The Acceptance of Domestic Ambient Intelligence Appliances by Prospective Users

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Abstract. Ambient intelligence (AmI) is a growing interdisciplinary area where the focus is shifted towards users instead of merely emphasizing the technological opportunities of AmI. Different methods are employed to understand the adoption of AmI appliances by users. However, these are often small-scale methods that are focused on specific subgroups. Large scale quantitative studies to understand the adoption of AmI appliances are scarce. In this study, a questionnaire was designed to examine how the Dutch people (n = 1221) perceive AmI appliances for domestic settings. Findings show that intention to adopt AmI appliances was low and that respondents had a negative to neutral attitude towards AmI appliances. On the basis of structural equation analysis, results suggest that adoption of AmI appliances could be explained by outcome expectancies of AmI appliances. The potential implications of the findings are discussed.

Keywords: ambient intelligence, pervasive technologies, technology acceptance.

1 Introduction

Enhanced computing power and convergence of technologies make it possible for embedded systems and appliances in the environment to adapt to and anticipate users' needs [30]. The integration of these systems and appliances in everyday lives of people is a particular vision of the future called Ambient Intelligence. Ubiquitous computing, pervasive computing and calm computing are synonyms of AmI, which refer to visions of people surrounded with embedded computing which is mostly invisible to the user [46, 6, 17]. Different names emphasize different aspects of this vision, but, Abowd and Sternbenz [1] have noted, they all have one thing in common, namely the desire to create a more symbiotic relationship between humans and their environment. Therefore, in the rest of this paper we will use the term Ambient Intelligence (AmI).

In the ubiquitous computing field, various methods such as ethnographic studies [29], scenarios and risk assessment [25], historical analysis [47] and interviews combined with diary studies [19] are used to get a better understanding of ubicomp and its possible consequences in different domains. However, large-scale quantitative studies of the acceptance of AmI appliances are scarce. This study aims to, first, increase the diversity of formative evaluation results for AmI appliances by using a large-scale,

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survey-based, quantitative study and, second, to empirically investigate the perception of a large group of prospective users toward AmI appliances. Here we present results from a large scale quantitative study exploring people's attitudes and intentions towards AmI appliances for domestic settings. Furthermore, we attempt to predict which variables influence the future adoption of AmI appliances. We conclude the paper reflecting on the anticipated adoption and use of domestic AmI appliances.

2 Related Work

Researchers from different backgrounds try to gain understanding of AmI in various settings to inform future design and to evaluate what kind of implications AmI can have for prospective users. In this section, we discuss the diversity of methods in relevant studies that used some form of formative evaluation of AmI appliances.

Health care is seen as a potential area where AmI could provide many benefits for both the patient and the care giver and where different research methods are used to explore this area. Interviews are widely applied in this area, for example to address the physical and cognitive needs of elderly to support their daily activities [36], to investigate the needs of technologies for elderly [7] and combined with a two-week phone diary study to explore the needs and implications of eldercare technologies [14].

Studies have also been undertaken which focus not only on health care for elderly but on the general needs and expectations of people regarding AmI. Venkatesh *et al.* [44] used photographs and illustrations of smart homes and appliances during interviews to gain insight into the attitude and potential interest of American household members towards the home of the future. To explore the requirements that people have for domestic AmI technologies workshops were used in a European study. Pictures of emerging technologies were shown to residents of five homes to trigger future scenarios [4]. Interviews combined with dairies were used for 47 people from different European countries (Norway, Finland, Hungary, and UK) to gain insight into user receptions of AmI [19]. Here, the respondents were mainly recruited through the researchers' social networks and therefore white collar workers were overrepresented. Garfield [23] investigated the acceptance of the pc tablet as an example of ubiquitous computing in an organizational context. She conducted a longitudinal, qualitative study based on interviews with participants who voluntarily used the tablet for a three-month period. As mentioned earlier, survey-based studies are scarce in the ubicomp field. Only recently a survey-based study has taken place in Germany to measure the experiences of people with ubicomp technologies, specifically focusing on privacy issues [42].

This brief overview of studies shows that different methods such as small-scale questionnaires, focus groups, interviews, diary studies, and cultural probes studies are the most frequently used methods to elicit responses from users regarding AmI technologies. However, these are often small-scale methods that focus on specific subgroups. In many other fields, from the pharmaceutical industry to technology product development, large-scale survey methods are commonly used [13]. As AmI technologies will ultimately be woven into society and into the everyday lives of many people [18], large-scale quantitative studies can be a valuable addition to

current methods to provide an overall picture and understanding of the anticipated adoption of AmI technologies by a large, diverse group of people. Therefore, in this research a large-scale survey was adopted to examine the anticipated adoption of AmI technologies.

3 Research Questions

Precursors of AmI appliances are entering the public domain and research activities worldwide have been employed to realize AmI. However, not enough knowledge is available about people's perceptions of domestic AmI appliances to understand and inform the future development of AmI. Therefore, the following research questions are addressed:

RQ1: How are the benefits and disadvantages of domestic ambient intelligent appliances perceived by potential users?

RQ2: What are the attitudes and intentions of potential users regarding ambient intelligent appliances?

Another aim of this study is to explore the variables which could explain and predict the anticipated adoption of ambient intelligent appliances. Therefore, a third research question is proposed:

RQ3: Which variables explain and predict the attitudes and intentions for adopting ambient intelligent appliances in domestic settings, and what are their relationships?

