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Human-Robot Interaction in senior health care: a qualitative cases-study research on seniors experiencing a robot-coached functional rehabilitation exercise.

Running title: **Robot coach from seniors' point-of-view.**

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest. The authors declare the Research involves volunteer human participants who have been fully informed and have provided written consents regarding their participation to this Research programm.

Abstract. Telemedecine and assistive robot are an issue for aging well at home. This qualitative research consisted in four study cases regarding elderly users experiencing a functional rehabilitation exercise coached by an assistive robot. It focused on the inner concerns elicited during the Human-Robot-Interaction and their evolution along the course of the experience. The data were collected and processed according to a course-of-action analysis framework. The results showed that eight typical concerns shape the users' interactions with the robot. This research highlighted that interacting with robots can produce a range of unexpected consequences such as emotional, behavioural reactions, as well as some questions about identity. This might counteract the initial design or even have a negative impact such as self-harm or rejection. One assumption guiding this work is that the activity-oriented approach provides a new, specific and better understanding of a Human-Robot-Interaction activity. This may provide guidelines for health and care roboticists and robotic interface designers. It also draws attention to the role the social environment plays regarding Human-Robot-Interaction.

Key-words: user's experience; assistive robots; elderly; acceptability; motivation; course-of-action.

1 Introduction

The late Western World demography studies report a decreasing number of births (birth rate 4,9 in 1950, 2,47 today according to UNO) and longer life expectancy. Seniors aged 60 and more will represent 30% of the population in 2030. This demographic evolution, together with a shortfall of nurses and caregivers plus the health care cost, are the reasons why technology - and more specifically robotics – is being given increasing attention (Broekens et al. 2009). Technology can provide therapy oversight, coaching and motivation (Okamura et al. 2008). As an example, physical exercise has preventive effects on aging (Vuillemin 2012). It is widely recommended to seniors wishing to age in place in order to maintain their autonomy. Robots, and particularly assistive robots, have the potential to support physical activities in many ways. They are designed to be used at home and assist some physical tasks an elderly person may not be able to do in full autonomy (e.g. getting up, feeding, washing...). They also can promote physical and cognitive exercise (Görer et al. 2013). Some of these robots can fulfill a combined role of coach and social companion in order to motivate (Obo et al. 2015). Recently assistive robots have been designed to monitor the user during physical functional rehabilitation therapy (N'Guyen et al. 2016). Thus, the aim of this exploratory study was to analyse the users' experience during a rehabilitation exercise program delivered by a robot coach to senior people. This work addresses a question of crucial importance about the perception of robots by senior people, and about their potential coaching role in functional rehabilitation exercise.

2 State of the art

2.1 Research advances in human - robots interactions

The implementation of new technology such as robots to support health care and physical activity have been investigated, and recent research has provided evidence of positive outcomes. First, studies investigated the effects of assistive social or companion-type robots on the health and wellbeing of the elderly living in nursing or collective home. Some results showed positive outcomes on health variables such as mood or loneliness (Broadbent, Stafford, MacDonald 2009), and some more positive effects on psychological variables such as social connections and communication (Bemelmans, Gelderblom, Jonker, De Witte 2012). Second, a number of studies showed the potential of robots to enhance engagement, motivation and physical activity (Fasola, Mataric 2013; Obo et al. 2015). Third, robots have been successfully used for rehabilitation (Fazekas et al. 2006; Brewer et al. 2007). A recent study demonstrated that patients preferred the robot to a human assisting them with the exercises (Cherry et al. 2016). Nevertheless, those positive outcomes depend on how people accept robot interactions. Forth, the last decade has seen a number of studies focused on users' experiences of the robot interactions (Anzalone et al. 2015). In psychology, socio-psychology and ergonomics, this type of research were conducted within a variety of theoretical frameworks (Pino et al. 2015) used to understand user acceptance and user behaviour of information technology. The Theory of Reasoned action (TRA) by Fishbein and Ajzen (1975) pointed the link between behavioural aim and attitude. The Theory of planned behaviour (TPB) by Azjen (1985) added three constructs predicting intentions : attitude, subjective norm, and perceived behavioural control (Brown et Venkatesh 2005). The Technology Acceptance Model (TAM) (Davis 1989) has enhanced the perceived usefulness, the ease of use and perceived ease of use (determinants of Perceived Ease of Use being Integrating Control, Intrinsic Motivation and Emotion). The UTAUT model by Venkatesh, Thong and Xu (2016), for Unified Theory of Acceptance and Use of Technology, has established that performance expectancy, effort expectancy, as well as social influenced impacted on behavioural intention to use technology, whilst behavioural intention and facilitating conditions determined technology use. The TAM model is today the most commonly used model to investigate user acceptance of technology in health care (Broekens et al. 2009).

