How elderly users of a socially interactive robot experience adaptiveness, adaptability and user control

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Abstract

Older adults prefer an assistive technology that can be adaptive to their needs. However, as an assistive social robot that is autonomous has the possibility of being pro-actively adaptive this could cause feelings of anxiety. Analyzing the results of a study with video's that feature an assistive social robot in alternate conditions we found that although older adults prefer a robot to be adaptive rather than adaptable, they still want to maintain a sense of user control.

1. Introduction

As technological advances make it possible for systems to respond to users with more flexibility and autonomy, it becomes more common for these systems to adapt or be adapted. For some systems this concerns user-adaptation, possibly by learning from interaction or by detecting the specifics of a user [1, 2]. For context-aware systems it means gathering information from the environment to adapt themselves to the current situation [3, 4]. These developments lead to adaptive applications in many different domains, including shopping recommenders that direct consumers to products that may be of interest to them [5], mobile agents monitoring the user's surroundings in crisis situations [6] and personalized tours [7, 8].

However, for aging adults, adaptive technology has its own requirements and perspectives. It is essential for this specific user group that assistive devices be either adaptive (self-adapting) or adaptable (can be adapted) because of the changing needs of the users [9]. Growing older is a process during which physical and mental functions of our bodies gradually become less usable, due to which we need help, either in the form of humans or in the form of assistive devices. Older adults usually want neither humans nor devices to help them out when this help is not yet needed. They do not want a device to help them remember things as long as their memory still (more or less) functions and they do not want to be helped walking as long as they can still manage to walk by themselves. It is appreciated however, if these devices or people become helpful as soon as help is needed. This is partly to postpone the use of these devices because they could be stigmatizing (see for examples Forlizzi et al. [10] and partly because the users want to keep their independence and remain using their physical and mental capabilities as long as possible [11, 12].

This makes adaptivity a reoccurring requirement in projects concerning eldercare technology in general [9, 13, 14] and more specific in robot and screen agent technology [10, 15-17]. There is however an issue that needs to be addressed, concerning both the interpretation of the concept of and the response to adaptive technology. This response is not always positive when it concerns systems that autonomously adapt to the user or the environment. Especially when these systems become more sophisticated, they perform actions that users never experienced from similar systems before [18], and this makes these systems to be perceived as unpredictable and unreliable [19, 20].

As Dautenhahn [21] points out, there are two views in HRI on this that appear contradictory. On the one hand, there are indications that more autonomy would lead to more useful agents [22] while on the other hand, there are indications that predictability and controllability should prevail [23]. As we can generally state that adaptivity potentially makes the user feel no longer in control, the question is: should a system therefore be less adaptive? Should it rather be adaptable, or perhaps adaptive but with a form of user control? Should a system ask for confirmation before it autonomously adapts? Several studies addressed these questions, finding that indeed the desire for user control limits the acceptance of autonomy [24-26], which means there is a delicate balance between automation/autonomous behavior and user control. We want to know how this intervenes with the interpretation and perception of adaptivity by our target group of aging adults.

The concept of adaptivity as addressed in the above mentioned studies covers in fact two notions that are related, but nonetheless refer to different underlying processes: adaptability and adaptiveness. The notion of adaptability refers to the user being able to adapt a device or system to his or her demands or needs; adaptiveness refers to the system adapting autonomously. Both adaptive changes – the first by the user and the second by the system itself – are supposed to be related to the gradually growing need for assistance by an older adult. Furthermore, the notion of adaptiveness does not suggest either presence or absence of user control: adaptiveness could for example be performed either with or without asking this user for approval. In the latter case we speak of user control, which is lacking when a system adapts without asking for approval.

Thus we have the following interpretations of the concept of adaptiveness:

- adaptable: the user adapts the robot to his or her changing needs;
- adaptive with user control: the robots adapts to observed changing needs of the user after the user has agreed to this;
- adaptive without user control: the robot adapts to observed changing needs of the user without seeking agreement of the user.

In this study we will try to establish which of these make an assistive social robot most acceptable for aging adults. We will do this by carrying out an experiment using a video of an elderly user with an assistive social robot. It has four conditions: a neutral one, an adaptable one, an adaptive one with user control and an adaptive one without user control.

2. Method

We used a video of a robot interacting with an elderly actor instead of a real live HRI trial to create the four conditions. Using video's in HRI trials is found to be a method that leads to results that are comparable to live trials [27, 28].

