Experiments with Vizzy as a Coach for Elderly Exercise

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ABSTRACT

Vizzy is a wheeled humanoid robot carefully designed for an enjoyable / pleasurable interaction with humans. In this paper evaluate Vizzy's application as an exercise coach according to user's perceived robot aesthetics, trust, confidence, and enjoyment. We describe the proposed robotic platform skills, interfaces, and interaction modes. We have deployed Vizzy in three care centers in Portugal for the promotion of exercise activities and tested its performance with 36 elderly users. Survey data collected after the interaction with the robot show a good acceptance of the robotic platform as an exercise coach. From observations and short interviews, we also extracted a set of guidelines that led to several improvements and ideas for future work.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Field studies**; *Graphical user interfaces*; • **Computer systems organization** → **Robotics**; • **Applied computing** → Health informatics;

KEYWORDS

Human-Robot Interaction, Robot Coaches, Acceptability, Exergames, Elderly Care

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Figure 1: Vizzy inviting a lady. The "wizards" act as technicians and control the robot behind the gaming platform.

1 INTRODUCTION

Sedentarism is the adoption of behaviors characterized by reduced physical activity, consequently increasing health risks[6, 12]. It mostly affects the elderly population segment, that tends to have a more sedentary lifestyle [6]. This problem is becoming particularly serious in modern societies, where aging populations are growing at a fast pace [10]. In Portugal, in 2015, elderly population (over 65) represent 20.3% of the population and is expected to increase to 26.2% by 2030 [2].

The AHA project[1] is a project funded by the Portuguese Government that is developing technological solutions for the prevention of sedentarism in the elderly. A recent development is an augmented reality gaming platform, denoted PEPE (Portable Exergame Platform for the Elderly) [15], that projects games on the floor and allows users to control the game with body movements. A portfolio of exergames for improved fitness of the elderly has been developed in [4], and runs on PEPE for easy deployment and testing with end-users in elderly institutions.

In this paper we study the role of the Socially Assistive Robot (SAR) Vizzy [11] in inviting, engaging and motivating older adults in a elderly institution to play the exergames (see Figure 1). In a sense, Vizzy plays the role of a human-like coach. As a coach, Vizzy should be perceived as competent on its job and users should trust the robot's advice. To keep people engaged and motivated on a regular basis, the interaction with Vizzy should be pleasant. First it approaches a possible user and initiates a dialog-based interaction that aims at sparking the interest for the game. If the person agrees, the robot guides the user to PEPE and explains the game. When the user is ready, the game is started. During the game execution, Vizzy provides verbal motivation: (i) correcting players if necessary (ii) motivating players to advance their performance. This interaction paradigm is tested with a Wizard-of-Oz (WoZ) interface (Figure

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[1] http://aha.isr.tecnico.ulisboa.pt

1), since the dialogue and head gestures systems are not yet fully automated.

Most of the robot coaches for elderly described in the literature exploit interaction modes based on imitation games (see Section 2). In our work, the games are projected on the floor by PEPE and the game elements are controlled by tracking the user's body. Vizzy has to instruct people on how to play exergames. In the experiments described here, the game was the classic *Pong!* where the user moves a bar to prevent a ball from exiting the game area (see Section 4.3).

This paper contributes to the literature on robot coaches for exercise in two important ways. First, on the technological side we describe the skills and interfaces developed for Vizzy to implement the desired interaction modes and give the users an enjoyable / pleasurable experience. Second, we perform a technological acceptability study to assess the viability of the proposed system for deployment in elderly care centers, evaluating Vizzy's aesthetics and people's perceptions regarding trust, competence and enjoyment.

2 RELATED WORK

The benefits of social robots as exercise coaches for the elderly has been studied in several works during the last decade.

In [3] the user sits in a chair facing the robot, and performs arm exercises demonstrated by the robot, either one gesture at a time or a sequence of gestures. The robot monitors the gestures of the users and provides real-time feedback. The roles of robot and human can be reversed, i.e. the user demonstrates gestures for the robot to imitate. The results have shown a clear preference of older adults for the physically embodied robot coach with respect to a virtually embodied coach (a robot animation in a computer screen).