Advances in research showed that robot acceptance has proved to be an important issue among staff and patients (Brewer et al. 2007). The success of such programs depends on users' acceptance (Chau et Osborne 2017). Focusing on groups in many countries, Bedalf and al. (2016) suggested that older people are open to the idea of having a robot supporting them in their daily life. A new insight to their acceptance of the robot is that they want the robot to operate at the same level of intelligence as a human caregiver. Furthermore, the acceptance of robots is culturally dependant (Broadbent et al. 2017) and perceived enjoyment (Heerik et al. 2008) is a source of acceptance for robot companion. Gaps between needs and solutions offered by the robot and lack of experience with technology have been identified as the most important barriers for robot acceptance (Pino et al. 2015).

Taken together, quantitative studies using TAM perspective pointed out that the users need to be aware of robots potentialities, to accept them as opportunities and to make sense of robots behaviours or motions (Broadbent et al. 2017). Though predictive, it is limited and does not provide sufficient understanding or information to create user acceptance for new systems (Mathieson 1991). Thus, qualitative investigation of the human – robot interaction (HRI) is needed.

2.2 Qualitative investigation for HRI

For over a century, qualitative researches have aimed at revealing, in a holistic approach, the sense-making process, which results from the interaction of an human or participant with his natural environment. Qualitative research explores the experiences of participants and the meaning they attribute to it. The aim of the qualitative research is to observe, report, analyse and interpret the complexity of a dynamic phenomenon, which changes continuously in response to prevailing conditions. Study case is still the dominant research method in qualitative analysis. The qualitative approach considers a reality, which can be seen as constructed *by* a user rather than by a designer *for* a user (italic added). The participant is active in the sense-making process. A qualitative approach for HRI seems to be appropriate to answer questions such as what are seniors' concerns when they experiment a robot designed to coach them rehabilitation activity? This study was conducted within the course-of-action framework as a diachronic analysis of users concerns within a test situation setting an individual exercise session coached by a Poppy robot.

Recent studies in psychology and ergonomics have investigated human - machine or objects interaction by reconstructing how individual cognitions adjust over time (e.g., Poizat 2010). They use the theoretical and methodological framework of the course-of-action, originally developed in the French language for research in ergonomics (Theureau 2006) after Peirce's semiotic (1902), Merleau-Ponty's Phenomenology of perception (1945) and Varela and Maturana's *autopïèse* (1974) and *enaction* (1987) concepts. The method involves resetting of the participant in the initial activity using its material traces such as auto-confrontation video methods. The aim of these methods is to lead the participants to elicit their pre-reflexive consciousness. A major component of pre-reflexive consciousness is the focus on the dynamic of the participants concerns. Within the framework, a concern refers to participants' interests, focuses or perceptions and/or intentions. Concerns can be defined and specified at any given instant regarding what makes sense or contributes to sense making for the participant. If we assume that an participant concern orients his/her situated activity as related to a specific moment, time and environment then an investigation of such concerns and their categorization into typical concerns can be expected to describe the emotional and cognitive experience of each participant.

