AIBOCOM: DESIGNING ROBOT ENHANCED HUMAN-HUMAN REMOTE COMMUNICATION TECHNOLOGY

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ABSTRACT

We present a novel method with the long-term goal to enhance human-human remote communication by using robots as social mediators, complementing current internet conferencing technology. Two pet-like robots, which interact individually with two remotely communicating users, allow the users to play an interactive game cooperatively. An exploratory pilot study tested this remote communication system with 10 pairs of users. Evaluation instruments included questionnaires, video observations and screen captures. This paper focuses on the analysis of the questionnaire results. The study tested two experimental conditions, characterised by two different modes of synchronisation between the robots that were located locally with each user. In one mode the robots incrementally affected each other's behaviour, while in the other mode, the robots mirrored each other's behaviour. This pilot study aimed to identify users' preferences for robot mediated human-human interactions in these two modes, as well as investigating users' overall acceptance of such communication media. Findings indicated that users preferred the mirroring mode and that in this pilot study robot assisted remote communication was considered desirable and acceptable to the users.

Keywords: *HRI, remote communication, social mediation*

1. INTRODUCTION AND BACKGROUND

As more people occasionally or permanently live far away from their friends and families, communication is essential to maintain and strengthen relationships. The goal of our research is to enhance the quality of remote communications in cases where actual face-to-face contact is not possible. Audio (voice) communication is currently used by many devices including telephones (mobile or fixed), computers, entertainment consoles and even wrist watches, but video images are currently available only through broadband internet based applications such as Skype, MSN, ICQ, etc. However, even though computer-based video conferencing systems offer both video and voice, they do not offer tactile sensation (touch) as an important medium that could be transferred

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over distance. Touch might provide more interactive and enjoyable communications if the means of interaction are designed appropriately and are acceptable to users. Such technology might include robots or a device worn by the user (e.g. tactile gloves [1]). Furthermore, robot embodiment has positive implications for human-computer interaction [2], especially in computer games [3]. Robots currently available, in various forms and shapes (including dogs, dinosaurs, birds etc.) have been used for domestic entertainment purposes and some offer advanced social interactions with humans [4].

We used the AIBO ERS7 from Sony [5] to investigate the role of a touch for an interactive robot because of its advanced technology, pet-like appearance and readily available programming tools. AIBO has a friendly 'cute' appearance and entertainment capabilities, including a range of autonomous behaviours. Furthermore, it is generally well received by its users [6] and is used in both university research and as a household 'pet'. Because the remote interaction we studied concerns two users, a novel computer application named AIBOcom has been developed to socially connect the users and undertake the communication between the robots. Note, our software does not depend specifically on any particular robot being used.

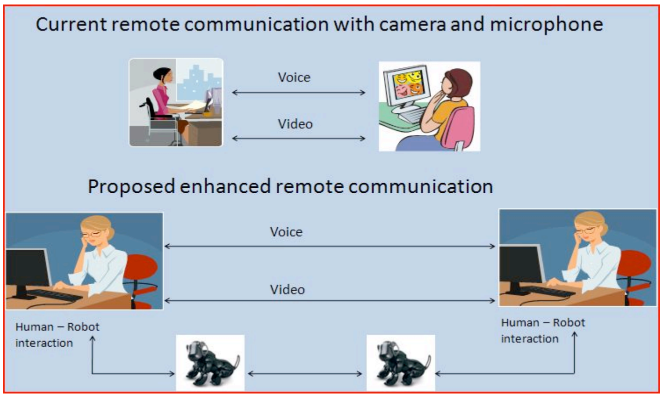


Figure 1: Current remote communication versus proposed new robot-mediated approach

AIBOcom controls two AIBOs, each interacting with a remote user, providing the ability to play a 2-player game via the AIBOs. The human-robot interactions were designed and developed bearing in mind both robot and human perspectives for robot "sociability" (cf. [7-8]). The purpose of the game in the experiment was to guide a virtual character in a computer maze by using the AIBO as an interaction tool (conceptually as a 'joystick') by moving a toy object (i.e. a pink ball) in front of AIBO. Note, unlike a 'joystick' each robot is an autonomous system with its own set of behaviours, sensing abilities, and internal variables ("needs", cf. [9-10]) and the user is expected to interact with the AIBO like a real pet in order to cope with these dynamic changes. During the game, the AIBOs autonomously execute dog-like behaviours (Human-AIBO interactions, cf. [11-12]) controlled by the internal variables. In order to complete the game, both users have to co-operate by using voice and body gesture, and by interacting with their robots. This co-operation is essential since each AIBO affects the other AIBO's internal states at every interaction and time step which drives and executes predefined expressive behaviours.

