Supporting the Adaptation of Agents' Behavioral Models in Changing Situations by Presentation of Continuity of the Agent's Behavior Model

Yoshimasa Ohmoto[1][a], Junya Karasaki[2] and Toyoaki Nishida[2,3]
[1]*Faculty of Infomatics, Shizuoka University, Hamamatsu-shi, Shizuoka-ken, Japan*
[2]*Department of Intelligence Science and Technology, Kyoto University, Sakyo-ku, Kyoto, Japan*
[3]*Faculty of Informatics, University of Fukuchiyama, Fukuchiyama-shi, Kyoto, Japan*

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Abstract: In this study, we attempted to make participants continually estimate an agent's behavioral model by having the agent itself present the continuity of its behavior model during a task. By doing so, we aimed to encourage users to pay attention to changes in the agent's behavioral model and to make the user continuously change the relationship between themselves and the agent. In order to make the participants continually estimate the agent's behavioral model, we proposed the method of "presentation of continuity of the agent's behavior model." We implemented agents based on this and conducted an experiment using an animal-guiding task in which one human and two agents cooperated. As a result, we were able to significantly increase the degree to which participants paid attention to the agents and induce active interaction behavior. This suggests that the proposed method contributed to maintaining a relationship between the agents and the participant even in changing situations.

1 INTRODUCTION

In various aspects of society, complex problems arise that cannot be handled by a single person. To deal with such problems, plans are designed and managed, and tasks are executed (Jennings et al., 2014). In recent years, the importance of cooperation between humans and agents in problem-solving has been recognized (van Wissen et al., 2012), and systems used to support cooperation have been designed (Pacaux-Lemoine et al., 2017). By utilizing the strengths of humans as well as agents in cooperatively executing tasks, both entities can solve problems more efficiently than if they work separately.

To solve complex problems, Allen et al. proposed a flexible interaction strategy called a "mixed-initiative interaction" (Allen et al., 1999). In a mixed-initiative interaction, the roles of each subject are not predetermined, and the goal is to accomplish the task while dynamically changing the roles and initiatives of both. This mixed-initiative interaction is particularly important in cooperative tasks where it is difficult to capture the full scope of the plan, the plan is fluid, or where the capabilities, environment, and information obtained by each entity are different.

Gianni et al. (Gianni et al., 2011) pointed out that achieving a mutually initiated interaction between humans and agents involves challenges in four areas: "allocation of responsibility for tasks between humans and agents," "methods for switching initiative between humans and agents," "methods for exchanging information between humans and agents," and "building and maintaining a shared awareness of the state of humans and agents." In order to "build and maintain a shared awareness," humans must spontaneously and continuously approach agents.

To build and maintain a shared awareness, a wide range of information needs to be exchanged between humans and agents. Awareness includes the relationships among team members, goals to be achieved, tasks required to achieve them, actions of individuals and reasons for their actions, and changes in the surrounding environment (Atkinson et al., 2014; Lyons, 2013). Cheetham et al. (Cheetham and Goebel, 2007) categorized this information into "facts and beliefs, reasoning, and conclusions." If an agent has a certain "reasoning," it is likely that it should be presented in a proactive manner.

Creating agents for mixed-initiative interactions with humans has been attempted before, with some

[a] https://orcid.org/0000-0003-2962-6675

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success (Chen et al., 2019; de Souza et al., 2015). On the other hand, to realize a two-way change in initiative, it is necessary to encourage a mutual voluntary change of initiative by confirming the constructed shared awareness, rather than by using interface functions. In order to encourage users to voluntarily switch initiatives, the agent's intention model must be predicted. Several agent design methods have been proposed that focus on the cognitive property that the intention model of the agent as predicted by the user influences the interaction (Kiesler, 2005; Matsumoto et al., 2005). It is believed that when an agent has a certain purpose, the user will infer some intentions toward the agent. In this study, the agents record the events they experience and the information they collect from other users and agents, and decide their own actions based on these records, thereby implicitly presenting the agents' intentions during a series of tasks and making it easier for users to infer the agent's intention model.