3 Method

This qualitative approach complies with the recommended report standards (O'Brien et a. 2014).

3.1 Participants and setting

The size of the sample was an empiric choice. The participants consisted of 4: one woman and three men (M age = 70, SD = 9). They will be designated as A, B, C and D, and collectively as the participants or the actors. None had any previous experience of exposure to any assistive robot. This robot was a 3D humanoid Poppy robot conceptualized by INRIA laboratory, France. It was visibly a moving mechanical object (exposed plastic parts, mini-motors, screws, nuts and wires). At that point of its development it had no expression and no capacity of interacting with its environment. The participants were selected according to three *criteria* related to health care assistive robots potential users: (1) aged 60+ (aged from 60 to 79), (2) living at home in a rural environment, and (3) no known or obvious cognitive mental decline. D had had a stroke five years before, and still suffered from a left shoulder and arm movement deficiency. D was looked after by a medical team, part of whom stood in the test room during the test. A simple description of the robot had been given to A, B and C the day before the test : "*The robot looks like a mechanic Lego, or a Meccano, it is rather small, just the top part, it will not talk*". They were given a consent form to read, fill up and sign as well as an authorization for the use of their image for scientific purposes to which they fully and with no reserve subscribed to. The setting of the test meant to reproduce the conditions of a senior ageing at home and living alone. Four video cameras were placed in the test room in order to capture the robot as well as the participant's motion. The test involved a multidisciplinary team of ergonomics scientists, medical scientists, computer scientists (CS), physiotherapists and engineers collaborating in designing the study case. The CS team needed to compare two different 3D capture motions equipment to find out which would be best for a future evolution of the Poppy robot to detect and measure the difference between the movements shown by the robot and the one performed by the participants. An important consequence of this multidisciplinary test was that the participants were asked to wear sensors and other bits of equipment before starting the test. They rather enjoyed "*looking like a robot*". A second consequence was that there were 4 video cameras and up to 7 people gathered in the test room.

3.2 Procedure

First, the robot had to be programmed to be able to demonstrate a movement. One possible way was to code a specific program. The alternative we chose was for the researcher to manipulate the robot and perform the required movements while they were being computer-recorded. Therefore, by pressing "play", the student in charge would make the robot execute the movement. The test consisted of seven different sets of movements defined by the multidisciplinary staff. Only the torso and the arms were involved. The motion had been planned to be realistic enough to map human gestures and was progressively more difficult to perform. The general sequence involved an one-arm gesture, then a symetrical repetition of the movement with the other arm, then the use of the two arms simultaneously. Some movements were horizontal, others were vertical. They were some up-liftings, pushings and circles makings. The last one was a leaning and bending on one side with an up-lifted arm above the head bending the same way. The student explained to the participant that the robot would perform one sequence whilst the participant, who was seated facing the robot, would observe. Then the robot would repeat the sequence and this time the participant would copy it. There would be a pause between each sequence, due to the time required to record then bring the robot back to its original posture and set the next sequence. For each participant, the test followed the same pattern and lasted approximately a half hour. Apart from ocasional visits from the lab director and the CS supervisors, the student and the researcher were handling the test. The medical team (doctor, physiotherapist) stepped in the lab only for D.

