services in open public environments [17]. Kory et al. used two robots for a storytelling-task to improve children's language-learning [18]. Leite et al. also focused on storytelling with multiple robots and reported that interactive narratives with multiple robots are a promising approach for the development of children's social-related skills [19]. These research works showed the effectiveness of using multiple robots to transfer information to people. However, since their focuses are different from peer pressure from robots, such research is different from ours.

Similar to our motivation, Brandstetter et al. investigated peer pressure from multiple robots [20] in a reproduction of Asch's experiment with four robots or four human experimenters. They investigated the levels of pressure from the robots in both non/ambiguous situations. As in the original experiment, they confirmed peer pressure effects with human experimenters, but the robots did not show any significant effects of peer pressure. In this research work, we also use multiple robots to investigate peer pressure from robots. The main differences between our research work and Brandstetter's work is the number of robots and the synchronized behaviors.

DESIGN

Task design

In this study, which resembles Brandstetter's work [20], we prepared visual judgment tasks along the lines of Asch's experiments [2][3] by considering aspects of the Sherif experiment: ambiguous situations for conformity effects [1]. Fig. 2 shows an example of the line tasks in this study, where the participants have to identify the corresponding lines from candidates A to C.

On the left side are displayed three lines whose lengths differ from the correct line in a range of +/- 1 to 3 mm. One of the three lines corresponds to a line on the right side labeled "?". The right side line has three different lengths: 50, 100, and 150 mm. Since these lines look ambiguous, distinguishing them might be difficult for participants.

System design

We referred to both the Asch and Brandstetter experiments to determine the number of robots for our study. Asch investigated the relationships between conformity and group size [21]. The former increased immediately when a group had three people and did not appreciably increase by adding more people (Fig. 3). On the other hand, Brandstetter's experiment with four robots showed that using more robots over the saturation number in the human case did not exert peer pressure on people, even in ambiguous situations [20]. Therefore, at least four robots were inadequate to create peer pressure from them.

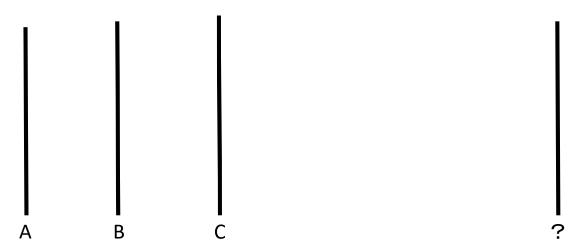

Fig. 2 Example of line task

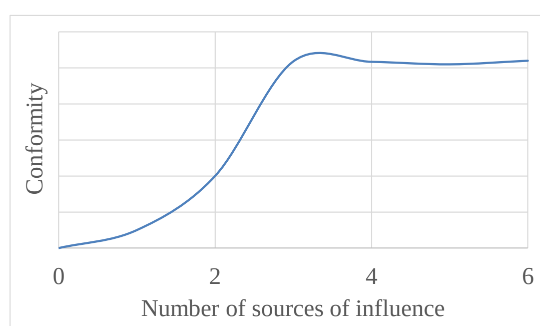

Fig. 3 Relationships between conformity and group size, original graph [21]

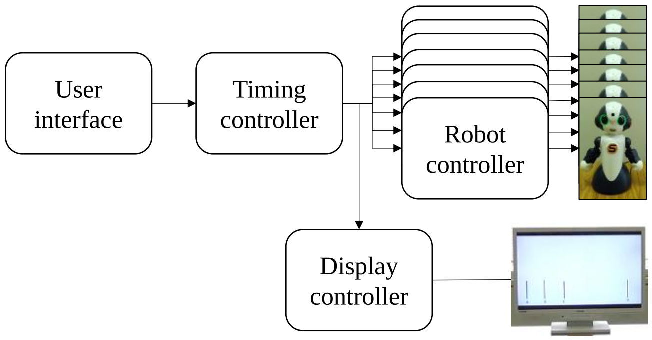

Fig. 4 System overview

After considering these research works, we chose six robots, which is two more than the saturation number in the human case. To increase the power of many, we also investigated the effects of the synchronized behaviors of robots. Since past work reported that unanimity increases the power of social influence [2], we believe that showing unanimity by synchronized behavior will increase the power.

Since the effects of such a large number of robots and their synchronized behaviors remain unknown under the context of peer pressure, our design includes heuristic points. But we believe that investigating these effects will be helpful to understand how people are influenced by interaction with a group of robots. By considering both the task and system design, we developed an experiment system for this study and described its details in the next section.

SYSTEM CONFIGURATION

Figure 4 shows an overview of our multiple robot controller system that consists of the following five components: user interface, timing controller, robot controller, display controller, and a robot. The total number of robots was seven: an MC robot and six answerers. All of the systems are connected through a wired/wireless LAN. The details of each component are described as follows.

