Questioning Items' Link in Users' Perception of a Training Robot for Elders

Emanuele Antonioni[1], Piercosma Bisconti Lucidi[2], Nicoletta Massa[3], Daniele Nardi[1], and Vincenzo Suriani[1]

[1] Dept. of Computer, Control, and Management Engineering
Sapienza University of Rome, Rome (Italy)
{lastname}@diag.uniroma1.it.
[2] Sant'Anna School of Advanced Studies, DIRPOLIS Institute, Pisa, Italy
piercosma.biscontilucidi@santannapisa.it
[3] Department of Psychology, Sapienza University of Rome,
nicoletta.massa@uniroma1.it

Abstract. Socially Assistive robots are becoming more common in modern society. These robots can accomplish a variety of tasks for people that are exposed to isolation and difficulties. Among those, elderly people are the largest part, and with them, robotics can play new roles. Elderly people are the ones who usually suffer a major technological gap, and it is worth evaluating their perception when dealing with robots. To this end, the present work addresses the interaction of elderly people during a training session with a humanoid robot. The analysis has been carried out by means of a questionnaire, using four key factors: Motivation, Usability, Likability, and Sociability. The results can contribute to the design and the development of social interaction between robots and humans in training contexts to enhance the effectiveness of human-robot interaction.

Keywords: Robot trainer · Ageing society · Social Robots

1 Introduction

Social Robots (SRs) are often seen as the next widespread commercialized technology, since they find new fields of application year after year, especially in care-taking contexts. Typical examples are robots caring for the elderly or supporting children in the autism spectrum [4]. Especially in the case of assistive robotics for the elderly, the Covid-19 pandemic impressed an important acceleration both to research and to the commercialization of social robots [7]. This aspect is added to the progressive aging of Western societies and a progressive decrease in the number of human care-takers compared to the elderly population. One of the biggest challenges for social robotics today is therefore being able to take over part of the care-taking activities. This must be achieved by respecting the principles of human-centered design, and it is generally necessary to consider the ethical issues that Social Robotics raises [16]. Against this backdrop, assistive robotics for elders does not aim only to release human care-takers from the heaviest duties: the main objective of this technology, in line with the EU ethics guidelines [17], is to empower individuals, improve their autonomy, and their quality of life. As widely demonstrated, physical and psychological health are highly correlated aspects of humans' life, and the research has highlighted the inversely proportional relationship between physical activity, disability, and mortality, especially in the elderly population group [8] [9], which nevertheless continues to represent the least physically active. Social Robotics can help the elderly population in maintaining optimal physical fitness, improving their autonomy and quality of life. The scope of this study is to understand if a NAO Robot with a high level of social interactivity and with a very positive interaction style is more effective than a neutral one to engage elders in training exercise. We set up a 2x1 between-subjects design with one independent variable: the degree of social interactivity and positivity of the interaction. The interactions provided by the two NAO were highly different in terms of interactivity: the positive NAO before starting with the training exercise, introduced itself to the user, it called him by his name during the training and used both positive feedback and the pronoun "we" instead of "you" to create an atmosphere of teamwork during the exercises; while the neutral NAO started the workout with no preliminary interaction, did not use reinforcements and only described briefly the type of exercise the user should perform. In general, through the training, the "positive NAO" provided positive reinforcements toward the user (e.g., "You are doing great!", "Well done", "We are a good team!"), instead of the "neutral NAO" that only explained the exercises giving no feedback. We designed the interactions referring to the field of sport psychology, where it is well known how the coaches' communicative skills correlate with athletes' motivation and with the quality and satisfaction associated with the performance and the coach as well [11] [13]. Moreover, a supportive attitude is linked with an increased adherence to a training program in the long term [2], and with the quality of life consequently, [3]. This is particularly important for the elderly population [18] [19] to whom our research is aimed. For these reasons, the "positive NAO" condition aims to recall the importance of the coach-athlete relationship, providing a communicative style where the social bounding was maximized to impact the motivation of the user and their interest in the training program. With this purpose, we expected to observe that the robot providing positive interactions would have higher scores in the following items: likability, sociability, usability, motivation. We discuss the questionnaire design in the section Experimental Design. We expected an increase in likability and sociability of the positive NAO, since it provided more interactions than the neutral one and was more supportive and, in general engaging, as above discussed. Therefore, the hypothesis of our work was that also with robot trainer the increase in likability and sociability would result in more motivation for the user.