3.3 Data collection

The data were collected according to a procedure defined by the course-of-action methodology (Theureau 2006). Two types of data were gathered: (a) non-verbal data, based on video recordings of the participants' behaviour during the sequences (see Photo I below) and ethnological observations written down by the researcher and (b) verbal-data, informal for some, formal for others, collected in the course of the tests and some pre- and post-tests interviews, among which a self-confrontation interview (see Photo II below) This later consisted for each participant in viewing his/her own test-film and stopping the video at any time whilst watching it, in order to show, explain, mime or comment on it. The researcher conducted the interview and could also stop the video and question the participant. The questions, according to Theureau's theory, dealt with the "Actual", that is what was happening and perceived in this course-of-action, with questions such as "*How do you feel now? What are you aware of? What are you doing here?*". Another range of questions deal with what Theureau calls "Potential", that is to say what was expected to happen, might happen, was wished or feared. This was related to questions such as "*What do you think would happen next? What were you expecting? What did you intend to do here?*". The self-confrontation interviews were filmed. One camera was settled so as to capture the screen on which the film of the test was played, as well as the participant watching it. To minimize the possibility that the participants would forget, inference or generalize about their thinking, the interviews were conducted within 24 to 72 hours after the test. The interviews lasted between an hour and an hour and a half each. This technique of self-confrontation interview is designed to account for the level of activity that is meaningful to the participant and the emergence of their pre-reflexive consciousness that guides their activity.

Photo I about here

Photo II about here

3.4 Data processing

All the verbal exchanges, which occurred between the participants and the main researcher during the interviews, were then fully transcribed in a four columns board names Table I.

Table I about here

One column was related to the time precisely quoted to match the following columns, the second contained the *verbatim* of what had occurred during the experience. The third column contained the *verbatim* of the self-confrontation interview. The last column consisted in ethnographic notes and photos taken by the researcher during the test and/or the self-confrontation interview. The data were then processed in four steps: (a) identifying discrete sense-making units, (b) categorizing these units into typical concerns (what the participants focused on), (c) ensuring trustworthiness of the data and analysis (d) analysing temporal evolution of typical concerns.

3.5 Identifying meaningful units

Data were processed by selecting discrete meaningful units. These units are assumed to be the expression of the participant's experience (Theureau 2006). They were feelings, focuses, perceptions, actions and communications. During the exercise sequence, a total of 242 such discrete units were identified: 72 units for A, 28 units for B, 101 units for C and 34 units for D.

3.6 Categorizing the meaningful units into typical concerns

An analysis of the successive participants' concerns enabled them to be organized into more general categories of similar types of concerns, that is to say typical concerns. They were distinguished on the basis of three *criteria*: a) the meaning of each category of typical concern, b) the same level of generality across the categories, and c) a label sufficiently discriminating to avoid overlap (Corbin et Strauss 2008). The categories were defined one by one. A new category was created each time a concern did not match an existing category or when a sufficient number of units pointed to a common and specific concern. Eight categories of typical concerns were identified.

3.7 Coding the categories

A code was given to every single unit. (i.e: C6-S3-AC2-09:57). It reported the category number, the participant name, the designation of the film and the time the Unit occurred in the film. The purpose of it being to data-visualize the relationship between the evolution of the concerns and the exercises progression in time. (See Figure I below).

3.8 Coding the time line

T0 stood for the time before exercise 1 started. T1 stood for the time to perform exercise 1 and so on. T8 stood for the time following the end of exercise 7. (See Figure I below).

3.9 Trust worthing the data and analysis

To ensure the credibility of the data categorization two trained investigators processed them. These two researchers had already coded protocols of this type in earlier studies, and were familiar with course-of-action theory. The reliability of the coding procedure was assessed using Bellack's agreement rate (Van Someren, Barnard, Sandleberg 1994). The initial agreement rated 83% for the categorization of typical concerns. Any of these initial disagreements were resolved by discussion between the researchers. They debated their interpretations until a consensus was reached regarding the number of categories and their labelling. Finally, agreement rate reached 98%.

4 Results

This section is divided into three parts: (a) the eight typical concerns, (b) the dynamic of concerns during the exercise sequences, and (c) four cases focus on the human-robot interaction.

4.1 Typical concerns

First, the analysis revealed that the four participants shared eight typical concerns experienced during the course of their interaction with the robot. The concerns were designated as C followed by a concern category number from 1 to 10 (see Table II). The ones which gathered the most important number of units were : C3 - to self-evaluate oneself (33 units) ; C5 - to catch up with speed, the rhythm (33 units) ; C7 - to notice or admit a difficulty (30 units) ; C8 - to notice a human-robot difference (29 units).

