Social Robots for Engagement in Rehabilitative Therapies: Design Implications from a Study with Therapists

Katie Winkle
Bristol Robotics Laboratory
Bristol, U.K.
k.winkle@bristol.ac.uk

Praminda Caleb-Solly
Bristol Robotics Laboratory
Bristol, U.K.
Praminda.Caleb-solly@uwe.ac.uk

Ailie Turton
Bristol Robotics Laboratory
Bristol, U.K.
Ailie.Turton@uwe.ac.uk

Paul Bremner
Bristol Robotics Laboratory
Bristol, U.K.
paul.bremner@brl.ac.uk

ABSTRACT

In this paper we present the results of a qualitative study with therapists to inform social robotics and human robot interaction (HRI) for engagement in rehabilitative therapies. Our results add to growing evidence that socially assistive robots (SARs) could play a role in addressing patients' low engagement with self-directed exercise programmes. Specifically, we propose how SARs might augment or offer more pro-active assistance over existing technologies such as smartphone applications, computer software and fitness trackers also designed to tackle this issue. In addition, we present a series of design implications for such SARs based on therapists' expert knowledge and best practices extracted from our results. This includes an initial set of SAR requirements and key considerations concerning personalised and adaptive interaction strategies.

KEYWORDS

Socially Assistive Robotics; Engagement; Motivation; Therapy; User Study

ACM Reference Format:
Katie Winkle, Praminda Caleb-Solly, Ailie Turton, and Paul Bremner. 2018. Social Robots for Engagement in Rehabilitative Therapies: Design Implications from a Study with Therapists. In *HRI '18: 2018 ACM/IEEE International Conference on Human-Robot Interaction, March 5–8, 2018, Chicago, IL, USA.* ACM, New York, NY, USA, 9 pages. https://doi.org/10.1145/3171221.3171273

1 INTRODUCTION

It is well acknowledged that the success of rehabilitative therapy is related to the amount of exercise or practice the patient carries out (e.g. [25], [23], [22]). Rehabilitation therefore typically relies on the patient completing significant amounts of self-directed exercises in-between therapy sessions, however low engagement with such exercises is a known issue (e.g. [21], [9], [33]). Using socially assistive robots (SARs) to tackle low engagement in rehabilitative therapies is still relatively unexplored compared to e.g. in autism therapy with children [3]. Preliminary experiments suggest that SARs can have a positive impact on engagement/ motivation in such applications, particularly in stroke (e.g. [29], [35], [13]) and cardiac rehabilitation [16]. However, detailed research into the requirements and design of interaction strategies and behaviours for such robots is yet to occur.

We hypothesise that using SARs in rehabilitative therapies could improve patient engagement by facilitating self-practice exercises. However, we suggest further research into the detailed design of interaction strategies and behaviours for such robots is required if they are to have maximum positive impact. User-centered and qualitative design methods are increasingly employed in designing SARs and informing their interaction behaviours (e.g. [17], [19], [1]). Considering the real world deployment of SARs in therapy, therapists are both domain experts and also potential end-users. Specifically concerning SARs for use in therapy, this is the first study to our knowledge which takes an expert-informed/user-centred design approach to generating initial design requirements and robot behaviour guidelines.

2 RELATED WORK

Concerning SARs for engagement in therapy, Kang et al. undertook one of the first feasibility studies demonstrating their potential by demonstrating a hands-off robot for encouraging breathing exercises in a hospital setting [15]. Gockley and Mataric then demonstrated that even very simple robot behaviours might have an impact on compliance with stroke rehabilitation exercises [13]. This was further developed by Tapus and Mataric who highlighted the link between personalised robot behaviours and user task performance in e.g. stroke rehabilitation exercises [30]. A more recent study considering SAR feedback styles again demonstrates the utility of SARs in rehabilitation, with users showing improved task performance during an sessions [29].

Whilst these studies demonstrate the potential for SARs in therapy, they are primarily concerned with testing impact rather than exploring use cases, generating design recommendations or informing robot behaviour design. Concerning feasibility, previous studies with users and/or healthcare professionals have explored the the use of SARs for older adults, e.g. for mental health [14], long term care [19] and home assistance [37]. Previous attempts to

HRI '18, March 5–8, 2018, Chicago, IL, USA

ACM ISBN 978-1-4503-4953-6/18/03.
https://doi.org/10.1145/3171221.3171273

Table 1: Study Participants

Study	Participants
Focus Groups *(N = 20)*	8 Physiotherapists (P1 - P8) 7 Occupational Therapists (OT1 - OT7) 3 Speech Therapists (SL1 - SL3) 2 Sports Rehab. Therapists (SR1, SR2)
Interviews *(N=8)*	3 Physiotherapists (P1, P2, P6) 2 Occupational Therapists (OT1, OT6) 3 Speech Therapists (SL1, SL2, SL3)

design social robots and other assistive technologies for engagement and motivation have typically utilised theoretical models from psychology (e.g. behaviour change theory [7]), ethnographic observations of human interactions [28] or machine learning (e.g. [4], [18]). As such, this work aims to explore the role of SARs in rehabilitative therapies specifically, and to generate expert informed design recommendations and SAR behaviour guidelines for further investigation.

3 RESEARCH QUESTIONS

The aim of this study is to explore the potential for SARs to be used in rehabilitative therapy with domain experts (therapists) in order to inform future development of appropriate HRI strategies. In order to first give strength to our hypothesis that SARs could be beneficial for engagement in therapy, we ask:
i) what is the importance of self-practice in therapy, and how is it typically facilitated?
ii) how might SARs be useful in supporting rehabilitative therapies?

In order to generate design recommendations and inform HRI strategies to be tested with end users, we then ask:
iii) how is engagement measured?
iv) what is the role of a therapist in influencing patient engagement?
v) how might we tailor SAR behaviours to individual patients?