User interface

To simultaneously control multiple robots, we developed a simple user interface with several buttons that are used to send a scenario to the timing controller. Each scenario includes information about when and which robot will execute a behavior (motion and speech sets) and shows images on the display. These scenarios are analyzed by the timing controller and sent to both the robot and display controllers. The operator controls the start timing of each scenario by the user interface, but after sending a scenario, each robot automatically behaves as defined by the scenario.

Timing controller

This module synchronizes each robot behavior and precisely shows images on the display. When an operator sends a scenario to the timing controller, it generates command sets for each robot, displays images by analyzing the scenario, and sends the command set and the start timing to each controller. To avoid influence from the network delay, each controller is connected to the same NTP server to synchronize the clocks between PCs.

Robot controller

The robot controller manages a robot's behavior, which is motion and speech sets. In advance we prepared robot behaviors and registered them to each robot controller, which executes a registered behavior based on the timing information from the timing controller. When a behavior is executed, it controls each motor and starts to play a robot's sound.

Display controller

The display controller manages the displayed images and shows an image based on the timing controller's signal.

Robot

We used "Sota," which is an interactive humanoid robot characterized by its humanlike physical expressions. It has two DOFs in its arms, three in its head, and one in its waist. Its hands are soft material to ensure safety. The robot is 280 mm tall and is equipped with a CCD camera and microphones. Since Sota's CPU is Edison, users can connect and control it by Wi-FI. We used a corpus-based speech synthesis to generate speech [22].

EXPERIMENT

Hypotheses and Prediction

Based on human science literature, the power of math exists in the context of social influence, e.g., peer pressure [2, 23]. These research works also report that the size of the group and unanimity increases such social influences. On the other hand, in human-robot interaction research fields, other kinds of social influences exist, such as social facilitation [8, 9], but no peer pressure effect by multiple robots has been observed yet [20]. To investigate whether multiple robots can exert peer pressure, we employ more robots than past research work [20] and synchronized behaviors to increase unanimity, which is related to the power of peer pressure. If our system effectively produces synchronized behaviors among multiple robots, people will feel more pressure than from just non-synchronized multiple robots. This pressure will probably cause more errors during the experiments and create conformity to the robot answers; peer pressure from robots will be observed. Based on these considerations, we made the following predictions:

Prediction 1: The synchronized behaviors of multiple robots will produce more feelings of pressure during the interactions than the non-synchronized multiple robots.

Prediction 2: People will make more mistakes and act in conformity with the robot answers when they interact with the synchronized multiple robots than those who interact with non-synchronized multiple robots or do not interact with them at all.

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Environment
We conducted an experiment in a laboratory room. Fig. 5 shows a map of the environment. Seven robots (one MC and six answerers) and a display were placed on the desk in room A. The MC robot is on the right of the display, and the other six robots are answerers. The operator is placed in room B, sends start signals to the robots, and monitors the entire system. The participants were placed in front of the display, and the distance between them and the display was 180 cm. We recorded all of the experiment's data with two cameras and one microphone.

Participants
Twenty people (10 women and 10 men, who averaged 35.5 years of age, S.D 9.7) participated in the experiment. In the experiment, 18 participants made at least one error in all of the conditions. We targeted these 18 individuals to evaluate how the robot's behaviors influenced their answers.

Conditions
We used a within-participant experiment design to evaluate and compare the effects of multiple robots and their synchronization behaviors. In each condition, the number of trials was 18 and errors on 12, as in Asch's experiment.

Sequence condition
This condition reproduces Asch's experiment with multiple robots. In the beginning, the MC robot requests that a participant answer a question after the robot to the participant's right answered it. Each robot looked at the next answerer after responding to the question (Fig. 6, left; the fifth robot is answering and the fourth robot is looking at the fifth robot). Therefore, the five robots first answered the question in order, then the participant answered it (Fig. 6, right; the participant is answering and the fifth robot is looking at the participant), and finally the sixth robot answered, too. After the sixth robot answered, the MC robot asked the next question. The answers of all the robots were identical, but they made errors on 12 of the 18 trials.

Synchronization condition
This condition investigated the effects of the synchronized behaviors of the robots. Here, the MC robot requested that a participant answer a question after all the robots had already answered. However, unlike the *sequence* condition, all the robots simultaneously answered the question (Fig. 7, left); they looked at the participant after they answered the question in unison. Therefore, first the six robots simultaneously answered the question, and then the participant answered it (Fig. 7, right). The answers of all the robots were the same; they again made errors on 12 of the 18 trials.

Alone condition
This condition investigated the ratio of the correct answers of the participants without the robot's behaviors. In this condition, the MC robot requested that a participant answer a question alone, and then the MC robot immediately asked the next question after the participant answered the robot. During the condition, the other six robots did nothing.

