Effective Use of Smart Home Technology to Increase Well-being

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***Abstract*—The effectiveness of smart home technology in home care situations depends on the acceptance and use of the technology by both users and end-users. In the Netherlands many projects have started to introduce smart home technology and telecare in the homes of elderly people, but only some have been successful. In this paper, features for success and failure in the deployment of new (ICT) technology in home care are used to revise the technology acceptance model (TAM) into a model that explains the use of smart home and telecare technology by older adults.**

In the revised model we make the variable 'usefulness' more specific, by describing the benefits of the technology that are expected to positively affect technology usage. Additionally, we state that several moderator variables – that are expected to influence this effect – should be added to the model in order to explain why people eventually do (not) use smart home technology, despite the benefits and the intention to use. We categorize these variables, that represent the problems found in previous studies, in 'accessibility', 'facilitating conditions' and 'personal variables'.

I. Introduction

THE Technology Acceptance Model (TAM, Fig. 1) introduced by Davis [1], [2], is an adaptation of the Theory of Reasoned Action (TRA [3, [4]]) to the field of Information Systems. According to TRA, a person's performance of a specified behavior (e.g. system usage) is determined by his or her behavioral intention (BI) to perform the behavior, and BI is jointly determined by the person's attitude (A) and subjective norm concerning the behavior in question [1]. TAM posits that perceived usefulness (U) and perceived ease of use (E) determine an individual's intention to use a system, with 'intention to use' serving as a mediator of 'actual system use'. U is also seen as being directly impacted by E. Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance", i.e. "capable of being advantageously", while perceived ease of use can be described as "the degree to which a person believes that using a particular system would be free of effort" [5]. Researchers have simplified the original TAM by removing the attitude construct found in TRA from the current specification [1], [6]. The removal of this legacy of TRA resulted in a direct relationship between beliefs (such as usefulness and ease of use) on behavioral intention. Research [6] has indeed confirmed that the relation between attitude and behavior is doubtful, as attitudinal constructs are non-significant when other key predictors like usefulness and ease of use are part of the model (e.g. [7], [8]).

Reference [2] developed a questionnaire to measure the variables perceived usefulness (U) and perceived ease of use (E) of the Technology Acceptance Model. The items of TAM's U and E are selected under the assumption that these items correspond to the evaluation and validation that people make unconsciously, resulting in the intention to perform a certain behavior. The items were chosen by reviewing 37 research papers on user reactions to interactive systems and were additionally pre-tested in interviews. Perceived usefulness and perceived ease of use are both measured by means of a six-item scale, with 7-point scales having likely-unlikely endpoints, ranging from extremely, quite, slightly, to neither. The U items involve statements on the improvement of a person's performance, the increase of a person's productivity, enhancement of effectiveness, and usefulness. The E items involve statements on ease of learning to operate the system, ease to get the system do what the person wants it to do, ease of becoming skilful, and ease of use. BI is measured by self-prediction of future use, by means of behavioral expectation statements and 7-point scales. System usage is measured using a 7-point frequency scale and a descriptive checkbox format.

TRA and TAM assume that when someone forms an intention to act, that they will be free to act without limitation. In practice constraints such as limited ability, time, environmental or organizational limits, and unconscious habits will limit the freedom to act. Attempts to extend TAM have generally taken one of three approaches: by introducing factors from related models, by introducing additional or alternative belief factors, and by examining antecedents and moderators of perceived usefulness and perceived ease of use [6], [9]. Our aim is to introduce a model that explains why a smart home or telecare system is accepted or not by its (end)users, in order to advise corrective steps.

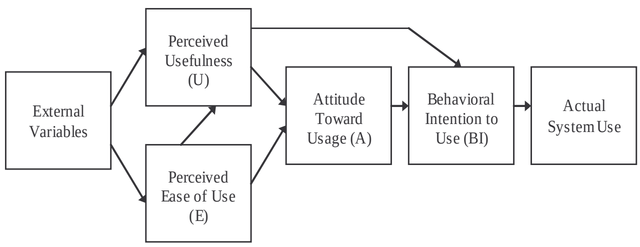

Fig. 1. Technology Acceptance Model (TAM) [1].

