Exploring Impact of Demonstration in Socially Assistive Robots' Exercise Instruction

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***Abstract*—Exercise is an essential ingredient in public health and with increased obesity rates, an aging population and a stretched healthcare system, socially assistive robots (SARs) could be employed to give in-home personalised exercise instruction. This study implements a simple physically training instructor with a NAO robot, a small humanoid socially assistive robot. First it was determined whether SARs could successfully lead an exercise routine, then how important a robot demonstration would be to assist the delivery.**

Two exercise routines consisting of 5 exercises where tested on a total of 16 participants of varying gender aged in their 20s. One routine had just verbal instruction and the other with verbal instruction and demonstration. Statistical analysis of the results has showed that demonstration not only improved the user rating for the workout, but also improved motivation, clarity and the participants perceived safety whilst performing the exercise. However this study is only a preliminary investigation, the limited number of participants and the limited participant diversity necessitates further research. Before SARs can be widely implemented in public homes a more comprehensive study with a larger sample of diverse participants and more extensive exercise routine should be conducted.

I. Introduction

Regular physical exercise is crucial for maintaining a healthy lifestyle, prolonging health-span and as a preventative measure for age related diseases such as Osteoporosis Musci et al. (2019), Howe et al. (2011). However there are numerous barriers that may affect some people and prevent them from engaging in regular exercise such as access to professional trainers, confidence issues or personal mobility limitations.

Socially Assistive Robots (SARs) - robots designed to provide human assistance through social interactions - offer a solution to some of these hurdles. SARs could be utilised as a physical training coach, offering personal and accessible exercise coaching deployed to the users on home. This approach could help alleviate the pressure on the healthcare system by improving public health and by facilitating in-home rehabilitation exercise routines.

Although there is significant promise for this use of SARS, there has been limited research in their effectiveness in guiding physical exercise. This study aims to address this gap by implement a NAO robot, a type of SAR, to further understand how SARs can be used to instruct a user through a simple exercise routine.

This study will address the following research questions:

1) Can socially assistive robots guide a human through a simple exercise routine?
2) Does physical demonstration improve the humans ability to perform the exercise?

This paper will review the relevant literature determining the current state of the art for SARs use in physical training in section II. A detailed description of the chosen experimental methodology and exercise routine will follow in section III. The results will be presented, analysed in IV and a critical discussion of the findings and their implication will follow in section V. The paper will conclude with a summary of the studies contributions and recommendations for future work will follow in section VI.

II. Related works

With societies increasingly sedentary lifestyle, changes to lifestyle have necessitated the need for technological involvement. This has propelled the use of AI and robotics in healthcare, particularly socially assistive robots such as SoftBank Robotics America (2023)'s NAO robot by Lin et al. (2018) and Lee et al. (2022). Its humanoid form and ease of programming using Choregraphe make it an interesting platform for such purposes.

The NAO has previously shown potential as a rehabilitation and fitness coach. Assad-Uz-Zaman et al. (2019) focused on its effectiveness for the improvement of both physical and cognitive abilities in stroke patients, with Lewis et al. (2016)

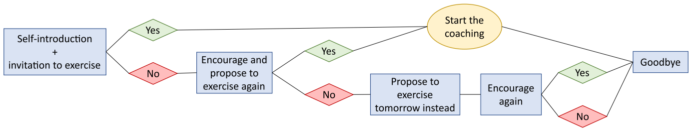

Fig. 1: The introductory diagram from our coach robot. This part is common for the two modes of training.

coupling the NAO robot with an animaloid robot to guide the elderly into a warm-up and exercise routine. Despite some technical challenges the robot was well received and successful in its objectives.

Two studies, Assad Uz Zaman et al. (2020) and Avioz-Sarig et al. (2021) successfully combined a NAO robot and Microsoft Kinect 3D cameras in a system designed to provide real-time feedback and fitness training. Results were positive for both studies, The participant in Avioz-Sarig et al. (2021) expressed an increased motivation when using the robot, although negatively commented on the NAO's toy-like appearance. The NAO robot successfully lead an upper body rehabilitation routine in Assad Uz Zaman et al. (2020).

Görer et al. (2013) incorporated NAO into an Ambient Assisted Living (AAL) environment whereby it assists the elderly with home exercises . In this study the NAO was welcomed as a fitness instructor. Softbanks Pepper robot has been used as a running coach for beginners with success, further illustrating the potential of socially assistive robots by Winkle et al. (2020).

The NAO has been studied in other fields such as education, welfare and social interaction by Amirova et al. (2021). Despite some challenges like data security and standardisation the NAO holds promise for applications such as therapy and rehabilitation and is a valuable research tool for further experiments into HRI.

The aforementioned studies have confirmed the NAO robots utility for safe human-robot interaction and physical training. Building on this research, our study will use NAO robot as an exercise coach to promote physical well-being through guided exercise routines.

III. Methods

The hypothesis that **a social robot will be able to guide someone to do simple exercises better with demonstration than without** was formulated. The social assistive NAO robot was used to verify or invalidate this assumption.

