Evaluation of exercise motivation competence of a humanoid robot: a case study in Brazil

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***Abstract*— Regular physical exercise and decreasing sedentary behavior are essential for the health of adults [1]. However, even with well known benefits, in 2016, it was determined that the prevalence of insufficient physical activity in the world population was 27.5% [2]. In this paper, we utilized a humanoid robot as an instructor for physical exercise in a stationary bicycle. By applying questionnaires as well as recording sensor data, we measured the impact of the robot in the motivation and other psychological aspects, as well as the performance in 14 participants. The participants were males and females with an average age of 23.5 ± 2.38 years, and were equally and randomly divided in two groups: one with the robot instructor, and a control group. They performed two exercise sessions, after which they answered the questionnaires. The results were not statistically significant ($p < 0.05$), but show a trend of the robot having a positive impact in the group that interacted with it, regarding their motivation, pleasure and enjoyment. The interaction also seems to have positively influenced the mood of the participants. The perceived effort, as well as average speed and cycled distance did not seem to have been influenced by the robot. Future studies, with a larger sample size, are needed to confirm the trend shown here.**

Fig. 1: The robot Beo from startup Qiron Robotics, utilized in this experiment.

I. INTRODUCTION

The regular practice of physical exercise reduces the chance of developing chronic diseases and improves physical fitness, while still increasing the performance in daily activities and overall quality of life [1]. However, even with clear and well-known benefits many people still struggle with a lack of motivation to exercise.

In Brazil, 62.1% of the population aged 15 and older don't practice any type of sport or physical activity, according to the Pesquisa Nacional por Amostra de Domicílio (PNAD), in 2015 [3]. Additionally, the practice of physical activity seems to decline with increasing age, where 72.4% of the population aged 60 or older, in Brazil, are sedentary. In the world, a report that compiled over 300 surveys from 168 countries determined that the prevalence of insufficient physical activity was 27.5%, in 2016 [2].

As a result of this inactivity, there are several negative outcomes that can happen in later life. Older adults suffer from cognitive decline, lose their capability for independence and have increased odds of developing noncommunicable diseases (NCDs). It has been shown that physical exercise can delay, prevent and even revert these outcomes [4]. Older adults that exercise regularly have lower rates of dementia [5] and a significant lower number of falls [6], as well as better physical fitness in general [7].

Recently, the advancement of technology has made possible the development of robots with greater potential for human robot interaction (HRI). These robots are capable of seeing, listening, speaking and gesturing. In this context, the robots are seen as collaborators, assistants or even pets, instead of simply tools [8]. There are several applications of this type of social robots, such as the tourist guide RoboX [9], or the pet robot Sony AIBO [10]. In fact, this advancement of HRI technology gave rise to the emergent field of socially assistive robotics (SAR). These are robots where the intended end users are individuals with disabilities such as people in post-stroke rehabilitation, individuals with dementia, age-related complications, as well as children with autism [11].

A large portion of the studies in the fields of sports psychology, HRI and SAR have focused on effective ways to motivate users to perform physical exercises [12], [13], [14]. As a result, several psychological factors that influence the users' motivation to realize some physical activity have been established. Among such factors, we list the following that will be explored further in this study: enjoyment, perceived exertion, feelings and mood changes, as well as the users' perception of the robot.

In this work explored the possibility of using of a hu-

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manoid robot for enhancing the motivation during physical exercise. We investigate the effect over motivation, performance and psychological aspects in humans.

II. RELATED WORK

The idea of using a robot an instructor for physical exercises has been a focus of interest in the field of HRI for quite some time [15], with robots proving their effectiveness as motivators [16].

For instance, in a study [17], actual human-human interactions between instructors and their students of indoor cycling was observed. The authors noted that the instructors would continuously monitor the performance of the students, by observing their cadence, rhythm and physical load. The instructors gave instructions in short and objective sentences, analyzing the execution of the exercise and using methods such as repeating an instruction or changing their eye gaze. Based on these observations, the authors designed a dialogue model based on the following four types of sentences: preparation, instruction, repair and feedback. They implemented this model in an autonomous robot and realized an experiment with 8 participants for 18 consecutive days, with daily sessions of indoor cycling. The results showed that the use of the robot instructor lead to a better experience for the participants, with more intensive workout and increased motivation.