2.1. System

We were able to use video material made for the Robocare project by the Institute for Cognitive Science and Technology of the Italian National Research Council for research by Cesta et al. [29, 30] (Figure 1). We made four video's of the robot representing the four conditions. In all these videos, the robot had the same three functionalities which were already presented in the original video as developed by the Robocare researchers (the original video is available online at http://robocare.istc.cnr.it/videos/rbc-sample-1.avi):

1. monitoring the user and alarming if necessary;
2. helping to remember to take the right medication at the right time;
3. functioning as a fitness advisor (announcing that it is time for some exercise if the user has been seated too long).

In the first, neutral condition, the robot simply had al these functionalities: the user could not turn them on or off and the system did not modify them by itself. In the second, adaptable condition, the second functionality was shown to be turned on by the user. This function was most suitable to be the adaptable/adaptive feature: as we reported earlier, the reminder function could be something that made participants reject the use of a robot as long as they felt their memory was still good enough. In conditions three and four, both adaptive, the second functionality (medication reminding) was turned on by the system itself. In the third condition, there would be user control: the system would suggest the functionality to be turned on and would await the user's approval before doing this. In the fourth condition there would be no user control: the system would simply announce the functionality to be necessary and turn it on.

Figure 1. Still from the video's

2.2 Participants

We found 100 older adults willing to take part in the experiments who were living in apartments close to or within eldercare institutions in the cities of Almere and Amsterdam. Due to procedural irregularities, we had to omit 12 participants from the results. So our results feature 88 participants, from which 28 were male and 60 were female (which is in accordance with the demographic overrepresentation of women in this age group for this generation).

2.3. Procedure

There were three researchers who had all four videos on a laptop. They visited the participants, explained the set up of the experiment and showed one of the videos at each visit. Every participant just saw one video and the link of a participant to a video was randomly made. After this, the participant was asked to fill out the questionnaire. If any help reading the form was needed, it would be given, but to avoid influencing the participants, the researchers gave no explanation.

Category	Statement/question
Manipulation check	What happened in the last scene? a) The robot reminded the women that it was time to take her medication. b) The robot reminded the women that it was time to take her medication after she turned the option 'medication reminder' on. c) The robot told the women she had not taken her medication in time and asked if he should remind her. d) The robot told the women she had not taken her medication in time and that he would remind her.
User control	The woman in the video controls what the robot does and does not do.
Anxiety	If I should use the robot, I would be afraid to make mistakes with it If I should use the robot, I would be afraid to break something I find the robot scary I find the robot intimidating
Intention to use	I think I would use the robot if I could I am certain to use the robot if it is available I'm would gladly make use of the robot if it would be available
Perceived adaptivity	I think the robot can be adaptive to what I need I think the robot will only do what I need at that particular moment I think the robot will help me when I consider it to be necessary
Perceived usefulness	I think the robot is useful to me It would be convenient for me to have the robot The robot can help me with many things

Table 1. Questionnaire

We measured the adaptivity and the usefulness of the system as perceived by the participants as well as their anxiety and their intention to use the robot with questionnaire items as used in the Almere model [17]. This model has been developed to predict and explain acceptance of social assistive robots and the questionnaire has been validated. The questionnaire consists of statements that can be replied to on a five point Likert scale (from totally agree to totally disagree), with attributed scores from 5 to 1.

We added a control question to enable us to check whether the different versions would reflect the way the users perceived the robot. We made this a multiple choice question with four answers – answer a. corresponded with the first version, answer b. with the second one and so on (see Table 1). We also introduced a user control statement, saying that the user in the video had control over the robot. As with the regular questionnaire items, this could be replied to on a five point scale.

4. Results

The 88 questionnaire forms that turned out to be usable had the following numbers of participants divided over the four video's (Table 2).

Condition	*Description*	*N*
1	*Not adaptive, not adaptable*	*22*
2	*Adaptable*	*21*
3	*Adaptive user controlled*	*23*
4	*Adaptive not user controlled*	*22*

Table 2. Robot conditions and number of participants

We calculated Cronbach's Alpha and found all used constructs to be reliable: .792 for Perceived Adaptivity, .854 for Intention to Use and .825 for Perceived Usefulness.

		MC question				
		1	**2**	**3**	**4**	**Total**
Video	1	21	1	0	0	22
	2	3	16	1	1	21
	3	6	2	12	3	23
	4	1	0	2	19	22
Total		31	19	15	23	88

Table 3. Cross tabulation MC question and Video

To establish the strength of the association between the video versions and the manipulation check (MC) question (Table 6.4) we generated the cross tabulation which is presented in Table 6.7. The significance of this relation can be established by calculating Cramers V. This is a chi-square-based measure of nominal association which gives a normalized value between 0 and 1 [31]. In our case, the value for Cramers V is .714, which is significant at the 0.001 level. This means there is a strong association between the manipulation check question and the video versions:

participants generally perceived the amount of adaptability, adaptivity and user control that was consistent with the video version they had seen.