Existing user acceptance theories and models of technology such as the technology acceptance model (TAM) [15, 16] or the unified model of acceptance and use of technology (UTAUT) [45] could offer insight into the adoption process of ambient intelligent appliances. Only, they are usually applied to technologies which are fully developed and already in use. Furthermore, in TAM and UTAUT, performance expectancy and effort expectancy play an important role as predictors of technology acceptance intentions. However, because these predictors are very specifically operationalized at a level of detail that is not possible for technologies that do not exist yet, these predictors are only meaningful when people have at least some experience with the technology to be able to reflect on its performance. This is not yet the case with AmI appliances; they are not widespread and used by people. Therefore, using more general statements in the form of outcome expectancies [34] that people could have towards AmI technologies was more meaningful in this case. Furthermore, applying these models to a technology which is in its development phase means that only the anticipation of adoption and use can be investigated. For this purpose a new model has to be constructed. From the existing user acceptance theories and models of technology a number of relevant constructs are selected to investigate the anticipated adoption of domestic AmI appliances by prospective users. These constructs and their hypothesized relations form the basis of a conceptual model which will be used to explore the anticipated adoption of AmI appliances. This model will be tested in the user survey. In the next section, the conceptual model will be discussed in more detail.

4 Adoption of Ambient Intelligent Appliances: A Conceptual Model

Several factors influence the adoption of new technologies. Previous research on user acceptance of technologies has shown that factors such as social influence [41], performance expectancy, effort expectancy [45], attitudes, behavioral intentions [2], and outcome expectancies [34] play an important role in the adoption process of new technologies. Fishbein and Ajzen's theory of reasoned action (TRA) postulates that behavioral intentions are the most immediate determinant of behavior. Thus, we expect a strong correlation between people's intentions and their actual behavior. Therefore, we hypothesized that the anticipated intention to adopt AmI appliances will also strongly correlate with people's actual behavior to adopt these technologies and, therefore, intention to adopt AmI appliances will be included in the conceptual model.

We hypothesized that the specific characteristics of AmI will also play an important role in the adoption process. The specific characteristics of AmI such as its unobtrusiveness, invisibility, adaptability and pro-active anticipation of user behavior, are supposed to bring ease and convenience to everyday domestic life [40]. However, next to these potential positive benefits negative outcomes are also related to AmI, such as loss of privacy, loss of control, less reliability, and a low social acceptance of these technologies [32, 33, 37, 40, 8]. Loss of privacy and loss of control are often mentioned as potential negative outcomes of AmI in daily life or, in other words, as the "dark side" of AmI [43]. If users also have these concerns, this will probably have a negative effect on the adoption process of AmI appliances. McCullough [35] argues that we should pay considerable attention to privacy aspects in the development process of AmI. The loss of privacy and control are included in the conceptual model as perceived disadvantages because they can be seen as important potential barriers to the widespread adoption of AmI appliances. The potential positive benefits of AmI such as convenience, easiness, and personalization will be included in the model as perceived advantages of AmI appliances. In this study, we focused on the advantages and disadvantages to the ones currently dominating the literature, though we recognize that there are more and other benefits and disadvantages related to AmI, for example, having too much information, providing false information and using energy.

In addition to the perceived benefits and perceived disadvantages of AmI appliances, we hypothesized that attitude towards AmI appliances will also play an important role in the adoption process. Attitude towards a behavior is defined as "the degree to which performance of the behavior is positively or negatively valued" [21]. It refers to the desirability of the behavior, which is considered to be a function of the sum of the perceived values of the expected consequences of the behavior. We hypothesized that perceived benefits and perceived disadvantages of AmI appliances can influence people's attitude and, therefore, in the conceptual model perceived benefits and disadvantages will strongly correlate with people's attitude towards AmI appliances. Furthermore, we hypothesized that attitude strongly correlates with outcome expectancies because outcome expectancies are more specifically presented to future users (specified in specific items such as "I expect this technology to make everyday life easier") than the more general attitude concept (specified in general items such as "I think that using ambient intelligent appliances is good vs. bad"). It is also hypothesized that the more specific outcome expectancies will have a direct influence on

users' intentions to adopt AmI appliances. Thus, we hypothesized that attitude towards AmI appliances will influence the outcome expectancies of people and these expectancies will probably have a direct effect on intentions to adopt AmI appliances.

The variables of the conceptual model are not independent of each other. We hypothesized that if people have a negative attitude towards AmI appliances, they will probably perceive fewer benefits of them, and vice versa. Therefore, a reciprocal relationship is expected between the perceived benefits and the perceived disadvantages concerning attitudes towards AmI appliances. Figure 1 shows the proposed conceptual model, including its proposed relationships among predictive variables.

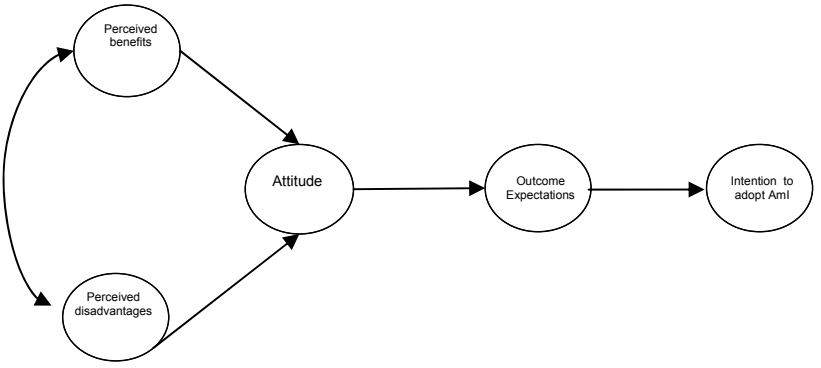

Fig. 1. Proposed path model

5 Method

5.1 Sample and Procedure

Members of a national panel ($N = 1539$) which is supposed to represent the Dutch population and is administrated by a research and consultancy company were invited via email to voluntary participate in the online survey. The survey was pretested by 25 people with ages ranging from 18 to 63 years on vocabulary, understanding of sentences, irregularities and length of time. Adjustments to the survey were made accordingly.