In [16] the humanoid robot NAO and a Microsoft Kinect sensor are used to promote imitation games with older adults. The robot presents the exercises and provides verbal and visual real-time feedback about the execution quality and quantity as well as improvement suggestions. About half of the participants judge the robot as a good motivator, whereas the other half reports that a human trainer would be a better motivator than the robot.

In [5] a similar setup is used to learn, from a human coach, a set of senior fitness exercises commonly used in nursing homes, and then the robot demonstrates the exercises to a subject. Results show that elderly people can successfully exercise with the assistance of the robot, while staying engaged over multiple sessions.

In [14] it is studied whether the mere presence of a humanoid robot giving instructions for the game is sufficient to motivate the user (the Robot Instructor role), or whether the robot should exercise along with the trainee (the Robot Companion role). The results show that users prefer the robot performing the exercise together than just giving instructions. However, the study was missing the case where the Robot Instructor could also give incentive and feedback during the subject's exercise. Also, this study was done only with young subjects.

Our work adopts a Robot Instructor role, as defined in the previous work, but adds to it strong incentive and feedback dimensions during the game execution. In our work the exercise is not based on imitation and the robots must invite users to join for the game, escort them to the play ground, verbalize game instructions, and provide real-time incentives. The purpose of the study is to assess the acceptability of the robot as an exercise coach in such an interaction paradigm.

3 VIZZY AS AN EXERCISE COACH

Vizzy is a general purpose SAR platform developed with careful appearance design considerations to facilitate acceptance and interaction with humans [11]. The robot has an anthropomorphic upper torso, with head and eye movements to move its head in a biologically inspired way [13] when looking at people's faces. It has two arms that provide non-verbal communicative gestures familiar to humans, such as waving, hand-shaking, pointing, among others. It is assembled on top of a mobile Segway platform to navigate autonomously in known environments. With its front and rear lasers, Vizzy is able to avoid obstacles along its way while localizing itself on a known map. Detection and tracking of people are achieved with the two cameras that Vizzy has as eyes. In addition, a Kinect on the robot's torso allows it to detect gestures and obstacles that the laser fails to detect.

For the AHA project, Vizzy was customized to be a personal trainer robot that promotes physical exercise and an active aging life among the elderly. New interfaces for communicating and interacting with the users in the given context (via verbal dialogue and head-eye gestures) were developed.

This paper tests the abilities of Vizzy for persuading seniors to exercise through exergaming, guide them to the exercise location, give them instructions to play and, when playing, monitor their execution and provide feedback and motivation. Such goals require advanced social engagement skills, such as fluid verbal dialogue and proper body language. At the moment the robot's dialogue and attention control systems are not fully automated so we have developed two user interfaces for easy speech, gaze control and navigation via WoZ. This way, we are able to explore and test variations of the interaction modes to realize the ones more suitable to our context.

3.1 WoZ Interfaces

We have developed two interfaces for easy commanding and visualization of the semi-automated components of the robot: (i) the dialogue control interface and (ii) the motor control system. These interfaces can run on different devices which gives us the possibility to distribute tasks between two operators.

3.1.1 Dialogue control interface. From the control menu (Figure 2) the "wizard" can select sentences from a predefined list hierarchically organized in dialogue categories as shown in Table 1. For instance, if the "wizzard" wishes to inform users that the game is over, she/he would press the game events button (button number 11 in Figure 2). The button would then expand and show the verbal intentions list as shown in Fig. 2(b). Upon selecting the "Game Over" verbal intention, the system would randomly select and speak one of the following utterances: "Game Over! Well Done!", "Nicely done, the game has ended", "Game finished. Good job", "It's game over. Nice job!".

The organization of these dialogue category buttons obey to a segmentation based on the various stages of interaction with the person (see Table 1). This option was taken to make wizard's

Button # (on Fig.)	Dialogue Category	Stage
1	Salutation	Preceding Game
2	Presentation	
3	Invitation	
4	Persuasion	
5	FAQ's	Before & During Game
6	Yes/No	
7	Humor	
8	Coaching	During & After Game
9	Positive Reinforcement	
10	Query User Condition	
11	Game Event	

Table 1: Dialogue interface buttons, categories and stages

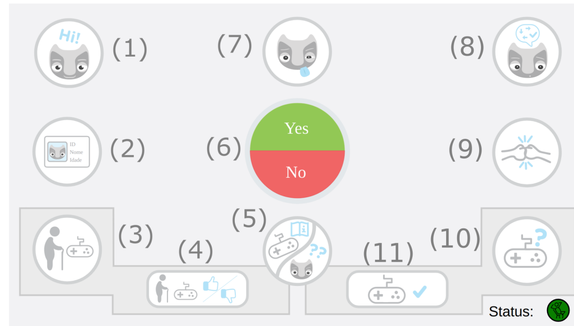
choices more intuitive and quick. The appearance of the buttons has been developed so that the intent of each category button is visual.