To establish the effect of our manipulations further, we compared the results of the participants that saw the first video to the scores related to the other three video's. We found that Perceived Adaptivity indeed scored much higher for the video's that featured an adaptable or adaptive robot (M=3.661, SD=.550 versus M=2.984, SD=654). Also Perceived Usefulness scored higher for these video's (M=3.742, SD=.882 versus M=3.303, SD=860), but there was no higher score on Intention to Use. We subsequently compared the non adaptive conditions (video 1 and 2) to the adaptive conditions (video 3 and 4) with a t-test. Perceived adaptivity was indeed higher in the adaptive condition set (M=3.674, SD=.566) compared with the non-adaptive condition set (M=3.302, SD=.673). This indicates our manipulation was successful.

To compare the four conditions represented by the four video versions, we used a one way ANOVA (box plots Figure 2 to 4), accompanied by a post hoc Games Howell comparison analysis as shown in Table 4. A Games Howell comparison [32] is a usual instrument in cases where multiple groups have to be compared pair wise [33]. As with t-test results, a positive value means a higher score for the first of the two compared groups and a negative score means a higher score for the second group. It does not require equal variances.

	2 to 1	**Sig.**	**3 to 1**	**Sig.**	**4 to 1**	**Sig.**
UC	.377	.430	.960*	.003	.273	.700
ANX	-.256	.655	.397	.278	.057	.989
ITU	-.325	.770	.833	.055	.318	.709
PAD	.650*	.005	.856*	.000	.515*	.044
PU	.014	1.000	.885*	.009	.379	.393
	2 to 3	**Sig.**	**2 to 4**	**Sig**	**3 to 4**	**Sig.**
UC	-.584	.234	.104	.299	.688	.130
ANX	-.654*	.049	-.313	.445	.340	.359
ITU	-1.157*	.002	-.643	.106	.514	.176
PAD	-.206	.545	.135	.860	.341	.176
PU	-.871*	.009	-.364	.411	.507	.176

Table 4. Games-Howell comparison

Remarkable in these results is the distinguishing score of the third condition in relation to the other ones. It scores higher than the first condition on User Control, Perceived Adaptiveness and Perceived Usefulness, and it scores higher than the second condition on Anxiety, Intention to Use, Perceived Enjoyment and - again - Perceived Usefulness. An adaptive robot that asks for confirmation (condition 3) is thus clearly perceived as more useful than a robot that is not adaptive.

Moreover, the adaptive version without user control (4) only scores significantly higher on Perceived Adaptiveness when compared to the first condition – it does not score higher on any other construct, compared to any other condition. Also, there is no significant difference between the two adaptive conditions (3 and 4). Apparently, only the combination of adaptiveness and user control can make a clear difference in user perception.

The plots shown in Figure 2 to 5 confirm the outstanding scores for the adaptive condition with user control, showing the third condition with the highest score on Intention to Use (Figure 2), Perceived Usefulness (Figure 5) and on User Control (Figure 4). Furthermore, the plot in Figure 4 shows what is also very clear in Table 0: both adaptability and adaptiveness lead to a higher score on Perceived Adaptiveness.