A computer game was used for the user to user interaction was made because:

1) Multi-player games offer enjoyment and collaboration for both users

2) It is a real time multi-goal system

3) It can be expanded easily

4) It supports various modes of operation and functionalities of the robots in our experiments

5) The concept can be easily understood and is familiar to most of the users

6) Users can play it simply by running the software alongside normal voice and video communication between the users.

2. BACKGROUND AND RELATED WORK

Previous research in the field of Human-Robot Interaction (HRI) which combines remote communication and robotics includes the Huggy Pajama [13]. This consists of a special wearable pyjama that is worn by a child and a huggable robotic bear. While a parent is away from the child, they can hug the robotic bear, which has embedded pressure sensors, and the hug is transmitted to the child via inflatable pads in the Pajama. Similar to this project is also the "Hug over distance" [14] which uses the same hardware to simulate the distant hug, although it focuses on couples rather than parent to child interaction. However, the system requires special hardware, which may be difficult to acquire and may be unacceptable to users, especially children. Furthermore, in order to "sense" the distanced hug, users are required to wear the special vest continually which might be impractical or unacceptable for long-term use.

The Poultry Internet [15] focuses on human to animal interactions, with similar principles to the Huggy Pajama, but uses a robotic animal that replicates movements. When an owner leaves an animal in care with another person, the system can provide comfort to the animal as it can perceives familiar petting from the owner. However, using the system on untrained animals is problematic as they will usually remove anything attached to their body (like bandages, stitches etc.).

The MIT Huggable platform [16] enhances remote communication between parents and children. The Huggable hardware is remotely controlled via a specially designed internet web interface. The robot can run in a semi-autonomous mode where it reacts to various external stimuli. An example usage for such a system is when a parent is away, they could use the web interface to connect to the robot bear and use it to read their child a story. The Huggable platform has also been used in a study [17], where the focus was on the hardware aspects of the robot which aimed to perform, react and perceive similarly to a real animal.

The Probo robot [18] has been designed to help children to overcome the stress and pain caused by hospital stays by creating a friendlier and cosier environment for children. Probo can play games and read stories when the child is alone. It can also be used in collaboration with paediatricians, psychologists and sociologists for applications in the field of Robot-Assisted-Therapy (RAT). Other studies have indicated that animals as therapeutic companions offer great benefits to people, including: lowering stress levels [19], reducing heart rate [20] and enhancing social facilitation [21]. Animal replacement robots are ideally suited to cases where it is impossible to use real animals due to dangers from e.g. bites, allergies and diseases.

The above-mentioned research projects investigate touch as a communication medium, which is a 'missing sense' in most current communications. They have shown that touch can improve interactions between humans and robots, even when the robot is located away from a tele-operator. Most of the research described above concern interactions involving only one robot. In this paper we evaluate communication between two remote users, interacting directly with each other by audio and video, but also using two interacting communicating robots as social mediators. The main advantage of the AIBOcom system is that it can be used on existing robot platforms (e.g. AIBO) and therefore does not require any expensive custom-made hardware to be designed and built.

3. RESEARCH QUESTIONS

The main research question is:

How should two interactive robots remotely influence each other's behaviours in order to enhance audio and video (AV) communications between two remote human users? Specifically, which of two modes of robot-robot communication implemented (mirroring mode and affecting mode) is preferred by users?

The system was designed to be expandable and to demonstrate various game modes. We included two game modes initially in order to test if users perceived and reacted differently to remote interactions via the robots. Our hypothesis was:

H1: Most users would enjoy and prefer the *mirroring* mode over the *affecting* mode.

We expected that the mirroring game mode, see detailed explanation below, might be more preferred by participants because it involves more user-to-user co-operation, better individual perception, superior localization and subsequently, better overall realization. Our secondary goal was to study and identify any systematic differences between potential user group characteristics including age, gender, and differences in preferences between strangers, friends and family members.

4. SYSTEM OVERVIEW: AIBOCOM

The AIBOcom software allows two robotic companions to be connected to a computer and handles the synchronisation between robot companions and users. AIBOcom can be expanded to support more robotic companions without altering the core program. The AIBOcom system for each user has three core components (Figure 2), game Interface, Connector and the Robot Program. The first core component controls all the high level functions and the game process. The second component is the connector that allows and interprets the communication between the core applications and the robots. Lastly, the Robot Program component is specific to each robot and controls its low level functions.

