Assessing acceptance of assistive social robots by aging adults

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6. Exploring adaptiveness, adaptability and user control

Parts of this chapter have been published earlier in (Heerink et al. 2008c; Heerink et al. 2008d) and (Heerink et al. 2010b)

6.1 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 (Benyon 1993; Cheverst et al. 2005). For context-aware systems it means gathering information from the environment to adapt themselves to the current situation (Scholtz et al. 2004; Schmidt 2005). 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 (Alpert et al. 2003), mobile agents monitoring the user's surroundings in crisis situations (Streefkerk et al. 2006) and personalized tours (Fink and Kobsa 2002; Wubs and Huysmans 2006).

However, for aging adults, adaptive technology has its own requirements and perspectives. As we discussed in section 4.4.3, it is essential for our specific user group of older adults that assistive devices be either adaptive (self-adapting) or adaptable (can be adapted) because of the changing needs of the users (Pew and Hemel 2004). 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. 2004) and partly because the users want to keep their independence and remain using their physical and mental capabilities as long as possible (Jorge 2001; Ebersole et al. 2003).

This makes adaptivity a reoccurring requirement in projects concerning eldercare technology in general (Yu et al. 2003; Miller et al. 2004; Pew and Hemel 2004) and more specific in robot and screen agent technology (Kawamura et al. 2003; Maciuszek and Shahmehri 2003; Forlizzi et al. 2004). We therefore introduced the construct of Perceived Adaptivity in our model (Section 4.4.3). However, as a construct within an acceptance model, Perceived Adaptivity is completely unprecedented. In a similar way as we designed an experiment that could justify the 'social constructs' in the previous chapter, we therefore designed an experiment that could justify the addition of Perceived Adaptivity. This means we want to establish whether a more adaptive robot is accepted better than a less adaptive robot.

There is however another question that needs to be answered, concerning both the interpretation of the construct 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 (Höök et al. 2000), and this makes these systems to be perceived as unpredictable and unreliable (Höök 1998; Jameson 2003).

As Dautenhahn (2004) 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 (Maes 1994) while on the other hand, there are indications that predictability and controllability should prevail (Shneiderman 1997). 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 (Gillies and Ballin 2004; Marble et al. 2004; Price et al. 2005), 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.

The statements that are used in our questionnaire (see Table 6.1) cover two concepts that are related, but nonetheless refer to different underlying processes: *adaptability* and *adaptiveness.*

PAD	*14. I think the robot can be adaptive to what I need*
	15. I think the robot will only do what I need at that particular moment
	16. I think the robot will help me when I consider it to be necessary

Table 6.1. Statements for the construct of Perceived Adaptivity (PAD)

The items can be interpreted as either the user being able to adapt a device or system to his or her demands or needs, or the system adapting autonomously. In our case 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 questionnaire items do 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 options to further specify the PAD-construct:

- 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.

Summarizing we state that in this chapter we will address two issues: confirming the relevance of the construct of Perceived Adaptivity by comparing a more adaptive version of a robot to a less adaptive one and solving the ambiguity of the interpretations of Perceived Adaptivity.

This means we want answers to the following questions:

- Does a robot that is more adaptive/adaptable have a higher score on Intention to Use than a less adaptive robot?
- Is there a difference considering the scores for Perceived Adaptivity and Intention to Use between an adaptive and an adaptable robot?
- When adaptive/adaptable, is there a difference in impact on the scores for Perceived Adaptivity and Intention to Use if there is more user control?
- Does a request for confirmation lead to a higher sense of control by the user?
- Is a more adaptive/adaptable robot found to be more useful than a less adaptive/adaptable one?

We will address these questions by rephrasing them in the form of hypotheses which we will test 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.

6.2 Focus within the model

Our focus for this chapter is on Perceived Adaptivity. Furthermore, since a more adaptive/adaptable system is expected to make this system more useful, we also focus on the relationship between Perceived Adaptivity and Perceived Usefulness, and on how this influences the Intention to Use. This means we are focusing as visualized in Figure 6.1.