Procedure
Before the first session, the participants were given a brief description of our experiment procedure. Since the experiment had a within-participant design, each participant joined three sessions of different conditions. We counterbalanced the order of the conditions, the answer labels, and the basic lengths of the lines. The participants filled out questionnaires after each session.

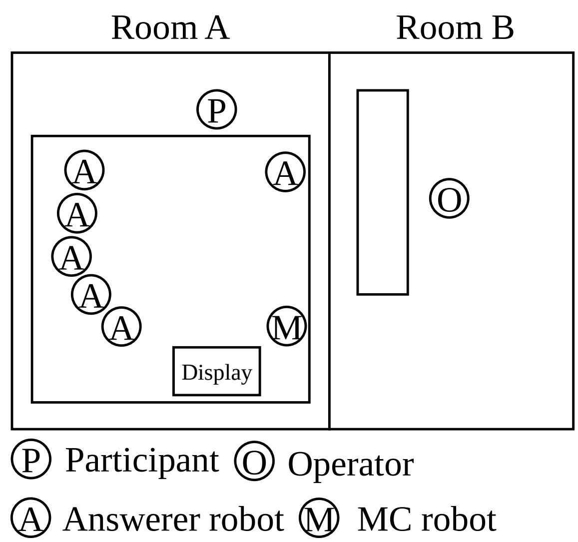

Fig. 5 Experiment environment

Fig. 6 Experiment scenes in *sequence* condition

Fig. 7 Experiment scenes in *synchronization* condition

Measurements

In this experiment, we used a questionnaire to measure on a 1-to-7 point scale one subjective item: the feeling of pressure from the robots. We also measured two objective items: the ratio of correct answers when the robots made mistakes and the ratio of conformity to wrong answers.

RESULTS

Verification of Prediction 1

Figure 8 shows the questionnaire results of the degree of pressure. We conducted a paired t-test and found a significant difference among the conditions (t (1, 17) = 3.03, p<.01, r=0.59. Prediction 1 was supported.

Verification of Prediction 2

Figure 9 shows the ratios of correct answers when the robots made mistakes in both the *sequence* and *synchronization* conditions and the *alone* condition (i.e., without robots). First, we conducted a one-factor within subject ANOVA of the ratios to investigate whether robot pressure caused more errors in the participants. The results showed a significant difference among the conditions (F (2, 34) = 3.26, p=.05, partial η^2=.58). Multiple comparisons with the Bonferroni method revealed a significant trend: *synchronization* > *alone* (p=.07), but no significance between *sequence* and *synchronization* (p =.51) and *sequence* and *alone* (p =.74).

We also conducted a paired t-test on the ratio of the participants' conformity to the robots' mistakes to investigate whether the participants conformed with them (Fig. 10). The results did not show a significant difference among the conditions (t (1, 17) = 1.21, p=.24). Prediction 2 was partially supported.

DISCUSSION

Relationship between perceived pressure and mistakes

Even though the experimental results did not show conformity by synchronizing multiple robots, it showed interesting phenomenon. Thus, participants make more mistake under *synchronization* condition than *alone* condition, but did not follow robots' answers. These results would suggest that the perceived pressure did not relate to the power of peer pressure, or the total power of perceived pressure is not enough to make peer pressure; because the average of the perceived pressure at the *synchronization* condition is larger than *sequence* condition but it was less than middle (four). If the robots could make more pressures, the latter assumption, i.e., whether the total power of perceived pressure related to conformity, can be unveiled; this is one of interesting future works.

Here another question arises. Do perceived pressures influence mistakes? In fact, the participants reported more feelings of pressure from the robots under the *synchronization* condition than the *sequence* condition. On the other hand, they probably felt less pressure from the robots under the *alone* condition because only the MC robot was working. Therefore, we analyzed the correlation between the perceived pressure and the ratios of the correct answers to understand the details of their relationship.