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II. COMMENTS ON TAM

A. Involving the End-Users

The original Technology Acceptance Model was developed for management purposes, for predicting computer acceptance in workplace settings. The research population of deskworkers, as well as students often used as research subjects in TAM-research, are a rather undefined group of users. The model thus has been generalized in such a way that it should also be applicable to specific technology acceptance situations, like smart home technology in home care. However, we believe that the model is less accurate by leaving out the end-user and the specific user-characteristics. In our case of an older population, we expect the users to be less computer literate than the average computer user [10], for example. When the TAM was tested in computer laboratories [1] and in workplace settings [6], the ease of use became nonsignificant in explaining intentional use over periods of extended and sustained usage. However, for older users it is relevant to know how to handle the system after some period of non-use [11]. When implementing smart home technology in home care situations it seems necessary to revise the model, not only because older adults may have a different view on technology usage, but also because the context of information technology in a home (care) situation differs considerably from a work environment. The 12 items for perceived usefulness and perceived ease of use of the TAM questionnaire [2], for example, were said to correspond to people's unconscious evaluation and validation, resulting in the intention to use a system. But we doubt whether they are general enough to represents the line of thought of older adults who will use the technology at home.

B. Usefulness Defined as Effectiveness

The TAM is helpful in predicting people's computer acceptance in organizational settings and has been developed with the underlying idea that through computer acceptance the performance of people will increase. The intention to use a system is therefore based on the extent to which people believe that the system will help them perform their job better (U), which can be outweighed by the effort of using the application, i.e. the believe that the system is too hard to use (E) [2]. When using the model in a home care setting, usefulness must be translated into a less job related measure. The goal of technology implementation in home care situations is to increase the well-being of elderly people, to increase their autonomy and independence, increase their sense of security, and to relieve the (informal) care. If the technology supports these goals, then people perceive the technology as useful [12]. Especially for older adults, it is important that they experience the effectiveness of a technology interaction quite early in the learning process [13]. Researchers in the area of ambient intelligence believe that the best way to increase usefulness, is by making the technology in an intelligent home environment sensitive, personalized, adaptive, anticipatory and responsive to people (e.g. [14]). Usefulness in this study relates to "effectiveness": supporting independent living of older adults, including the subjective appreciation of the technology by the end-users.

C. Intention to Use not as Valuable as Actual Usage

The TAM, as well as other models based on the theory of reasoned action (see for example [6]), states that technology usage is determined by the intention to use the technology. Although intention is often used as the key predictor for actual use, in practice the actual use can be obstructed by various constraints (like time or money [15]) and positively influenced by other variables (like facilitating conditions [6]). Research should therefore go beyond intentional behavior. However, only few models on technology acceptance have sought to predict usage behavior rather than intention (e.g. the Social Cognitive Theory [16], and the Model of PC Utilization [8]). The relevance of actual usage can be illustrated by an example from our study, where 69 elderly users had the intention to use new telecare technology that was installed in their homes. But after a few months, 17% of the users asked the care organization to disconnect them and to remove the technology. Apparently there were (not yet verified) variables that hindered the performance of their intentional behavior. These context variables, however, are not fully taken into consideration by the subjects when asked to self-predict their future behavior. To be able to pronounce upon actual system usage, we advise against using statements like "…I predict that I will use it on a regular basis in the future" [2] as indicators for actual use.

The difference between intentional use and actual use can be explained by the distinction between "attitude-acceptance" and "behavioral-acceptance" [13]. Attitude-acceptance includes an affective as well as cognitive component, which converge into a cost-benefits analysis of system usage. Behavioral-acceptance, on the other hand, refers to the observable part of technology acceptance: the actual usage. According to this concept, intentional use only partly describes technology acceptance, as acceptance contains an attitude towards technology usage, as well as the behavior itself.