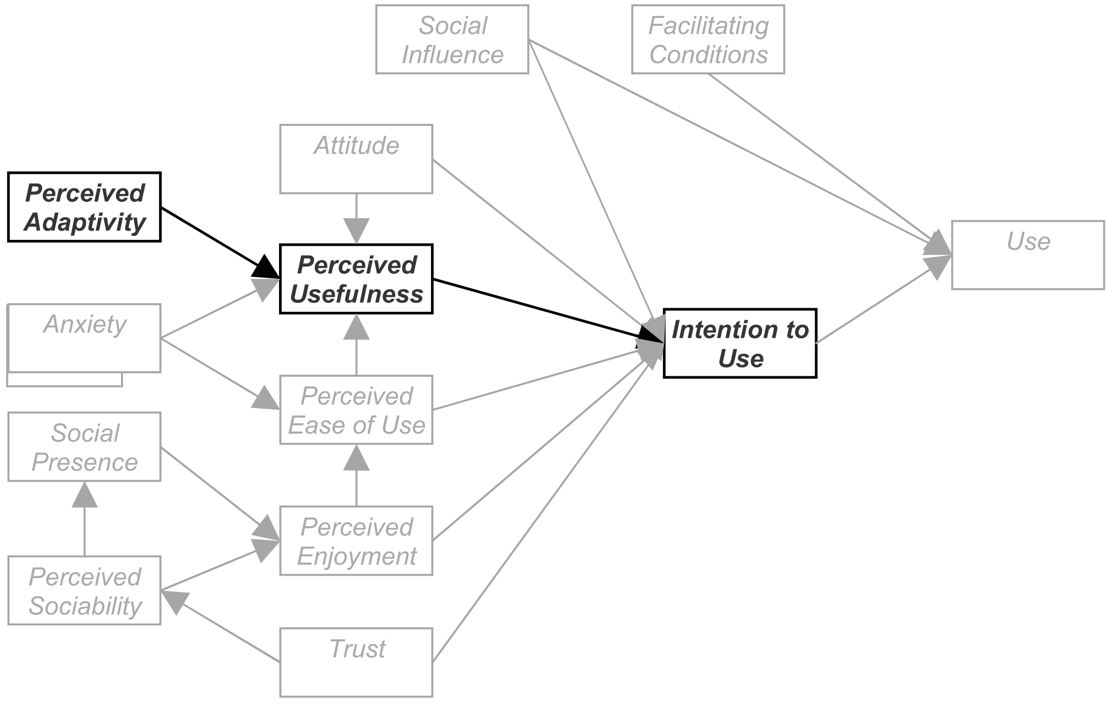

Figure 6.1. Focus of the experiment

We formed hypotheses to be tested, based on the questions we described in section 6.1 and on the overall assumptions concerning the relevant construct interrelations of our model. The first two hypotheses belong to the latter category, demanding a confirmation of assumed construct interrelations:

Exp4-H1 Intention to Use is determined by Perceived Usefulness.

Exp4-H2 Perceived Usefulness is determined by Perceived Adaptivity.

The third hypothesis assumes that our manipulations will be reflected in the score for Perceived Adaptivity:

Exp4-H3 The score on Perceived Adaptivity will be higher for the adaptable and both adaptive conditions compared to the condition that is neither adaptable nor adaptive.

Also, we expect the user control condition to have a higher score on related statements:

Exp4-H4 Participants will indicate to sense more user control in a condition where this is implemented.

Furthermore, we are interested in differences between the adaptable and adaptive conditions. As it is generally found that adaptiveness increases accessibility of assistive technology for elderly users (Jorge 2001; Miller et al. 2004; Pew and Hemel 2004), we expect that the Perceived Adaptivity of the adaptive versions leads to a higher score on Perceived Usefulness. This would subsequently affect Intention to Use.

Exp4-H5 *There will be a higher score on (a) Perceived Adaptivity (b) Perceived Usefulness and (c) Intention to Use for both adaptive conditions as compared to the non adaptive conditions.*

Moreover, we expect a difference between the two adaptive conditions with and without user control. As we stated in the previous section, the desire for user control limits the acceptance of autonomy: in general users seem to feel less anxiety for a robot if they experience more user control, we expect the user control condition to be preferred. This would be reflected in higher scores on Anxiety (this means less anxiety since the scores are reversed) and through Perceived Usefulness on Intention to Use

Exp4-H6 *There will be a higher score on (a) Anxiety (b) Perceived Usefulness and (c) Intention to Use for a condition with user control as compared to a condition without user control.*

6.3 Method

We wanted to set up an acceptance measuring experiment in which we could have an assistive social robot in four conditions: a neutral one that is neither adaptable nor adaptive, an adaptable one, an adaptive one with user control and an adaptive one without user control. To effectively compare these four conditions, we needed at least 20 participants for each condition, which meant we needed a group of at least 80 participants.

To meet this challenge, we decided to use 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 (Woods et al. 2006a; Woods et al. 2006b).

6.3.1 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. (Cesta et al. 2007; Cesta et al. 2007).