The 1221 panel members who responded (79.3% response rate) to the invitation were included in the sample. Pearson's chi-square test was used to test for differences in demographics between the respondents and the non-respondents. There was no significant difference between the non-respondents and the respondents concerning gender ($\chi 2$ (1, $N = 1539$) = .01, $p > .05$); age ($\chi 2$ (4, $N = 1539$) = 4.57, $p > .05$); education ($\chi 2$ (8, $N = 1522$) = 12.73, $p > .05$) and income ($\chi 2$ (6, $N = 1539$) = 4.06, $p > .05$).

In comparison with the Dutch population [11] gender was almost equally distributed (48% males compared to 49% of the adult Dutch population and 52% females compared to 51% of the adult Dutch population). Respondents younger than 25 years (7% compared to 12% of the Dutch population) and respondents of 65 years and older (5% compared to 17.4% of the Dutch population) are underrepresented in our sample. The other age groups were all slightly overrepresented, namely respondents aged 26 to 35 years (18% compared to 16.5% of the Dutch population), the group of 36 to 50

years (39% compared to 30% of the Dutch population) and the group of 51 to 65 years (31% compared to 24.1% of the Dutch population).

The higher education level of the respondents was also overrepresented in our sample. There were more respondents with a bachelor degree (32% compared to 16% of the Dutch population and a master degree (11% compared to 9% of the Dutch population) and respondents with only primary education or less were underrepresented (1.3% compared to 9% of the Dutch population). Of the respondents, 99.7% owned a computer and/or laptop and 99.2% had access to the internet in their own home. In the Netherlands, 88% of the population has access to a PC and 85% of the population has access to the Internet [12]. The sample of this study is thus not completely comparable to the Dutch population. As social demographics were no part of the hypothesized model to be tested we did not take the somewhat arbitrary step to weigh the results.

5.2 Measures

A questionnaire was designed to examine how people perceive AmI appliances in domestic settings. The questionnaire consisted of two parts. The first part of the questionnaire was dedicated to current possession of ICTs and domestic technologies in the home, past experience with computers, and attitude towards ICTs.

To assess whether respondents with a positive attitude towards current ICTs hold a more positive attitude towards AmI appliances, respondents' attitude towards current ICTs issues was measured with a scale consisting of six positive judgments (scaled 1 to 5 where 1 was totally disagree and 5 was totally agree) following Punie [39]. Punie distinguishes three different attitudes using this scale, namely: tech-phobes, the tech-nuanced and the tech-savvy. A tech-phobe attitude is characterized by a negative attitude towards technological development; a tech-nuanced attitude corresponds with a position between tech-phobe and tech-savvy and a tech-savvy attitude is a positive attitude towards technology.

Some judgments were rephrased to Netherlands-Dutch (Punie's was Belgian-Dutch) and some ICT examples were adjusted to suit current practice in the Netherlands (e.g. telephone was adjusted to internet).

Cronbach's alpha (α) was used as an indication of how well a set of items measures a latent construct. A scale is often regarded as reliable when Cronbach's α is at least .70 [38]. The internal consistency (Cronbach's α) of the ICT-attitude scale was .72.

The second part of the questionnaire started with a short description of what AmI is (i.e. *'a vision on the future which includes intelligent appliances that know what you want and automatically can do things for you. These intelligent appliances will also be available for the home'*). After the general introduction of AmI, four specific currently existing AmI appliances, were described in detail to explain their characteristics (i.e. after each description of an AmI application questions followed and then the second application was described, questions followed etc.). The AmI appliances where an intelligent fridge, an intelligent mirror, an intelligent TV and a set of intelligent appliances, labelled intelligent appliances for the home, which consisted of blinds automatically closing, lights automatically turning on and off when entering the door (and leaving the house) and the temperature automatically adjusting to a person when entering a room in the house because the temperature appliance 'knows'

what the persons likes. Each application except for the intelligent appliances was accompanied with a photo to give respondents a better idea of the specific application.

Perceived benefits. Perceived benefits of AmI appliances were measured with five items including: more or less perceived enjoyment, making usage more or less easy/complex, having more or less convenience, having more or less personalization, and perceiving more or less utility through usage of the particular AmI application (all scaled 1-5 where 1 was not at all enjoyable and 5 was very enjoyable, etc.). A Cronbach's α of respectively .88 for the intelligent fridge; α = .89 for the intelligent mirror; α = .83 for the intelligent television and α = .88 for the intelligent appliances indicated reliable scales to measure perceived benefits of the four AmI appliances.

Perceived disadvantages. Privacy and loss of control were two measures of the perceived disadvantages of AmI appliances. For each appliance two privacy items and two control items were used to assess how respondents perceive privacy and control aspects of AmI appliances. A high score (5) scale meant that the respondent regarded this aspect of the appliance as very attractive and a low score (1) meant very unattractive. We recoded the scale so that higher values reflect lower perceptions of privacy and control. The items for the intelligent fridge are given as examples (the items for the other three appliances were almost similar, they were only adapted to the specific characteristics of the appliances). The privacy items were *'this intelligent fridge can order foods and give you cooking tips if you give permission to the fridge to keep track of what you are keeping in your fridge' and 'when and how you use the intelligent fridge is being recorded by an intern system so that the intelligent fridge can better suit your wishes'*. The control items consisted of *'this intelligent fridge can automatically take over a couple of tasks from you such as keeping track of which foods are out of stock'* and *'this intelligent fridge can automatically take over a couple of decisions from you such as ordering foods at the grocery store if you have programmed the fridge to do this'*. The privacy items of the four AmI appliances were summed up to form one overall privacy construct (two items per appliances makes 8 items in total) and the control items (also in total 8 items) were also summed up to form one control construct. The internal consistency of the privacy scale was α = .88 and α = .85 for the control scale.