The goal of our research is to increase technology acceptance by elderly users. The optimum acceptance is actual usage, and not intentional use. Although intention to use a technology is considered as the main determinant for actual usage (according to TAM and TRA), we are interested in the "behavioral-acceptance" and the elements that determine this actual usage. In other words, as TAM is a predictor for usage intentions and for decision-making between multiple systems to introduce, the model that measures "just after a brief period of interaction" must be revised into a model on "long-term interaction" and actual acceptance.

III. REVISING THE TAM

Based on the comments described above, TAM is expected not to cover all relevant aspects necessary to predict actual smart home technology acceptance and use. Actually, user reactions in other studies on smart home

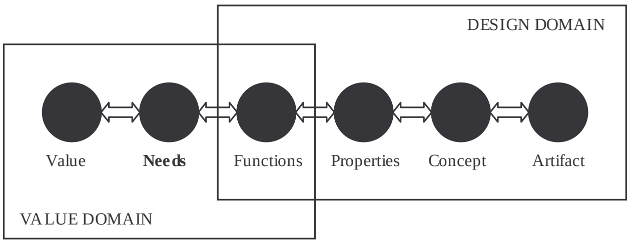

Fig. 2. The generic design structure [21].

technology in home care situations show that elements like costs, information supply, and experience influence the acceptance or rejection of the new technology (see for example [12], [17], [18]). Such elements, however, are not covered by the 12 items of the TAM [2]. Apparently, the TAM does not seem to take into account the context in which the technology is or will be used, while we hypothesize that context variables may determine (successful) usage, especially in case of smart home and telecare technology in home care situations. In the next section, we therefore describe a model, based on the concept of TAM, that better explains why smart home or telecare technology is accepted or not in home care situations.

A. *Needs and Dependence*

First of all, we believe that *personal needs* determine the added value of the technology, its usefulness or, as defined above, its effectiveness. People who need support in independent living, for example increased sense of safety and security by means of a personal alarm, are more inclined to use the new technology, than those who are not yet in need for support. As for any design, the initial consideration for smart home technology design should involve the needs of end-users, caregivers and other stakeholders [19], [20]. Reference [21] describes it as designing from a 'value domain' base, in order to get to a useful artifact (Fig. 2). For long, smart home and telecare technology was developed from a 'design domain' base; artifacts with certain properties being developed, or functions being translated into artifacts. By designing the technology based on the values of people who want to stay in their homes independently as long as possible, and the needs to satisfy these values [19], the usefulness of the technology is expected to increase, with increased technology usage as a result.

The 'need' is expected to be the driver for technology acceptance, i.e. if there is no need to be met, than the technology will not be used. In a study by [12] 90% of a group of 40 older subjects did not wear the panic button of the personal alarm. The reason not to wear this button was in 31 cases because they felt it was not necessary for them. The personal need clearly determines the technology usage is this example.

The personal needs can be described as the 'dependence' of the end-user, the care receiver. The level of dependence, within the scope of people's need for care, may vary from non-essentially (comfort) to vitally important (necessary for survival). At the same time, the personal needs and dependence may change over time, instantaneously or gradually [22]. When looking at the needs of people, it is important to take into account the level of dependency and whether it is a matter of acute or chronic dependency. The 'personal needs' therefore involve a description of people's situation. A challenge for the future is the translation or relationship between the needs and the technology (usefulness) [22]: what technological functionalities support certain needs?

B. *Benefits*

As discussed above, perceived usefulness is defined as 'effectiveness' and is dependent on the personal needs. Whereas the 'needs and dependence' are regarded as the driver for technology usage, the 'effectiveness' of the usage is considered as the pull factor. Not only TAM states 'the effects resulting from technology usage' (i.e. perceived usefulness) as the strongest predictor for behavioral intention to use [1], [2], but also many other acceptance models found 'usefulness' [23], 'job-fit' [8], 'relative advantage' [24], 'outcome expectations' [16], 'extrinsic motivation' [25], and 'performance expectancy' [6] respectively as the key predictor for (intentional) use. The variables mentioned here are concerned with effectiveness as a consequence of use. However, the intrinsic motivation, i.e. enjoyment related to the process of performing the behavior, may also be important in understanding technology acceptance and use [25], [26]. We therefore prefer to use the term '*benefits*' to define the beneficial outcome effects of technology usage, as well as subjectively perceived benefits of the behavior per se.