It was investigated if physical demonstration combined with vocal instructions by the robot help subjects perform the exercises better than only vocals. Two versions of the Choregraphe code were realised: the first with both a demonstration of the movements in the order previously mentioned, along with a vocal description of them, the latter with only the descriptions (that were the same as the previous one). Both versions include an introductory dialog as illustrated in Fig.1.

The five basic exercises selected are listed and illustrated in Fig.2. Their description by the robot is as follows:

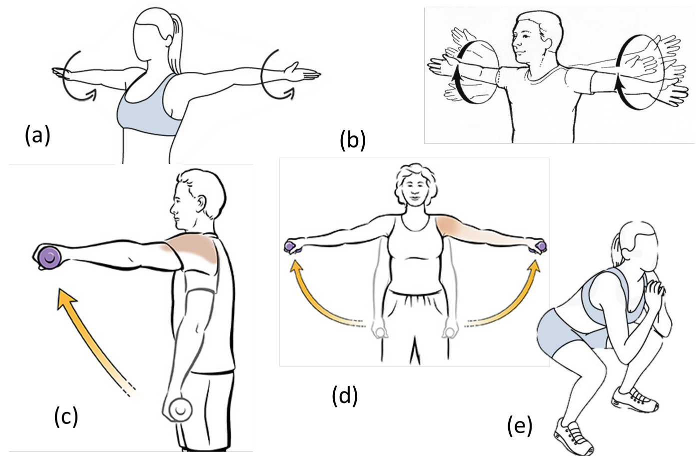

Fig. 2: The five chosen exercises and the sources of the images. (a): arms twists, *Arm circles* (2012). (b): arms circles, *Arm circles: Illustrated exercise guide* (2021). (c): frontal raises (without dumbbells), *Upper body exercises: Front raise* (n.d.). (d): lateral raises (without dumbbells), Theriot & Mueller (2022). (e): squats, *Squat Jacks: Illustrated exercise guide* (2021).

- **(a) Arms twists:** "Stand with your feet shoulder-width apart and extend your arms straight out in front of you, parallel to the ground. Engage your core and keep your chest up. Without bending your elbows, twist your hands all the way forward as far as you can go. Pause for a moment, then twist your arms in the reverse direction as far as you can go. Repeat this motion and keep in time with me!"
- **(b) Arms circles:** "Stand with your feet shoulder-width apart and extend your arms straight out to your sides. Engage your core and keep your chest up. Begin making small circles with your arms, rotating them backwards. Gradually increase the size of the circles, maintaining a controlled motion. Try and keep in time with me."
- **(c) Front raise:** "Stand up tall and start with your arms straight down. Keep your arms straight and raise them in front of you until you reach the shoulders level. Let's perform 5 repetitions."
- **(d) Lateral raise:** "Stand with your feet shoulder-width apart and hold your arms at your sides. Engage your core and keep your chest up. Lift your arms out to the sides, keeping your arms straight and your palms facing down. Lift your arms up until they are at shoulder height, or slightly above. Hold the position for a second, then slowly lower your arms back to your sides."
- **(e) Squats:** "Stand with your feet shoulder-width apart. Engage your core and keep your chest up. Lower your hips by bending your knees and pushing your hips back, as if you are sitting on a chair.Keep your knees in line with your toes and lower yourself until your thighs are parallel to the ground. Push through your heels and straighten your legs to return to standing position."

In the end, the participant was congratulated by the NAO for its effort: ”Nice job, you have completed all the workouts today.”

The process for running the experiment was first, to get the study ethically approved. The Ethical Review Checklist is available in the appendix section A. The participants were briefly explained what they will be doing during the experiment and read the participant information sheet (appendix section B), then asked to complete the informed consent form (appendix section C). A specific care has been taken to not reveal any of the exercise to the participants. After the experiment, they were asked to complete short questionnaire asking about their experience.

The questionnaire had one primordial question asking if the user was injured during the experiment. Came also 6 questions asking the users to express their agreement with statements on scales of 1 to 5, where 1 was the lowest level of agreement and 5 the highest. These questions were:

1) ”How do you rate your overall experience?”
2) ”Did you find the exercise instructions provided by the NAO robot clear and easy to follow?”
3) ”Were the exercises demonstrated clearly before starting the exercise?”
4) ”How safe did you feel during the exercise routine?”
5) ”How well could you hear the NAO robots instructions?”
6) ”How well did the instructions from the robot motivated you?”

Two other questions asking the subject to rate as ”not enough”, ”just right” or ”too many” were in the final questionnaire as well, being:

- ”Was the speed of the exercises the right speed?”
- ”Were there enough exercises in the exercise routine?”

The questionnaire was the same for the demonstrated and non-demonstrated version of the interaction, and there were boxes to tick to know which version the user went with.

This study involves 16 participants from the MSc Robotics class. 3 of the subjects were females (27%) and the rest were males (73%). The average age was 22 years.