Attitude. As a measure of attitude towards the four AmI appliances, respondents rated the use of the four appliances on six five-point bipolar scales. The scale endpoints were defined as good/bad, wise/unwise, beneficial/harmful, pleasant/unpleasant, valuable/worthless and enjoyable/unenjoyable. The internal consistencies of the attitude scales were respectively, α = .94 for the intelligent fridge; α = .95 for the intelligent mirror; α = .94 for the intelligent TV and α = .95 for intelligent appliances.

Outcome expectations. Expected outcomes (i.e. "using the ubicomp appliances, how likely are you to _") were measured in a Likert-type scale that ranged from 1 (very unlikely) to 5 (very likely). We used monetary outcomes (α = .92), activity outcomes (α = .89), social outcomes (α = .85), self-reactive outcomes (α = .89), novelty outcomes (α = .80) and fashion/status outcomes (α = .86).

Intention. Three intention measures asked the respondents to rate their intention to use each specific ubicomp appliance if they will become available on a five-point bipolar scale ranging from 'extremely unlikely' to 'extremely likely'. The three intention measures were: 'I intend to use this intelligent fridge if it will be available'; 'I

plan to buy this intelligent fridge as soon as it will be available' and 'I will use this intelligent fridge if it will be available'. Cronbach's α was respectively, .95 for the intelligent fridge; .95 for the intelligent mirror; .95 for the intelligent TV and .93 for intelligent appliances.

The questionnaire ended with socio-economic questions (i.e. age, gender, education level, income, household situation, and amount of leisure time during a weekday).

5.3 Data analysis

SPSS v12 was used to analyze the data. Statistical comparisons between groups used Chi-tests for categorical data and Mann-Whitney tests for ordinal data.

Structural Equation Modelling using Amos 6.0 [3] with maximum likelihood estimation was used to test the hypothesized model to predict intention to adopt AmI appliances in domestic settings. As suggested by Holbert and Stephensen [26] the following model fit indices were used: the $\chi 2$ estimate with degrees of freedom given that still is the most commonly used means by which to make comparisons across models [27]. Additionally, the standardized root mean squared residual (SRMR) as a second absolute fit statistic [28] in combination with the Tucker-Lewis index (TLI) as incremental index and the root mean squared error of approximation (RMSEA) [10] are reported. Hu and Bentler [28] recommend using a cutoff value close to .95 for TLI in combination with a cutoff value close to .09 for SRMR to evaluate model fit and the RMSEA close to .06 or less. Fit indexes are relative to progress in the field [22]. Although there are rules of thumb for acceptance of model fit (e.g., that TLI should be at least .95), Bollen [9] observed that these cut-offs are arbitrary. A more salient criterion may be simply to compare the fit of one's model to the fit of other, prior models of the same phenomenon.

6 Findings

The questionnaire on AmI appliances was designed to examine the perceptions of future users regarding AmI. It was also designed to get a better understanding of how specific AmI appliances are perceived and what respondents' attitudes are towards these appliances. However, since respondents already have certain attitudes towards today's existing information and communication technologies, we wanted to compare the results of the perceptions of AmI appliances with current attitudes towards information and communication technologies and therefore we also present these findings. Finally, we test which variables are strong predictors for the anticipated adoption of AmI appliances.

6.1 Attitude towards Information and Communication Technologies

Respondents' overall attitudes towards information and communication technologies were measured with a scale consisting of six positive judgments regarding information and communication technology issues (Cronbach's $\alpha = .72$). Overall, the respondents had positive attitudes towards information and communication technologies. The item *'the disadvantages which some technical appliances can cause just belong*

to this kind of appliance' scored the lowest (M = 3.42, SD = .96) and the item '*I find it good that when I want to know something, I can also get that information via technical appliances'* was the highest (M = 4.50, SD = .70).

There was no significant difference for gender and education regarding ICT attitudes. Respondents aged 26 to 35 years (mean rank = 664.64) and people older than 65 years (mean rank = 700.16) had a significantly more positive ICT attitude (χ^2 (4, n = 1221) = 11.72, $p < .05$) than other age groups. The group of respondents who did not provide answers about their incomes (mean rank = 557.18) and people who have an income of 1.5 times the average (mean rank = 584.65) had a significantly less positive attitude (χ^2 (6, n = 1221) = 21.13, $p < .01$) towards information and communication technologies than the other income groups. People who earned three times the average income or more had the most positive ICT attitude (mean rank = 753.79). There was a significant correlation between age and income level (r = .70, n = 1221, $p < .05$), which indicates that people who are older have a higher income.

Generally, the respondents had a positive attitude towards information and communication technologies. The overall score of the ICT-attitude scale ranging from 6 to 30 is the sum of the six items on a five point scale ranging from 1 = totally disagree to 5 = totally agree. Thus, although the overall attitude towards information and communication technologies was high, based on the mean score of the ICT-attitude scale (M = 23.88, SD = 3.48), three ICT groups were formed to assess differences in their attitudes towards AmI appliances. The first group (range 6 to 23) had the most negative attitude towards information and communication technologies (labeled the tech-phobic) and consisted of 42.8% of the sample. The second group (range 24 to 25) was labeled the tech-nuanced group and consisted of 24.2%. The last group, the tech-savvy (range 26 to 30) consisted of 33% of the respondents.