While perceived usefulness is measured by means of a questionnaire [1], [2], benefits can be measured more specifically. The beneficial outcome effects of smart home technology we expect to influence technology usage are, for instance: living independently for a longer period of time; sense of safety; and unburden informal care [12], [17], [22], [27]. These effects can be studied by means of more objective measurements than 'perceived usefulness'. As every benefit comes with downsides, the variable 'benefits', however, not only consists of objectively measurable effects, but also of the subjective appreciation and evaluation of the technology and its usage. This is comparable with the cost-benefit-analysis, described by [28] in the adoption process of new communication technologies. It seems important to includes these in the model of technology acceptance, as the subjectively perceived benefits may be different from or additionally to the originally assigned or expected benefits [20].

A relevant aspect of the 'benefits' of technology, it that they are subjective to change. Over time – especially after usage – the perceived benefits may change, and thus may result in an other outcome: i.e. non-use. This implies an iterative process instead of a static model (Fig. 3). The cycle corresponds with the stages of action as mention by [29]. The influence of benefits on use complies with the "gulf of execution" (A): bridging the gap between a person's goal and his intention ('Benefits') and the execution of the action ('Use') by specifying the action sequence. The effect of use on benefits, on the other hand, corresponds with the "gulf of evaluation" (B): evaluating

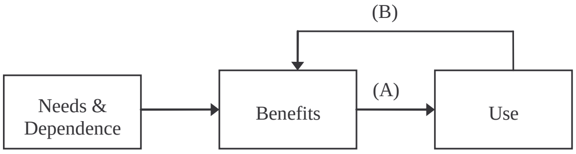

Fig. 3. The iterative process of ‘Benefits’ and ‘Use’ evaluation.

the outcome of the action and its effect on the environment.

The determinants of benefits are thus related to the increased effectiveness of the technology: increased sense of safety, increased autonomy and independence, increased well-being, and unburden of (informal) care. The subjective part of the benefits includes the subjective appreciation of the technology and its usage by the end-users after usage. As it involves an iterative process, the benefits and actual technology usage are subject to change.

C. Moderator Variables Influencing Actual Usage

The basic process through which technology usage develops – as proposed – is given in Fig. 3. However, this process is expected to be influenced by multiple moderator variables. The most significant variables in the situation of smart home or telecare technology in home care, are related to the main stakeholders involved in the implementation process of technology in home care: the designer, the care receiver, and the caregiver [20]. Designers of technology for elderly users are responsible for the ‘accessibility’ of the technology, while the caregiver, or care organization, is responsible for the ‘facilitating conditions’ concerning the implementation of telecare technology. The third moderator variable involves personal elements of the care-dependent end-user. These variables are described in more detail below.

1) Accessibility

According to TAM, perceived ease of use is the second predictor for intentional use. However, many researches have shown that ‘ease of use’ [1], [2], [24], [30], ‘complexity’ [8], and ‘effort expectancy’ [6] respectively only influences (intentional) use during the first time period of use, or only through the key predictor ‘usefulness’. As no direct effect of ease of use is found on (long term) technology acceptance, the variable is left out the iterative acceptance process (Fig. 3). Despite the omission of E, ease of use is expected to indirectly influence smart home technology acceptance through ‘benefits’ (in correspondence with [1], [2], [24], [30]). This rather ‘technology related’ variable is called ‘*accessibility’*, but should not be confused with the term used by [2], more comparable with ‘facilitating conditions’ (a variable that we will describe later). The ‘accessibility’ variable in our model is based on the idea that people can be excluded from accessing new technology due to physical, conceptual, economical, cultural, or social barriers [31]. The most important accessibility items here, are investments, such as costs for the individual, and perceived ease of use.