4 MATERIALS AND METHODS

This study consisted of 5 focus groups and 8 interviews with therapists from a range of disciplines (occupational therapy, physiotherapy, sports rehabilitation therapy and speech & language therapy) as listed in Table 1 (total pool N = 21, 3 male & 18 female, average age 40.5). Note that all interview participants apart from SL4 also took part in a focus group. Therapists were recruited by email communications to local hospitals, private practices, through advertising to university staff and through communications to contacts of the research team. Demographic information collected included time since qualified, time spent practising since qualified and typical service areas/ users worked with. All focus groups and interviews were carried out at the Bristol Robotics Laboratory. This study was approved by the ethics committee of the Faculty of Environment and Technology of the University of the West of England.

4.1 Focus Groups

Given our hypothesis concerning SARs for self-practice, we first wanted to explore the role and facilitation of self-practice in therapy. Additionally we wanted to see how therapists envisaged SARs being useful in therapy more generally. The focus group schedule, given in Table 2, was designed to explore these issues in addition to factors that might impact patient engagement. For this, we used a ranking exercise to facilitate reflective in-group discussion. Participants were randomly allocated to one of five focus group sessions based on availability. All discussions were moderated (following guidelines from qualitative methods literature [2]) by the first author. Focus groups lasted between 60 and 100 minutes.

We predicted that few participants would be familiar with the concept of SARs. As such, we decided to give two on-topic demonstrations using the robot Pepper[1] half way through the focus group. This allowed us to explore the use of SARs both whilst participants were still naive and then again when they were more informed about the technology. Throughout all discussions a collage of images showing an additional 10 different social robots was put on screen. The moderator also referred to these during discussions to make clear that Pepper is just one example of a SAR.

The first demonstration showed Pepper facilitating some typical wrist exercises for arthritis; Pepper explained the exercise with reference to images on the tablet, imitated checking the user's motion, counted hold times and gave encouragement. The second demonstration showed Pepper facilitating preparation of a microwave meal; Pepper gave step by step instructions and prompts, again with reference to images on the tablet. The demonstrations were live, with the moderator playing the role of a patient (undertaking the requested exercise, providing verbal responses of yes/no as appropriate etc) and interacting with Pepper directly.

4.2 Interviews

The interview schedule, given in Table 3, was designed to explore the role of the therapist with respect to patient engagement in more detail. It was refined based on the results of the focus groups, which suggested the importance of personalised approaches for different patients. Interviews were carried out on a 1:1 basis, at a later date to the focus groups. Interviews were also led by the first author, and lasted between 50 and 105 minutes.

Ahead of the interview, we asked participants to think about two patients 'who have different levels of adherence, engagement or differing motivational needs'. We started the interview talking about those patients before talking about different patient needs and approaches more generally. In order to explore the concept of a categorisation framework, which we initially identified as one possible method of generating semi-personalised robot behaviours, we used the National Health Service (NHS) Healthy Foundations Life-stage Segmentation Model Toolkit [8]. This tool identifies 5 personas with different motivation to engage in a healthy lifestyle, and was designed primarily to inform health intervention design.

4.3 Analysis

Focus group and interview data were coded for key results using a combined deductive and inductive approach to coding [11]. This approach consisted of initial codes being generated based on the literature review and research questions. Two members of the research team then independently coded a transcript with this and

[1] https://www.ald.softbankrobotics.com/en/robots/pepper

Table 2: Focus Group Schedule & Topic Guide

Pre-Session Questionnaire
Acceptance & usability based on UTAUT [32] Semantic difference on where robot can be most useful
Pre-Demo Discussion
Initial thoughts on use of robots in therapy and application ideas Prescription of self-directed exercises or tasks at home Reporting of self-directed exercises: use, accuracy, methods Engagement and motivation: how to monitor and influence *[Group Activity]* Ranking of factors affecting engagement taken from literature plus any additional identified
Project Presentation & Robot Demonstrations
Brief (10 minute) presentation covering project aims and related literature Pepper demo 1: Exercise based physiotherapy Pepper demo 2: Cognitive support occupational therapy
Post-Demo Discussion
Demo feedback Revisit of question on how robots could help in therapy Data collection capabilities of the robot
Post-Session Questionnaire
as Pre-Session Questionnaire with addition of identification of potential use cases (types of therapy and patient)

Table 3: Interview Schedule & Topic Guide

Reflection on Two Patients
Unprompted description of pre-selected patients Reasons for choosing these patients given context Different ways of working with these patients and why
Categorisation Activity
(Introduce the concept of categorisation) Thoughts on the concept of a categorisation framework (Introduce NHS Healthy Foundations Segmentation Kit [8]) NHS Categorisation of initial two users Custom categorisation framework or other approaches: patient traits (and identification of), related approaches
Use of Feedback
Technical vs. motivational feedback/ positive reinforcement Feedback triggers
Progressive Conditions
Reflecting on progress for motivation, and motivation generally with progressive conditions

generated any additional codes inductively as required. The results were discussed and a final coding scheme was generated for application to the transcripts.

5 FINDINGS

5.1 Self-Practice in Rehabilitation

All participants identified as prescribing self-practice to their patients, and indicated this was directly related to the overall success of the therapy programme.

"With the work that I do, engagement in those exercise programmes is going to be what gets people better" (P7).

Most participants referred directly to there being clear evidence that rehabilitation success is related to the amount of practice, and that this conflicts with the cost/availability of private services and increasing restrictions in NHS services resulting in an increasing focus on patient self-management and self-practice.

"The NHS would like to provide more but often can't so you find yourself having to move towards a real push for you know self management and the patient to do a lot more of what you've said rather than necessarily being able to spend as much time as you might like to" (P5)

5.2 Measuring Engagement

Completion of self-practice and patient progress were typically cited as easy to obtain long-term measures of engagement; however it was noted that patient reporting of self-practice is not always accurate. Participants found it slightly more difficult to identify measures of engagement within session, but typically listed social cues such as body position, facial expression, eye contact and amount of questioning or discussion.