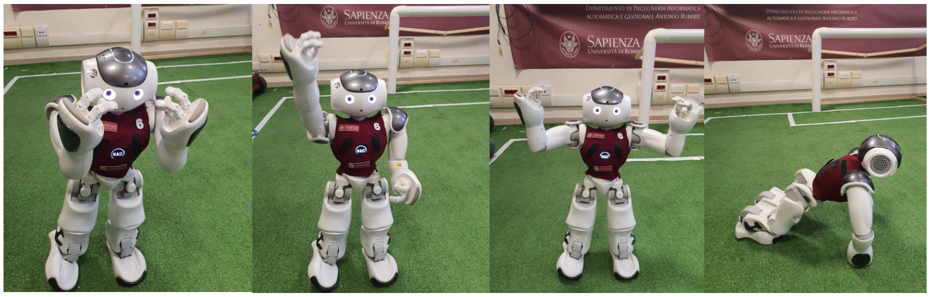

Fig. 1. Some of the exercises that are part of the developed routine. It is possible to notice how the robot can mimic even complex exercises to train the user.

2 Methodology

As mentioned in Section 1, the human-robot interaction procedure has been carried out by using the NAO Robot. The NAO Robot is a humanoid robot that performs complex motions thanks to its 25 degrees of freedom. For this task, the robot version chosen is the NAO V6[4]. In this version, it embeds a quadcore CPU manufactured by Intel. The computational capabilities combined with the set of sensors already on board of this robot allow it to be suitable for several tasks and, hence, become a trainer capable of demonstrating physical exercises, as shown in Fig.1. The set of the onboard sensors of the robot include two cameras, four microphones, IMU, touch and force sensors, and sonars. The interaction with the user can happen using the robot microphones, speakers, and touch sensors. By relying on these capabilities, the implemented training routine has been carried out combining all these communication channels, as an evolution of [1]. This routine allows to show the exercises and to supervise the execution of the human by tracking the posture of the trainee person. Each exercise has been designed by modeling the end-effector trajectories for the limbs of the robot. An interaction routine has been developed on top of the set of exercises. This routine has been then differentiated for creating the positive and the neutral attitude. Particular attention has been paid to the communication setup and even the voice of the NAO has been designed in velocity and pitch to make the robot more gender-neutral and to better communicate with the user.

2.1 Training Routine

The training routine has been developed within the Choregraphe[5] environment by using built-in functions and python modules. It has been designed to support real-time execution checking and a pool of exercises that can be easily chosen in the training routine. Each exercise's routine follows the schema depicted in the

[4] www.softbankrobotics.com/emea/en/nao
[5] http://doc.aldebaran.com/2-4/software/choregraphe/index.html

Fig. 3. Each exercise starts with an introduction that contains an explanation of the exercise and optional motivational interaction with the trainee that depends on the execution modality that can be positive or neutral. Then, the robot executes the planned exercise, and, thanks to parallel modules, the execution is fully monitored and supported. In fact, a correction module checks the human posture through the cameras. At the end of the execution, the robot chooses to go ahead or to repeat the current execution. In the positive training execution, at the end of the exercise, the robot provides positive reinforcements by voice and uses gestures to emphasize them. Some frames of a training routine and interaction with the user can be seen in Fig. 2.