6.2 Perceived Benefits and Disadvantages of Domestic AmI Appliances

To answer the first research question concerning the perceived benefits and disadvantages of AmI appliances, the perceived benefits were measured separately for all four AmI appliances. The perceived benefits of the intelligent fridge and intelligent mirror were regarded as low by the respondents. The mean value *(SD)* for the intelligent fridge ranged from 2.20 *(1.14)* to 3.23 (*.99*) and the mean for the intelligent mirror ranged from 2.35 (*1.18*) to 2.97 (*.90*). Respondents perceived the intelligent TV, with a mean ranging from 2.34 (*1.04*) to 3.61 (*.98*), and intelligent appliances, with a mean ranging from 3.00 (*1.16*) to 3.62 (*.89*), as having slightly greater benefits. See Table 1 for the exact means and standard deviations of the perceived benefits of the four AmI appliances.

Among the three groups with different attitudes towards information and communication technologies, significant differences were found in how they perceive the benefits of AmI appliances. The tech-savvy group perceived all four AmI appliances as having more benefits, followed by the tech-nuanced and the tech-phobes. Consider intelligent appliances as an example. The tech-savvy group (mean rank = 717.45) perceived intelligent appliances as having significantly greater benefits (χ^2 (2, n = 1221) = 92.31, $p < .001$) than the tech-nuanced (mean rank = 658.26) and the tech-phobic groups (502.32).

Table 1. Descriptive statistics and Cronbach's α of perceived benefits and perceived disadvantages of AmI appliances

	M	SD
Perceived benefits intelligent fridge (α = .88)		
Enjoyment	3.03	1.28
Ease	2.20	1.14
Convenience	3.23	.99
Personalization	2.92	1.13
Usefulness	2.40	1.17
Perceived benefits intelligent mirror (α = .89)		
Enjoyment	2.83	1.22
Ease	2.69	1.03
Convenience	2.97	.90
Personalization	2.76	1.10
Usefulness	2.35	1.18
Perceived benefits intelligent TV (α = .83)		
Enjoyment	3.61	.98
Ease	2.82	1.12
Convenience	3.57	.92
Personalization	3.37	1.06
Usefulness	2.34	1.04
Perceived benefits intelligent appliances (α = .88)		
Enjoyment	3.45	.97
Ease	3.00	1.16
Convenience	3.62	.89
Personalization	3.46	.98
Usefulness	3.34	1.16
Perceived disadvantages: Loss of privacy (α = .88)		
P1 intelligent fridge	2.96	1.20
P2 intelligent fridge	3.19	1.16
P1 intelligent mirror	3.23	1.11
P2 intelligent mirror	3.60	1.19
P1 intelligent TV	2.48	1.08
P2 intelligent TV	2.94	1.08
P1 automatic appliances	2.80	1.08
P2 automatic appliances	2.53	1.05
Perceived disadvantages: Loss of control (α = .85)		
C1 intelligent fridge	2.85	1.14
C2 intelligent fridge	3.63	1.19
C1 intelligent mirror	2.90	1.09
C2 intelligent mirror	2.83	1.20
C1 intelligent TV	2.32	.99
C2 intelligent TV	3.63	1.07
C1 automatic appliances	2.74	1.07
C2 automatic appliances	2.63	1.07

The disadvantages of the AmI appliances were in general perceived as varying from not very attractive to neutral to the respondents (see Table 1). With regard to privacy aspects of AmI appliances, the intelligent mirror's sending private information (such as weight and blood pressure) to the doctor was least appealing to the respondents (M = 3.60, SD = 1.19). Respondents seemed to have fewer privacy concerns with the intelligent TV's keeping a record of programs the user watches and, based on this recorded list, suggesting a list of interesting programs for the user (M = 2.48, SD = 1.08). A similar response was seen when intelligent appliances keep track of temperatures in the home and adjust the temperature based on the recorded list of previous temperatures (M = 2.53, SD = 1.05). Respondents did not find it very attractive that AmI appliances could do things for them when this caused a loss of control over tasks typically done by the user. The intelligent fridge ordering food (M = 3.63, SD = 1.19) and the intelligent TV ordering products (M = 3.63, SD = 1.07) were found to be the least attractive. The intelligent TV taking over the selection and recording of movies seemed to be a little bit more attractive to the respondents (M = 2.32, SD = .99).

How privacy and control aspects of AmI appliances were perceived differed significantly among the three ICT groups. The tech-savvy group (mean rank = 506.30) significantly had the fewest problems (χ^2 (2, n = 1221) = 77.92, p < .001) with the privacy aspects, followed by the tech-nuanced (mean rank = 581.03) and the tech-phobic groups (mean rank = 708.58). The tech-savvy people (mean rank = 502.87) were also significantly more positive χ^2 (2, n = 1221) = 76.70, p <.001) towards the

idea that AmI appliances could take over some control tasks, as compared to the tech-nuanced (mean rank = 591.03) and the tech-phobic (mean rank = 705.59).

6.3 Attitude, Outcome Expectations and Intention to Adopt AmI Appliances

The results for research question two concerning the attitudes and intentions to adopt AmI showed that respondents did not have a pronounced attitude towards AmI appliances. The attitude towards all four AmI appliances varied from a neutral to a slightly positive attitude. People seemed to have a more positive attitude towards the intelligent TV and towards the intelligent appliances than towards the intelligent fridge and intelligent mirror (see Table 2).