The RoboCare project concerns a service type robot. It is cylinder shaped and mobile (wheels), and it is connected to a system that features sensors and cameras. It has the possibility to produce pre-programmed speech. There is a version with a screen on which a female face is displayed to embody the conversation. The robot serves both as an interface to 'smart home' technology and as an autonomous actor, retrieving information from it's intelligent environment and acting upon this. The RoboCare project is not so much focused on developing a robot as to an environment, an intelligent home of which a robot is an integrated part (Bahadori et al. 2003). Published research related to

RoboCare is focused on technical matters or design issues – for example comparing responses to a robot with a screen, a face or just a voice.

We made four video's of the robot (see screenshots in Figure 6.2), 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.

Figure 6.2. Stills from the video's

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.

So these were the four conditions, represented by four videos:

1. Not adaptive, not adaptable.
2. Adaptable, not adaptive.
3. Adaptive, not adaptable, with user control.
4. Adaptive, not adaptable, without user control.

6.3.2 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 incomplete questionnaires and other 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). Table 6.3 lists their age, education and computer experience.

	Minimum	Maximum	Mean	Std. Deviation
Age	58	99	77.73	8.727
Experience	1.00	5.00	1.966	1.266
Education	2	10	4.78	2.120

Table 6.3. Descriptive statistics for age, computer experience and education

6.3.3 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. So every participant just saw one video and the link of a participant to a particular video was randomly made. After this, the participant would be 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.

6.3.4 Questionnaire adaptation

Although we are focusing on just a part of our model, we used the complete questionnaire of the new model (as presented in Table 4.6). This would enable us to compare the results to those of our previous experiments and even add the cases of all experiments for which the same questionnaire was used (this will be carried out in Chapter 8).

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 6.4).

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.

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 that she had taken her medication in time and asked if he should remind her next time. d. The robot told the women that she had taken her medication in time and that he would remind her next time.
User control	The woman in the video controls what the robot does and does not do.

Table 6.4. Added statements for user control and manipulation check question

6.4 Results

The 88 questionnaire forms that turned out to be usable had the following numbers of participants divided over the four video's (Table 6.4).

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

Table 6.4. Robot conditions and number of participants

Table 6.5 shows the descriptive statistics for the combined scores on the conditions.

	Minimum	Maximum	Mean	Std. Dev.
User Control	1	5	3.32	.977
Anxiety	1.25	5.00	3.671	.734
Attitude	1.33	5.00	3.167	.922
Facilitating Conditions	1.50	5.00	3.477	.7386
Intention to Use	1.00	5.00	3.402	1.052
Perceived Adaptivity	1.33	5.00	3.492	.645
Perceived Enjoyment	1.50	5.00	2.955	.860
Perceived Ease of Use	1.60	5.00	3.559	.714
Perceived Sociability	1.00	4.25	2.696	.645
Perceived Usefulness	1.00	5.00	3.633	.893
Social Influence	2.00	5.00	3.205	.730
Social Presence	1.00	4.40	2.830	.533
Trust	1.50	5.00	3.602	.898

Table 6.5. Descriptive statistics for combined conditions

Calculating Cronbach's Alpha (Table 6.6) we found that all of the constructs were reliable, except for Facilitating Conditions, which also was not reliable if one of the questions were omited. Since we hypothesized (see section 4.4.1 and 4.5) this construct only to relate to actual use, which was not measured in this experiment, this was not a relevant construct for our hypotheses. We therefore omitted it from the results of this experiment. For the other constructs we had to omit statements 21 (PENJ5), 22 (PEOU1), 37 (SI3) and 45 (Trust3). These were also omitted in our previous experiment.

Construct	**Alpha**	**Construct**	**Alpha**
Anxiety	*.701*	*Perceived Ease of Use*	*.842*
Attitude	*.763*	*Perceived Sociability*	*.717*
Facilitating Conditions	*.426*	*Perceived Usefulness*	*.825*
Intention to Use	*.854*	*Social Influence*	*.701*
Perceived Adaptivity	*.792*	*Social Presence*	*.735*
Perceived Enjoyment	*.756*	*Trust*	*.758*

Table 6.6. Cronbach's Alpha

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 (Cramér 1999). 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.

		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 6.7. Cross tabulation MC question and Video

To establish the effect of our manipulations further, we compared the results of the participants that saw the first video (neither adaptable nor adaptive) to the scores related to the other three video's that concerned either adaptable or adaptive conditions. Table 6.8 shows 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 this did not lead to a higher score on Intention to Use. This means Hypothesis 5 is partly confirmed.

variable	t	Sig.	variable	t	Sig.
Anxiety	.417	.677	Perceived Sociability	1.763	.082
Attitude	1.432	.156	Perceived Usefulness	2.035*	.045
Intention to Use	1.133	.260	Social Influence	2.632*	.011
Perceived Adaptivity	4.762**	.000	Social Presence	.835	.407
Perceived Enjoyment	.606	.547	Trust	1.591	.115
Perceived Ease of Use	1.565	.121	User Control	2.988*	.004

Table 6.8. T-test comparing video 1 related scores (neither adaptable nor adaptive) to the scores related to the other video's (adaptable/adaptive)

We subsequently compared the non adaptive conditions to the adaptive conditions. The first category consisted of the scores for video 1 and video 2 and the second of video 3 and 4. Table 6.9 shows the t-test scores to compare these two condition sets. 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.