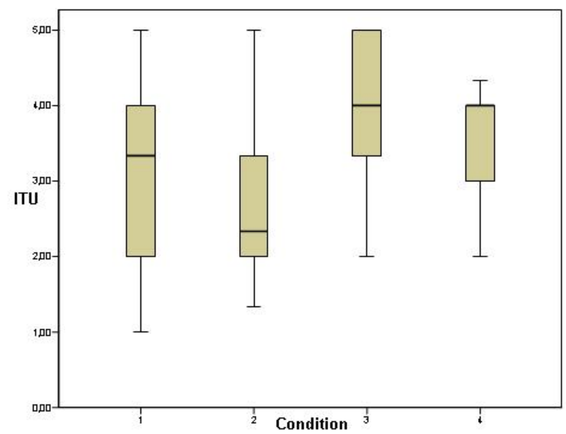

Figure 2. Box plot for Intention to Use

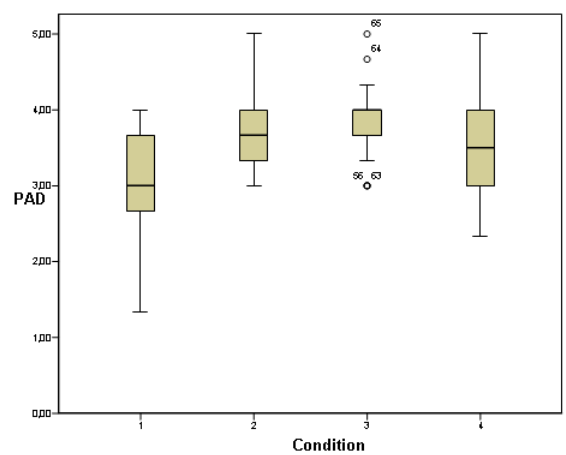

Figure 3. Box plot for Perceived Adaptivity

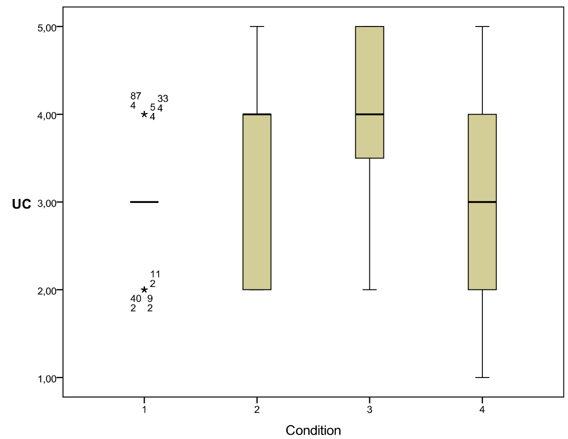

Figure 4. Box plot for the user control question

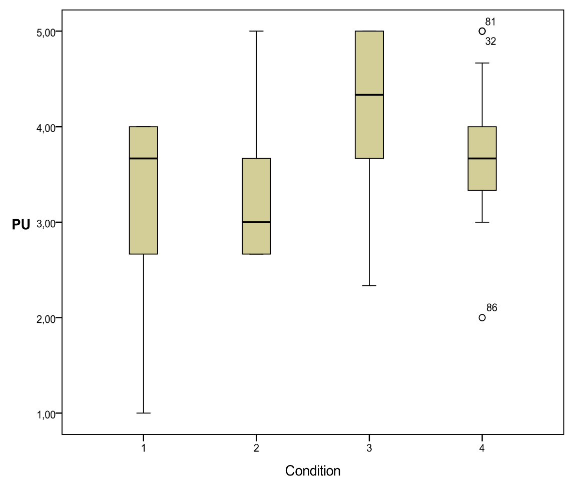

Figure 5 Box plot for Perceived Usefulness

Table 5 shows correlation scores. Perceived Adaptivity correlates with Perceived Usefulness and both these constructs correlate with Intention to Use. Moreover, the score on user control correlates with the construct of Anxiety: the more user control is perceived, the less anxiety is experienced.

		UC	ANX	ITU	PAD	PU
ANX	Corr	.372**	1	.188	-.009	.151
	Sig.	.000		.079	.931	.161
ITU	Corr	.008	.188	1	.373**	.718**
	Sig.	.938	.079		.000	.000
PAD	Corr	.162	-.009	.373**	1	.338**
	Sig.	.132	.931	.000		.001
PU	Corr	.193	.151	.718**	.338**	1
	Sig.	.072	.161	.000	.001	

Table 5. Pearson correlation scores

5. Conclusions and discussion

First of all it is remarkable that the adaptable condition (condition/video 2) is not accepted better, but both adaptive conditions (3 and 4) scored higher. Most clear however, are the outstanding results for the adaptive condition with user control (condition/video 3). We thus conclude that adults prefer a system that adapts itself, requiring limited or no knowledge on operating it, but still leaving the user in control: when adaptive, a request for approval before adapting (suggesting more user control) leads to a higher score on acceptance.

We also established that a request for approval by an adaptive robot (condition 3) does not directly lead to a higher sense of control by the user when compared to an adaptive robot that did not ask for approval (condition 4). However, the adaptive robot asking for approval (condition 3) scored significantly higher on user control than the non adaptive, non adaptable robot (condition 1).

We find that these results show that – indeed – there is a subtle balance between autonomous adaptivity and the desire for user control as we stated in the introduction of this chapter. Further research using similar measuring instruments could establish where this balance differs for different systems, user groups and perhaps stages in aging.

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