Table II about here

4.2 Dynamic of concerns during the exercise sequence

The Figure I (see below) showed that some concerns (C3, C5), not all, were expressed all along the test.

Figure I about here

The spectrum of concerns also started at a high range: T1 started with 39 units and T2 with 71 units. Most concerns had a peak moment: C1 at T1 and T2, C5 and C7 at T2, C3 at T4 regarding the participants' focuses and interactions at that moment in time. A peak of concerns rose at T2 but for C2 and C4.

The specific exercise required at T2 was an horizontal lift-up movement of the upper-arm whilst the elbow was kept loose. This exercise had to be performed by one arm, then the other, then two arms simultaneously. It had been planned to be "second" in term of difficulty in the progress of the sequences. All participants faced ergonomic difficulties to perform it, some found it unusual, unnatural or "*never to be asked*". A wide range of unexpected concerns raised: speed, self-evaluation, starting time, emotions, robot identity, the nature of the task. After the peak, the concerns generally lowered and smoothened towards the end of the exercise. Six units were registered at T5, 14 at T6 and 25 units at T7.

4.3 Four cases focus of a human-robot interaction

According to the course-of-action framework, singular and personal experiences emerge from the coupling of the environment with each participant's previous experience. The data revealed that though the purpose of the test was announced in the same way to the four participants, each one experienced a different situation according to one's perception of this human-robot interaction. The following part of this paper defines each participant's experience then presents some unexpected aspects of the complexity of the situation that was studied.

4.3.1Various profiles of engagement

Participant A focused on moving at the robot's rhythm and speed (16 units) and on starting just at the same time (8 units). This required a lot of efforts (9 units). A main categories profile was: C5-C8-C4. B focused on the difficulty B met (10 units) on copying the movement (5 units) and on all that prevented B from copying right (4 units). B main categories profile was: C7-C1-C6. C was hugely concerned by self-evaluation (25 units). C wanted to perform and focused on finding ways of catching up with the speed (13 units), noticing all the differences (11 units) which might have helped him/her not to be surprised and be able to anticipate (11 units). C main categories profile was: C3-C5-C6-C8. Finally, D focused on the difficulties he/she met (10 units) to simply copy the movements (8 units). The differences between D and the robot enhanced them (6 units). D main categories profile was: C7-C1-C6. This results showed how specifically each participant interacted with what was supposed to be a similar situation.

4.3.2 The test recalled emotional memories

C (aged 76) took an RAF pilot test fifty years ago and failed for “lack of reflexes”. A reason he/she never subscribed to, being an athlete. C still felt he/she had to prove being quick enough and they were wrong at the time. C competed with the robot and with oneself. C : “An awful lot of things physical that I’ve done in my life have been done euh because… when you’re told you’re not good enough to be an RAF pilot, that sits with you for the rest of your life”, “there you are, with a lot of technicians around you and you get in to know unfamiliar equipment and put on unfamiliar clothes and, and then, you, you know you‘re not gonna crash it, are you ?“, “I could make a mess of the test… by just simply not managing to do it properly”. Though C was fifty years older this early experience of failure put C under pressure in order to catch up and never be late especially since no sign and no indication was given about when to start or stop, time had not mentioned as being an issue.

4.3.3 The test challenged unexpectedly

B (aged 79) attended a senior gym class on a regular basis and felt quite fit. He/She faced difficulty trying to copy the second exercise and was not happy with it. B: “*It’s hard but these are not, these are not movements one would normally do*”, “*I practise gym, gym for seniors, and we do not do these kind of movements. And I think our coach is pretty qualified herself*”. He/She accepted personal failure but blame the robot for its lack of competency in comparison with what a real professional gym coach would do.