To easily access the dialogue interface from different devices, we developed the GUI as a web-page with HTML and JavaScript. ROS communication was possible with the *roslibjs* library. The robot hosts the GUI web-page using an Apache server. It communicates with *ROS* via the *rosbridge_websocket* communication server and uses *actionlib* to request a speech action from a node (Speech synthesis server). With the current implementation, this node uses *NUANCE SPEECH*'s [2] web services for speech synthesis. Speech actions contain the desired utterance, its language, and the desired voice. In this way, we can easily change the voice and language as needed. To allow the "wizard" to listen to what users say we use an available ROS package (*audio_common*) that streams the microphone's inputs over the network.

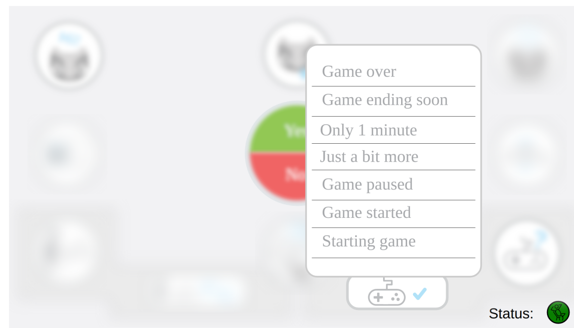
3.1.2 Motor control interface. The Rviz tool is the default visualization and control application in ROS. However, early experiments showed us that these default plugins and views are not sufficient to easily control our robot's movements in a robust way. One essential function that the WoZ interface must provide is the ability to easily move the robot's head directly from the GUI. Accurate gaze control is crucial to let a user know that the robot is indeed talking to her/him instead of the person that is right next to her/him. Furthermore, head movements can be a complement to verbal actions, clarifying users regarding the robot's intentions (especially for people with hearing problems). This functionality was implemented within the *ClickableGazeDisplay* view. The clickable view allows the "wizard" to simultaneously view the scene from one of the robot's cameras and choose a point for the robot to look at with a mouse click (left view on Figure 3).

Another problem with the default Rviz interface is the inability to override the navigation planner commands and manually control the steering of the robot for a fine positioning of the robot posture with respect to the person. For that purpose, we implemented a new plugin that lets the "wizard" control the robot's velocities directly from Rviz with the W, A, S, D keys (*WASDTeleop tool*).

[2] https://developer.nuance.com/public/index.php?task=home



(a)



(b)

Figure 2: The dialogue control GUI (a) is composed by a set of buttons grouping several verbal intentions into categories. When pressed, the buttons will expand (b) presenting the available verbal intentions.

We also use the default functionality provided by Rviz to view obstacles detected by the robot's front and back laser scanners, its estimated location on the map, and to use the robot's autonomous navigation capabilities.

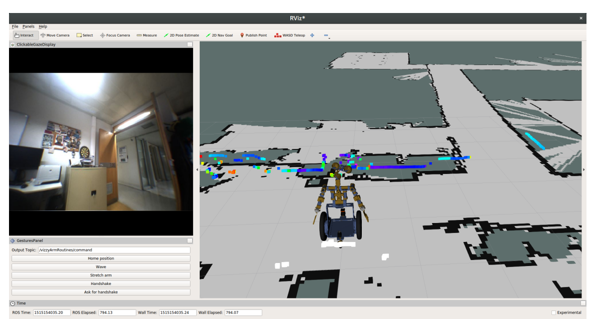


Figure 3: The robot control window (Rviz) with our custom plugins (*ClickableGazeDisplay* and *WASDTeleop*). Base control can be achieved with a planner or manually with the keyboard and gaze by clicking on the camera image. The right part of the screen shows the map, the robot and obstacles, enabling the "wizard" safely control the robot.