More recently, in another study [18], it was shown that exercising with a humanoid companion is better than exercising alone. The authors realized an experiment with 56 participants with an average age of 25.5 years performing two exercise sessions. They were divided in three different groups: first, which they realized both exercise sessions by themselves; second, where they first exercised alone and then were instructed and praised by the robot; third, same as the second group, but the robot also performed the movements together with the participants. The results showed that participants felt more motivated, confident and tried harder in the third group. The second group compared to the first didn't show significant differences, and some participants didn't enjoy the presence of the robot as just a verbal instructor.

Inspired by these works, we investigate the potential effects of employing a humanoid robot as an instructor for indoor cycling sessions. To the best of our knowledge, this is the first study of this kind sampling from the Brazilian population – it's worth noting that people in South America are typically much less frequently exposed to robots than in developed countries. Other studies employing humanoid robots in HRI in the Brazilian context do exist, most notably the work of Romero in the context of Education and Autism (see for instance [19]), but there is none in the context of motivating physical activities. Another distinct feature of our work is that we employ a 3D printed humanoid robot manufactured by a Brazilian startup company, with a rich capacity for conveying emotions, using OLED displays for graphic expression as eyes. We included the same questionnaire used by Schneider and Kummert [18] to evaluate people's perception of the robot, and we compare our results to theirs, which employed a NAO robot [20] as a robot instructor.

III. METHODOLOGY

A. Robot

The robot utilized in this experiment was the robot Beo, shown in Fig. 1. Beo is developed by the startup Qiron Robotics [21], from Brazil. It is a humanoid robot with 42 cm of height and 9 degrees of freedom, three for each arm and three for the head. Beo has wheels for locomotion and two OLED displays posing as eyes. Using a camera and microphone, it can perform various HRI tasks, such as object detection and person recognition, speech recognition as well as speech synthesis, and non-verbal communication, using the arms and head in combination with the eyes, allowing the robot to better express a range of emotions.

The robot operated in a fully autonomous way, measuring the passing time and reading sensor data from the bicycle, to determine the appropriate sentences to speak. Based on the work from [17], we've implemented three of their four types of sentences: preparation, instruction and feedback. Table I presents the sentences that Beo said during the exercise sessions and their respective type.

Fig. 2: Placement of the stationary bicycle and robot Beo in the experiment room.

B. Experiment

The experiment was performed with 14 participants, both male and female, with an average age of 23.5 ± 2.38 years. They were university students between 20 and 28 years of age, recruited voluntarily using an online form created with Google Forms. The participants filled out their name, age, gender, major, whether they smoked or not, if they suffered from some disease or disability and their frequency of physical activity. The following were defined as exclusion criteria: smokers and participants who suffered from heart, respiratory or metabolic disorders or disabilities. After selecting participants that fit the criteria, they were instructed to: not make use of alcoholic beverages or other drugs (except for contraceptives) in the 24 hours previous to the experiment; not eat in the hour preceding the experiment, and, eat at least