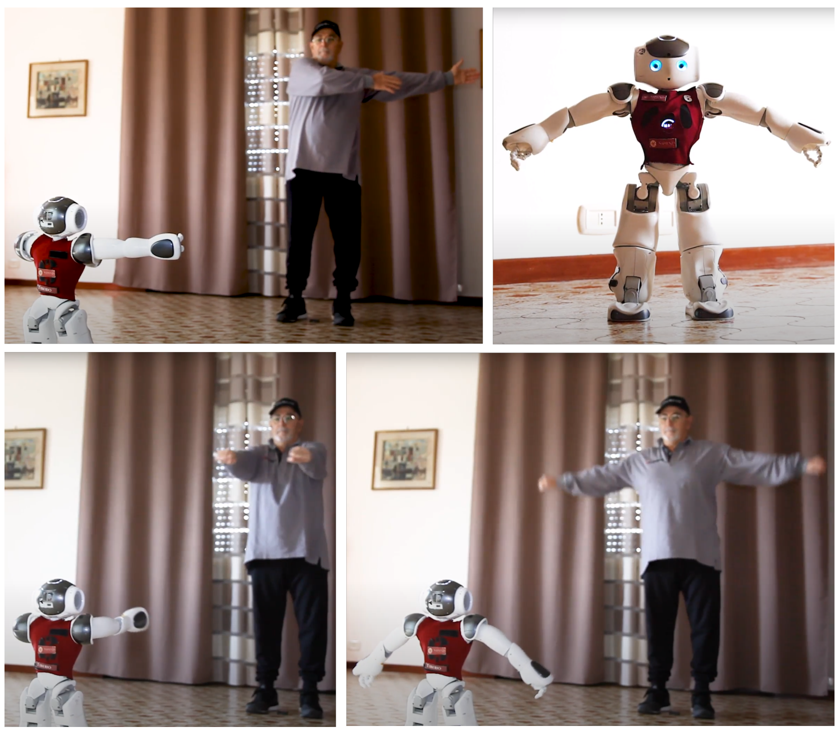

Fig. 2. Some frames taken from the videos that have been shown in the questionnaire.

2.2 Participants

The total number of involved participants is 63, with an average age of 77 years. They have been divided into two balanced samples, composed of 31 and 32 participants each. The two samples have been created by relying on the preliminary answers provided by the participants. In fact, we used age, gender, and a self-evaluated sport capability to create the two matched groups. Both samples

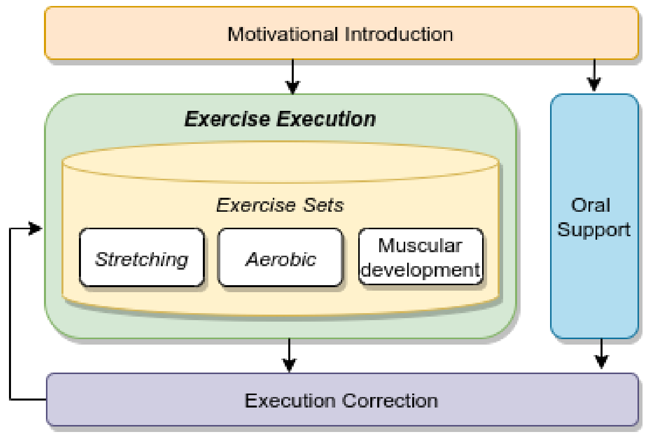

Fig. 3. Schema of the single exercise training routine. This procedure is common to both the positive and neutral trainer. The execution is fully monitored and supported. At the end of the execution, the robot chooses to go ahead or to repeat the current execution.

have the same average age (77), and the standard deviation on the two samples are respectively 5.37 and 4.8. The gender balance is 15-17 and 14-17 for the Male-Female ratios in the two samples, respectively.

The participants have been engaged by Fondazione Mondo Digitale[6] that, among other activities, delivers digital education programs for elderly people.

2.3 Experimental Design

Due to the Covid-19 pandemic, we used online questionnaires because it was not possible to conduct the study in presence due to restrictions. In the first phase of the study, a preliminary online questionnaire was used to collect anamnestic information relating to age, gender, nationality, education, and participants' perceived physical condition. Subsequently, they were assigned to the two experimental groups ("Positive NAO" and "Neutral NAO") and were asked to watch a video - that lasted approximately four minutes - where the NAO trainer provided either a high social bounding or a low social bounding toward the user. Then the participants were asked to fill a 12-questions questionnaire. They had to rate Motivation, Usability, Likability, and Sociability with a 5-point Likert scale (1=Strongly agree, 5=Strongly disagree). The questionnaire is based on the ALMERE questionnaire for Sociability (Perceived Sociability in ALMERE), Usability (ease of use in ALMERE), and Likability (Perceived Enjoyment in ALMERE). The Motivation item included the following questions:

The questions for the motivation item were inspired to [14]

- I would be curious to try the same workout

6 https://www.mondodigitale.org/it

- I would be happy to train with this robot
- I think that train with the robot is useless

The video representing the complete interaction routines of with "Positive NAO" can be found at https://youtu.be/isad9g-Lc6E. The video for the "Neutral NAO" can be found at https://youtu.be/W9OY19zzlwM.