There are many situations in which the construction of shared awareness is required. "Facts and beliefs" and "conclusions" can be shared in advance before the task occurs, but "reasoning" must be updated in real time. However, especially when an agent or system is the interaction partner, users often do not assume that the partner's "reasoning" model will be updated by a consistent mechanism. We hypothesized that by explicitly stating that the agent updates its behavioral model during the task in a consistent manner, the user will notice that the agent's behavioral model is updated within a predictable range, and will change the relationship between themselves and the agent to accommodate the change.

The purpose of this study is to make users pay attention to the changes in the agent's behavioral model and to make the relationship between the user and the agents change adaptively. For this, we proposed a method of presentation of continuity of the agent's behavior model that explicitly states the relevance of past actions as the basis for the agent's actions while performing continuous interaction with the agent, including chatting, and examined its effectiveness.

2 PRESENTATION OF CONTINUITY OF THE AGENT'S BEHAVIOR MODEL

Our ultimate goal is to build shared awareness among the users and the agents in a collaborative task, which is one of the concerns in realizing mixed-initiative interaction. In this study, by encouraging the participants to continue to estimate the other person's behavioral model forcing making them recognize the relationship between the behavior expressed during the interaction, we attempted to support users in adapting to changes in the agent's behavioral model in changing situations. This is referred to as "presentation of continuity of the agent's behavior model (PCB)".

As an approach to realize continuous estimation of agent's behavioral model during interaction, considering "behavior selection based on temporal continuity," we considered 1) presenting a rationale for the agent's actions based on information obtained in successive events that occurred during the task, and 2) conducting chats related to the agent's personality and the actions performed during the events in scenarios with low work density.

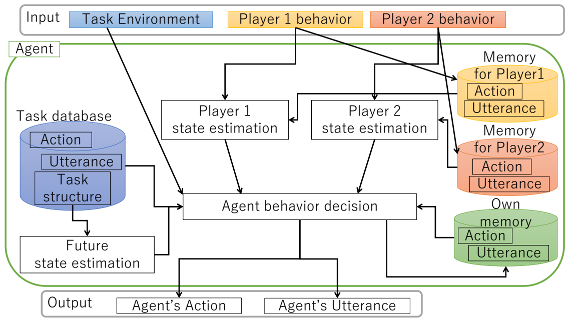

Figure 1: The component diagram of the agent.

2.1 Behavior Selection based on Information Obtained in Events

We considered a behavioral model in which an agent records the events it experiences and the information it collects from other users and agents, and determines its own behavior based on information obtained in successive events. The component diagram is shown in Figure 1. By using this, the agent can change the basis of the action it presents according to the surrounding situation and the history of its past actions.

The agent memorizes the actions and utterances of other users and agents, and selects the behavior to be performed from among the predetermined options based on the information about them in the past and the information about the current surrounding environment. When the agent decides on its own behavior, it also records that action in the memory and uses it for deciding on the next behavior. In this way, the data that can be used to make decisions increases over time, but is also lost from the memory as time passes. In addition, there is a future estimation component to predict future events based on past events. In the current implementation, this future estimation component is maintained as a tree-structured conditional branching database based on a pre-analyzed task structure. The actions and utterances selected by the action decision component are all selected from those in the database.

2.1.1 Presenting Evidence based on Experience

If a user is unaware that the agent's actions and decisions are related to the user's actions and the events of the task, it becomes difficult for the user to assume an agent's behavior model. To overcome this issue, we added a mechanism to the action decision component that clearly presents the fact that the agent is acting based on past information that is continuous in time as the basis for the action in the scene where the agent made the decision.

In situations where an agent decides on an action, it expresses verbally which information from past events, the current environment, or future speculation most strongly influenced the choice. Furthermore, in situations where other agents are acting, when it is possible to predict from which information the action was chosen, the information on which the action is based is communicated to the surroundings. In either case, the expression itself is predetermined and concise.