Table 2. Descriptive statistics and Cronbach's α of attitudes towards AmI appliances

	M	SD
Attitude intelligent fridge (α = .94)		
Good/bad	3.00	1.09
Wise/unwise	2.89	1.07
Beneficial/harmful	2.88	1.04
Pleasant/unpleasant	2.91	1.22
Valuable/worthless	2.71	1.09
Enjoyable/unenjoyable	3.07	1.36
Attitude intelligent mirror (α = .95)		
Good/bad	2.89	1.10
Wise/unwise	2.91	1.13
Beneficial/harmful	2.74	1.00
Pleasant/unpleasant	2.68	1.19
Valuable/worthless	2.75	1.15
Enjoyable/unenjoyable	2.86	1.32
Attitude intelligent TV (α = .94)		
Good/bad	3.35	.98
Wise/unwise	3.08	.92
Beneficial/harmful	3.06	.96
Pleasant/unpleasant	3.48	1.09
Valuable/worthless	3.15	.94
Enjoyable/unenjoyable	3.58	1.15
Attitude intelligent appliances (α = .95)		
Good/bad	3.45	1.02
Wise/unwise	3.38	1.02
Beneficial/harmful	3.37	1.01
Pleasant/unpleasant	3.60	1.08
Valuable/worthless	3.28	1.02
Enjoyable/unenjoyable	3.51	1.14

The attitude towards AmI appliances differed significantly among the three ICT groups. The tech-savvy group had the most positive attitude towards all four AmI appliances. The intelligent TV is taken as an example. The tech-savvy group (mean rank = 692.17) had a significantly more positive attitude (χ^2 (2, n = 1221) = 49.15, p <.001) towards the intelligent TV than the tech-nuanced (mean rank = 638.48) and the tech-phobic (mean rank = 532.96).

Respondents seemed to expect the most from AmI appliances in terms of activity and monetary outcome. These outcome expectancies are more focused on making daily life easier (e.g., "to make your everyday life easier", M = 3.19, SD = 1.11) and bringing more enjoyment (e.g. "to make daily domestic activities more pleasant" M = 3.22 SD = 1.13). Social outcomes which focus on the enhancement of social relations or the building of social relations through AmI appliances scored the lowest of all outcome expectations (see Table 3).

For all four AmI appliances (intelligent fridge, intelligent mirror, intelligent TV, and intelligent home appliances), the behavioral intention to adopt the appliances was measured in order to answer research question two. Respondents' intentions to adopt the four appliances were generally low (see Table 4). The intention to adopt the

intelligent mirror was the lowest and the intention to adopt the intelligent home appliances (e.g., blinds automatically closing) was the highest.

The intention to adopt AmI appliances differed significantly among the three ICT groups. The tech-savvy group had a higher intention to adopt all four AmI appliances than the tech-nuanced and the tech-phobes. For example, the tech-savvy (mean rank = 685.09) had the highest intention (χ^2 (2, n = 1221) = 45.62, p <.001) to adopt the intelligent mirror compared to the tech-nuanced (mean rank = 637.63) and the tech-phobic (mean rank = 538.89).

6.4 Explaining and Predicting Adoption of AmI Appliances

Prior to the analyses, data were checked for normality; no significant deviation from normality was found (skewness and curtosis Z < 1.96). The variables (e.g., intention,

Table 3. Descriptive statistics and Cronbach's α of outcome expectations of AmI appliances

	M	SD
Activity outcomes (α = .89)		
To make it easier for you	3.38	1.07
Because it offers you more freedom	3.07	1.07
Because it makes the tasks in the home more pleasant	3.25	1.07
To make daily domestic activities more pleasant	3.22	1.13
Because you like to use such appliances	2.85	1.25
To be entertained	2.46	1.20
Monetary outcomes (α = .92)		
To be able to do different things at once	3.07	1.09
To have more control over your daily life	2.88	1.08
Not to have to do everything yourself	2.94	1.12
To make your everyday life easier	3.19	1.11
Because it is convenient that you do not have to carry out certain tasks yourself	3.03	1.14
To save time	3.06	1.21
Social outcomes (α = .85)		
To strengthen my relationship with family and friends	1.98	1.07
To be able to communicate with family and friends	1.95	1.08
To maintain valuable contact with others	2.33	1.17
To belong to a particular group	1.61	.85
To have something to talk about with others	1.74	.95
Self-reactive outcomes (α = .89)		
To have something to do	1.97	1.07
When you are bored	2.02	1.16
To relax	2.66	1.23
When you do not have anything to do	2.10	1.10
To feel less lonely	1.79	.96
As a way to pass time	1.68	.94
Novelty (α = .80)		
Because it is something new	2.28	1.11
To be able to use the internet via the intelligent fridge	1.68	.96
To be able to order products via the intelligent TV	1.86	1.01
To actively monitor your health through the intelligent mirror	2.55	1.29
To discover new possibilities	2.97	1.17
Fashion/Status (α = .86)		
Because these appliances are modern appliances	2.21	1.16
To keep up with the newest technology	2.54	1.19
Because it belongs to your lifestyle	2.10	1.12
Because it increases your status	1.60	.86

Table 4. Descriptive statistics and Cronbach's α of intention to adopt AmI appliances

	M	SD
Intention to adopt intelligent fridge (α = .95)		
I intend to use this intelligent fridge if it is available	2.14	1.25
I plan to buy this intelligent fridge as soon as it is available	1.93	1.08
I will use this intelligent fridge if it is available	1.98	1.14
Intention to adopt intelligent mirror (α = .95)		
I intend to use this intelligent mirror if it is available	1.93	1.08
I plan to buy this intelligent mirror as soon as it is available	1.79	1.01
I will use this intelligent mirror if it is available	1.83	1.06
Intention to adopt intelligent TV (α = .95)		
I intend to use this intelligent TV if it is available	2.76	1.18
I plan to buy this intelligent TV as soon as it is available	2.50	1.13
I will use this intelligent TV if it is available	2.56	1.20
Intention to adopt intelligent appliances (α = .93)		
I intend to use these intelligent appliances if they are available	2.78	1.13
I plan to buy these intelligent appliances as soon as they are available	2.67	1.14
I will use these intelligent appliances if they are available	2.72	1.21

attitude, perceived benefits, and privacy) used for each of the four AmI appliances were summarized to construct 'overall' variables regarding adoption of AmI appliances. In other words, the intention scales of the four AmI appliances were summed up in one overall scale to measure intentions to adopt AmI appliances, the four attitude scales were summed up to measure overall attitudes towards AmI appliances, et cetera.