IV. Results

The average results from the 16 participations’ questionnaire are visualized using bar plots in Fig.3 with the standard deviation as error bar for the two conditions of the experiment. The whiskers are crossing only for the answers about the ability to clearly hear the robot instructions, meaning that this criterion probably cannot be used to distinguish the two conditions. However, this is seems possible with the five other criteria.

The histograms of the answers (Fig.4) allows to visually predict that there is no question for which the distribution of the answers for both versions of the experiment were normal. The normality of the data is checked using the Shapiro & Wilk (1965)’s test, as it was evaluated the best by Mohd Razali & Yap (2011) using Monte-Carlo simulation. All p-values are greater than 0.05, meaning that none of the data follows a normal distribution. Thus, a non-parametric test is be used to calculate the statistical significance. As there are two study groups, the Mann-Whitney U test is chosen, following Giuliani (2023)’s lecture recommendations. The results of the test are reported in Table I. The p-values (probabilities that the null hypothesis is true) are all below 0.05, which is an usual significance level in research (Giuliani (2023)). Thus the null hypothesis is rejected (the null hypothesis states that no relationship exists between the two observed experiment conditions), this means that **there is a statistically relevant difference between the two conditions**.

Results	U statistic	p-value	Cohen’s d
Overall Rating	57	0.008	1.47
Overall Clarity	61.5	0.002	1.68
Clear Demonstration	59	0.003	1.59
Feeling Safe	57	0.008	1.4
Hearing the Robot	52	0.0033	1.09
Exercise Motivation	62	0.001	1.67

TABLE I: Statistical analysis of the numeral results from the user questionnaire

The effect size using Cohen’s d value is also shown in Table I. All the values are above 1.2, so the effect size for every parameter can be considered as ”very large” according to Sawilowsky (2009) (except for ’hearing the robot’ that has 1.09 and can be classified as ”large” only), meaning that there is a **strong relation between the results for the demonstrated and non-demonstrated versions**. All the statistical tests and graphs were computed using the Python code in appendix section D.

For the questions about the speed of the exercises and their amount, the distribution of the answers by the study participants are as in Fig.5.

V. Discussion

The results shown in Figures 3, 4, and 5 show promise for the use of robots in this application. The use of simultaneous demonstrations not only improved the overall rating of the routine but also the motivation, clarity and perceived safety throughout the exercises. Visually from the graph you can determine a clear separation between the two test conditions which is then reinforced statistically with the Shiparo-Wilk and Mann-Whitney U tests. All of the numerical test conditions had a ’p’ value of under 0.05, meaning that the null hypothesis can be rejected and the difference is due to the variables tested.

With the NAO robot demonstrating the alongside the verbal instruction and setting the pace for the exercise clearly made the participants feel more engaged in the activity. Conversely, without the demonstration you could see that participants were a lot less confident that they were doing the right movement, and often missed something the NAO said which meant they struggled to do the exercise correctly. Without the NAO physically keeping time participants where left to guess and struggled to maintain a common speed. A verbal time check would have likely improved this. Interestingly the demonstration had a clear improvement to the perceived safety of the exercises, likely come from the increased confidence that they were performing the exercise correctly. Of the 8

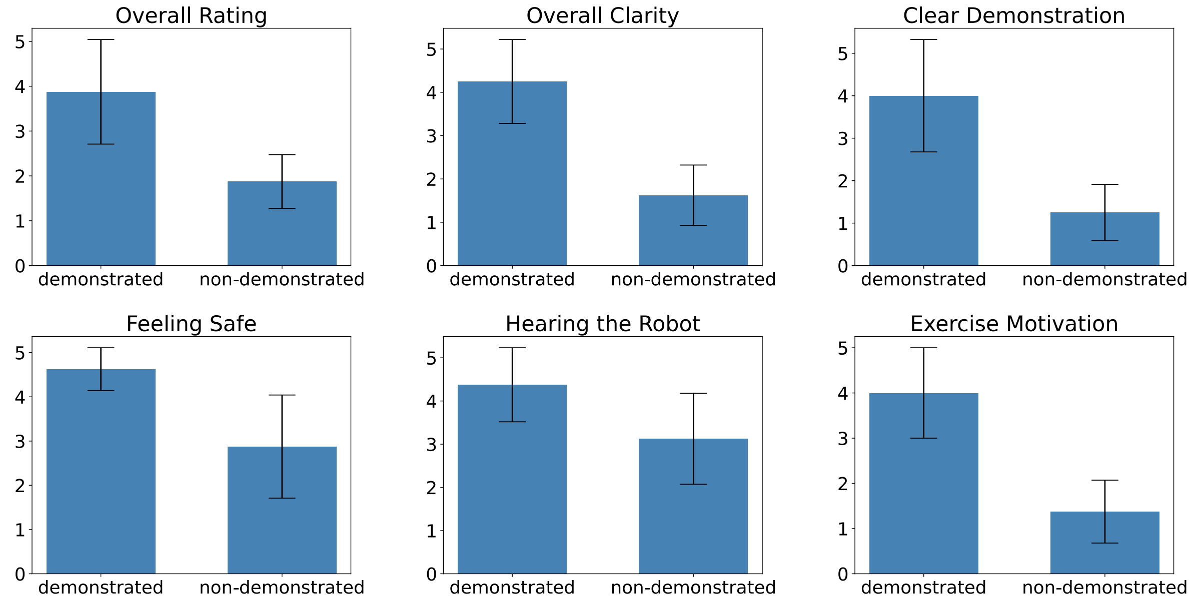

Fig. 3: Bar plots of the results from the questionnaire with standard deviations as error bars. The order from top-left corner to bottom-right is the same as the questions in section III.