4 END-USER TRIALS

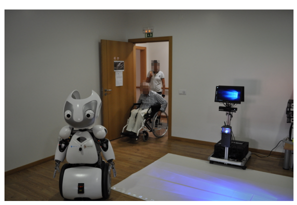
The robot Vizzy was tested at three elderly care institutions in Portugal. A summary of the facilities, the participants of the test and the test conditions can be found in Table 2. A more detailed explanation follows below.

4.1 Experimental protocol

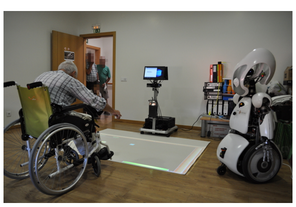
The robot approaches and invites an user to play an exergame (Figure 4(a)). If the person accepts, the robot leads the person towards the PEPE game platform (Figure 4(b)). Then, the robot introduces the game giving instructions on how to play. During the game, the robot also assists the person with corrective instruction if necessary. A second role of the robot is engaging the person during the game by providing feedback, and by assessing interactively with the person if the game can continue or if it should stop (Figure 4(c)). At the end of the game, each participant answered a questionnaire after taking a picture with the robot (Figure 4(d)).

The tests were performed in the presence of the caregivers and, when necessary, with their assistance. Their comments and opinions were also noted and were very useful to fine tune the interaction process between the robot and the elderly.

(a)



(b)



(c)

(d)

Figure 4: Experimental protocol. The robot invites the person (a) and guides the person to the gaming area (b). Upon arrival the robot explains how to play the game and motivates the person based on the performance (c). Posing for a photo before the questionnaire (d).

4.2 Participants

The participants (a total of 36) are the regular users of the institutions and include mostly elderly. The actual age range went from 65 to 94 years old (μ = 80.83, σ = 5.84). Most of the participants where female (26 female participants), as the male percentage of the population at these ages is lower. Some of the subjects live independently while others are institutionalized.

4.3 Test conditions

The game could be played in two ways. More fit subjects played the game while standing and controlled the game by walking left and right. Other subjects played the game while sitting on a chair and controlled the game by waving their hand, either by suggestion of the caregivers or by their own preference. The spacial conditions were different at each location. On LATI all the participants where in the same room as the game's platform, on CSCNSM the waiting room and playing room were separate but people could see other people playing, and on RSB the waiting and playing rooms were completely isolated.

4.4 Questionnaire

In Table 3 we present the questionnaire items used to evaluate the experience with Vizzy. All the measures used a five-point Likert scale ("totally disagree" = 1 to "totally agree" = 5). Items were adapted from the Godspeed Questionnaire [1], ALMERE model [7], and the scales proposed by Jiun-Yin et al [9].

5 RESULTS

5.1 Questionnaire Results

On Figure 5 we report the mean value of the questionnaire responses to questions related to the Perceived Competence (PC), Perceived Enjoyment (PE), and Perceived Trust (PT). We performed a One-Sample t-test comparing the mean score to the neutral value of the scale. All the results are significantly higher than the neutral value. The users perceived the robot as competent (PC: $\mu = 4.47$, $\sigma^2 = 0.41$), had high trust in the robot (PT: $\mu = 4.36$, $\sigma^2 = 0.79$), and enjoyed interacting with the robot (PE: $\mu = 4.67$, $\sigma^2 = 0.47$). The measures used for these three dimensions (PC, PT, PE) showed high internal consistency (Cronbach's $\alpha > 0.7$).

Figure 6 reports the mean value of user's evaluation of the robot's aesthetic characteristics. We performed a One-Sample t-test comparing the mean score to 3 (the neutral value of the scale). For light blue colored bars a bigger score represents a better evaluation. In average, people think that the robot's movements are elegant (A2: $\mu = 3.81$, $\sigma^2 = 0.78$), the robot's voice is pleasurable (A4: $\mu = 4.50$, $\sigma^2 = 0.83$), and Vizzy's facial expressions (including responsive (A5: $\mu = 3.89$, $\sigma^2 = 1.24$). Although it needs more validation, these results show that the WoZ setup allows people to successfully control the robot's movements in a way that people find appropriate, and that the selected voice is suitable. Users thought that the robot was not too bulky (A3: $\mu = 2.31$, $\sigma^2 = 1.075$). For people, it's pretty obvious that the robot looks artificial (A1: $\mu = 3.78$, $\sigma^2 = 1.66$) and has a machinelike appearance (A7: $\mu = 2.39$, $\sigma^2 = 2.016$). On average people liked the robot (A8: $\mu = 4.56$, $\sigma^2 = 0.71$) and thought that the robot is cute (A6: $\mu = 4.36$, $\sigma^2 = 0.81$).