Original Sentence (Brazilian Portuguese)	English Translation	Type
Olá, tudo bem? Meu nome é Beo e eu vou te ajudar neste exercício.	Hello, how's it going? My name is Beo, and I'm going to help you during this exercise.	Preparation
É só sentar na bicicleta e esperar a sirene.	Just sit on the bicycle and wait for the buzzer.	Instruction
Tocará a primeira sirene! Depois dela, comece a pedalar.	The first buzzer will sound! After it, start cycling.	Instruction
Você pode começar a pedalar agora.	You can start cycling now.	Instruction
Já passamos da marca de 1 minuto.	We are now past the 1 minute mark.	Feedback
Estou recebendo dados do sensor que está ligado na ergométrica.	I'm receiving the data from the sensor in the bicycle.	Feedback
Vi que você já percorreu 100 metros! Está indo bem.	I see you've cycled over 100 meters! You're doing great.	Feedback
Você já pedalou por 2 minutos.	You've already cycled for 2 minutes.	Feedback
Você está pedalando bem, continue assim.	You're cycling great, keep going.	Feedback
Chegamos na metade! Já se passaram 3 minutos	We're halfway through! Three minutes have passed already.	Feedback
Você já percorreu 300 metros.	You've already cycled 300 meters	Feedback
4 minutos! Está quase lá, agora faltam só 2 minutos.	4 minutes! You're almost there, only 2 minutes left.	Feedback
Você está indo bem, daqui a 30 segundos tocará a segunda sirene.	You're doing well, in 30 seconds the second buzzer will sound.	Feedback
Tocará a segunda sirene! Depois dela, pedale em velocidade máxima.	The second buzzer will sound! After it, cycle at your maximum speed.	Instruction
Você pode correr mais rápido. Vamos lá, só faltam 30 segundos.	You can cycle faster, come on. There's only 30 seconds left.	Feedback
Uau, você está rápido! Vamos lá, faltam só 30 segundos.	Wow, you're so fast! Come on, there's only 30 seconds left.	Feedback
Você foi muito bem, parabéns.	Congratulations, you did great.	Feedback
Muito obrigado por participar, até logo.	Thanks for participating, see you.	–

TABLE I: Sentences spoken by Beo during the exercise.

three hours before; wear comfortable clothing for exercising in a stationary bicycle.

The participants realized two 6-minute sessions of exercise with a 10-minute rest in between. Prior to the start of the first session and after each session the following physiological data were recorded from each participant: blood pressure, body temperature, heart rate and respiratory frequency. These data were collected by health professionals and were used to verify if the participants were fit to start or resume the exercise. The participants were divided equally and randomly into two groups: group A, which only received instructions before the start of the first session and were given no further instructions during the sessions, and group B, which also received the same instructions before the start of the first session but interacted with the robot instructor during the second exercise session.

The exercise sessions consisted of cycling in a stationary bicycle placed in a room without the presence of other humans. Each subject was previously instructed that the exercise sessions would last for a total of 6 minutes and were divided into two phases. In the first phase, the subject was instructed to cycle at a reasonable pace for 5 minutes, followed by the second phase, cycling at his maximum pace for a minute. A buzzer sound, reproduced by a smartphone, was utilized to signal each phase of the exercise: the first time, to start the exercise (first phase); a second time, to signal the start of the second phase; and a third time, to signal the end of the session. Fig. 3 shows a diagram of the structure of the experiment.

The first session was realized in the same way for participants of both groups, using only the buzzer to signal the session's phases and no further instructions. After the end of the first session, during the 10-minute break, physiological data was collected from the subject to determine if they were apt to continue the experiment. At this point, depending on

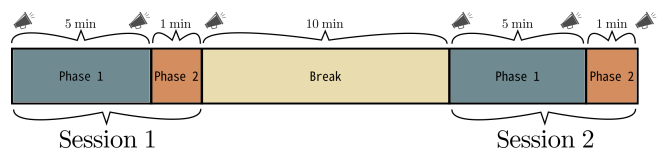


Fig. 3: A diagram of the structure of the experiment, which was divided in two sessions with two phases, and a rest time in between.

which group, the second session was realized in the following ways:

- Group A – No instructor: The robot Beo was covered with a sheet and left on the ground next to a table in front of the stationary bicycle, hidden from the participants' view. The robot could not be seen and did not interact in any way. The subject, then, realized the exercise session by himself or herself, without additional instructions.
- Group B – Instructor robot: Before the start of the second session, the robot Beo was placed on top of a table in front of the stationary bicycle, as shown in Fig. 2. Beo communicated with the participant speaking the sentences presented in Table I, as well as gesturing with arms and head, and eye expressions. During the realization of the session, only the subject and robot were present in the room. Participants were not previously warned that they would be instructed by a robot, and their first contact occurred when they entered the room for the second exercise session.