2.1.2 Chatting as Continuous Interaction

When users and agents collaborate on long-term tasks, their work density is not always constant, and it is expected that there will be a mixture of busy and relatively relaxed situations. The interaction decreases when the work density is low, and the user pays less attention to the agent. This inhibits the user from continuously estimating the behavioral model of the agent.

To prevent such a situation, we added a mechanism to the action decision component for "chatting to share information about user and agent's personal experiences" and "chatting about events performed in the past" in situations where the work density is low. By referring to past events, we expected to confirm each other's "facts and beliefs" that were implicitly shared before. In the chat that shared information about personal experience, we encouraged the estimation of the agent's behavioral model by talking about episodes related to the agent's preferences.

3 EXPERIMENT

We attempted to support the participant's adaptation to changes in the agents' behavioral model even in changing situations by making them recognize the relevance of the agent's actions through the proposed PCB. We implemented agents that acted based on the model, and conducted an experiment using a task of crowd guidance. The group with two agents that implemented PCB was called the "continuity presentation group (CP-group)", and the group with two agents that did not present the basis for their actions or engage in chitchat, but whose behavioral model itself was the same, was called the "non-presentation group (NP-group)".

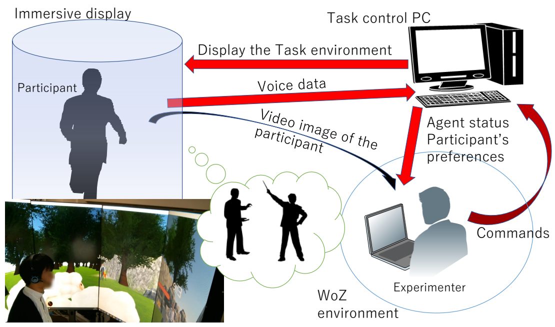

Figure 2: The experimental setting.

3.1 Experimental Setting

The experimental setting is shown in Figure 2. We used a 360-degree immersive display consisting of eight portrait orientation LCD monitors with a 65-inch octagonal screen. In this environment, participants can easily look around in the virtual space with a low cognitive load, similar to the real world. A participant's virtual avatar was controlled using a game pad. Participants wore a headset with a microphone. In order to ensure a verbal response, the participant's speech was transmitted to an operator through the microphone, and the agent's speech was output by the operator based on predetermined rules (Wizard of Oz: WoZ).

3.2 Procedure

First, the experiment was explained to the participants, and they were asked to practice the manipulation of the task. The manipulation practice was completed when the participants felt that they could operate the task at a level that would not interfere with the experiment.

After providing a brief explanation of the main session, the experimenter began recording the video and started agent interaction. The participants performed the task sequentially. In the main session, a WoZ operator partially controlled agent behavior. The WoZ operator input a reaction command to the agents based on predefined rules and reaction patterns when the participant tried to interact with the agents. During conversational interaction, the conversation between the two agents was automatically controlled based on the predetermined scenario. After all sessions were completed, a questionnaire was administered to obtain a subjective evaluation of the participants.

We conducted an experiment with 27 Japanese university students (aged 19 to 24 years, mean = 22.7, SD = 2.64). Sixteen were male and eleven were female. The participants were divided into two groups. The members in the CP-group included 13 participants (eight male and five female) and the remaining participants were included in the NP-group.

3.3 Description of the Task

The participants played a game in which two agents (John and Ellie) and one participant worked together to guide animals in a virtual space. Here, the participant and the agents are referred to as "players". The objective of the task was for the three players to cooperate in guiding multiple animals (sheep) wandering around the game field to the goal point in virtual space. At first, there were only two sheep, but they were scattered near the route to the goal point, and the goal was to collect those sheep while heading for the goal point. In this task, it was necessary for players to flexibly coordinate how to deal with problems that arise periodically in the task while cooperating to achieve a single goal.