Significantly more discussion was focused on the recurrent theme of participants *'getting a feel'* for the patient; which all participants found very hard to verbalise and explain. Typically this would be done in initial interviews or discussions, from which participants felt they could generally predict how engaged a patient would be and what sort of approach might be appropriate with them.

"I think the really important bit is the initial subjective interview with the patient, you need to know the whole psychosocial background really and understand where they are and really by identifying their goals and things you get a good idea, you get a good feel, from verbal and non-verbal communication" (P1)

All participants highlighted how much this impacted on their approach to working with the patient. Key identified patient traits are discussed in detail under Section 5.4: Personalised Approaches. Most participants further suggested that *'reading'* a patient this way was an intuitive skill, built up with experience over time.

5.3 Therapists' Role in Patient Engagement

Discussions on this topic typically centered around two key themes, i) identifying and tackling barriers to engagement and ii) improving intrinsic motivation. All participants recognised their role in motivating the patient.

"Do you find yourselves having to motivate patients?" (Mod.) [strong agreement from all] *"And that's hard when you're working in an NHS field, you know that they need it, you know that's their personality but you just can't, can't give that"* (P4)

Some participants also felt they had a role in providing external motivation to a patient through generating some sense of 'accountability', but pointed out the aim was always for improved intrinsic motivation. This also fed into ideas around positive reinforcement.

"They want to be held accountable to somebody [agreement from all] *they're not being held accountable to themselves so they put you into a position of accountability and therefore they're doing it to please you when in fact it should be about pleasing themselves."* (P5)

In cases where patients were already intrinsically motivated, participants still identified the need to facilitate engagement, e.g. by helping them schedule a convenient time or suggesting prompting and data recording methods to target memory issues.

Results from the ranking exercise undertaken in focus groups made it clear that factors affecting engagement are very individual to each patient. No group generated the same hierarchical ranking as another, one group concluded it was impossible and in all groups the task prompted significant deliberation, discussion and disagreement. However, some key themes concerning how therapists typically target patient engagement did emerge from this task as well as additional interview discussions. These were:

- providing meaningful positive reinforcement
- improving knowledge and understanding of the patient's condition, therapy and its benefits
- personalisation of exercises based on interests
- reflection on goals/ functional benefits of exercises
- empowerment of the patient
- relationship/ rapport between the therapist and patient

It also became clear that, as with factors affecting engagement, specific instances of these were different for each therapist-patient pair. This is discussed further in the following section.

5.4 Personalised Approaches

Results from the focus groups made it clear that personalised approaches are key to motivation and engagement in therapy. Taking a 'client centered approach' and tailoring therapy to the patient more generally was raised as best practice across professions.

"I would always take a different approach with every patient, so even if I was looking at two patients with sore knees I'd be taking different approaches with those two people based on their beliefs and expectations of the treatment." (P1)

We explored this further in the interviews using an NHS categorisation framework for health behaviours, as discussed in Section 4. All participants could see the worth of trying to tailor behaviour of a SAR based on the patient, and agreed that there was value in identifying patient traits to inform that. Further, all could identify somewhat with the NHS framework descriptors and personas. 7/8 participants however struggled with the concept of labelling people into discrete categories, and preferred to instead talk about specific patient traits and how those informed their approach. The patient traits consistently linked with informing therapist approaches are listed in Table 4. Complimentary therapist approaches identified as being adaptable to each patient are listed in Table 5.

Other factors were identified as being important to engagement and therefore would be targeted by the therapist (e.g. enjoyment of session) however these were less linked directly to specific patient traits. In Section 5.2 we discussed the concept of therapists *getting a feel* for patients and their likely engagement. Many of these patient traits might be identified this way, e.g. through an initial interview. Other methods of learning about a patient included reading their case notes or assessing medical history, talking to friends, family or other health professionals, and observing a patient's surroundings (particularly in the home).

Table 4: Key patient traits identified as informing therapist approaches to facilitating and encouraging patient engagement with therapy.

Previous activity levels/ engagement in sport
Indicates whether patient is likely to understand the concept of training, and what expectations they may have about returning to a certain level of activity. Informs e.g. approach to exercise programme.
Employment status
Indicates the time pressures patients are likely to be under; but may also give an idea of work ethic, education level and socio-economic situation. Informs e.g. approach to scheduling sessions.
Motivation/ Self-efficacy
Indicates how willing the patient is to change intrinsically already. Informs e.g. amount of positive reinforcement given and style of motivational messages.
Cognition
Establishes how much a patient can understand and remember. Informs e.g. communication style and approach to exercise programme.
Education/ Intelligence
Indicates how much patient is likely to know about their condition as well as therapy and its benefits. Also raised as being potentially linked to motivation and likely linked to socio-economic situation. Informs e.g. how knowledge and information is delivered.
Family/ Social Support Situation
Indicates whether additional external motivation and support is likely to be provided.
Functional Goal(s) and/or Interests
Functional goals establish patients' main reason(s) for being in therapy, potentially giving insight into motivation levels. Interests give the therapist something to incorporate into exercise design or social interaction for rapport building. Both can be used for improving motivation.

5.5 Use of SARs in Rehabilitation

Initially, in the pre-demo discussions of focus groups, participants struggled to see how SARs could be useful in therapy. Some of the

Table 5: Key elements of therapy that therapists will personalise to the patient in order to facilitate and encourage engagement.