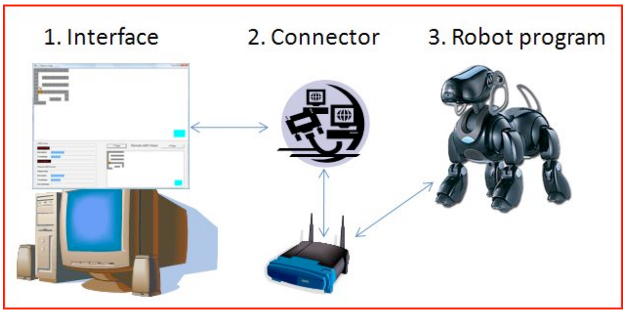


Figure 2: AIBOcom system components

4.1. Interface

The Interface is a computer application that users interact with and it controls the network connection between the users and robots and manages the game. It comprises the game interface to a maze game, the main goal of which is to guide a virtual character to the exit of the maze with the help and cooperation of the remote user. The main control is a pink ball moved in front of the AIBO's visual field. The AIBO robot moves its head to follow the ball, and the virtual character on screen moves horizontally or vertically inside the maze accordingly. The user on the remote side also controls such a virtual character and the maze includes locked doors which require the users to co-operate to open.

The game has two modes:

Mode 1 is a *mirroring* mode. Both users control the same virtual character and both only see one character on the screen. Every movement they carry out via their AIBO and the pink ball is averaged, and combined with the movements suggested by the other user. Thus, goal-directed movements in the virtual maze only succeed if both users cooperate and synchronize their own movements through Skype using voice and video gestures. During the game, every interaction with the local robots affects each robot's internal variables' values and states. These are then synchronized with those of the other robot, thus influencing the remote robot's behaviour and vice-versa. As a result, the robots mirror each other's behaviours and internal states. From an external observer's point of view both robots may appear to be controlled by the same program, but they are in fact operating autonomously with sensory input augmented from the remotely located robot.

Mode 2 is an *affecting* mode. Each user controls their own virtual character, but can see the other user's virtual character on a separate mini-screen in order to synchronise their movements. Both users have to guide their virtual characters in front of the same locked door in order to unlock it. Furthermore, since each robot is independent from the other, in terms of their respective internal states and variables, both users also have to satisfy their local robot's individual needs. Otherwise doors will remain locked, or the virtual character will not move if the real robot feels 'tired or bored'. Also, whenever a robot's internal state reaches a certain threshold, it will execute a predefined expressive behaviour (e.g. 'tiredness', 'happiness' etc.) and at the same time it will send these values to the other remotely based robot, thus affecting the remote robot's internal state variables.

Besides the game interface, the main screen also shows four bars which reflect the current (internal) states of the local AIBO, which currently includes 'boredom', 'happiness', 'friendliness' and 'excitement'. These levels change over time, to simulate dynamically changing aspects of real dog behaviour and needs. Each user can also see the remote user's robot's internal states in the same screen in order to coordinate their movements and achieve their common goal.

4.2. Connector

The connector handles all the incoming information from the Interface and interprets and sends it to the AIBO Robot Program. It is the link between these two components and is specific for each robot type. The connector program was written in C++ and compiled as a DLL library file.