Also, participants who viewed the adaptive robot video were found to have a higher score on Intention to Use and a more positive attitude toward the robot. They percieved the robot more as enjoyable and more useful. Furthermore, participants in the adaptive condition reported to feel less anxiety toward the robot and found other people's opinions about using the robot (social influence) more important.

variable	t	Sig.	variable	t	Sig.
Anxiety	2.334*	.022	Perceived Sociability	.306	.761
Attitude	3.023*	.003	Perceived Usefulness	3.523*	.001
Intention to Use	3.485*	.001	Social Influence	2.178*	.032
Perceived Adaptivity	2.807*	.006	Social Presence	.350	.727
Perceived Enjoyment	2.298*	.024	Trust	1.655	.102
Perceived Ease of Use	1.150	.254	User Control	2.170*	.033

Table 6.9. T-test comparing adaptive to non adaptive

To compare the four conditions represented by the four video versions, we used a one way ANOVA (see box plots Figure 6.3 and 6.4), accompanied by a post hoc Games Howell comparison analysis as shown in Table 6.10. A Games Howell comparison (Games and Howell 1976) is a usual instrument in cases where multiple groups have to be compared pair wise (Zwick 1986). 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.

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.

	2 to 1	Sig.	3 to 1	Sig.	4 to 1	Sig.	2 to 3	Sig.	2 to 4	Sig	3 to 4	Sig.
UC	.377	.430	.960*	.003	.273	.700	-.584	.234	.104	.299	.688	.130
ANX	-.256	.655	.397	.278	.057	.989	-.654*	.049	-.313	.445	.340	.359
ITU	-.325	.770	.833	.055	.318	.709	-1.157*	.002	-.643	.106	.514	.176
PAD	.650*	.005	.856*	.000	.515*	.044	-.206	.545	.135	.860	.341	.176
PENJ	-.268	.615	.582	.078	-.034	.999	-.849*	.011	.234	.254	.616	.114
PEOU	.236	.645	.393	.186	.182	.863	-.157	.850	.054	.996	.211	.791
PU	.014	1.000	.885*	.009	.379	.393	-.871*	.009	-.364	.411	.507	.176

Table 6.10. Games-Howell comparison between the four conditions

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 6.3 to 6.6 confirm the outstanding scores for the adaptive condition with user control, showing the third condition with the highest score on Intention to Use (Figure 6.3), Perceived Usefulness (Figure 6.5) and on User Control (Figure 6.6). Furthermore, the plot in Figure 6.4 shows what is also very clear in Table 6.10: both adaptability and adaptiveness lead to a higher score on Perceived Adaptiveness.