4.3.4 The test questioned the identity of the robot

The participants designated the robot as “Poppy”, “the robot”, “ the computer” or “the machine”. D: “*the robot does it, well it is programed to do so of course, so it does it naturally”, A: “I had dehumanized the robot, I was just noticing the mechanical part of it”, “We had to twitch ours arms there, for the robot that was somehow difficult to do”, C: “the way that robot comes to rest is particularly robotic”.* When the test was done, D kissed the robot goodbye for D liked it, found it was a “*smart little one*”.

4.3.5 The test raised human identity questions

Interacting with the robot led the participants to reflexive questions about what they were really doing, what they were really asked to do, and even whom they were, regarding to whom they thought they were. A: “*I had to overcome this personal challenge*”. C had to succeed, for “*physical problem might lead to mental problems about physical competence*”, “*if you want to love someone you must first of all love yourself. And if you wish them to love you then you must be lovable, physical competence is… is important, at any age*”. B: “*I noticed it was... more flexible than me !*”. C: “*There are some elements of competitiveness. Whichever can do this better? Me or the machine?*”.

4.3.6 The test raised ambiguity

The dynamic of the relation – who imitates who? - as well as the adjustment to the machine produced questions and doubts.

C : “*Do I have to imitate the robot or is the robot imitating me?*”, “*Was I expecting to take copy of every tiny movement Poppy made? Or was I expected to copy the general movement? That Poppy made?”*, “*It’s just that, just that you have to imitate a limited joint movement with a much more flexible joint movement*.”

4.3.7 The test reveals a need for guidance and reassurance.

Participants suggested that the HRI should be mediated. *C did not hear well: "that's another instruction that I missed. Or wasn't made clear." B: "Oh well, if I had been put there on my own, I may not have felt that proud, no, no; having people around makes you feel all right.". D: "I was trying to meet somebody's eyes, I was trying to know if I was ok, if somebody would raise the thumb up to mean "yes, great", I was not looking for compliments but some encouragement to pursue".*

As a result of the *couplage* (Theureau 2004; 2006) in the enaction process, these singular experiences revealed the Human-Robot-Interaction complexity and raised unexpected reactions regarding to the aim of exercise.

5 Discussion

Because exercise is medicine, and robotics used in health care offer resources for sustaining physical activity (e.g., Fasola et Mataric 2013), this exploratory study investigated participants' experiences in a rehabilitation exercise session coached by a robot. It focused on the types of concerns elicited during their experience. As a result, the study cases of four seniors showed that a) eight typical concerns impacted their interactions with the robot, b) the concerns evolved within the progression of the experience, as in a learning process, c) each participant had a singular experience regarding robot acceptance. These results furnish insights about the potentialities and the limits of robots used to coach physical exercise to the elderly. The results are hereafter discussed according to three points that could address new insight for acceptance: robots sustain motivation; learning the task and the robot's use; and contributions for designers.

5.1 Motivation: Robots challenge us

Previous research demonstrated that robots have the potential to enhance motivation and physical activity (Obo et al. 2015), and that perceived enjoyment (Heerik et al. 2008) is a source of acceptance for robot companion. Our results showed how a robot coaching experience could motivate senior people. In this study, A and C were motivated to perform the task, while B was challenged by a personal cognitive difficulty and D by a physical deficiency. Complementary, motivation came from the test conditions: the sharing of the experience, the clothes change, with equipment and sensors (to wear for the motion capture test taking place at the same time) that made them look a little robotic themselves. By analysing the recovery-from-stroke-situations using assisting robots, Cherry and al. (2016) demonstrated that patients preferred the robot to a human assisting them with the exercises, despite technical and ergonomic difficulties. Here, D trying hard to do as good as possible worried the physiotherapist who thought D would harm oneself by reaching too wide an amplitude according to D's capacity. D was aware and paid attention to the difficulty but not as much to the stress put on her/his body.