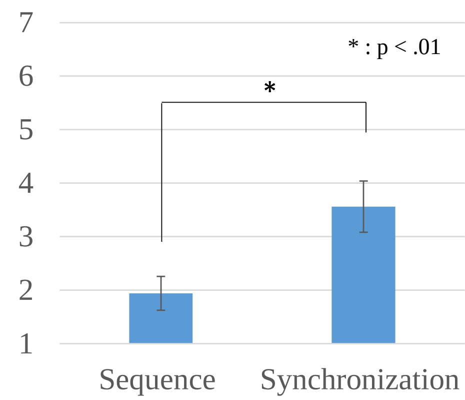

Figure 8. The questionnaire result of the degree of pressure

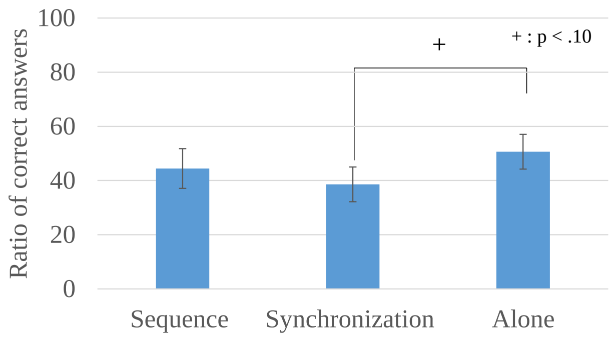

Fig. 9 Ratios of correct answers in all conditions

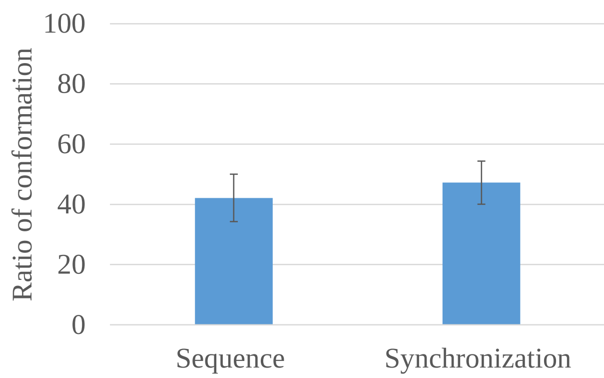

Fig. 10 Ratios of conformity in both *sequence* and *synchronization* conditions

Correlation analysis using the Pearson correlation did not reveal any statistical significance in both the *sequence* condition (Pearson correlation = -.29, p = .24) and the *synchronization* condition (Pearson correlation = -.05, p = .85). This result indicates that the perceived pressure did not have any correlation to the ratio of the correct answers. We must investigate other kinds of variables to explain these phenomena, for example, why the participants made more errors in the *synchronization* condition. Even though our findings did not clearly explain what feelings are related to the ratio of mistakes, this research provides one implication. We need a careful behavior design about using multiple robots because their synchronization behaviors might cause incorrect human judgments, such as deceptive advertising uses.

Why didn't the participants conform to the robots?

More robots and their synchronization behaviors were still insufficient to create conformity among the participants in our current settings. Here we discuss what factors are essential to cause people to conform to robots.

First, people perceive robots as different from humans [6, 7]; they do not treat them as humans. If a robot were to establish a rapport or a social relationship with people, their responses might be different. In this research work we did not include any interaction design or context to create such relationships between the robots and the participants.

Another perspective is the authority of the robots. If people felt great respect for them, their opinions might change. Geiskkovitch et al. reported that a robot's authority influenced people's behavior [24]. They investigated whether participants continued to perform a tedious task under a robot's direction by controlling its authority and concluded that its perceived authority status was more strongly correlated to obedience.

Robot appearance and size are also related to the power of pressure. When people face larger or stronger robots, they might feel physical pressure. In this study, the participants probably did not experience such pressure. After the experiments, several participants described the synchronized robots as cute. We also investigated their feelings of enjoyment about their interaction with the robots, and these results showed significant differences between the *sequence* and *synchronization* conditions by paired t-test ($p<.01$). This results indicated that participants felt more enjoyment under the *synchronization* condition than the *sequence* condition.

Limitations

Since this study investigated the effects of peer pressure from multiple robots, we cannot generalize about our predictions from it. Even though this experiment showed that pressure effects increased the mistakes of people by synchronized multiple robots, it still did not show peer pressure. It was also conducted within the framework of an academic study. The participants only had limited interaction with desktop-sized robots. Thus, the effect shown in the experiment might be moderated if they interacted with a robot with a different appearance or size. Of course, the number of interacting robots would also influence the experiment results; we only used six robots.

Only adults participated in our experiment. If children or seniors were to interact with our robot, they might perceive a different level of peer pressure from the synchronized multiple robots. Also, the effects of pressure from multiple robots are related to ethical issues. We conducted this experiment under an academic context, but we need to carefully design multiple robot behaviors in real world contexts. These limitations will be tested in the future, perhaps with different kinds of robots or societal contexts.

CONCLUSION

In this research work, we focused on the effects of peer pressure from multiple robots. Even though previous research reported less peer pressure from multiple robots, the effects of synchronized behaviors that increase pressure remain unrevealed. To investigate the effects of peer pressure from synchronized multiple robots, we conducted a within-subjects experiment in which multiple robots provided incorrect answers under an ambiguous situation.

Our experimental results indicated that synchronized multiple robots exerted more pressure on participants, as we assumed, and increased their error rate more than a situation where these robots did not provide incorrect answers. However, the peer pressure effects are not completely clear from the experiment. We believe that our findings will provide several implications to the development of robot applications that simultaneously use multiple robots, especially for commercial or advertising purposes.

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