Improving Knowledge & Understanding
e.g. targeted use of evidence, choice of language and level of detail when trying to help patients understand why what they're doing is important and beneficial
Exercise Style
e.g. whether exercises sessions are based more on traditional workouts or instead 'disguised', incorporated into daily activities etc.
Engagement Strategies
i.e. ways in which therapist addresses low engagement e.g. gamification/ competitiveness, distraction techniques.
Use of Feedback & Positive Reinforcement
e.g. style (challenging, technical or functional, reassuring), level of detail, amount etc.
Provision of Additional Support
e.g. exploring other health issues, providing additional lifestyle guidance such as eating/drinking prompts, relaxation techniques etc.
Incorporation of Functional Goal(s)/ Interests
e.g. reflecting on functional rather than medical progress, using interests for distraction or enjoyment.
Reminders & Prompts
e.g. whether jointly agreeing a time, an external prompt or reminder system, a method of self-reporting etc.

physiotherapists had seen and used physically assistive rehabilitation systems and commented they had been expecting to see something similar. Most suggestions referred to current technologies such as smartphone applications, computer software and fitness trackers. However, as the discussion progressed and participants were asked to reflect on factors affecting engagement, without moderator reference to SARs, many then brought up the idea of using a SAR to aid with that:

"If you've got a buzz on your wrist telling you to move...it does get them thinking about it, so if you've got some humanoid or puppy doing a similar sort of thing, because compliance is a massive issue" (P2)

"I could really see a place for that bit between sessions to help maintain motivation and erm engagement in carrying out what otherwise could be quite mundane therapy programmes" (P6)

After the demonstrations participants specifically identified and commented on the ways in which a SAR might add value to existing technologies. Most of this discussion centered on the value of embodied interaction for engagement and enjoyment. 8/21 participants also named specific smartphone applications or computer software they currently use for providing feedback, that they would like to see integrated with a SAR for motivation.

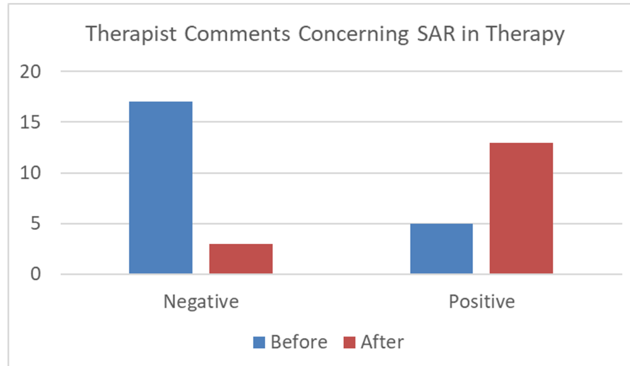

Figure 1: Shift in valence of participant comments before and after witnessing focus group demonstrations and project talk.

"It's just amazing how it moves, just that interaction with the eyes and the eyelashes and stuff so it kind of makes it feel like there's something, a more personal feel to it or, I know personally for me, that I would work better with that than just looking at a tablet." (P2)

"people with a brain injury...they will use something like an iPad and it will be like step by step instructions...they've got the photo and they've got a voice prompt...I can set it for a certain time for the alarm to go off so it'll say 'don't forget you need to do x' but I think that with this, such presence...they may be less likely to forget that they were doing something. I like that." (SL2)

"A lot of the time we use kind of targets or something for patients to aim at and I wonder if that could be included within the screen or being able to reach out for Pepper's hand" (P4)

Our results also suggest that seeing a robot demonstration midway through the focus group had a significant impact on participant acceptance. Figure 1 shows the shift in valence of comments coded under 'Therapist Opinions' and labelled as positive or negative during our data analysis. We suggest that this is worth considering as part of a mutual shaping approach to HRI design as proposed elsewhere [36].

In terms of specific applications and use cases, participants immediately identified using the robot as a mediator within session when working with children. For adults, participants saw it more as a tool for patients to use in-between therapy sessions. Participants unanimously agreed that children would love to work with the robot; and many felt the benefits could be equally enjoyed by adults too.

"I think the value of novelty and fun is so therapeutic for adults as well...the effect, just seeing it interactive made me feel a bit happier...it's just nice" (OT5)

Participants did suggest however that there may be some patients who had simply no interest in working with a robot. Some participants suggested this might be linked to age but others disagreed. Participants all agreed however that personalisation of the robot and its motivational strategies would be particularly important when working with adults, both for acceptance and for maximising impact.

5.5.1 Concerns. Initially, participants' concerns were centered on the value a robot could add to existing technologies and whether that justified any additional associated cost. This significantly reduced after the robot demonstrations, however some participants still questioned exactly how *'fancy'* the robot needed to be in order to have a positive impact. Another key concern raised by multiple participants was whether a robot could ever really be adaptive enough, or be able to *'read'* the patient as discussed in Section 5.2.

"We get our input from what we observe we don't often have the person say things we just observe them and know what we need to do, so how does a robot then observe a person without you having to instruct it?" (OT4)

More practical concerns focused on the medical needs of specific patients, e.g. being able to recognise the speech of a dementia patient. As these are very specific to particular use cases we do not dwell on them here, but such practical requirements must be well considered when designing assistive robots for real world use.

In terms of facilitating exercise sessions, one key concern was around giving accurate demonstrations and feedback. Participants were wary of the robot trying to technically evaluate patients performance and hence suggested asking patients to self-rate instead. In fact, this was highlighted as a positive thing that therapists themselves often do, in order that patients learn to recognise good performance. Additionally, whilst participants liked the idea of the robot demonstrating exercises itself, they were wary of it not being able to do so accurately and so suggested it might be better to use a tablet or other conventional method.

5.5.2 Novelty Effect. As most focus group participants had very little previous experience with robots, the well known 'novelty effect' phenomena (e.g. [12]) might have influenced their responses to the demonstrations given. However, given that the post-demo discussion predominantly focused on extracting informed requirements and robot behaviours, rather than exploring acceptance, we do not feel this significantly detracts from our key results.

Considering our final application, we suggest that a well-designed SAR should be able engage users in therapy and continue to be useful to therapists beyond the novelty effect. This is backed up by long term HRI studies in related settings (in the home, care and assistive/service settings e.g. [6]), some of which suggest that novelty can be replaced with familiarity, which can lead to increased acceptance and willingness to overcome shortcomings. Alternatively, rehabilitative therapy often lasts only for a fixed period of time (6 - 12 weeks) and intensive training within this period can shorten this time even further. As such, therapeutic benefits might be achieved before boredom with the robot sets it.