3 Experimental Evaluation

This chapter presents the findings that emerged from the results obtained from the responses of the subjects. The elderly pool has been divided into two subgroups subjected to two different implementations of the robot interaction routine. The first group followed a robot designed to offer a positive interaction, encouragement, confrontation with the participant, and positive reinforcement. The second group instead followed a robot that proposed a neutral interaction, limiting the confrontation with the participant and without providing any type of reinforcement. Each participant have seen the video individually. The responses to the questionnaire proposed to the participants refer to four items: (1) Motivation, (2) Usability, (3) Likability, and (4) Sociability. Each response was mapped to the individual items using a numerical value in the range $(-2, +2)$.

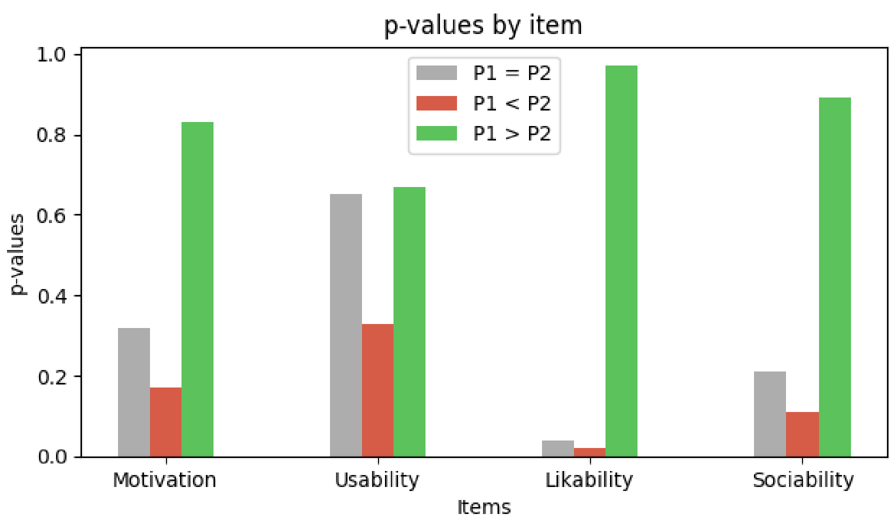

Fig. 4. p-values for different precondition hypothesis on the four items

3.1 Results

We summed numerical values extracted from each question based on the reference item. Table 1 shows means and standard deviations on the individual items

List of values				
Variable	Motivation	Usability	Likability	Sociability
μ_{pos}	1.33	2.55	1.78	1.79
σ_{pos}	1.81	1.29	1.65	2
μ_{neu}	0.67	2.7	0.67	1
σ_{neu}	2.87	1.91	2.17	2.46

Table 1. Table of experimental values

for both samples. We can see that the averages for the Motivation, Sociability, and Likability items are higher in the case of the positive sample and lower in the case of the neutral sample. From the analysis of the table, however, it is clear that all of the values reported are subject to high variance, that makes it difficult to extrapolate information straightforwardly from the trend of the averages of the individual samples. To gain an additional level of insight, we evaluated a p-value test for each item, proposing three different conditions: (1) $P1 = P2$, (2) $P1 < P2$, and (3) $P1 > P2$. Figure 4 shows the obtained values. The analysis of these p-values provides us with statistically significant results only in the case of Likability. In fact, in the condition P1 = P2, the effect on this item is the only one below the 0.05 threshold, thus passing the p-value test. Therefore, we can say that the data in our possession clearly expressed a higher Likability in the sample exposed to the robot with positive behavior. However, concerning the other items, it is not possible to provide a similarly conclusion using the p-value. Therefore, the results led us to develop a second level of analysis for these items. The p-value result indicates the impossibility of accurately inferring whether the difference in results for the Motivation, Usability and Sociability items is due to a structural difference in the samples (in our case, the different attitude of the robot) or sampling noise. Hence, we perform a further and more in-depth analysis of these items.
Considering the values in the table 1, we call μ_{pos}, μ_{neu}, σ, n the μ of the positive sample, the μ of the neutral sample, the standard deviation of the positive sample and the number of samples of the positive sample. We want to demonstrate, the following hypotheses:

- $H_0 \rightarrow \mu_{pos(mot)} = \mu_{neu(mot)}$
- $H_1 \rightarrow \mu_{pos(us)} = \mu_{neu(us)}$
- $H_2 \rightarrow \mu_{pos(soc)} = \mu_{neu(soc)}$

So we evaluate three values $z_0, z_1, and z_2$ for each hypothesis. By applying the hypothesis test formula [6]

$$z_i = \frac{\mu_{pos} - \mu_{neu}}{\frac{\sigma}{\sqrt{n}}} \quad (1)$$

we obtain: $z_0 = 1.8$ $z_1 = -0.77$ $z_2 = 1.95$. The z_0 results is inside the reference range $(-1.96, +1.96)$, so the hypothesis H_0 can be confirmed.
The z_1 result confirms the hypothesis H_1 being inside the range $(-1.96, +1.96)$.
Finally for z_2 the result is borderline w.r.t the threshold range $(-1.96, +1.96)$, this does not allow us to perform a strong inference about the correctness of H_2.

3.2 Discussion

The results obtained from the p-value test and the subsequent hypothesis tests allow us to establish inferences on only three of the four proposed items. The p-value provides us with a confirmation of the success in implementing positive interaction traits for the robot, leading to higher results in terms of Likability for the positive robot compared to the neutral robot. The general increase in the robot Likability does not match an advantage in terms of Motivation and Sociability, this is a phenomenon that requires future development and further and more specific analysis. On the other hand, hypothesis testing confirmed the hypothesis of equality of the two averages between the samples concerning Usability, suggesting that this characteristic does not undergo appreciable variations based on the change in the robot's attitude. This phenomenon may indicate to us that a sympathetic and positive approach may not necessarily be more transparent in terms of clarity in how to use technologies as complex as the proposed robot. Ultimately, although the separation between samples was not always well defined, the overall results indicate a good acceptance of the proposed idea in the elderly population. This can be seen in Table 1 where the averages of all items in both samples are pointing towards positive values, despite high standard deviations.

4 Conclusion and Future Work

In this experiment we wanted to evaluate if a NAO trainer robot providing an engaging and positive interaction was more likeable than a robot with a neutral style of interaction. From the results obtained, it was possible to conclude that, in the case of the "positive NAO", the Likability item increased, while the same did not happen for the "neutral NAO" as we expected. Therefore, the people who viewed the video where the robot trainer implemented a positive interaction, with reinforcements and encouragement, ended up perceiving it as more pleasant than people watching the neutral interaction.

While in the case of Likability we saw a clear outcome, distinguishing the results of positive Nao from the neutral one, this is not true for the other items. Though for Sociability we are not able to deduce anything from our statistical results, the hypothesis test done for Motivation and Usability suggests that a greater enjoyment in the interaction does not result in an incentive for the training activity. This goes against some suggestions of the current literature on trainer robots [5] [10] [15]. Certainly, a more in-depth analysis must follow. In future studies, we aim to investigate the reason why the results between the positive and the neutral NAO were not sufficiently differentiated in statistical terms. Our hypothesis, to test in future works, is that (especially) the elderly population might be enthusiastic and astonished for the very fact of seeing an interacting robot. In our case, the association Mondo Digitale who put us in contact with the participants' deals with topics concerning the digitalization of the elder populations; therefore, it is very likely that participants were tech enthusiasts. Therefore, as in the NATRS (Negative attitude toward robots scale) [12], we plan to carry on a study in order to test our hypothesis on the over-enthusiasm effect on the elder population interacting with robots, possibly designing an "Over-enthusiastic attitude toward robot scale".

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6 Contributions

D. Nardi conceived the experiment, supervised and managed the project, revised the manuscript.
N. Massa and P. Bisconti designed the style of robot's interaction, the questionnaire and discussed the implications of the results.
E. Antonioni and V. Suriani designed the robot's routine, performed statistical analysis; discussed the results.
All authors contributed to the writing phase.

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