5.2 Observation Results

From informal observations and interviews we collected some information about the interactions that led to a fine-tuning of the interfaces and suggest future improvements.

Since it was the first time these group of elderly people were seeing the robot, several people reported that they were feeling anxious with the interaction. Some people were "frozen" gazing

Institution	Acronym	Subjects (female/ male)	stand/ seat	Ages
LATI - Liga dos Amigos da Terceira Idade	LATI	11 (9/2)	10/1	72-91
Centro Social Comunitario da Nossa Sra. dos Milagres	CSCNSM	10 (6/4)	4/6	65-88
Residência Sénior de Belverde	RSB	15 (10/5)	9/6	70-94

Table 2: Information about the subjects participating in the experiments as well as about the institutions and the conditions where the experiments took place.

Perceived Competence (PC)	**Perceived Trust (PT)**
1: I think the robot is competent	1: I trust the robot when it gives me an advice
2: I think the robot is reliable	2: I am assured that I can perform the activity when I am invited by the robot
3: I think the robot is an expert/knowledgeable	**Aesthetics (A)**
4: I think the robot is intelligent	1: The robot looks artificial to me
Perceived Enjoyment (PE)	2: I think the robot's movement is elegant
1: I enjoy the robot talking to me	3: I think the robot is too bulky
2: I find it fun interaction with the robot	4: I think the robot's voice is pleasurable
3: I find it enjoyable interacting with the robot	5: I think the robot's facial expressions (including gaze) are responsive
	I find the robot's appearance: 6: - Creepy (1) ... Cute (5) 7: - Machinelike (1) ... Humanlike (5) 8: - I dislike it (1) ... I like it (5)

Table 3: Questions given to the elderly. Answers are numbered from 1 (totally disagree) to 5 (totally agree).

at the robot for some time without knowing if they should really interact with Vizzy or not. However, after this initial state, people started to speak and interact more confidently with the robot.

We noticed that one of the most important elements for interaction is the gaze direction while talking. If Vizzy's gaze direction is ambiguous or does not match expectations (e.g. Vizzy's gaze direction points to a different person), the user does not engage in an interaction and asks for confirmation to the caregivers. This happened during the first experiment, where the WoZ gaze interface was keyboard-based (i.e. up/down/left/right directions controlled using a key stroke), thus not precise enough. This led us to improve the GUI WoZ interface with the *ClickableGazeDisplay*, as explained in Section 3.1.2. In the remaining experiments during the interaction with the elderly we did not notice any interruptions nor questions due to Vizzy's gaze direction. Head control also seemed to have some effect when trying to persuade a person to play the game. We observed with several people that when the robot nodded up and down while asking them to play, people would agree more easily to participate. This effect needs further investigation.

In the first institution the experiment was performed in a group environment. We noticed that elderly users were supportive of each other. It was common to see people trying to explain the game to their colleagues when they were failing to understand it from the robot. In the other institutions, despite the game was played individually, the phase where the robot invites users to participate was made in a group environment. It that case it was common see

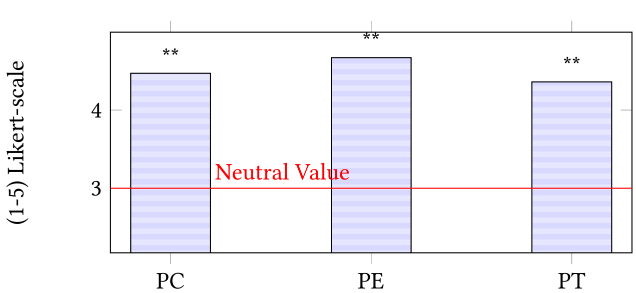


Figure 5: Survey results: $** \equiv p < 0.005$
Perceived Competence (PC): $t(35) = 13.80$, Cronbach's $\alpha = 0.78$.
Perceived Enjoyment (PE): $t(35) = 21.21$, Cronbach's $\alpha = 0.83$.
Perceived Trust (PT): $t(35) = 9.16$, Cronbach's $\alpha = 0.71$.