6 DESIGN IMPLICATIONS

Our results suggest three key scenarios in which a SAR might be used to improve engagement with rehabilitative therapies:

(1) facilitating children's practice exercises in school or at home
(2) mediating children's therapy (i.e. being used as an engagement tool by the therapist within session)
(3) facilitating adults' exercises and related lifestyle support at home

SARs for use in children's therapy, both in mediation and facilitating practice, is a significant area of research within the robotics community already [3]. In our work we focus instead on working with adults, given the documented adherence and engagement issues identified in Section 1. Therefore, the following design implications are tailored to scenario 3.

6.1 Key Considerations

The results of this study give strength to our hypothesis that SARs could be helpful for improving engagement with rehabilitative therapies. Specifically our results suggest that the embodiment and interaction capabilities of a SAR might help to tackle the issue of low engagement in a way in which things like smartphone applications, computer software and fitness trackers cannot.

Participants felt that patients would find a SAR more engaging, more enjoyable to work with and harder to ignore, dismiss or forget about than current methods. Many other benefits of SARs were proposed by the participants, however most of these follow on from the benefits of other modern methods, e.g. a potential lack of embarrassment exercising with a device rather than a person. Further, a SAR must still offer all of the functional capabilities of existing technologies in order to be useful in the real world. To this end, the linking of SARs with existing technologies such as smartphone applications and computer software, particularly those that already deal with providing specialist technical feedback, should be explored.

We propose that a SAR for rehabilitative therapies should aim to improve engagement by i) improving ease of access and ii) providing motivational support. Proposed robot behaviours and functionalities to address these aims are presented in Sections 6.2 and 6.3 respectively. Many existing methods already address these aims to some degree; so all functionalities are listed for completeness and only embellished in cases where use of a SAR specifically might offer additional value. In addition, we suggest that SAR interaction and engagement strategies must be personalised and adaptable to the user; this is discussed in detail in Section 6.4.

In this study we do not consider how patients would gain access to a SAR. Examples suggested organically during focus group discussions included prescription through the NHS, self funded ownership and communal provision in specialist residential homes. This, along with the nature of a patient's condition, would determine whether permanent, long term access to the robot would be possible and/or necessary. We do not consider here how a SAR might specifically help the patient to become more self-sufficient; although we recognise the importance of this in instances where the robot is to be removed or returned. Specifically, we focus only on using the robot as a practical tool and interaction partner for facilitating self-practice exercise sessions at home.

6.2 Improving Ease of Access

We identify the following key robot functionalities for improving ease of access to self-practice. Additional detail is provided in instances where SARs might offer additional value compared to current methods, as indicated by *.

(1) Scheduling, reminders and prompts*
(2) Facilitating the exercise session*
(3) Data recording
(4) Communication link to therapist

6.2.1 Scheduling, Reminders and Prompts. Ideally, the robot should approach and prompt the user to start exercising at the pre-agreed time; potentially also giving the user an advance reminder (e.g. 20 minutes ahead of time) that they are scheduled to exercise shortly. How the robot deals with non-compliance should be decided as part of a higher level, personalised engagement strategy, as discussed in Section 6.4. However, there is an opportunity for SARs to add value here by:
i) dealing with non-compliance in a socially appropriate way based on user (i.e. reacting to real-time social cues and/or as per therapist strategies noted in Tables 4 and 5)
ii) learning about the user to inform which behaviours to perform when, e.g. learning which social cues are linked to engagement and likelihood of compliance
iii) adapting both scheduling practicalities (e.g. suggesting new times, reminder settings) and its social behaviour in order to maximum likelihood of compliance.

6.2.2 Facilitating the Exercise Session. The robot should guide the user through exercises and activities prescribed by the therapist; ideally by displaying and referring to a video demonstration. Additional value could be generated by utilising the embodiment of the SAR during exercises; e.g. using the robot end effectors as targets for exercise. Motivational improvements linking to SAR interactions within session are discussed in the following session.

6.3 Improving Motivation

Here we list general strategies the robot could employ in order to motivate the user. All of these strategies are employed in some way by existing methods designed to improve motivation. However, participants felt that embodied interaction with a social robot would add value to items 1-5 even if there was no specific additional functionality gain. Participants also suggested robot specific behaviours for enjoyable interactions. These were mainly based either on physical contact between the patient and the robot (e.g. a high-five) or through the robot being 'entertaining' through use of its body (e.g. dancing, cheer-leading etc.).

Existing literature reinforces these ideas. Previous research has demonstrated the value of embodiment in similar scenarios (e.g. [31], [34]). Furthermore, social HRI studies have demonstrated the impact of specific robot behaviours (including touch) on motivation [20] and persuasion [5]. Based on this, it seems worthwhile to further develop and test specific social robot behaviours targeting motivation in rehabilitative therapies.

As identified in Section 5.4, the way in which a therapist might try to improve a patients motivation is very specific to that individual; the general strategies here require personalisation to be effective. This is discussed in detail under Section 6.4.

(1) Reflecting on progress & goals
(2) Improve knowledge & understanding
(3) Provide positive reinforcement & motivational feedback
(4) Allow therapist to access engagement data and remind users of this
(5) Make exercising enjoyable

6.3.1 Accountability & 'Being Watched'. The concept of patient accountability to the therapist is discussed in Section 5.3. Participants were unable to agree whether the presence of the robot, and it 'watching' and monitoring users engagement would be able to replicate that phenomena. It would be worthwhile to test user compliance with a SAR with and without therapist data sharing capabilities in order to investigate this. The presence of a robot has been demonstrated to change people's behaviour in terms of e.g. honesty and obedience [10] and decision-making [27]; therefore it is reasonable to expect some change in patient's behaviour just from introducing a robot into their self-practice.