After each exercise session, the participants were prompted to fill five questionnaires regarding their perception of motivation, humor, enjoyment, feelings and perceived exertion. The questionnaires were: (1) a Motivation Scale; (2) the Brunel Mood Scale (BRUMS); (3) the Physical Activity

Enjoyment Scale (PACES); (4) a Feelings Scale (FS); (5) the Rated Perceived Exertion (RPE); and (6) The Godspeed Questionnaire [22]. In addition to the questionnaires, the performance of each subject during the exercise sessions was measured by recording the average speed and total cycled distance.

The data was analyzed using the statistical software Past (version 3.25) and XLMiner Analysis ToolPak. We performed descriptive statistics for frequency verification, percentage, average, median and standard deviation, as well as Shapiro-Wilk test for the verification of normality of the distributions. Regarding inferential statistics, we utilized Student's T-test. The significance level was chosen as 5%, such as that the results were considered statistically significant for $p < 0.05$.

IV. RESULTS

Table II shows the characteristics of genre, sedentary and major of study of the 14 investigated subjects.

TABLE II: Characterization of the investigated subjects

Variables		Frequency	%
Gender	Men	8	57,14%
	Women	6	42,85%
Sedentary	Yes	9	64,28%
	No	5	35,71%
Major	Computer Engr.	7	50%
	History	2	14,28%
	Social Sciences	2	14,28%
	Music	1	7,14%
	Visual Arts	1	7,14%
	Control and Automation Engr.	1	7,14%

Fig. 5a presents the results of the motivation of the participants, gathered using the motivation scale. The score of this scale ranges from 0 to 6, where higher numbers correspond to higher motivation. The results show that there was an increase in the motivation for group B, that interacted with the robot in the second session, meanwhile group A had a decrease in the motivation. This may suggest that the robot had an impact in the motivation of participants, however the difference was not statistically significant ($p < 0.05$). These results are similar to the findings by [16], which used a robot to motivate older people to practice simple physical exercises.

Group	Session	Distance (km)	±	Speed (km/h)	±
A	1	655.22	97.24	6.56	0.98
A	2	689.27	99.01	6.89	0.98
B	1	718.66	41.47	7.18	0.42
B	2	728.69	35.73	6.81	0.33

TABLE III: Results of cycled distance and average speed.

Fig. 5b shows the results regarding the enjoyment of the participants. It can be observed that there was an increase of 1.15% from the first session to the second session for group A and 7.49% for group B. Once again, this suggests that the robot might provide a more carefree and fun environment, however the difference is not statistically significant with $p > 0.05$.

The main intent of the Feelings Scale was to measure the pleasure of the participants after realizing the exercise. The participants had to choose a number between -5 and +5, where higher numbers correspond to more pleasure. Fig. 5c shows that group A had a decrease in pleasure from the first to the second session, while group B showed an increase. This difference may suggest that people might find the exercise more pleasant when interacting with the robot, however the difference was not statistically significant with $p > 0.05$.

The performance of the participants is presented in Table III which shows the average and standard deviation of the speed and distance for both sessions of both groups. It can be seen that, from the first to the second session of group A there was an improvement of 4.94% relative to group B ($t(6) = 1.59; p = 0.16$). In group B, the improvement from the first to the second session was only 1.37% ($t(6) = -0.42; p = 0.68$). Regarding average speed, group A had an increase of 4.78% from the first to the second session ($t(6) = -4.31; p = 0.0049$), while group B had a decrease of 5.15% ($t(6) = 1.59; p = 0.16$). These results suggest that the robot didn't have an impact in the performance of the participants, similar to the findings reported in [18], but contrary to [17].

The BRUM scale was designed to measure the following six different humor states: tension, depression, anger, vigour, fatigue and confusion. Fig. 7 presents the results of the BRUMS for group A and for group B. It can be noted that there was a drop in the vigour score for both groups in the second session, more pronounced in group A. The fatigue also increased more from the first to the second session in group A. Tension, depression, confusion and anger were higher in the first session of group B, but also had a larger decrease after the second session. This shows a trend that the robot may have a positive impact in the mood of the participants, however the results were not statistically significant ($p < 0.05$).