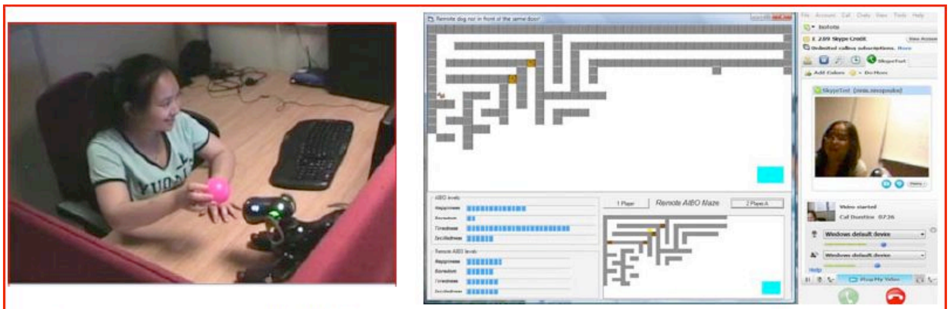
4.3. Robot program

The robot program has been written in the URBI [22] language which is standard for various robots including the AIBO. The program functions concern body movements and expressions which mimic aspects of real dog behavioural expressions. These behaviours and expressions were tested informally with several other robotic researchers from our research group at the design stage in order to achieve a consistent interpretation. A final test was then performed at the National Space Centre in Leicester over two days. Many users, including children, tested the system and mentioned any difficulties and problems they had with the game, which contributed significantly to the development of AIBOcom and the experiment design. The AIBO program is responsible for executing the dog behaviours, communicating with the Connector (e.g. sending sensory input) and executing the autonomous ball tracking algorithm. The expressive behaviours include body movements, facial expressions and barking as the AIBO is capable of showing facial expressions by an array of LEDs on its face and can produce several barking sounds from a speaker. It has touch sensors located on its head, back and under each paw. The sensory information is proportional to the touch pressure, so the AIBO program can perceive petting or hitting. The autonomous ball tracking algorithm allows the AIBO to follow the pink ball and even when it loses the ball, the algorithm is capable of remembering the last known position of the ball and will search in that direction.

5. EXPERIMENT

5.1. Procedure

The participants' ages ranged from 15 to 50 year (mean 27.8 years). Most of those were University students. The participants were arranged in different groupings in order to study differences in the interactions when playing the game between; strangers, friends, family members, male with male, male with female and between various ages and occupations. Two AIBO robots were used for the experiment. A robot was placed in front of each user and next to their screen to allow them to interact with the robot and play the computer game simultaneously. In order to identify the importance of the environment, 10 participants were tested in a university office environment and 10 in a home environment. Two participants were seated in different rooms in front of a computer running the AIBOcom system (Interface) and an AIBO robot. They communicated with a camera and a microphone using the Skype audio-video communication application. First they were given a three page quick-start manual that had all the basic information to start playing the game and controlling the AIBO. The game details were explained to both participants and their questions answered. They were then left alone to familiarize themselves with the system by playing the game in single player mode (i.e. the same maze game as previously described, but played by one user and the local robot) for 5 minutes. If no problems were reported, the experiment started proper, and participants started the two player game mode with five minute sessions playing modes 1 and 2. Game modes were referred to the users as mode 1 and mode 2, not affecting and mirroring to avoid any bias. The first 10 participants played mode 1 first and then mode 2, the order reversed for the remaining 10 participants to counterweight for familiarization and game order factors.



A user interacting with AIBO *Computer maze game interface*

Figure 3: Two users playing the affecting mode

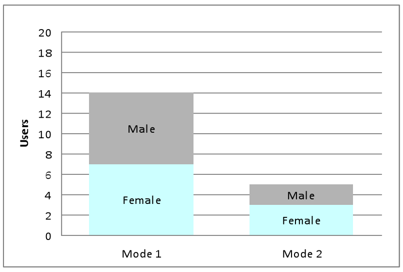
Each experiment was conducted following the same procedure to avoid possible influences on the study and the results. Each participant sat in a different room, and they completed demographic and consent forms before the experiment. During the game, AIBOcom automatically logged the game details such as user position, AIBO variables, remote user position etc. and stored them in a data file with timestamps. In addition, video (behavioural) data was collected. At the end of each experiment, participants were given questionnaires to assess their game experiences and preferences in mode 1 and mode 2. Results of the questionnaire data are presented below. The other data collected is currently being analysed.

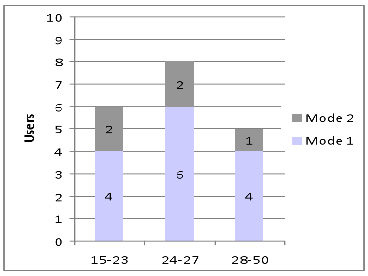
5.2. Experiment results

The results are presented reflecting the basic questions asked in the questionnaire: The number of users who successfully finished both games (mode 1 and mode 2) within the 5 minutes time limit; how users enjoyed playing the including liking ratings for these two modes. Lastly which mode users preferred in the context of user-to-user cooperation preferences. For each question, we split the results into three age and different relationship groups and present the results in an overall graph. Furthermore, we distinguish data derived from male and female participants to present any possible variations between genders.