Measurement model. The initial measurement model generated a poor fit, $\chi^2(1035) = 8472.06$, $\chi^2/df = 8.19$, SRMR = .0649, TLI = .864 , RMSEA = .077 (CI: .075, .078). Items with highly correlated error variances identified by post-hoc modification indices were removed. Although the Cronbach's alpha of the indicators of novelty was above the aspiration level ($\alpha > .70$), the error variances co-varied with various indicators of other constructs and were, therefore, excluded from further analysis. The observed items of monetary outcomes and activity outcomes were loaded on both latent variables. This was also the case for the observed items of social outcomes and self-reactive outcomes. With regard to the content of their items, the four constructs were indeed closely related and were, therefore, reconstructed into two new constructs. The new construct of monetary outcomes and activity outcomes was labeled instrumental outcomes; the combination of the constructs social outcomes and self-reactive outcomes was labeled personal outcomes. This procedure resulted in a reduced number of observed indicators of the latent constructs. The internal consistency of the measures to predict adoption of AmI appliances was above the aspiration level ($\alpha > .70$). The modified measurement model generated a good fit, $\chi^2(209) = 779.32$, $\chi^2/df = 3.73$, SRMR = .026, TLI = .976, RMSEA = .047 (CI: .044, .051).

Structural model. The results obtained from testing the validity of a causal structure of the hypothesized model showed a reasonable fit $\chi^2(222) = 1271.44$, $\chi^2/df = 5.73$, SRMR = .0597, TLI = .959, RMSEA = .062 (CI: .059, .066). Post-hoc modification indices suggested an improved fit by correlating the error terms of personal outcomes and fashion outcomes ($r = .67$, $p < .001$). The respecified model generated a good fit $\chi^2(221) = 930.31$, $\chi^2/df = 4.21$, SRMR = .0355, TLI = .972, RMSEA = .051 (CI: .048, .055). Table 5 summarizes the mean and standard deviation, Cronbach's α, the factor loading (β), and the squared multiple correlation (R^2) of the observed indicators to predict adoption of AmI appliances. The path model with standardized path coefficients is featured in Figure 2.

As shown in Figure 2, there was a significant direct effect of outcome expectations on the intention to adopt AmI appliances. Perceived benefits and perceived disadvantages had a significant direct effect on attitude. The attitude-outcome expectancies path, as well as the outcome expectancies-intention path, appeared to be significant. A correlation was found between perceived benefits and perceived disadvantages of AmI appliances, $r = -.93$, $p < .001$. This indicates that the error terms of the two constructs are very closely related.

Squared multiple correlations (Table 5) showed that the intention to adopt AmI appliances was accounted for 75%, the attitude towards AmI appliances was accounted for 89%, and the outcome expectancies of AmI appliances were accounted for 76%.

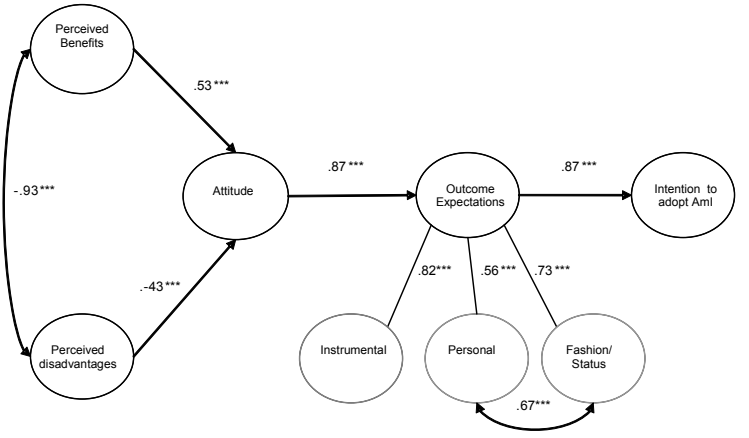

Fig. 2. Standardized path coefficients for the model to predict intentions to adopt AmI appliances

Note .The observed indicators of the latent constructs are not shown (see Table 5).
***$p < .001$. The error terms of the double-headed arrows are correlated.

Table 5. Descriptive statistics, factor loadings, squared multiple correlations and Cronbach's α of the observed indicators to predict intention to adopt AmI appliances

	M	SD	B	R^2
Intention (α = .97)				.75
I intend to use this AmI appliance if it is available	2.40	.90	.92	.85
I plan to buy this AmI appliance as soon as it is available	2.22	.85	.98	.95
I will use this AmI appliance if it is available	2.27	.89	.98	.96
Attitude (α = .95)				.89
ATT 1 (good/bad)	3.17	.81	.93	.86
ATT2 (beneficial/harmful)	3.01	.76	.85	.73
ATT3 (pleasant/unpleasant)	3.17	.88	.95	.90
ATT4 (valuable/worthless)	2.97	.81	.92	.85
Perceived benefits (α = .85)				
Enjoyment	3.23	.84	.89	.79
Easy	2.68	.82	.62	.38
Personalization	3.13	.83	.91	.83
Perceived disadvantage (α = .95)				
Privacy	2.97	.83	.94	.88
Control	2.94	.77	.96	.92
Personal outcomes (α = .86)				.32
To have something to talk about with others	1.74	.95	.78	.60
When you do not have anything to do	2.10	1.10	.78	.61
As a way to pass time	1.68	.94	.82	.67
To feel less lonely	1.79	. 96	.74	.54
Instrumental outcomes (α = .90)				.68
Because it makes the tasks that you perform in the home more pleasant	3.25	1.07	.87	.76
To make your everyday life easier	3.19	1.11	.84	.71
To make daily domestic activities in the home more pleasant	3.22	1.13	.84	.70
To not have to do everything yourself	2.94	1.12	.80	.65
Fashion/status outcomes (α = .87)				.53
To keep up with the newest technology	2.54	1.19	.83	.70
Because it belongs to your lifestyle	2.10	1.12	.80	.64
Because they are modern appliances	2.31	1.16	.85	.73

7 Discussion

In this study, people's perceptions of AmI appliances in domestic settings and the variables that explain and predict future adoption of these technologies were explored.