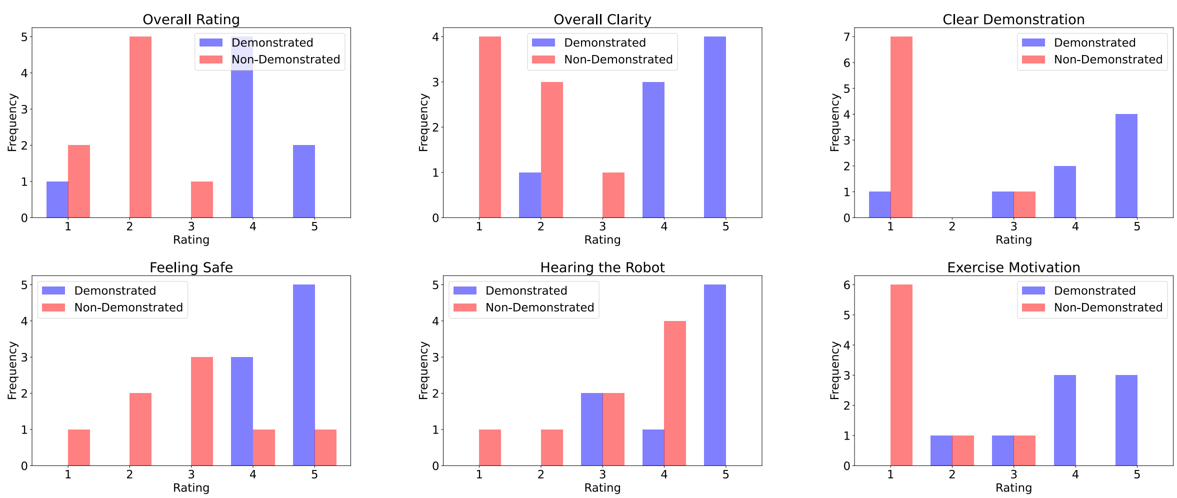

Fig. 4: Histograms of the results from the questionnaire. The order from top-left corner to bottom-right is the same as the questions in section III.

users who completed the demonstrated implementation 75% rated the demonstration clarity at 4 or 5 out of 5, proving that the NAO robot was capable of demonstrating exercises.

This study is limited by the small sample size and the limited diversity within that sample. SARs would likely be used with elderly people or those with health problems and therefore testing should have focused on these groups. Additionally due to the time constraints off the project only a simple exercise routine could be implemented, constructed mainly from exercises that people would likely already have knowledge of. A more accurate test would include more novel exercises so that the demonstrative qualities could be more accurately tested. Results could have been affected by the necessity of testing in a noisy classroom environment, potentially participants could have understood the instructions better if it was quieter. The questions used in the study could also be improved in further studies, a questions, a larger rating range and more participants would validate our results better.

Our research is in keeping with with other research findings such those found in Avioz-Sarig et al. (2021), Assad-Uz-Zaman et al. (2019), Assad Uz Zaman et al. (2020). Our system has successfully lead an exercise routine and the results have shown an increased motivation when using the robot. Our results highlight the potential for social robotic trainers but also the importance of demonstration in physical