Note, statistical tests were carried out where applicable. However, participant numbers were too small for the application of reliable statistical tests (Friedman etc.) for the combinations of sub groupings (age, gender, user-user relationships, environment etc.) within the sample. Nevertheless, there are some tendencies apparent in the data that are reported here as well as they may guide future work in this area.

5.2.1. Users finished the game in mode 1 and mode 2





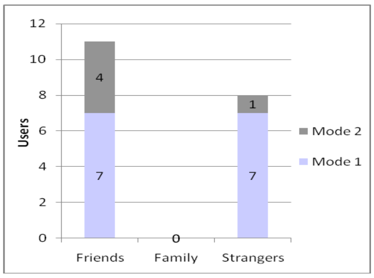
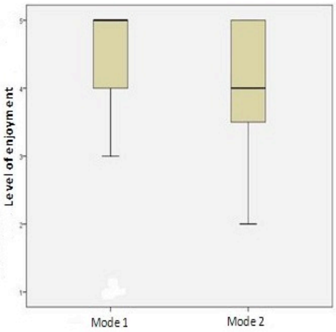
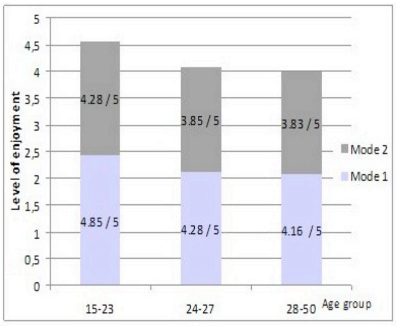


Figure 4: Mode 1 vs. 2 **Figure 5:** Age groups **Figure 6:** Relationship groups

Figure 4 shows the overall completion scores of the users playing mode 1 and mode 2. More users finished the mode 1 game (mirroring), compared to the mode 2 game (affecting). Figure 5 presents the difference between three age groups, especially between the two last age groups. Figure 6 shows results for various user-user relationship groupings. It should be noted that none of the family members managed to finish the game. A non-parametric Wilcoxon test was conducted to compare mode 1 and mode 2 for users who finished the game. A statistically significant difference between the completion rates of mode 1 and mode 2 was found (Z= -2.496, 2 tailed Sig. = 0.013). More users completed the mode 1 game as opposed to the mode 2 game.

5.2.2. Level of enjoyment





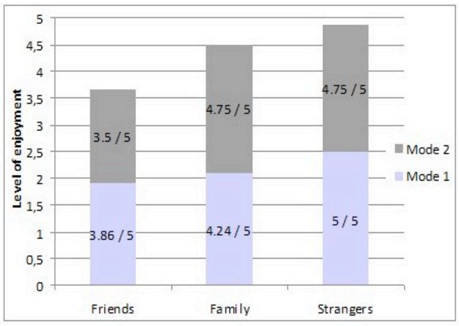
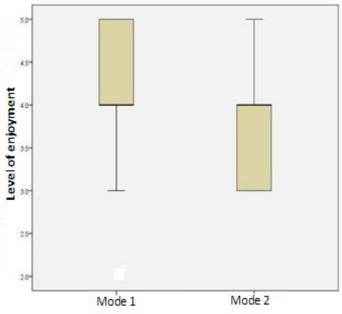
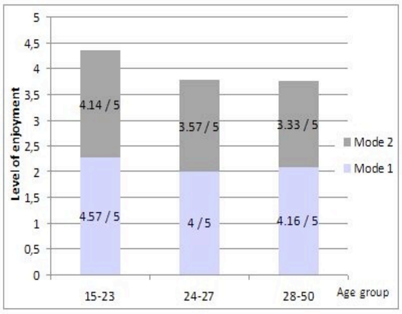


Figure 7: Mode 1 vs. 2 Figure 8: Age groups Figure 9: Relationship groups

Figure 7 shows the median values of the Likert [23] scale ratings from the questionnaire comparing users' enjoyment of mode 1 with mode 2. Figure 8 presents the average mode values according to three different age groups and Figure 9 presents the results categorised by the relationship status between the users. A non-parametric Wilcoxon test on users' enjoyment ratings confirmed a significant proportion of the sample stated that they enjoyed the mode 1 game more than the mode 2 game (Z= -2.179, 2 tailed Sig.= 0.029).