The perceived effort was measured using the rated perceived exertion (RPE) scale. The interval of the resulting score of this scale is from 0 to 10, where a 0 score would be a rest state, and a 10, maximum effort. Fig. 6 presents the results of the RPE. Group A had an increase of 2.9% ($t(6) = -1.54; p = 0.17$) from the first to the second exercise session. On the other hand, no difference was observed for group B ($t(6) = 0; p = 1.00$). This means that participants of group A found the second session to require more effort, while for group B it required the same perceived effort. This suggests that the robot might had some influence in the perceived effort between the sessions, however the results were not statistically significant with $p > 0.05$.

The users' perception of the robot was measured using the Godspeed Questionnaire [23]. Participants of group B, after the second exercise session, evaluated the robot regarding the following aspects: anthropomorphism, animacy, likeability, perceived intelligence and perceived safety. Fig. 4 presents

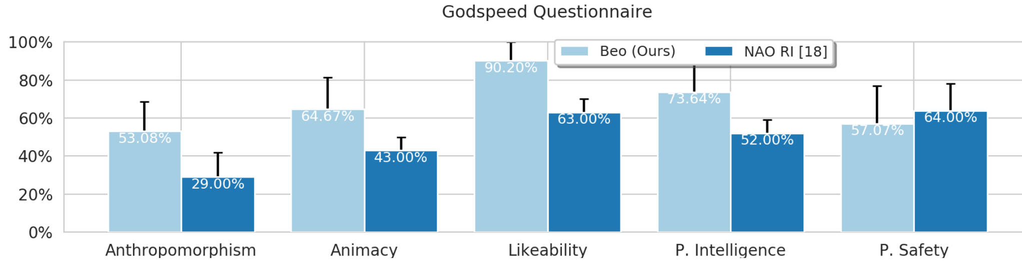
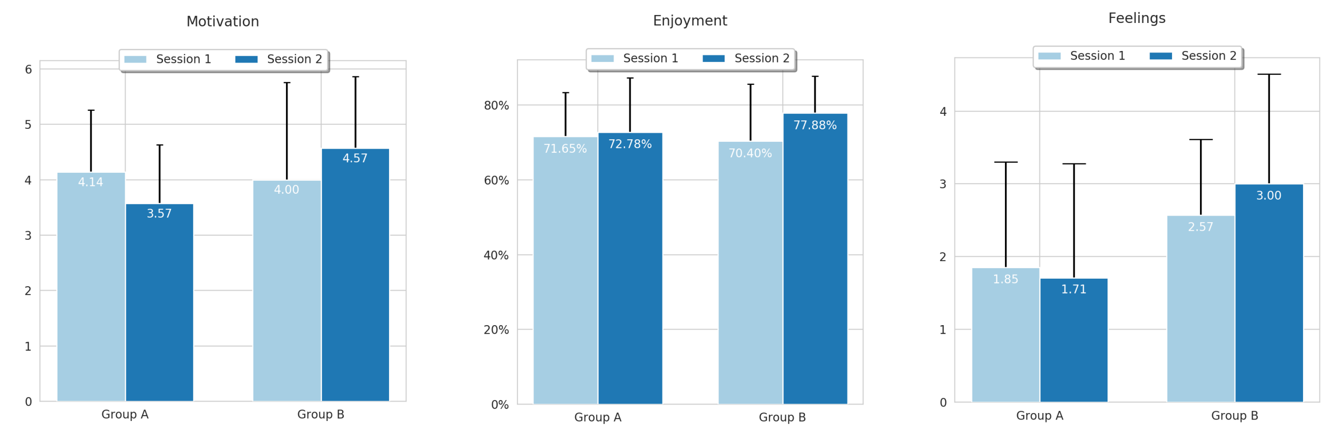


Fig. 4: Results of the users' perception of our robot Beo, compared to the NAO in the robot instructor (RI) condition from [18].