A standard route was shown on the game field, and the sheep might be found around the route. There were various obstacles in the field, and the player needed to guide the sheep to the goal point by avoiding or removing these obstacles. There were also items in the field, which could be picked up to remove obstacles and guide the sheep. The game score was calculated based on the number of sheep taken to the goal and the time taken to reach the goal.

On the way to the goal point, there were several objects that blocked movement. Those objects could be destroyed. Among the objects that blocked movement were doors that could not be destroyed but could be unlocked. Destroying or opening an object without using an item (a weapon or a key) took a relatively long time, which reduced the score obtained when the goal was reached. This was taught to the participants.

Figure 3 shows a bird's eye view of the field where the participants performed the animal guidance task. The orange line represents the standard route to the goal, and the circled numbers indicate the locations where events occurred in the task. The starting point

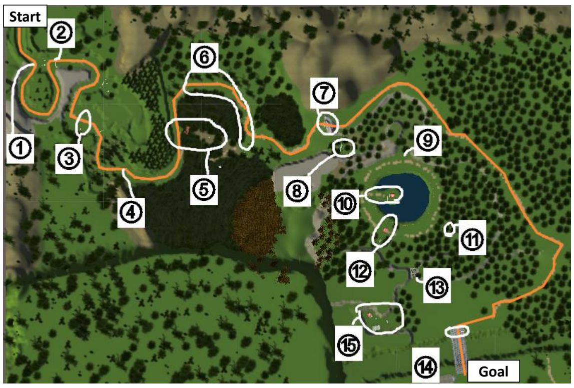

Figure 3: The event map of the game field.

is in the upper left corner, and the players took the sheep scattered around the route to the farm at the goal point. When the players used the map item, the white lines and numbers in Figure 3 were erased.

1. Players introduced themselves.
2. One of the agents picked up a map.
3. A flag and a weapon were placed on the floor.
4. The players experienced that destroying an object reduced their stamina, and that it was easier for the sheep to get lost if the same player kept holding the flag.
5. A sheep was hiding in a side street.
6. If the players chose to ignore the sheep, they needed to break the fence on the road ahead.
7. The route was blocked by a large rock. There was no other choice but to deviate from the route and continue through the forest.
8. The entrance to the forest was blocked by a fence. The players were able to open it and proceed from the menu command.
9. The players could find a pen with sheep trapped in it in the middle of the pond. The two agents told the participant that they would move to the left to find a way back to the standard route, and told the participant to go to the right to catch the sheep.
10. The participant was able to open the fence of the pen and catch the sheep. A sign on the side described the traps to catch sheep further along the route.
11. The two agents who were separated from the participants picked up a weapon here.
12. The participant and the agents met up before here. There was a trap to catch sheep that the participant had read about on the sign. If the participant had not shared this information with the agents in advance, the agents would have triggered the trap.

13. The route was blocked by a small rock. By using an item, they were able to efficiently remove the obstacle.
14. The route was blocked by a gate. The key to open the gate could be found by looking around or by looking at the map.
15. The players opened the fence and obtained the key. If the participant spotted sheep, the participant could take them away.

3.4 Behavior of Agents in the CP-group and the NP-group

The two agents in each group had different preferences in the way they performed the task. So, each agent gave different directional advice.

In the CP-group, two types of behavior were presented: (1) when the agents acted at a certain point in time, they indicated that they had a consistent basis with their previous actions, and (2) when the work density in the task execution was low, they gave their impressions based on the previous events. The agents in the CP-group and NP-group performed the same actions and judgments related to task execution. The differences in the agents of each group are shown below.

Situations That Require Action, Such as Breaking an Object, Catching Sheep, or Holding a Flag.

CP-group: In situations where it was judged that the agent should take active action, one agent proposed the action while stating the basis, and the other agent acted by indicating that he or she agreed. In situations where the participant should perform the action, one agent suggested the action while stating the basis.