5.2.3. Cooperation preference between two modes





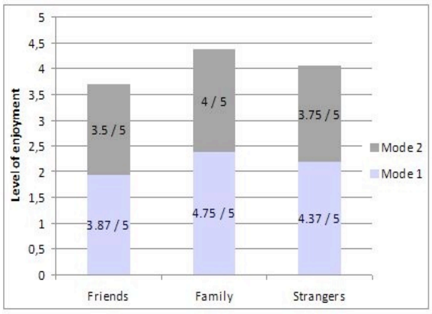


Figure 10: Mode 1 vs. 2 Figure 11: Age groups Figure 12: Relationship groups

Figure 10 compares the median mode values gathered from the cooperation question for game mode 1 and mode 2. Figure 11 shows the average mode values for the three age groups and Figure 12 presents the co-operation enjoyment ratings for various relationships. A non-parametric Wilcoxon test found a significant difference in ratings (Z= -2.161, 2 tailed Sig.= 0.031) in favour of mode 1.

6. DISCUSSION

Our original research hypothesis is supported by the results of the statistical analysis which shows significant differences for user enjoyment, cooperation and game completion scores in favour of the mode 1 (mirroring) game. Furthermore, most users also agreed they want to use such technology for remote communications in the near future. Additionally, a common explanatory comment associated to the enjoyment question was "because it was fun" which indicates that the system supports a fun game context. We suggest that users find the mode 1 game cooperation more understandable and 'direct' since they were interacting with each other during the game with no delays. Furthermore, mode 1 (mirroring) displays only one virtual character on the screen, which probably helped users to realize the context and purpose of the game better than in the mode 2 (affecting) game. The robotic companions also behaved differently for the two game modes, and users apparently rated the robot's behaviours better when the game was perceived as a 'centralized system' (with the two robot's closely mirroring each other's behaviour) rather than as 'individual displays' (with the two robots only influencing each others' behaviour but behaving differently from each other most of the time). Since this was a pilot study, the number of participants was limited to 20, too small for reliable Friedman tests to investigate systematic differences relating to age, gender, environment and relationship factors. However, considering the figures showing the raw results for different user groups, the following observations can be made: Female participants appeared to enjoy the game and the cooperation in both modes more than male participants did. Comparing various age groups between 15 and 50 years of age we cannot identify any difference in completion scores, but there is a noteworthy decrease in level of enjoyment and preferences in the context of cooperation with increasing age. This may imply that older people need more familiarization with new technologies in order to accept and adopt them.

Regarding the relationship between communicating user pairs, when friends played with each other they tended to get higher completion scores when finishing the game in mode 2 (affecting). This may be because the mode 2 game requires more vocal interaction between users in order to coordinate the virtual maze characters, and friends are already more familiar with each other. It is also noticeable that none of the (pairs of) family members managed to finish the game in the required time. However, since 50% of the family group were above 45 years old, this may be an effect of our previous interpretation where older people needed more time to familiarize themselves with new technologies.

With regard to enjoyment, the 'strangers' group found the games very enjoyable followed by the family group and lastly friends respectively. This could be interpreted that strangers find the remote interaction and communication among them more interesting and enjoyable than the other user groups. However, with regard to cooperation within the games, family group users had the highest overall rating followed by strangers and then friends. Family members may have found the cooperation among them easier and more enjoyable because of the level of familiarity with each other.

7. CONCLUSIONS

A majority of participants enjoyed both game modes (mirroring and affecting) and most managed to finish the games within the 5 min period allocated. Our findings support the original hypothesis that users would prefer the mirroring (mode 1) game. Also, the results imply some possible differences between demographic groups. However, these tendencies may only be present in 'initial encounters' with the new technology, and may be eliminated when more time will be given to participants for familiarization with the system. Note, in preliminary tests users who tested our system without any time constraints showed improvements in their game playing in their next trial. These could to be the subject of further research in more focussed future experiments with larger sample sizes.

Our pilot study with 20 participants requires further experiments to support and expand on our initial findings. However, as the results indicated a preference for the mode 1 game, our next studies will focus more on mode 1 (mirroring) and less on mode 2 (affecting). However, users' preferences may change over the long-term and as the mode 2 game did receive some positive ratings it will not be excluded altogether from future studies.

A video camera captured all user interactions with the robot and a screen-shot program was running on both computers capturing the AIBOcom and Skype interfaces. These data remains to be analysed and to be compared with the questionnaires. A more extensive study should be conducted regarding users' demographic data to identify and support any potential connection between the mentioned user groups. The results from this study will inform our future work on remote human-human interaction and communication with robots as social mediators.

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