(a) Result of participants perception of motivation.

(b) Result of the participants enjoyment, measured using PACES.

(c) Result of the feeling scale, which measured the pleasure of the participants.

Fig. 5: Results of the Motivation Scale, PACES and Feelings scale.

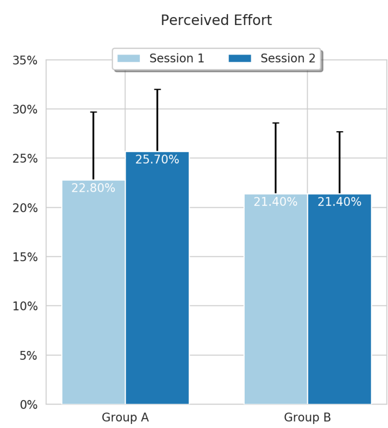


Fig. 6: Result of the perceived effort.

the results of the evaluation, with the scale plotted as a percentage from 0% to a 100%. For comparison, we present the results of our own robot Beo with the results of the NAO in the robot instructor (RI) condition from [18], which applied the same questionnaire. Our robot was perceived as more anthropomorphic, more animated, more intelligent and much more likeable. For perceived safety, Beo scored slightly lower than the NAO. We believe our robot was regarded as more human-like in general due to the fact that Beo interacted with the participants throughout the whole exercise session, while the NAO only provided feedback at the end of the test. Another factor at play, might be that Beo has a larger range of expressive motions, using its OLED displays for eyes, while NAO only has a LED light.

V. CONCLUSION

This work explored the use of a humanoid robot for motivating physical exercise and measured its influence regarding the motivation, performance and other psychological aspects in 14 participants. Even though the results were not statistically significant, a trend can be observed where the use of an instructor robot may positively impact aspects such as motivation, pleasure and enjoyment of such exercise sessions. This trend demonstrates that the use of instructor robots has the potential to motivate people to engage to exercise, resulting in better health quality and facilitating independence in later life. A positive influence in the discussed aspects can result in more willingness to perform physical exercise. Enjoyment is linked to the engagement to exercise programs [24] and is also considered an effective motivator [25]. A positive affective response can also be a significant predictor of the adherence to exercise, resulting in more effective sessions and a positive memory of the experience [26], [27].

Future works include using the robot as a motivation for people in need of assistance, such as older people and patients in hospitals and clinics. In these contexts, the robot could be introduced in a homecare environment. Another

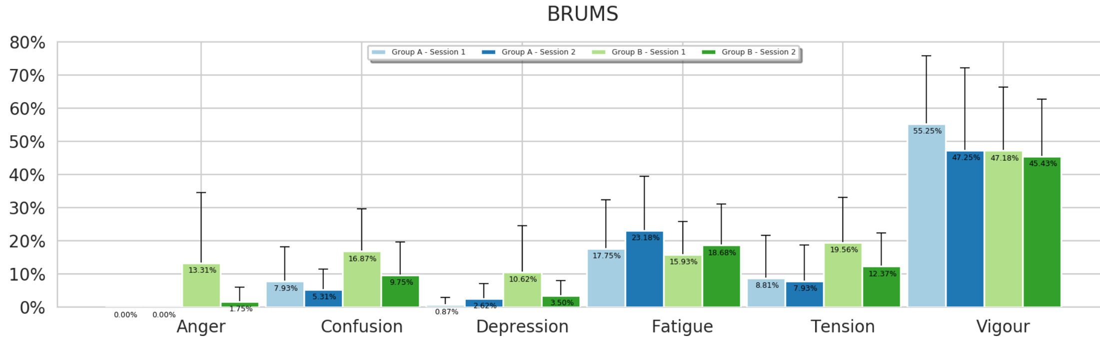


Fig. 7: Effect on the mood of the participants, measured using the BRUM scale.

interesting research path is investigating the effect of the use of such robots in long-term interactions. This might show the impact of the novelty factor during the interactions, and require more complex HRI capabilities to maintain the users engaged.

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