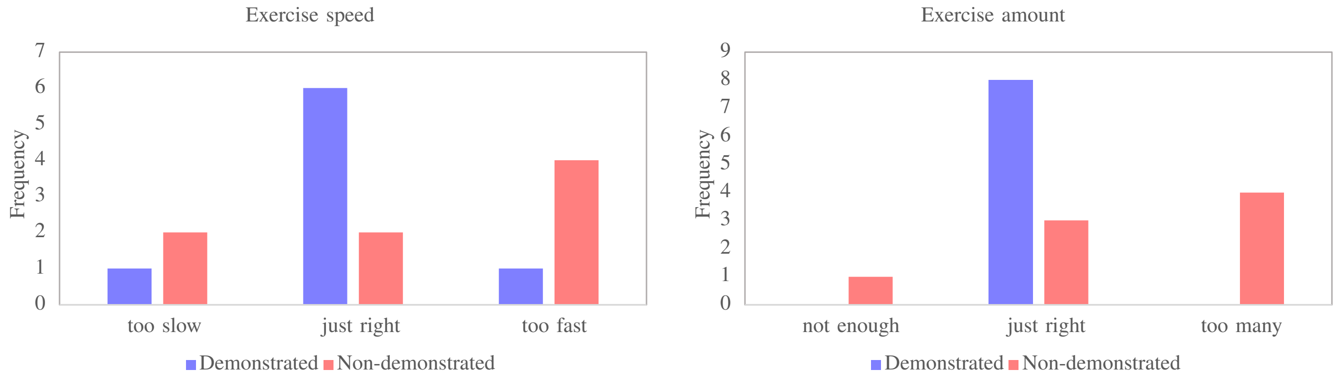

Fig. 5: Histograms for the answers about the speed and amount of exercises

instruction. This will be an important hurdle to overcome because robots are often constrained by their limited degrees of freedom and will struggle to mechanically perform some movements. In this situation other methods of demonstration could be explored such as video demonstrations or even augmented reality. Results from this study and similar studies could be used to influence the design of purpose build SARs to be used as physical trainers in the future.

As a group we worked well together, each person was designated a exercise to program and this was then copied into a main program and the the two implementations created. My contribution to the study was the creation of the squats, lateral raises and assisting with the arm twists. I initially combined the exercises into one program and conducted testing formatting the exercises into a common routine. For the collection of the data I created the questionnaire with Yuxuan and I made the python script for the graph creation and statistical analysis. For the common written parts of the paper re-wrote the literature review, assisted in writing the results section and conducted extensive editing throughout.

VI. Conclusions

From reviewing the related literature and from our own finding there is potential for SARs to be used for physical training. The NAO robot used in this study was capable of providing safe and engaging instruction for a simple exercise routine. The quality of the instruction and exercise routine was significantly improved with the inclusion of physical demonstration frm the NAO robot. Our study contributed to the research in Human-Robot interaction by exploring the role physical demonstration by robots in an instructional setting. Our results reinforce the hypothesis that physical cues will enhance the understanding of the instruction, and in doing so increase the motivation and perceived safety of the users.

Our findings are particularly significant for those people who currently require assistance in exercising such as the elderly or those with health problems. With an aging population and current pressure on healthcare systems already very high finding new ways to deliver rehabilitative and preventative exercise in the home is an important area to research. Widespread usage of these technologies could contribute to improved public health and well-being and prolong independent living of the elderly.

Future research in this area should focus on these areas:

- **Improved DOF:** Purpose built humanoid robots could be utilised to better demonstrate a wider variety of exercises.
- **Feedback:** Improved sensors should be utilised so that the robot can provide feedback on the exercises and ensure that the user has performed the exercise.
- **Demonstration modalities:** Addition modes of demonstration should be explored, these could include video or augmented reality or a mixture of both.
- **Testing:** More testing off the priority group must be carried out. The sample size must be increased and the diversity among the participants improved. Additionally more a more complex and comprehensive routine should be developed to more accurately determine the limits of this technology
- **Personalised routines:** Routines could be personalised to the capabilities of the user and should automatically adjust as the user gains in fitness over time.
- **Ethics:** Collaborative studies between researchers, industry and government should be carried out so that when the technology is ready the SARs can be safely incorporated into the users homes.

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Appendix

A. Ethical Review
B. Study Information Sheet
C. Informed Consents
D. Python code for the statistical tests and graphs

Faculty of Environment & Technology
Faculty Research Ethics Committee (FREC)

Ethical Review Checklist for Undergraduate and Postgraduate Modules

Staff and PG research students must not use this form, but should instead, if appropriate, submit a full application for ethical approval to the Faculty Research Ethics Committee (FREC).

Please provide project details and complete the checklist below.

Project Details:

Module name	**Human Robot Interaction**
Module code	UFMFHP-15-M
Module leader	Paul Bremner
Project Supervisor	**Paul Bremner**
Proposed project title	**Nao Robot HRI Module Task**

Applicant Details:

Name of Student	Thomas Rowland, Samuel Frank, Yuxuan Wang, Sakshi Jadhav
Student Number	18007687, 22071792, 22071739,22071797
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	CHECKLIST QUESTIONS	Yes/No	Explanation
1.	Does the proposed project involve **human tissue, human participants, animals, environmental damage, or the NHS.**	Yes	*Participants will be asked to follow the NAO robot leads in simple exercises such as squats, lateral raises, front raises and spinning their arms in a circle.*
2.	Will participants be clearly asked to give consent to take part in the research and informed about how data collected in the research will be used?	Yes	There will be a handed out sheet indicating the data to be collected and their usage, one of our operator will explain again orally the purpose, process and potential risks before the experiment. The data collected will be later showed to the respective participants for final decision of whether using their data or not.
3.	If they choose, can a participant withdraw at any time (prior to a point	Yes	The experimental data of each participant will be recorded individually and will be recorded on a