A robot is far from being a neutral coach for physical activity. The use of robots as technological artefacts to provide physical activity needs more investigation in order to understand how it could sustain motivation for exercise, and what kind of motivation sustain acceptance.

5.2 Learning the task and the robot's use

A few studies suggest that robots are effective for physiotherapy (Fazekas et al. 2006), or that old people provide better assessment of the physical robot coach compared to virtual systems (Fasola et Matarić 2013). In this study, the effectiveness of the movement learning process was not assessed. Nevertheless, many concerns aimed at learning, and performing the movements the robot demonstrated. Regarding the evolution of the main concern (39 units in T1, 71 units in T2, down to 6 units in T5), an hypothesis can be made that the participants learnt the movements as well as they learnt to deal with the robot, so that they elicited less typical concerns about efforts, emotions with on-going the course of action. It could be hypothesized from the dynamic of concerns that HRI provides a learning situation with transform the actor's activity.

One major difficulty the participants concerns revealed may be interpreted as a consequence of anthropomorphism. When trying to understand or interact with an unfamiliar non-human agent, people use their knowledge of themselves as a basis for understanding these entities (Broadbent 2017). They try to recognize human attitude or movement behind the robot. B: "*There you had to swirl its arms so the robot could perform that movement. It has motors, not articulations, he is not as flexible as us*". In this study, C6 could be considered as a consequence of this anthropomorphic tendency. D: "*The robot is quite closed to the movement to demonstrate*". Because old people want the robot to manifest the same level of intelligence as a human coach (Bedaf and al. 2016) in this study they provided advices for next design process. Broadbent (2017) showed that the more social agent a robot is planned to be, the more it has to perceive and understand human behaviour on top of acting in a human like way to favour acceptance. The appearance of the robot (shape, face, eye contact, tune of voice) will depend on the task, and the expectation the person has of a human performing that task. Thus, based on our results, anthropomorphism could indeed be a design principle to support acceptance in HRI.

5.3 Contribution to assistive robot design

Qualitative studies provide insights on complex phenomenon such as human-robot interaction during learning and performing a movement sequence. Such research in ergonomics also aims at providing feedback for designers and developers (Theureau 2006). Because gaps between needs and solutions offered by the robot have been identified as the most important barriers for robot acceptance (Pino et al. 2015), our results should furnish precious information. Especially, the main typical concerns (C3, C5, C7, C8) provide information, which would be useful for robot designing and robot-coaching situation setting and using. First, one way to favour the use of such a robot would be to eliminate all sources of ambiguity, regarding identity, tasks, expectations, aims, issues and coherence of tasks... The less ambiguity, the less questions that may detract from the purpose of the exercise. To evaluate the potential ambiguity of such an interaction, a guide or question form would need to be conceived and tested. A second way of favouring acceptance would be to limit the stress due to the situation by reducing or eliminating any kind of competition or challenge between the human user and the robot. A solution may be to reinforce the authority of the user over the robot that should be able to choose the task difficulty or the exercise levels. The suppression of ambiguities would also contribute to lower the stress level. A third way would be to prepare the users to share feelings, emotions and reactions, even unexpected ones. The interest of such perspective to enhance robot acceptance would require further inquiries.

6 Conclusion

In this study, some results have confirmed that acceptance is linked to personal factors such as motivation and self-esteem. Results also provided insight about how to develop seniors' acceptance for assistive robots. Nevertheless, a common charge against case study research is that its findings are not generalizable. Advocates of case study respond to this by arguing that case study gives access to the inner lives of people, to the emergent properties of social interaction, and/or to the underlying mechanisms which generate human behaviours (Gomm et al. 2000). Though one case produces a small piece of evidence, the repetition of observations across a series of cases can build a database of evidences, and shape theory in an inductive way (Meganck et al. 2017). Furthermore, new researches with a larger sample are needed to verify how robots' potentialities and behaviours impact users' learning and performing.