The results show that increasing the diversity of formative evaluation methods for AmI contributes to a wider understanding of the acceptance process of AmI technologies. The results of this large-scale, survey-based study indicate that respondents perceived the benefits of the four AmI appliances as varying from low to neutral. Enjoyment and convenience often scored the highest of all the measured perceived benefits for all four AmI appliances (other perceived benefits were ease of use, personalization, and usefulness). Attitudes towards AmI varied from negative to neutral and the intention of prospective users to adopt AmI appliances was low.

The structural equation analysis showed that outcome expectancies of domestic AmI appliances could largely predict the intention to adopt these appliances. This finding indicates that people's expectations about a new technology play a very important role in anticipating the adoption of a new technology. More specifically, instrumental, personal, and fashion outcomes have a large influence on the intention of prospective users to adopt AmI. This finding is interesting from both a theoretical and practical standpoint. For theory development, using outcome expectancies as a predictor for technology acceptance appears to explain people's intention to adopt a new technology to a large extent. From a practical point of view, designers and producers of AmI technologies could focus on these outcomes expectancies, namely instrumental, personal, and fashion outcomes, to better obtain the attention of prospective users.

In this study, the perceived disadvantages of AmI appliances appeared to be the loss of privacy and the loss of control. The findings show that there is statistical evidence for a relationship between perceived benefits and perceived disadvantages of domestic AmI appliances. However, on the basis of the results of this study, the exact nature of this relationship is unclear. It could be that benefits and disadvantages of these appliances act simultaneously, or that one of the constructs has a stronger influence on the other. If the nature of this relationship is known, designers of AmI could keep this in mind when developing these technologies. For example, when it appears that people are willing to accept and use AmI appliances in domestic settings because they derive enough personal benefits from them, then some of the disadvantages of these appliances could be accepted by the majority. Or, if people are not willing to lose their privacy and control and thus perceive the disadvantages of these appliances as being stronger than the benefits, the intention to adopt AmI appliances will probably be lower. Further research could bring more insight into this reciprocal relationship.

Furthermore, the findings suggest that perceived disadvantages, in this case the loss of privacy and loss of control, did have a direct effect on attitudes towards AmI. When the disadvantages with regard to AmI were perceived to be high, the attitude towards these appliances was low and thus more negative. From the start of the development of AmI, loss of privacy and loss of control has been recognized as important concerns for the future success of the adoption of AmI technologies. Even though the specific features of AmI, such as being able to anticipate owner behavior by constantly using data about user behavior and personal routines, make it difficult to exclude all potential privacy and control disadvantages, designers should make the effort to minimize the loss of privacy and control for users from the start of the design process.

The AmI research field is a young domain and there is no common perception among ordinary people about its content and possibilities. The appliances in this study were specifically chosen to include a broad spectrum of domestic AmI appliances and to summarize key technology aspects of AmI. Appliances from other key areas such as health and energy saving might deliver different outcomes in terms of acceptance. However, since these AmI appliances are used more often in previous studies [e.g., 41] we wanted to maintain the continuity of the research field.

In future research, we hope to investigate some of the questions raised by this research study. First, the influence of one's social network is known to be an important factor in technology acceptance. Rogers postulates that diffusion of an innovation happens when this innovation is communicated through certain channels over time in a social system [41]. AmI is still in a research and development phase and not widely available on the market, so our focus was not on social influence. Yet, we do believe that one's social network plays an important role in the acceptance of new technologies, especially, for those technologies meant for private settings such as the home and not for an organizational context where it can obligatory to accept and use new technologies. We are currently expanding the model by including social influence as a variable to investigate the role of social influence in the acceptance process of these technologies.

Second, this study was done in a Western-European country with a high penetration and use of both the mobile phone and the internet [20]. Bell et al. [5] argue that there are cultural differences in technology behavior and that we have to take these into consideration when designing technologies for domestic settings. Even among European countries, differences were found in the use of mobile ambient intelligent services [22]. Therefore, the results cannot automatically be translated to other countries and cultures. Furthermore, the sample was relatively ICT-minded, which could lead to two different conclusions. First, if ICT-minded people are not very positive about ambient intelligent appliances, the population at large would be even less positive. Second, and opposite, less-ICT-minded people would embrace ambient intelligent appliances because they are supposed to be relatively easy to use and can be smoothly integrated into everyday environments. More research is needed to determine how this acceptance process precisely works in these groups. However, it is important to pay attention to this finding to ensure that ambient intelligent appliances will be adopted by everybody and not just by a certain group of people.

Ambient intelligence is cheered and criticized for its possible influential role in people's everyday lives. Obviously, more research is needed to assess the variables and their interrelationships as ambient intelligent appliances become more widespread in societies. Most importantly, variables such as real user experience of AmI should be incorporated into future studies. Overall, this study presents evidence that people's current attitudes and outcome expectations of ambient intelligent appliances are important factors to consider when anticipating the future adoption of ambient intelligent appliances in domestic settings.

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