	CHECKLIST QUESTIONS	Yes/No	Explanation
	of "no return" in the use of their data)? Are they told this?		non-copyable medium, such as paper also the participants will be clearly informed about their right to withdraw from the study anytime they wish. When the participant refuses to use their data, the medium and the corresponding data recorded would be destroyed under the supervision of participants
4.	Are measures in place to provide confidentiality for participants and ensure secure management and disposal of data collected from them?	Yes	The data will be recorded on individual, non-copyable medium, after the participants allowed the usage of their data, their names would be erased and for further processing. The data of a particular person would be separated into different parts then mixing with the same part from other participants and would be hand out to only one of the team members, the data would be destroyed after the final results are calculated and checked. Along with that the team member with the confidential data will trained on the data protection protocols to maintain the confidentiality and security of the data throughout the study.
5.	Does the study involve people who are particularly vulnerable or unable to give informed consent (eg, children or people with learning difficulties)?	No	This experiment set up two different scenarios with one including direct command and the other involves encouragement, this requires the participants possess cognitional equivalent to a common human to comprehend ad respond to instructions provided by the robot.
6.	Could your research cause stress, physical or psychological harm to humans or animals, or environmental damage?	No	Physical: The entire experiment is done on a enclosed environment with all of the team members ready for help, the platform to place the robot would be large and sturdy enough to prevent damage on the equipment. Boundaries would be set to avoid direct physical interaction with the robot and the participant. The exercise

CHECKLIST QUESTIONS		Yes/No	Explanation
			postures were designed to be casual and would not cause over stressing or bending or exhaust the participants. The physical of the participants would be asked individually in private and included into the pre-experiment form, Psychological: The sentence and the dialog of the robot has been carefully designed and selected to exclude any possible offences in gender, religion etc. The gesture performed by the robot both in the exercise postures and the posture performed during dialogs would not cause any offence or present or resemble to any symbol that would related to negative and horrors such as Fascist or Terrorism. Before the experiment take place, participants would be ask some basic questions regarding their feelings and physical state. Participants would be asked to express if they felt being offended during the experiment, the experiment would be paused immediately to
7.	Could any aspects of the research lead to unethical behaviour by participants or researchers (eg, invasion of privacy, deceit, coercion, fraud, abuse)?	No	Collection of personal data or monitoring a person's activities may lead to privacy concerns but the consent forms given to the participants as well as in depth verbal information provided about the entire process and data handling along with that data security management practices followed by the researchers eliminates the possibility of unethical behaviour by the participants or researchers. The study would be conducted in accordance with ethical guidelines, regulations and participant approvals.
8.	Does the research involve the NHS or collection or storage of human tissue (includes anything containing human cells, such as saliva and urine)?	No	The study only collects data in the form of feedback from the participants as with respect to how the robot's working r how their experience with an instructor/motivator robot are. Thus it does not involve the National Health Service (NHS) or the collection or storage of human tissue, such as saliva or urine.

Your explanations should indicate briefly for Qs 2-4 how these requirements will be met, and for Qs 5-8 what the pertinent concerns are.

- **Minimal Risk:** If **Q 1 is answered 'No'**, then no ethics approval is needed.
- **Low Risk:** If **Qs 2-4 are answered 'Yes'** **and** **Qs 5-8 are answered 'No'**, then no approval is needed from the *Faculty Research Ethics Committee* (FREC). However, your supervisor must approve (a) your information and consent forms (Qs 2 & 3) and (b) your measures for participant confidentiality and secure data management (Q4).
- **High Risk:** If **any of Qs 5-8 are answered 'Yes'**, then you must submit an application for full ethics approval *before* the project can start. This can take up to 6 weeks. Consult your supervisor about how to apply for full ethics approval.

Risk Assessment: Separate guidance on risk assessment can be found on UWE's Health and Safety forms webpage at https://go.uwe.ac.uk/RiskAssessment. If needed, you must complete a Risk Assessment form. This must also be attached to your application for full ethics approval if your project is **High Risk**.

Your supervisor must check your responses above before you submit this form.
Submit this completed form via the *Assignments* area in Blackboard (or elsewhere if so directed by the module leader or your supervisor).
After you have uploaded this form, your supervisor will confirm it has been correctly completed by "marking" it as *Passed*/100% via the *My Grades* link on the Blackboard.

Further research ethics guidance is available at http://www1.uwe.ac.uk/research/researchethics

Study Information Sheet

Study Title: *Simple Exercise Instructor*

You are invited to take part in research taking place at the University of the West of England, Bristol. It is carried out as assignment for module UFMFHP-15-M Human-Robot Interaction. Before you decide whether to take part, it is important for you to understand why the study is being done and what it will involve. Please read the following information carefully and if you have any queries or would like more information please contact Thomas Rowland, Samuel Frank, Yuxuan Wang, Sakshi Jadhav, Faculty of Environment and Technology, Bristol Robotics Laboratory, University of the West of England, Bristol. The respective emails are: Thomas2.rowland@live.uwe.ac.uk, samuel2.frank@live.uwe.ac.uk, Yuxuan3.wang@live.uwe.ac.uk, sakshi2.jadhav@live.uwe.ac.uk.

