Investigation of Usability and Sense of Agency with Manual/Automatic Cybernetic Avatar Operation

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***Abstract*— Cybernetic Avatar (CA) gains much interest since it can be used for interacting with other people remotely. There are many aspects that can be improved to make CA operation more natural and comfortable. We attempted to apply some automatic movements to the CA by learning from the operation history of each user. We then investigated user's satisfaction of operation using the System Usability Scale and Sense of Agency Scale.**

Keywords—Cybernetic Avatar, Remote Control Robot, System Usability Scale, Sense of Agency

I. Introduction

Cybernetic Avatar (CA) is an innovative technology that is very useful nowadays. Users can remotely operate avatars, such as robot CA or Computer Graphic CA (CG-CA) from anywhere [1]. However, long time avatar operation can result in user fatigue and boredom. To cope with this issue, we attempted to make the CA to learn from the operator's past behavior. Each operator can have a different operation style, so the training data for each person were derived from their own operation history. We expected that this automated system would make the operation of CA more convenient and comfortable while maintaining a natural feeling. In other words, we want to improve usability while maintaining the sense of agency in CA operation.

II. Methodology

In this study, we simulated two situations using video recordings of a guest coming to talk with the participant. Each participant was asked to act like a company receptionist and control the CA remotely. The CA used in this study is a small table-standing robot named "Sota" [2]. It was programmed to have simple movements such as nodding, hand raising, bowing, etc. To operate the CA, participants make the robot move using a joystick while talking with the guest in the video-simulated situation. The conversation dialogues are pre-defined to control the timing. The duration of each video is around 30-40 seconds.

Each participant completed the experiments five times for each video. In the first iteration, no automatic robot action was performed. In the next iterations, the system learned from the user's commands in previous iterations to make the robot move automatically. Participants could control the robot's movement in two styles: using one button and using four buttons of the joystick. In the 1-button condition, they could only press the "Start" button to invoke robot action, but they could not select which action to be performed. Our system selected an action based on action selections made by the subject in the past. If there was no previous data, the system randomly selected an action to be performed. In the 4-buttons condition, subjects could select a robot action directly from the four buttons on the joystick. There were 19 participants in our experiments, resulting in a total of 380 trials.

After each iteration, we asked each participant to answer the questionnaire including the "System Usability Score" proposed by Brooke [3] and the "Sense of Agency Scale" proposed by Tapal et al. [4]. We also recorded the joystick button pressing as well as the robot actions performed in each trial.

III. Results and Discussion

The questionnaire results for the "System Usability Score" were calculated with the scale 0 to 100. For the "Sense of Agency Scale", we selected the positive questions and summed all answers together, as well as the negative questions. Therefore, the scores for positive and negative sense of agency are ranged from 0 to 42 and 0 to 49, respectively.

The button pressing data were categorized into two types. If a user presses the start button or any command button when the robot is idle, this button press invokes robot action. This type was considered as *valid* presses. If a user presses a button while the robot is performing an automatic action, these button presses are ignored. We considered these as *invalid* presses.

For the usability evaluation, we compared the score of each iteration in each condition, as shown in Figure 1. In the sense of agency evaluation, we compared the summed score of positive

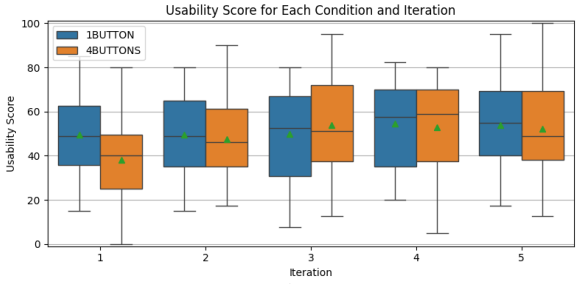

Fig. 1. System Usability Score for Each Condition in Each Iteration

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agency questions for each iteration in each condition, as illustrated in Figure 2.

In Figure 1, the system usability score seems to be increasing when the experiment is repeated for many iterations. This effect is clearer in the 4-buttons condition. Analysis of Variance (ANOVA) results show that the System Usability Score is significantly different among iterations for the 4-buttons condition ($F(4,185)=3.9810$, $p=0.0040$), but for the 1-button condition, the differences are not significant ($F(4,185)=0.6795$, $p=0.6070$). The reason for increasing of usability score could be because of subjects are getting familiar with the system so they can press the buttons on the joystick easily in the later iterations. Another reason is that we have added the automated actions mechanism to make the robot moves automatically using operation data in the past. In later iterations, the robot always moves more than in earlier iteration as shown in Figure 3. From this figure, the number of automatic actions increases dramatically. There are statistically significant changes between iterations for both 1-button ($F(4,185)=50.6640$, $p<0.001$) and 4-buttons condition ($F(4,185)=84.6007$, $p<0.001$).