Future study could complete the first-person point of view with a third-person point of view. According to Poizat and al. (2012) first-person data is suitable for retracing the dynamics of individuals' lived experience, whereas third-person data could help the researcher to highlight behaviours or constraints that could not spontaneously be described by actors. For an example, the biomechanical measures could help us to compare the gap between the movement the robot demonstrated and the movement the patient did (N'Guyen et al. 2018). Finally, by combining qualitative and quantitative analysis, future research could provide significant issues on the relationships between robots' artefacts and users' experiences.

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Annexes

Photo files

Photo I**.** C attends the test.

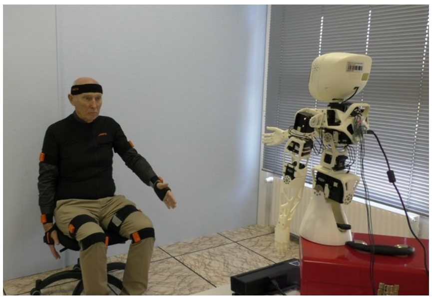

Photo II**.** C attends the self-confrontation interview.

Table files

Table I.The four columns board

Time	**Verbatim of the activity**	**Verbatim of the self-confrontation**	**Ethnographic notes and photogram**

03:25	D : « je vais vous montrer l'exercice 2 » Poppy montre exo 2. S4 monte le bras D et plie son coude	**18:23** Par contre la rotation je vous dis euh, surtout regardez l'autre là-bas (il montre robot)**18:35** Ouais c'est celui là que j'avais du mal. Parce que lui montait son avant-bras comme ça (il mime) et moi je pouvais, je pouvais pas (il plie son coude D, se ravise, change de bras) j'étais comme ça là (il plie son coude G).	A : (mouvement de tête, ne semble pas satisfait de son mouvement) 

Table II. Exemple of meaningful units per category of concern

Concern category number	Category name (units number)	Meaningful units
C1	**to perform the task well (27)**	*"I was told I was to copy the movement of the machine. So copy the movements of the machine means copy the movements of the machine !...machine does it you do it"* , *"Indeed you just had to copy what it did*"
C2	**to deal with personal emotions (17)**	*Is it a matter of personal pride that you can manage this kind of thing ? I am an able bodied person I am not, you know, hm, …. Physically pretty competent and I would aim not to make a mistake in this kind of thing", "I was mainly afraid I would not succeed", "if you miss, you are quite annoyed and I don't like it*"
C3	**to self-evaluate (33)**	*"So I'm not giving myself more than 6 out of ten for this" , "Well, I have uplifted my arms too high, see, I haven't observed properly"*
C4	**to keep producing an effort (13)**	*"I concentrated very hard on seeing how, how the robot moves.", "One minute was enough for then you were quite happy to relax again", "I'm fairly well involved in the task"*
C5	**to catch up with the speed, the rhythm (33)**	"*The speedier the movement is, the riskier it is to make a mistake and not copy exactly*", " *it's to be in time...that was the exercise*", "*the rhythm was not too fast*", " *sometimes I would slow down then to catch up the pace I had to speed up (sigh)*"
C6	**to notice a human-robot differenc**e (29)	"*there for instance I've bended the elbow whereas there's no bend in the elbow at all", "Because the robot is not a human skeleton, right, does the human skeleton imitate the robotic skeleton or is the robotic skeleton imitating the human skeleton ?", " It has motors, not joints, not as souple as u*s"
C7	**to identify a difficulty (30)**	*"No I can't bend my elbow the way it does it, no I can't. Can anyone do by the way ? ", "In that movement you see there are different rotations which go on in way which doesn't go on in you arm. Or don't go in mine anyway."*
C8	**to try not to be surprised (21)**	"*one is on the alert. What's gonna happen next ?", "When one does it for the first time, on might be surprised", "There may be a bit of confusion, there, see ? the movement is quite sudden"*

Figure files

Figure I. Evolution of the concerns along the time of the exercises.