Who is organising the research?

The project is led by Thomas Rowland, Samuel Frank, Yuxuan Wang, Sakshi Jadhav University of the West of England. Manuel Giuliani is the supervisor for this research. Please find their details at the end of this document.

What is the aim of the research?

The overall aim of the research is: D*oes demonstration improve the quality of instruction for a simple exercise routine?*
The purpose of this study is to assess the improvement in motivation and instruction clarity when a robot physically demonstrates the exercises compared to using just verbal instruction.

Why have I been invited to take part?

We are recruiting participants who are already working at the University of the West of England and are aware of the current risk and safety procedures due to COVID-19 restrictions.

Do I have to take part?

You do not have to take part in this research. It is up to you to decide whether or not you want to be involved. If you do decide to take part, you will be given a copy of this information sheet to keep and will be asked to sign a consent form. If you do decide to take part, you are free to stop and withdraw from the study at any time without giving a reason.

What will happen to me if I take part and what do I have to do?

You will first be asked to sign a consent form, and read a privacy notice. You will then be instructed to perform repetitions of 5 different exercises. They have been ordered in a way so that the warm up is achieved through the earlier exercises and have been ordered from easiest to hardest. They are: arm twists, arm circles, lateral raises, front raises and squats. Depending on which implementation you do the NAO robot will either give you instructions just verbally or both verbally and with a demonstration.

The study will take approximately *5 minutes* per person

Data will be gathered using the following methods:

- Written report of the dialog between the participant and the robot
- Written report of an oral feedback between the participant and the experimenter
- Possible questionnaires/forms
- Photos of the participants doing the exercises

What are the possible risks of taking part?

Cramps (a warm up will be done to reduce this risk) and usual sports injuries (very limited due to the warm up and the high simplicity of the tasks)

What will happen to your information?

All the information we receive from you will be treated in the strictest confidence.
All the information that you give will be kept confidential and anonymised. You will be assigned a participant ID that you can use to request the removal of your data from the study up to 7 days after completion of the experiment. After this point, the anonymised data will be analysed, and we will ensure that there is no possibility of identification or re-identification from this point.

Hard copy material (the consent form) will be kept in a locked and secure setting to which only the researchers will have access in accordance with the University's and the Data Protection Act 2018 and General Data Protection Regulation (GDPR) requirements.

Where will the results of the research study be published?

The results of this usability study will be reported in the coursework report for UWE module UFMFHP-15-M Human-Robot Interaction.

Who has ethically approved this research?

The project has been reviewed and approved by University of the West of England University Research Ethics Committee. Any comments, questions or complaints about the ethical conduct of this study can be addressed to the Research Ethics Committee at the University of the West of England at: Researchethics@uwe.ac.uk

What if something goes wrong?

If you have any questions about the ethical conduct of this research, have any complaints or concerns, or are uncertain about any aspect of your participation please contact the project supervisors or the University's research ethics committee.

Project Supervisor:
Professor Manuel Giuliani manuel.giuliani@uwe.ac.uk

What if I have more questions or do not understand something?

If you would like any further information about the research please contact in the first instance:

Samuel2.frank@live.uwe.ac.uk
Thomas2.rowland@live.uwe.ac.uk
Sakshi2.jadhav@live.uwe.ac.uk
Yuxuan3.wang@live.uwe.ac.uk

Thank you for agreeing to take part in this study.

You will be given a copy of this Participant Information Sheet and your signed Consent Form to keep.

Consent Form

Study Title: *Simple exercise instructor*

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I have freely volunteered and am willing to participate in this study.
I am willing to have my questionnaire responses collected.

Name (Printed)………………………Thomas Rowland…………………………………….

Signature……………………………TR………………………. Date………25/04/2023……….

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Name (Printed)………………………Sashimi Jadhav…………………………………….

Signature……………………………SJ………………………. Date………25/04/2023……….

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Name (Printed)………………………Reshma…………………………………….

Signature……………………………Reshma……………. Date………25/04/2023……….

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Name (Printed)………………………Venti…………………………………….

Signature……………………………Venti………………………. Date………25/04/2023……….

Consent Form

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I am willing to have my questionnaire responses collected.

Name (Printed)………………………Samuel Frank…………………………………….

Signature……………………………SF………………………. Date………25/04/2023……….

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I am willing to have my questionnaire responses collected.

Name (Printed)………………………Sakshi Jadhav…………………………………….

Signature……………………………SJ………………………. Date………25/04/2023……….

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Name (Printed)………………………Ollie Girling…………………………………….

Signature……………………………OG………………………. Date………25/04/2023……….

Consent Form

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Name (Printed)………………………Toba…………………………………….

Signature……………………………Toba……………………… Date………25/04/2023……….

Consent Form

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Name (Printed)………………………Michelle Sharma……………………………………

Signature……………………………MS………………………. Date………03/05/2023……….

Consent Form

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Name (Printed)………………………Weiling Guo…………………………………….