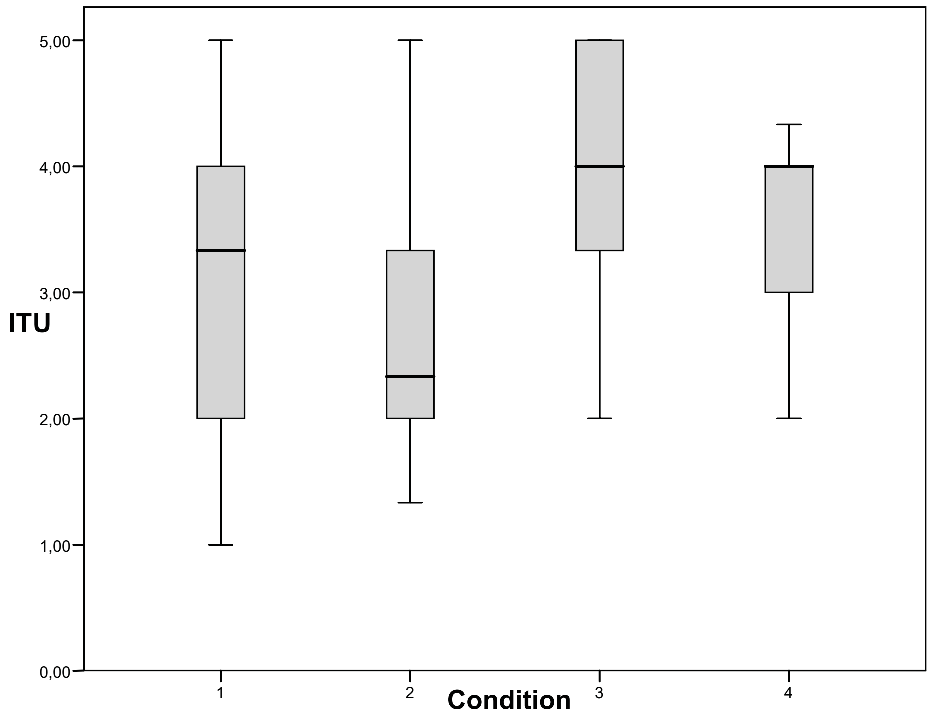

Figure 6.3 Box plot for Intention to Use

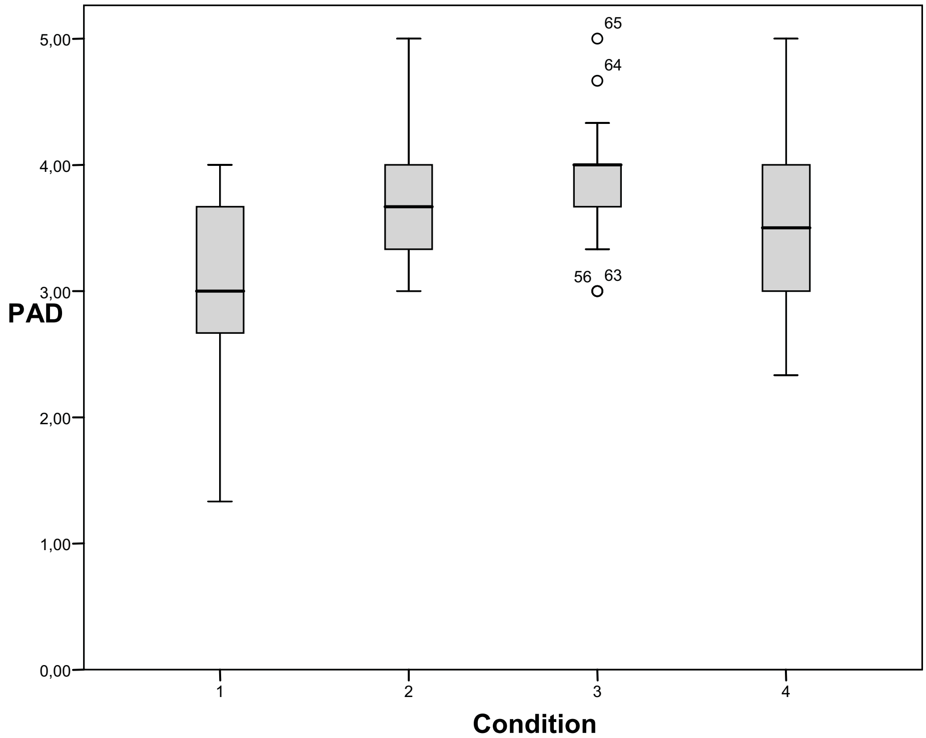

Figure 6.4 Box plot for Perceived Adaptivity

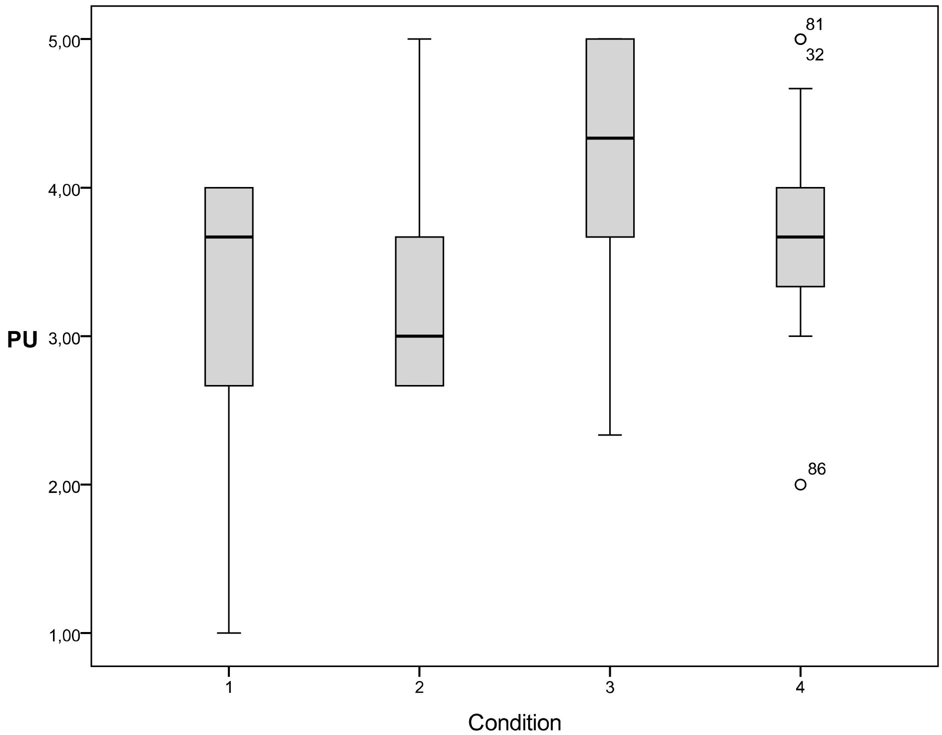

Figure 6.5 Box plot for Perceived Usefulness

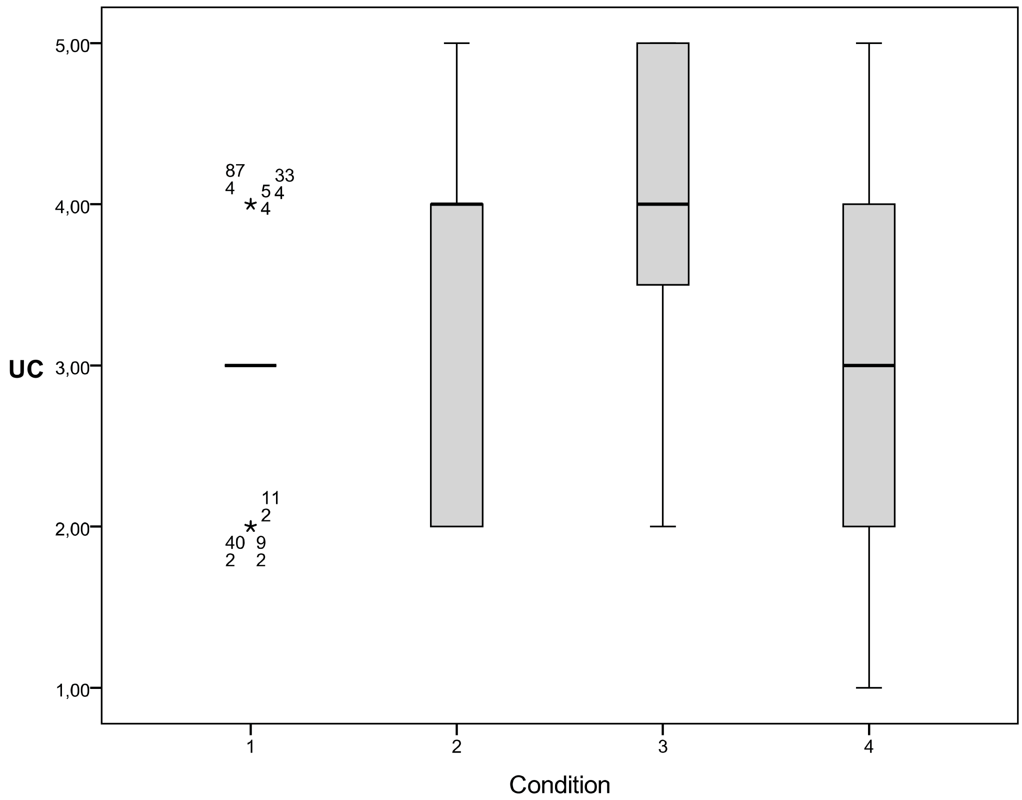

Figure 6.6. Box plot for the user control question

Table 6.11 shows correlation scores concerning the constructs that are relevant here plus the score on the user control question (a complete list can be found in appendix E). Perceived Adaptivity correlates with Perceived Usefulness. As can be expected, the score on user control (UC) correlates with the construct of Anxiety: the more user control is perceived, the less anxiety is experienced.