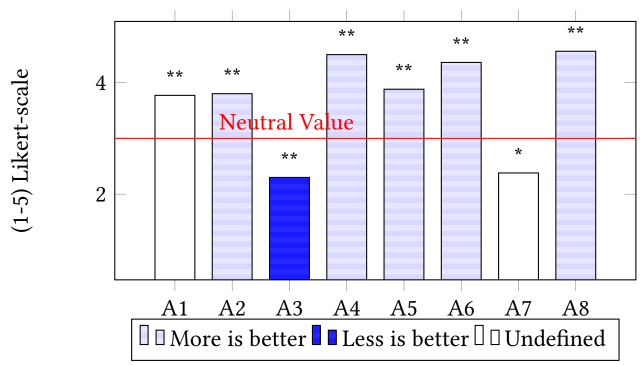


Figure 6: Survey results for the aesthetics' dimension. $** \equiv p < 0.005$, $* \equiv p < 0.05$. **A1:** $t(35) = 3.61$. **A2** $t(35) = 5.43$. **A3:** $t(35) = -4.01$. **A4:** $t(35) = 9.88$. **A5:** $t(35) = 4.78$. **A6:** $t(35) = 9.08$. **A7:** $t(35) = -2.58$. **A8:** $t(35) = 11.07$.

people persuade colleagues to participate in the experiment when the robot was unable to do it. In general, we saw that elderly people were interacting more spontaneously in group environments. Nonetheless, these observations need future validation.

During some experiments, it was noticed that the robot's voice commands when providing corrective instructions were not being understood. One of the occupational therapists suggested a problem with long phrases such as: "The ball is going to the right, go to the right." Instead, we should use usual effective statements, for example: "Right! Left!". Another identified limitation of the dialogue system is the small repertoire of sentences of the same type. This lowers the level of personalization of speech perceived by each person, since they realize the same phrases are being reused. Between experiments we increased the number of phrases of each type to provide the robot with a richer and less predictable speech.

We tried to use some humour in some of the robot's utterances. Interestingly enough, people did enjoy these sentences and started to interact more with Vizzy. In a certain way, we sensed that people felt challenged by the robot. One example was when Vizzy said to the user: "I bet you haven't exercised this much since you were 20 years old", to which the person (that was not responding to the robot robot until then) laughed and replied: "What? I exercise a lot! Everyday I go up and down my stairs!". Speaking sentences with humour seem to have great potential to enhance human-robot interaction and motivate people. However, it is very challenging to automate this kind of behavior. People's reactions are dependent on cultural background and current psychological state.

Several professionals and older people showed a desire to acquire the robot, with different motivations and objectives. Professionals focus their expectations on the robot as a complement to their action. Such a tool as a robot could manage and energize some activities in group within an institution. They also expect that the robot can somehow help them with routine bio-medical measurements. The elderly who showed openness to this type of technology, do so in terms of benefits of physical exercise combined with the companionship component that Vizzy can offer. The main barrier mentioned by professionals is relative to the cost that this type of technology can possess. The general institutions across the country are private institutions of social solidarity, which may have monetary limitations for the acquisition of this type of solution. However, private institutions, in smaller number, have a greater financial margin to acquire technological solutions like these. Two directors of two elderly institutions have told us that a robot in a private institution can function as a differentiating factor of innovation of activities and resources compared to other institutions.

6 CONCLUSIONS

We have described the use of Vizzy as a coach for elderly exercise. Test with 36 users in 3 different institutions show a good acceptability of the system, measured by a quantitative analysis of questionnaires. Qualitative observations and informal interviews raised some interesting points for future developments.

In the short term we intend to integrate arm gestures in the robot. The addition of arm gestures will complement the verbal communication both for the game instructions and correction of movements during the exercise execution.

During the experiments we noticed that the elderly usually initiate the interaction with an handshake gesture. We are currently developing a comfortable and natural handshake gesture for Vizzy [8], which will be integrated in future studies.

Many elderly have a very competitive nature. We observed an interest from several participants in knowing the scores of the other participants to try to excel. It would be interesting to the robot to use this fact to stimulate the competition among users and motivate them to play longer because they have goals/scores to achieve.

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