NP-group: In situations where it was judged that the agents should take active action, one agent proposed what to implement, and the other agent acted by indicating his approval. In situations where it was judged that the participant should perform the action, one agent proposed what should be performed.

Scene Where Players Moved with Sheep in Tow.

CP-group: Each agent engaged in chats related to his or her own occupation and other personalities, chats about their impressions of the previous events, and chats about speculating on future scenes based on past events. In some cases, the agents chatted with each other, but in other cases, they asked the participant for his or her opinions.

NP-group: The players moved basically in silence. In situations where task hints were required, the agents muttered the hints.

Agents' Behavior When Agents and Participant Were Acting Separately.

CP-group: In addition to the content of the chats between events, the agents also chatted about what each other was doing during their separate activities. These chats could also be heard by the participant via walkie-talkies. The agents did not talk to the participant when they were working.

NP-group: The players worked in silence. If a task hint was available on the agent side, the agents muttered. This mumbling was also heard by the participants via walkie-talkies.

Differences in the Behavior of the Two Agents.

Commonality: Hints that required consideration of the task were often stated by Ellie, whereas intuitive actions were more often carried out by John. John and Ellie had common criteria for how to proceed with the task, such as breaking obstacles or bypassing the route.

CP-group: Each agent presented actions and opinions that were considered appropriate in each situation based on their own preferences. In chatting and rationale situations, John had a weak outlook on the future and relied on his intuition, while Ellie preferred to see the whole picture and sometimes admonished John.

NP-group: Same as the CP-group, each agent presented actions and opinions that were considered appropriate in each situation according to their own preferences. However, they did not indicate that they had a common basis with their previous actions, and did not engage in chats that were not directly related to task execution.

3.5 Result

3.5.1 Differences in the Attention That Participants Paid to the Agents

We attempted to determine how much attention the participants paid to the agent's actions and state during the task. However, in situations where the participant and the agent were acting together, it was difficult to determine whether the participant's action was the result of paying attention to the agent or the result of understanding the task situation. Therefore, in events where the participant and the agents acted

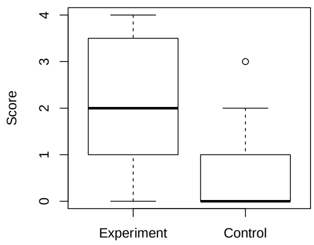

Figure 4: The number of participant's actions that would have occurred if the participant had paid attention to the agent's actions and state.

Table 1: The number of participants who actively exchanged information with the agent in these events.

	active	non-active
CP-group	9	3
NP-group	3	10

separately, we counted the participant's actions that would have occurred if the participant had paid attention to the agent's actions and state. The target events were Events 9, 10, and 13: whether the participant properly observed the agents when they went their separate ways in Event 9, whether the participant shared information with the agents after obtaining information that only the participant could know in Event 10, and whether the participant thought of a way to break through Event 13 after considering the items obtained by the agent in Event 11.

Figure 4 shows the result. The mean for the CP-group was 2.08 (SD = 1.44), and the mean for the NP-group was 0.69 (SD = 0.95). Wilcoxon's rank sum test showed that there was significantly more attention to the agents in CP-group ($p = 0.010$).

The behaviors in Event 10 and 13 required strong proactivity. Therefore, we examined the number of participant who actively exchanged information with the agent in these events. The number of people who took any of the actions is showed in Table 1, and the result of Fisher's exact test showed that there were significantly more active participants in CP-group ($p = 0.017$).

3.5.2 Number of Utterances

The number of utterances is considered to be a straightforward indicator of participants' aggressiveness. Therefore, we counted the number of utterances of the participant during the task. As the CP-group and NP-group had different opportunities to talk depending on whether or not there was a situation to chat, we counted the number of utterances during the execution of the event that were common to both groups. We excluded utterances without linguistic meaning, such as exclamations and affirmations.