6.4 Personalisation & Adaptability

Our findings suggest it is vital for the robot to be personalised to the user in its overall functional, motivational and interaction strategies as well as able to adapt in real-time to user behaviour during interactions. We term these as high level personalisation and real-time adaptation respectively.

6.4.1 High Level Personalisation. Based on the findings presented in Section 5.4, we suggest that a discrete categorisation framework of user 'motivation type' and associated robot settings is unlikely to achieve the necessary level of personalisation. Instead, we propose that high level personalisation can be achieved by adjusting a number of key robot characteristics based on particular patient traits. This choice of robot settings is based on the customisable elements of therapy also identified in Table 5 combined with the robot functionalities discussed in Sections 6.2 and 6.3.

A brief description of each setting is given below, along with the patient traits identified as potentially being relevant (taken from Table 4). Associated personality traits have been linked to settings according to equivalent mappings identified by therapists, as discussed in Section 5.4. However, further refinement of traits, and testing and development with end users is required for refinement and validation. To this end, *User Preference* has been included as an additional 'patient trait' for settings which might be chosen directly by the user rather than as a result of traits. Note that we do not consider here medical factors linked to the user's condition; this will have very specific impacts on particular settings.

(1) Style of Approach
Whether the robot should take e.g. a more direct, workout based style or a more friendly, indirect approach to exercise sessions. This would impact e.g. use of language, level of formality and amount of unrelated interaction.
Previous activity; Self-efficacy; Education
(2) Reminder Protocol
The process by which the robot reminds users about/ prompts users to start exercising, e.g. is it at a set time, do they get advance reminders, flexibility (e.g. how often can they say no), the way in which negative responses are dealt with etc.
Employment; Social support

(3) Knowledge Delivery Approach
How the robot delivers information aimed to increase knowledge of condition and/or therapy and its benefits. To include e.g. whether knowledge should be more technical or functional based, how often it should be delivered, method of delivery etc.
Previous activity; Self-efficacy; Cognition; Education; Functional goals/interests
(4) Use/ Desired Impact of Feedback
Tailoring of motivational messages and feedback e.g. to be more challenge focused/ competitive versus reassurance based.
Previous activity; Self-efficacy; Cognition; Education; Functional goals/ interests
(5) Engagement Strategies
Strategies combating a lack of engagement during exercise sessions. To include e.g. distraction techniques, gamification or increased social interaction. Further design, testing and validation of such strategies is required.
Self-Efficacy; Cognition; Social support; Functional goals/ interests; User preference
(6) Robot 'Persona'
Characteristics of the robot's persona, to include e.g. gender, voice options.
User preference

6.4.2 Real-time Adaptation. Building on the the idea of overall personalisation, the robot should also adapt its behaviour in real-time based on the user during exercise sessions and other interactions. This adaptation should be informed by the high level personalisation described above. Whilst our study highlighted the importance of such adaptation, it was more difficult to isolate specific user cues and the therapist behaviours to which these would be linked.

The use and tailoring of feedback was one therapist behaviour consistently linked with real-time adaptation and user cues. Specifically, participants discussed being empathetic as they encouraged the patient (i.e. by recognising and acknowledging fatigue or discomfort) and using personalised feedback or positive reinforcement (as per the high level personalisation) when most needed. This correlates with Schneider et al.'s finding that users exercise for longer with SARs which include acknowledgement in their motivational model [26].

In order to maintain engagement during an exercise session, the robot should employ pre-defined strategies as discussed in the previous section (e.g. gamification/competitiveness, additional social interaction etc.). However, to do this it must be able to recognise when the user is disengaged. Some initial real-time measure of engagement are identified in Section 5.2. Existing research on automatic analysis of engagement demonstrates it is possible, but heavily dependent on user personality; further reinforcing the importance of personalisation in this context [24]. We expect more about this, as well as about real-time adaptation more generally, will be learned by observing/ coding real-world therapist-patient interactions.

6.4.3 Configuring Personalisation and Adaptation. We propose the development of a simple interface in which therapists, users and appropriate others (e.g. family) can enter data regarding the above identified patient traits in order to inform the robot's settings. As discussed previously, the exact list of traits required requires further consideration. Additionally, traits require further development for implementation e.g. what 'options' or labels should exist for each trait, are they discrete or continuous etc.

It may be that some robot settings can be adjusted directly, rather than being based on patient traits. These might include e.g. reminder or robot persona settings. Given that our participants had to significantly reflect on the reasoning for their behaviour, but were easily able to identify particular patient traits, it seems valuable to explore linking robot settings and behaviours. This way, therapists only have to deal with patient traits, which they may be more comfortable with.

7 CONCLUSION

This work presents the findings of a study with therapists exploring patient engagement in therapy and the potential for SARs to improve this. We analyse the findings with a view to informing the field of social robotics, specifically in relation to HRI and the design of SARs in this context. These include key robot functionalities, considering how SARs might add value to existing methods, and discussion of the need and type of personalisation. To this end, we also present an initial list of key robot characteristics which should be personalised and specific user traits these might link to.

The therapists that we engaged with were very positive and accepting of how SARs could play a role in improving patient engagement with self-exercises. However significant further work is required to develop and test detailed interaction and motivation strategies which employ the personalisation previously mentioned. This is likely to also involve the development and testing of specific robot behaviours.

8 LIMITATIONS AND FURTHER WORK

This work was limited to a study of therapists; it is intended that the results should be used to inform preliminary interaction strategy design work for first stage testing and meaningful co-design sessions with real end-users. Additionally, we identify the need to carry out ethnographic observation studies of therapist-patient interactions in order to assess the more real-time and tacit elements of interaction. The results presented here are also limited by participants' exposure to and understanding of SAR technologies; the impact of the 'novelty effect' having been previously discussed in Section 5.5.2.

ACKNOWLEDGMENTS

This work was supported by the EPSRC Centre for Doctoral Training in Future Autonomous and Robotic Systems (FARSCOPE) at the Bristol Robotics Laboratory.