Signature……………………………Weiling ………… Date………03/05/2023……….

UWE Bristol University of the West of England

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Name (Printed)………………………Haoyang Li…………………………………….

Signature……………………………Oscar Li…………. Date………03/05/2023……….

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Name (Printed)………………………Finn Heath…………………………………….

Signature……………………………FH…………………. Date………03/05/2023……….

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Name (Printed)………………………Yuxuan Wang…………………………………….

Signature……………………………Will Wang……………. Date………03/05/2023……….

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Name (Printed)………………………Shule Hou…………………………………….

Signature……………………………Shule………………………. Date………03/05/2023……….

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Name (Printed)………………………Tianyi Liu…………………………………….

Signature……………………………Tianyi………………………. Date………03/05/2023……….

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Name (Printed)………………………Yihao Zhou…………………………………….

Signature……………………………Yihao………………………. Date………03/05/2023……….

D. Python code for the statistical tests and graphs

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.stats import mannwhitneyu, ttest_ind, shapiro
plt.rc('font', size=20)
# Question results
questions_data = {
    "Overall Rating": ([4, 5, 1, 5, 4, 4, 4, 4], [1, 3, 2, 2, 2, 2, 2, 1]),
    "Overall Clarity": ([5, 5, 2, 5, 5, 4, 4, 4], [1, 3, 2, 1, 2, 2, 1, 1]),
    "Clear Demonstration": ([5, 5, 4, 5, 4, 5, 3, 1], [1, 3, 1, 1, 1, 1, 1, 1]),
    "Feeling Safe": ([5, 5, 4, 5, 5, 4, 4, 5], [4, 3, 3, 3, 2, 2, 5, 1]),
    "Hearing the Robot": ([5, 5, 3, 4, 3, 5, 5, 5], [1, 3, 2, 4, 4, 4, 4, 3]),
    "Exercise Motivation": ([4, 5, 2, 5, 3, 4, 5, 4], [1, 3, 1, 1, 1, 1, 2, 1])
}


# Loop through each question and perform the appropriate test
for question, data in questions_data.items():
    demonstrated, non_demonstrated = data

    # create the bar plots with whiskers
    dem_mean=np.mean(demonstrated)
    ndem_mean=np.mean(non_demonstrated)

    dem_std=np.std(demonstrated)
    ndem_std=np.std(non_demonstrated)

    STD=np.std(demonstrated+non_demonstrated)
    cohen=abs(dem_mean-ndem_mean)/STD
    # print(question+" Cohen's d="+str(cohen))

    plt.figure(question)
    plt.bar(['demonstrated','non-demonstrated'],[dem_mean,ndem_mean],0.6,yerr=[dem_std,ndem_std],capsize=15
                                                      ,color='steelblue')
    plt.title(question)
    plt.savefig("PATH"+question.replace(" ","_")+'.svg',format='svg')
    plt.show()

    # Check if data is normally distributed using Shapiro-Wilk test
    stat_d, p_d = shapiro(demonstrated)
    stat_nd, p_nd = shapiro(non_demonstrated)

    alpha = 0.05

    # If both samples are normally distributed, use t-test, otherwise use Mann-Whitney U
    if p_d > alpha and p_nd > alpha:
        stat, p = ttest_ind(demonstrated, non_demonstrated)
        test_name = "t-test"
    else:
        stat, p = mannwhitneyu(demonstrated, non_demonstrated)
        test_name = "Mann-Whitney U test"

    # Print the results
    print(f"\nQuestion: {question}")
    print(f"Using {test_name}")
    print('Statistics=%.3f, p=%.3f' % (stat, p))

    # Interpretation

    if p > alpha:
        print('Same distribution (fail to reject H0)')
    else:
        print('Different distribution (reject H0)')

    # Create a new figure for each question
    plt.figure(figsize=(10, 6))

    # Define bins as 1-6 (the range of ratings)
    bins = np.arange(1, 7)

    # Calculate the histogram values for demonstrated and non-demonstrated
    demo_values, _ = np.histogram(demonstrated, bins=bins)
    non_demo_values, _ = np.histogram(non_demonstrated, bins=bins)
```

```python
    # Arrange the bins and data for side-by-side bars
    bar_width = 0.35
    index = np.arange(len(bins) - 1)

    # Plot the bars for demonstrated and non-demonstrated
    demo_bars = plt.bar(index, demo_values, bar_width, label='Demonstrated', alpha=0.5, color='blue')
    non_demo_bars = plt.bar(index + bar_width, non_demo_values, bar_width, label='Non-Demonstrated', alpha=
                                                       0.5, color='red')


    # Add title and labels
    plt.title(question)
    plt.xlabel('Rating')
    plt.ylabel('Frequency')
    plt.xticks(index + bar_width / 2, bins[:-1])  # set x-ticks in the middle of the grouped bars

    # Add legend
    plt.legend()
    plt.savefig("PATH"+question.replace(" ","_")+'.svg',format='svg')
    # Show the plot
    # plt.show()
```