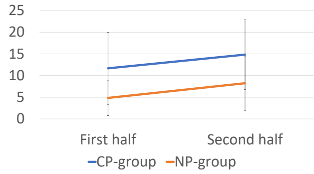

Figure 5: The number of utterances in the event that were common to both groups.

The results are shown in Figure 5. We performed the two-way analysis of variance (group: continuous or discrete x half: first or second). Between the CP-group and NP-group, there was significantly more the number of utterances in the CP-group ($F(1, 23) = 5.99$, $p = 0.023$). Furthermore, between the first and second half of the task, significantly more the number of utterances was in the second half ($F(1, 23) = 17.66$, $p = 0.00030$). The second half of the task was more complex and required more speech than the first half, which may have led to more speech. However, it is interesting to note that there is a difference between the CP-group and the NP-group regardless of the task content.

3.5.3 Questionnaires

Participants' subjective evaluations of the agent and the task were investigated using questionnaires. For Q01 through Q06 and for Q09 through Q14, participants responded with a 7-point Likert Scale. The results are showed in Figure 6. The participants answered Q07, Q08 and Q15 with a value from 0 to 100. The results are showed in Figure 7. To examine the differences between the CP-group and the NP-group, Wilcoxon's rank sum test was conducted for each questionnaire item, but no significant differences were found.

Q01 and Q02, Q03 and Q04, Q05 and Q06, Q07 and Q08, Q09 and Q10, Q11 and Q12, and Q13 and Q14 of the questionnaires asked the same questions about the impressions of "John" and "Ellie" respectively. Wilcoxon's signed rank test was conducted to examine the difference between the CP-group and NP-group, but no significant difference was found here.

3.5.4 Correlation Analysis of Questionnaires

We analyzed whether there were correlations between "John" and "Ellie" on the same questions. The results showed that most of the questions had significantly high correlations (above 0.7). However, only in the case of Q07 and Q08, no significant correlation was found in the NP-group (CP-group: correlation coefficient 0.85, $p=0.00042$; NP-group: correlation coeffi-

Figure 6: The results of questionnaires of Q01 to Q06 and Q09 to Q14.

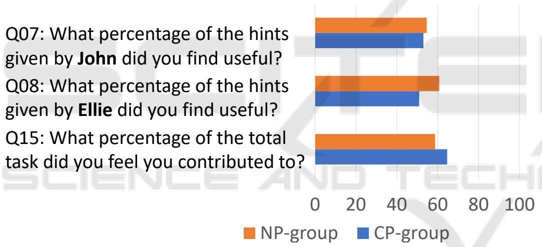

Figure 7: The results of questionnaires of Q07, Q08 and Q15.

cient 0.49, p=0.085). The questions were "What percentage of the hints given by John/Ellie did you find useful?"

This result is a bit surprising. Intuitively, it is possible that by continuing the interaction while presenting a continuity of each agent's behavioral model, the individuality of the agents could be understood and they could be recognized as individual entities. In order to speculate on the cause of this result, we calculated the correlation with this question for John and Ellie. The results showed that there were differences between the CP-group and the NP-group in the correlations between "Q01 and Q07" and "Q02 and Q08". There were also differences between the CP-group and NP-group for the correlations between "Q09 and Q07" and "Q10 and Q08".

Between "Q01 and Q07" and "Q02 and Q08". Questions Q01 and Q02 were "During the entire task, did you pay attention to the actions of John/Ellie?" When the correlations were calculated, the correlations for John's impression were 0.75 for the CP-group and 0.19 for the NP-group. The correlations for Ellie's impression were 0.76 for the CP-group and 0.46 for the NP-group. In other words, for both John and Ellie, there were significantly high positive correlations in the CP-group, but none in the NP-group.

Between "Q09 and Q07" and "Q10 and Q08". Questions Q09 and Q10 were "Did you feel that John/Ellie was observing and understanding your behavior well?" When the correlations were calculated, the correlations of John's impression were 0.58 for CP-group and 0.74 for NP-group. The correlations for Ellie's impression were 0.32 for the CP-group and 0.79 for the NP-group. In other words, the NP-group showed significantly high positive correlations for both John and Ellie, but the CP-group showed relatively weak correlations for John and no correlations for Ellie.