REFERENCES

[1] S. Azenkot, C. Feng, and M. Cakmak. [n. d.]. Enabling Building Service Robots to Guide Blind People a Participatory Design Approach. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (2016-03). 3–10. https://doi.org/10.1109/HRI.2016.7451727
[2] Rosaline Barbour. [n. d.]. *Doing Focus Groups.* Sage.

[3] Momotaz Begum, Richard W. Serna, and Holly A. Yanco. [n. d.]. Are Robots Ready to Deliver Autism Interventions? A Comprehensive Review. 8, 2 ([n. d.]), 157–181. https://doi.org/10.1007/s12369-016-0346-y

[4] Jeanie Chan and Goldie Nejat. [n. d.]. Social Intelligence for a Robot Engaging People in Cognitive Training Activities. 9, 4 ([n. d.]), 113. https://doi.org/10.5772/51171

[5] Vijay Chidambaram, Yueh-Hsuan Chiang, and Bilge Mutlu. [n. d.]. Designing Persuasive Robots: How Robots Might Persuade People Using Vocal and Nonverbal Cues. In *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction* (2012). ACM, 293–300.

[6] Maartje M. A. de Graaf, Somaya Ben Allouch, and Tineke Klamer. [n. d.]. Sharing a Life with Harvey: Exploring the Acceptance of and Relationship-Building with a Social Robot. 43 ([n. d.]), 1–14. https://doi.org/10.1016/j.chb.2014.10.030

[7] Roelof A. J. de Vries, Khiet P. Truong, Cristina Zaga, Jamy Li, and Vanessa Evers. [n. d.]. A Word of Advice: How to Tailor Motivational Text Messages Based on Behavior Change Theory to Personality and Gender. 21, 4 ([n. d.]), 675–687. https://doi.org/10.1007/s00779-017-1025-1

[8] DH, HIPD Social Marketing and Health Related Behaviour. [n. d.]. Healthy Foundations Life-Stage Segmentation Model Toolkit. ([n. d.]). http://www.cancerresearchuk.org/prod_consump/groups/cr_common/%40nre/%40hea/documents/generalcontent/cr_045215.pdf

[9] Rebecca Forkan, Breeanna Pumper, Nicole Smyth, Hilary Wirkkala, Marcia A. Ciol, and Anne Shumway-Cook. [n. d.]. Exercise Adherence Following Physical Therapy Intervention in Older Adults with Impaired Balance. 86, 3 ([n. d.]), 401–410. arXiv:16506876

[10] J. Forlizzi, T. Saensuksopa, N. Salaets, M. Shomin, T. Mericli, and G. Hoffman. [n. d.]. Let's Be Honest: A Controlled Field Study of Ethical Behavior in the Presence of a Robot. In *2016 25th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)* (2016-08). 769–774. https://doi.org/10.1109/ROMAN.2016.7745206

[11] Nicola K. Gale, Gemma Heath, Elaine Cameron, Sabina Rashid, and Sabi Redwood. [n. d.]. Using the Framework Method for the Analysis of Qualitative Data in Multi-Disciplinary Health Research. 13 ([n. d.]), 117. https://doi.org/10.1186/1471-2288-13-117

[12] R. Gockley, A. Bruce, J. Forlizzi, M. Michalowski, A. Mundell, S. Rosenthal, B. Sellner, R. Simmons, K. Snipes, A. C. Schultz, and Jue Wang. [n. d.]. Designing Robots for Long-Term Social Interaction. In *2005 IEEE/RSJ International Conference on Intelligent Robots and Systems* (2005-08). 1338–1343. https://doi.org/10.1109/IROS.2005.1545303

[13] Rachel Gockley and Maja J Mataric. [n. d.]. Encouraging Physical Therapy Compliance with a Hands-off Mobile Robot. In *Proceedings of the 1st ACM SIGCHI/SIGART Conference on Human-Robot Interaction* (2006). ACM, 150–155.

[14] PhD Jennifer Piatt, M. S. Shinichi Nagata, PhD Selma Sabanovic, M. S. Wan-Ling Cheng, PhD Casey Bennett, M. S. Hee Rin Lee, and PhD David Hakken. [n. d.]. Companionship with a Robot? Therapists' Perspectives on Socially Assistive Robots as Therapeutic Interventions in Community Mental Health for Older Adults. 15, 4 ([n. d.]), 29–39. https://doi.org/10.5055/ajrt.2016.0117

[15] Kyong Il Kang, S. Freedman, M. J. Mataric, M. J. Cunningham, and B. Lopez. [n. d.]. A Hands-off Physical Therapy Assistance Robot for Cardiac Patients. In *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005.* (2005-06). 337–340. https://doi.org/10.1109/ICORR.2005.1501114

[16] J. S. Lara, J. Casas, A. Aguirre, M. Munera, M. Rincon-Roncancio, B. Irfan, E. Senft, T. Belpaeme, and C. A. Cifuentes. [n. d.]. Human-Robot Sensor Interface for Cardiac Rehabilitation. In *2017 International Conference on Rehabilitation Robotics (ICORR)* (2017-07). 1013–1018. https://doi.org/10.1109/ICORR.2017.8009382

[17] Hee Rin Lee, Selma Sabanovic, Wan-Ling Chang, Shinichi Nagata, Jennifer Piatt, Casey Bennett, and David Hakken. [n. d.]. Steps Toward Participatory Design of Social Robots: Mutual Learning with Older Adults with Depression. In *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction* (2017) *(HRI '17)*. ACM, 244–253. https://doi.org/10.1145/2909824.3020237

[18] Iolanda Leite, Andre Pereira, Ginevra Castellano, Samuel Mascarenhas, Carlos Martinho, and Ana Paiva. [n. d.]. Modelling Empathy in Social Robotic Companions. In *Advances in User Modeling* (2011-07-11) *(Lecture Notes in Computer Science)*. Springer, Berlin, Heidelberg, 135–147. https://doi.org/10.1007/978-3-642-28509-7_14

[19] W. Y. G. Louie, J. Li, T. Vaquero, and G. Nejat. [n. d.]. A Focus Group Study on the Design Considerations and Impressions of a Socially Assistive Robot for Long-Term Care. In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication* (2014-08). 237–242. https://doi.org/10.1109/ROMAN.2014.6926259

[20] Kayako Nakagawa, Masahiro Shiomi, Kazuhiko Shinozawa, Reo Matsumura, Hiroshi Ishiguro, and Norihiro Hagita. [n. d.]. Effect of Robot's Active Touch on People's Motivation. In *Human-Robot Interaction (HRI), 2011 6th ACM/IEEE International Conference On* (2011). IEEE, 465–472.