		UC	ANX	ITU	PAD	PENJ	PEOU	PU
ANX	Corr	.372**	1	.188	-.009	.286**	.436**	.151
	Sig.	.000		.079	.931	.007	.000	.161
ITU	Corr	.008	.188	1	.373**	.531**	.403**	.718**
	Sig.	.938	.079		.000	.000	.000	.000
PAD	Corr	.162	-.009	.373**	1	.196	.280**	.338**
	Sig.	.132	.931	.000		.067	.008	.001
PENJ	Corr	.175	.286**	.531**	.196	1	.454**	.525**
	Sig.	.103	.007	.000	.067		.000	.000
PEOU	Corr	.223*	.436**	.403**	.280**	.454**	1	.428**
	Sig.	.037	.000	.000	.008	.000		.000
PU	Corr	.193	.151	.718**	.338**	.525**	.428**	1
	Sig.	.072	.161	.000	.001	.000	.000	

Table 6.11. Correlations between major items

We also tested the model validation hypotheses (Section 4.5) – again without H1 which concerns usage – with a regression analysis on the results for the combined conditions. Table 6.12 shows that Perceived Usefulness and Attitude are the main determining influences on Intention to Use. This means the strong utilitarian aspect of this robot type (it does not entertain like the iCat in the previous experiment) is reflected in the scores. Furthermore, it shows that Social Presence is not a determining influence on Perceived Enjoyment. This could have to do with the relatively low score of Social Presence (2.830 versus 3.600 in the previous experiment), which is not remarkable if we consider the fact that participants did not experience a real robot. Still Perceived Sociability did influence Perceived Enjoyment, indicating that the (lower scoring) abilities were still of influence on the way the robot was perceived, although this had no impact on Intention to Use.

Table 6.13 shows an analysis of the performance of the model for the four different conditions. It shows a relatively high R^2 score for the adaptable condition, which could be related to the strongly determining influences of Perceived Usefulness and Attitude. This can be interpreted as the participants having a positive attitude towards the robot, finding the adaptability very useful.

Hypothesis		Independent	Dependent	Beta	t	Sig
H2	(a)	PU	ITU	.330	3.642**	.000
	(b)	PEOU		.047	.624	.534
	(c)	ATT		.496	5.442**	.000
	(d)	PENJ		.031	.375	.709
	(e)	SI		-.015	-.192	.848
	(f)	Trust		.086	1.096	.276
	Model: R^2=.68; F=29.341; df=6,81; P=.000					
H3	(a)	ANX	PU	.047	.538	.592
	(b)	ATT		.552	6.637**	.000
	(c)	PAD		.185	2.251*	.027
	(d)	PEOU		.365	3.264**	.002
	Model: R^2=.50; F=20.757; df=4,83; P=.000					
H4	(a)	ANX	PEOU	.334	3.543**	.001
	(b)	PENJ		.359	3.809**	.000
	Model: R^2=.31; F=18.931; df=2,85; P=.000					
H5	(a)	PS	PENJ	.419	3.559**	.001
	(b)	SP		.169	1.433	.156
	Model: R^2=.30; F=17.626; df=2,85; P=.000					
H6		Trust	PS	.571	6.445**	.000
	Model: R^2=.33; F=41.533; df=1,86; P=.000					
H7		PS	SP	.632	7.565**	.000
	Model: R^2=.40; F=57.231; df=1,86; P=.000					

Table 6.12. Regression analysis on model validation hypotheses

Figure 6.7 shows a model diagram in which the confirmed construct interrelations are visualized.