These results can be summarized as follows: in the CP-group, whether or not the participant paid attention to the agent's behavior was related to whether or not the participant found the agent's hint useful, and in the NP-group, whether or not the participant felt that the agent was paying attention to the participant's behavior was related to whether or not the participant found the agent's hint useful. In other words, in the CP-group, the participants who were oriented toward active interaction with the agent thought the agent's hints were useful, while in the NP-group, the participants who were oriented toward passive interaction with the agent thought the agent's hints were useful. These results suggest that the way of relating the attention to agents' actions and the evaluation of agents' actions differed between the CP-group and the NP-group.

Between "Q11 and Q15" and "Q12 and Q15". The correlations between Q11 and Q15 and between Q12 and Q15 were also different. Questions Q11 and Q12 were "If the task had continued, how much do you want to continue working with John/Ellie after the task?" Question Q15 was "What percentage of the total task did you feel you contributed to?" The correlations were calculated. The correlations of John's impression were 0.80 for the CP-group and 0.047 for the NP-group. The correlations for Ellie's impression were 0.80 for the CP-group and -0.11 for the NP-group. In both cases, a significantly high positive correlation was found only for the CP-group. This indicates that the relationship between one's own contribution to the task and the evaluation of the agent's task performance is different between the CP-group and the NP-group. In other words, it suggests that in the CP-group, the participants' own subjective degree of contribution to the task was associated with their evaluation of the agent's behavior during the task.

3.5.5 Correlation between Behavioral Indices and Questionnaires

Correlation analysis was conducted to examine the relationship between each item of the questionnaires, the attention to the agent, and the number of utterances. As a result, there were significant correlations between the following items in the CP-group: Q15 and attention to the agent (0.66), Q15 and number of utterances (in first half (0.58), and in second half (0.65)). But, there was no significant correlation in the NP-group.

This indicates that in the case of the CP-group, there was a connection between the participant's own actual behavior and the evaluation of his or her contribution to the task. In other words, in the CP-group, the participants' own active involvement in the task and agent was perceived to be related to their subjective evaluation of their own contribution to the task, while this was not the case in the NP-group.

4 DISCUSSIONS AND CONCLUSION

In this study, we attempted to make participants constantly estimate the agent's behavioral model by having the agent itself present the continuity of the actions it performs in the task. By doing so, we aimed to help users continually adapt to changes in the agent's behavioral model even as the surrounding situation changed. Specifically, we 1) presented the basis for the agent's behavior based on information about successive events that occurred in the task, and 2) conducted chats related to the agent's personality and the events performed in the task even in situations where there were no events in the task. Using these, we examined the effects of "presentation of continuity of the agent's behavior model (PCB)", in which participants are made aware that the agent retains the same memories, personalities, and behavioral models throughout the task, and can therefore estimate the behavioral models associated with the agent's actions and opinions. We implemented agents that act based on this, and conducted an evaluation experiment using a guiding sheep task. As a comparison, we implemented agents like conventional agents that do not present the basis for their actions, but the behavioral model itself was the same.

The results of the experiment showed that the degree to which the participants in the CP-group paid attention to the agents was significantly higher than that in the NP-group. In addition, the number of participants who not only paid attention but also actively shared information was significantly higher in the CP-group. The number of utterances, which is considered to be an indicator of the participants' active approach to the agent, was also significantly higher in the CP-group. Therefore, we can suggest that the PCB encouraged participants to pay attention to the agent continuously, and elicited a positive attitude toward the interaction with the agents.