From Figure 2, the sense of positive agency is getting lower significantly in the later iterations for the 4-buttons condition ($F(4,185)=18.1821$, $p<0.001$) as well as the 1-button condition ($F(4,185)=3.9118$, $p=0.0045$). In the 4-buttons condition, participants in this condition can select a specific robot action manually by pressing one of four buttons on the joystick, for instances, if they press the "bow" button but the robot perform other actions because of automatic action mechanism, the subjects can feel less sense of agency since they know that the robot does not perform the action as desired. In the 1-button condition, the subjects can select only "Start" button to command the robot to perform some actions. If an automatic action happens at the same time with their button press, a subject will not know that current robot's action is performed because of their command or because of automated mechanism. However, if the robot moves when they do not press any button, they can know immediately that the robot does not respond to their command but doing something by itself, so the sense of agency also decreases significantly.

In Figure 4, this figure shows the number of invalid button presses in the 4-buttons condition compared with the sense of agency score. We can see that the sense of positive agency is opposite to the sense of negative agency by computing the Pearson Correlation Coefficient. The correlation value is -0.35 with p-value<0.001 for the sense of positive agency score, and the correlation value is 0.25 with p-value<0.001 for the sense of

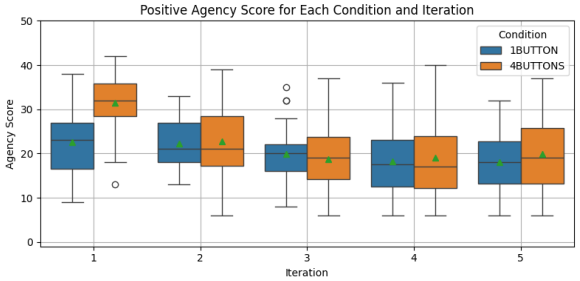

Fig. 2. Sense of Positive Agency Score for Each Condition in Each Iteration

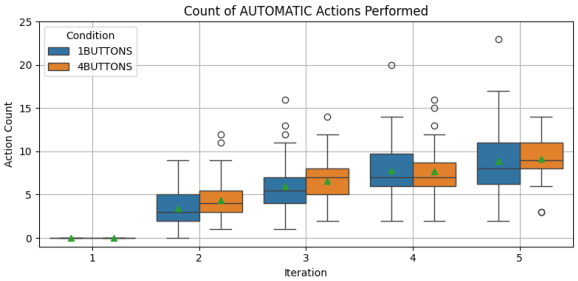

Fig. 3. Number of Automatic Actions Performed for Each Condition in Each Iteration

negative agency score. The results suggest that if the number of invalid button presses increases, the sense of positive agency score will be lower while the sense of negative agency score will be higher. This can be happened because in the current system, automatic action cannot be overridden i.e., the button presses from the subjects are always ignored if the robot is doing something. This makes the subjects have less sense of positive agency and have more negative agency sense. That is, subjects will have high sense of positive agency if they feel that they can fully control the robot and the robot response to them as they desired. To reduce the loss of positive sense of agency problem, we can try to allow the subjects to override automatic running actions. This attempt should be able to help increasing sense of positive agency even the robot is running many automatic actions.

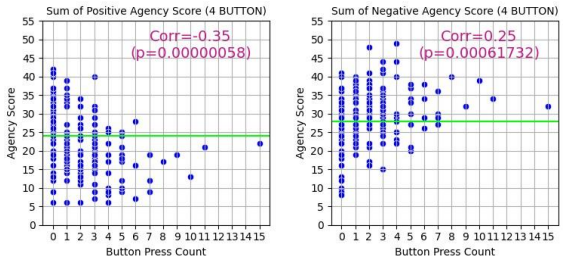

Fig. 4. Sense of Positive Agency and Sense of Negative Agency vs Numbers of Invalid Button Presses in 4-buttons condition

IV. Conclusion

We found that automatic actions performed by Cybernetic Avatars can improve the System Usability Score. However, the Sense of Positive Agency decreases when many automatic actions happened i.e., automatic action makes the system to be easier to use but if automatic action does not match with operator's intention, operator will lose their feeling of agency. This issue should be solved in our future work.

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