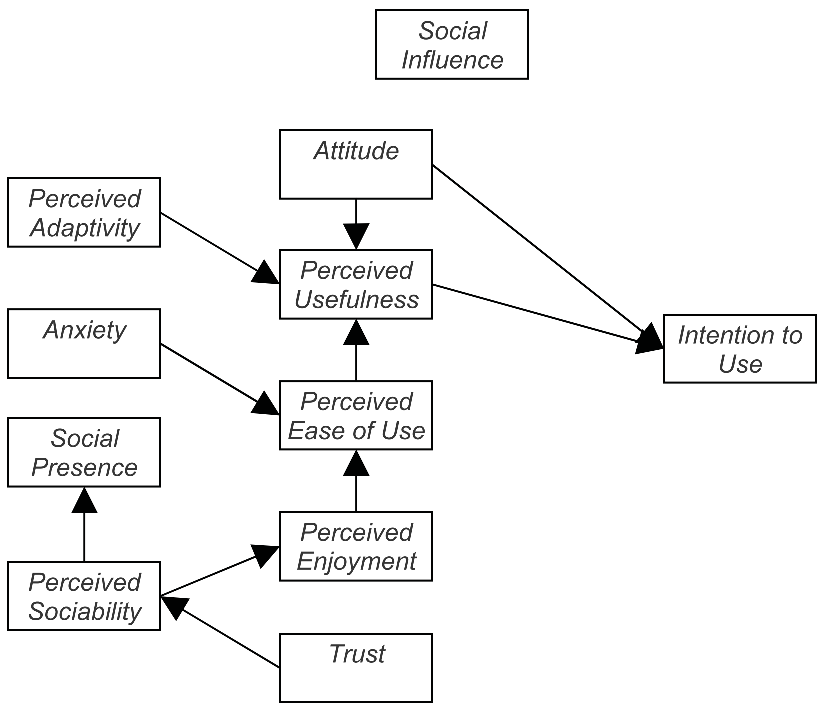

Figure 6.7. Confirmed relations

Condition	Independent	Dependent	Beta	T	Sig
Neutral	PU	ITU	.486	1.875	.080
	PEOU		-.033	-.153	.881
	ATT		.215	2.204*	.030
	PENJ		.098	.554	.588
	SI		.011	.064	.950
	Trust		.086	.413	.686
	Model: R^2=.69; F=5.676; df=6,15; P=.003				
Adaptable	PU	ITU	,598	3,015*	,009
	PEOU		-,116	-,604	,556
	ATT		,695	3,950**	,001
	PENJ		,137	1,213	,245
	SI		-,345	-1,572	,138
	Trust		,107	,640	,533
	Model: R^2=.88; F=16.445; df=6,14; P=.000				
Adaptive with user control	PU	ITU	,180	,853	,406
	PEOU		,235	1,335	,201
	ATT		,569	2,286*	,036
	PENJ		-,019	-,083	,935
	SI		,112	,512	,615
	Trust		-,107	-,574	,574
	Model: R^2=.69; F=5.974; df=6,16; P=.002				
Adaptive without user control	PU	ITU	,108	,547	,592
	PEOU		-,200	-,964	,350
	ATT		,642	2,854*	,012
	PENJ		-,142	-,585	,567
	SI		-,069	-,347	,733
	Trust		,450	1,971	,067
	Model: R^2=.62; F=4.129; df=6,15; P=.012				

Table 6.13. Regression analysis on ITU for the different conditions

Testing the moderating factor hypotheses (Section 4.4) with a Chow test leads to the results presented in Table 6.14. It shows only Hypotheses 1a, 1b and 5b: these were the only ones that could be tested, since the other hypotheses concerned construct interrelations that were not significant in the regression analysis (Table 6.12).

Hypothesis	Variable*Factor	Dependent	F	Sig.
MFH1a	Gndr*PU	ITU	1.454	.119
MFH1b	Age*PU	ITU	.913	.571
MFH5b	EDU*ANX	PEOU	.210	.988

Table 6.14. Chow's test on moderating factor hypotheses.

The table shows that we found no significantly moderating factors.

6.5 Conclusions

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 users prefer a system that adapts itself, requiring limited or no knowledge on operating it, but with still leaving the user in control.

Scores on Anxiety and Perceived Enjoyment also differ, especially between the second and the third condition, in favor of the adaptive one. This finding, combined with the results on the user control question, indicates that a robot that adapts itself after being permitted to do so, is more fun and less worrying. It is surprising however, that this does not lead to significant differences on the score for Perceived Ease of Use.

Looking back on our focus hypotheses (established in Section 6.2), we can confirm the first two construct interrelations: regression analysis shows Intention to Use is determined by Perceived Usefulness and the latter is determined by Perceived Adaptivity.

The third focus hypothesis can be confirmed. Not only did a t-test show clear differences between the first and the other conditions (Table 6.8), also the comparison scores (Table 6.10) show significant higher scores on Perceived Adaptivity for conditions 2, 3 and 4. Remarkably, scores for Intention to Use are the highest for the third version, but in our comparison analysis only the difference between the second and the third version is significant.

The fourth hypothesis cannot be fully confirmed: participants did indicate to sense more user control in a condition where this is implemented, but this is only true for the third condition (with user control) when compared to the first condition (see Table 6.10). Between the third and both second and fourth condition there is no significant difference although the score on user control was clearly the highest for the third condition (Figure 6.6). Our analysis did however show a strong correlation between user control and Anxiety (Table 6.11), indicating that an increased sense of control leads to anxiety decrease.

Furthermore, we can fully accept the fifth hypothesis: as the t-test results in Table 6.9 show, the scores Perceived Adaptivity, Perceived Usefulness and Intention to Use are clearly higher for the two adaptive conditions.

The last hypothesis has to be rejected, since (as Table 6.10 shows) the adaptive condition with user control (video 3) did not score higher on any construct than the adaptive version without user control (video 4).

This means we have found answers to the questions posed in section 6.1:

- We can state that in our experiment a robot that was more adaptive turned out to be more acceptable (i.e. leads to a higher score on Intention to Use) than a less adaptive robot, even if the latter concerned an adaptable robot. However, we could not establish an adaptable robot to be more acceptable than a non adaptable robot.
- When adaptive, a request for approval before adapting (suggesting more user control) leads to a higher score on acceptance.
- 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 justify the addition of Perceived Adaptivity to our model. However, they also 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.