The fact that the tendency of the participants' behavior did not change until the end of the task suggests that it contributed to maintaining the relationship between the agent and the participant even in dynamic situations. In previous studies, forced interaction and other methods were used to build and maintain an active attitude toward the agent (Ohmoto et al., 2016; Ohmoto et al., 2018), but the interest toward the agent decreased over time. However, in the present experiment, the participants paid attention to the agent even in the latter half of the task, so we can affirm that presentation of continuity is one of the methods to solve the issue faced in the previous works.

We examined participants' subjective evaluations of each of the two agents using a questionnaire, but there was no significant difference between the CP- and NP-groups here. By contrast, when we calculated the correlations between the questionnaire items and the behavioral indices in the CP-group and NP-group, there were several items that showed different trends. Correlation analysis suggested that the CP-group and NP-group differed in the following aspects: 1) the CP-group related participants' attention to the agent's behavior to their evaluation of the agent's behavior; 2) the CP-group related participants' degree of subjective contribution to the task to their evaluation of the agent's behavior, and 3) the CP-group related the participants' own active involvement in the task and agents to their own subjective degree of contribution during the task. Summarizing these results, it was suggested that the continuity presentation of the behavioral model made the participants aware of the relationship between their own actions and judgments during the task and the actions of the agent.

REFERENCES

Allen, J. E., Guinn, C. I., and Horvtz, E. (1999). Mixed-initiative interaction. *IEEE Intelligent Systems and their Applications*, 14(5):14–23.

Atkinson, D. J., Clancey, W. J., and Clark, M. H. (2014). Shared awareness, autonomy and trust in human-robot teamwork. In *2014 AAAI fall symposium series*.

Cheetham, W. E. and Goebel, K. (2007). Appliance call center: A successful mixed-initiative case study. *AI Magazine*, 28(2):89–89.

Chen, T.-J., Subramanian, S. G., and Krishnamurthy, V. R. (2019). Mini-map: Mixed-initiative mind-mapping via contextual query expansion. In *AIAA Scitech 2019 Forum*, page 2347.

de Souza, P. E. U., Chanel, C. P. C., and Dehais, F. (2015). MOMDP-based target search mission taking into account the human operator's cognitive state. In *2015 IEEE 27th international conference on tools with artificial intelligence (ICTAI)*, pages 729–736. IEEE.

Gianni, M., Papadakis, P., Pirri, F., and Pizzoli, M. (2011). Awareness in mixed initiative planning. In *2011 AAAI Fall Symposium Series*.

Jennings, N. R., Moreau, L., Nicholson, D., Ramchurn, S., Roberts, S., Rodden, T., and Rogers, A. (2014). Human-agent collectives. *Communications of the ACM*, 57(12):80–88.

Kiesler, S. (2005). Fostering common ground in human-robot interaction. In *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005.*, pages 729–734. IEEE.

Lyons, J. B. (2013). Being transparent about transparency: A model for human-robot interaction. In *2013 AAAI Spring Symposium Series*.

Matsumoto, N., Fujii, H., Goan, M., and Okada, M. (2005). Minimal design strategy for embodied communication agents. In *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication, 2005.*, pages 335–340. IEEE.

Ohmoto, Y., Takashi, S., and Nishida, T. (2016). Effect on the mental stance of an agent's encouraging behavior in a virtual exercise game. In *Cognitive 2016: The eighth international conference on advanced cognitive technologies and applications*, pages 10–15.

Ohmoto, Y., Ueno, S., and Nishida, T. (2018). Effect of virtual agent's contingent responses and icebreakers designed based on interaction training techniques on inducing intentional stance. In *2018 IEEE International Conference on Agents (ICA)*, pages 14–19. IEEE.

Pacaux-Lemoine, M.-P., Trentesaux, D., Rey, G. Z., and Millot, P. (2017). Designing intelligent manufacturing systems through human-machine cooperation principles: A human-centered approach. *Computers & Industrial Engineering*, 111:581–595.

van Wissen, A., Gal, Y., Kamphorst, B., and Dignum, M. (2012). Human–agent teamwork in dynamic environments. *Computers in Human Behavior*, 28(1):23–33.