[21] Simone D. O'Shea, Nicholas F. Taylor, and Jennifer D. Paratz. 2007 May-Jun. . . . But Watch out for the Weather: Factors Affecting Adherence to Progressive Resistance Exercise for Persons with COPD. 27, 3 (2007 May-Jun), 166–174; quiz 175–176. https://doi.org/10.1097/01.HCR.0000270686.78763.c8 arXiv:17558200

[22] Alex Pollock, Sybil E Farmer, Marian C Brady, Peter Langhorne, Gillian E Mead, Jan Mehrholz, and Frederike van Wijck. [n. d.]. Interventions for Improving Upper Limb Function after Stroke. In *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd. https://doi.org/10.1002/14651858.CD010820.pub2

[23] Alex Pollock, Charla Gray, Elsie Culham, Brian R Durward, and Peter Langhorne. [n. d.]. Interventions for Improving Sit-to-Stand Ability Following Stroke. In *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd. https://doi.org/10.1002/14651858.CD007232.pub4

[24] H. Salam, O. Celiktutan, I. Hupont, H. Gunes, and M. Chetouani. [n. d.]. Fully Automatic Analysis of Engagement and Its Relationship to Personality in Human-Robot Interactions. 5 ([n. d.]), 705–721. https://doi.org/10.1109/ACCESS.2016.2614525

[25] Emma J. Schneider, Natasha A. Lannin, Louise Ada, and Julia Schmidt. [n. d.]. Increasing the Amount of Usual Rehabilitation Improves Activity after Stroke: A Systematic Review. 62, 4 ([n. d.]), 182–187. https://doi.org/10.1016/j.jphys.2016.08.006

[26] Sebastian Schneider, Michael Goerlich, and Franz Kummert. [n. d.]. A Framework for Designing Socially Assistive Robot Interactions. 43 ([n. d.]), 301–312. Issue Supplement C. https://doi.org/10.1016/j.cogsys.2016.09.008

[27] Christopher Stanton and Catherine J. Stevens. [n. d.]. Robot Pressure: The Impact of Robot Eye Gaze and Lifelike Bodily Movements upon Decision-Making and Trust. In *Social Robotics* (2014-10-27) *(Lecture Notes in Computer Science)*. Springer, Cham, 330–339. https://doi.org/10.1007/978-3-319-11973-1_34

[28] L. Sussenbach, N. Riether, S. Schneider, I. Berger, F. Kummert, I. Lutkebohle, and K. Pitsch. [n. d.]. A Robot as Fitness Companion: Towards an Interactive Action-Based Motivation Model. In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication* (2014-08). 286–293. https://doi.org/10.1109/ROMAN.2014.6926267

[29] Katelyn Swift-Spong, Elaine Short, Eric Wade, and Maja J Mataric. [n. d.]. Effects of Comparative Feedback from a Socially Assistive Robot on Self-Efficacy in Post-Stroke Rehabilitation. ([n. d.]), 764–769 pages.

[30] Adriana Tapus and Maja J Mataric. [n. d.]. Socially Assistive Robots: The Link between Personality, Empathy, Physiological Signals, and Task Performance.. In *AAAI Spring Symposium: Emotion, Personality, and Social Behavior* (2008). 133–140.

[31] Adriana Tapus, Cristian Tapus, and Maja Mataric. [n. d.]. The Role of Physical Embodiment of a Therapist Robot for Individuals with Cognitive Impairments. In *Robot and Human Interactive Communication, 2009. RO-MAN 2009. The 18th IEEE International Symposium On* (2009). IEEE, 103–107.

[32] Viswanath Venkatesh, Michael G. Morris, Gordon B. Davis, and Fred D. Davis. [n. d.]. User Acceptance of Information Technology: Toward a Unified View. 27, 3 ([n. d.]), 425–478. arXiv:30036540

[33] Marjolein Visser, Robert J. Brychta, Kong Y. Chen, and Annemarie Koster. [n. d.]. Self-Reported Adherence to the Physical Activity Recommendation and Determinants of Misperception in Older Adults. 22, 2 ([n. d.]), 226–234. https://doi.org/10.1123/japa.2012-0219

[34] Joshua Wainer, David J Feil-Seifer, Dylan Shell, Maja J Mataric, and others. [n. d.]. Embodiment and Human-Robot Interaction: A Task-Based Perspective. In *Robot and Human Interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium On* (2007). IEEE, 872–877.

[35] R. Wilk and M. J. Johnson. [n. d.]. Usability Feedback of Patients and Therapists on a Conceptual Mobile Service Robot for Inpatient and Home-Based Stroke Rehabilitation. In *5th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics* (2014-08). 438–443. https://doi.org/10.1109/BIOROB.2014.6913816

[36] Katie Winkle, Praminda Caleb-Solly, Ailie Turton, and Paul Bremner. [n. d.]. Mutual Shaping of HRI for Social Robots in Therapy. ([n. d.]).

[37] Ya-Huei Wu, Christine Fassert, and Anne-Sophie Rigaud. [n. d.]. Designing Robots for the Elderly: Appearance Issue and Beyond. 54, 1 ([n. d.]), 121–126. https://doi.org/10.1016/j.archger.2011.02.003