The reason that economical accessibility gets such prominent place in the model, is because almost every older adult, when introduced to smart home technology, is interested in the monetary costs for him or her to use it [17], [18]. Unfortunately the financial puzzle is often unsolved when the technology is introduced, as there are many stakeholders involved to whom the financial benefits are not yet clear. However, when individual costs are *not* taken into consideration, little can be said about actual technology acceptance by the end-users. This was demonstrated in a study by [32] in which 68 older adults and 113 caregivers were asked what technological functionalities they wished to use. The percentages of intentional use (e.g. 80% wished for a fire alarm, about 75% wished for a personal alarm) dropped dramatically when people were asked what they were willing to pay for it: approximately 55% wished for a fire or personal alarm if they had to pay 5 euros a month. Less urgent of safety related functionalities dropped even worse (see Table 1).

As mentioned before, ‘perceived ease of use’ is considered to have an indirect effect instead of a direct effect on (intentional) use, as “…no amount of ease of use can compensate for a system that does not perform a useful function” [33]. Non-monetary ‘accessibility’ items that are previously mentioned by end-users involve the complexity and user-unfriendliness (e.g. [12], [27]), especially the difficulty of knowing how the technology works the next time (i.e. ‘memorability’ [34]). The fact that these usability elements can change usage behavior through a change in perceived benefits can be explained by a change in ‘conceptual accessibility’. There may be a large conceptual distance between an 82-year old woman with only a television and telephone network connecting her to the outside world, and for instance the World Wide Web. When the ease of use reduces cognitive overload and the conceptual distance, and supports intentional use, the conceptual accessibility can increase [11]. The benefits may become obvious to the user, with (increased) use as a result.

As a moderator variable, ‘accessibility’ can be considered as technology specific. The accessibility determinants involve not only usability design elements (such as learnability, efficiency, memorability, errors, satisfaction [34]) or system characteristics, but also a

Table 1. Percentages of acceptance as a function of ‘costs’ [32].

Older adults (n = 68)	Price (euros) a month			
Functionality:	-	*1*	*5*	*10*
Fire alarm	79	70	55	46
Personal alarm	67	67	58	42
Automatically TV off	55	42	19	15
Baseboard to cover cables	45	39	11	5
Caregivers (n = 113)				
Functionality:	-	*1*	*5*	*10*
Fire alarm	84	74	52	45
Personal alarm	80	69	57	53
Automatically TV off	57	36	17	12
Baseboard to cover cables	38	28	9	7

description of investments (costs).

2) Facilitating Conditions

A second moderator variable that is expected to influence (smart home) technology acceptance relates to the organizational, caregivers' part: '*facilitating conditions*'. The organizational and technical infrastructure to support the use of the system has often been studied as direct or indirect determinant of (intentional) use. 'Facilitating conditions' [6], [8], 'compatibility' [24], and 'perceived external behavioral control' [7], [23] respectively appear to influence only initial technology acceptance, and should therefore be taken into consideration in an early stage of implementation planning.

Especially for older adults, the facilitating conditions of technology usage seems important in explaining (intentional) technology usage. Reference [15] found access barriers, like money and income, as important variables that determine internet usage by older adults. The opposite of access barriers or situation constraints are facilitating conditions [6], such as technology support and information. The facilitating conditions mentioned in studies on smart home acceptance involve technology support, for example support by the organization involved or family members, effective communication, and project coordination [17], [18], [27]. We believe that in case of elderly users these facilitating conditions are very important for smart home technology acceptance, and should therefore be part of the model.

It should be taken into account that facilitating conditions, like technical support, may influence other variables, like self-efficacy and accessibility [26]. When the organization of support and technology use is inaccessible to the end-users, they may become insecure and unmotivated to use the technology. However, we expect the direct influence of facilitating conditions on actual usage to be stronger, than the indirect effects. The facilitating conditions in our model involve training, documentation, and user support, and can be analyzed and described for each smart home project.

3) Personal Variables

In addition to the system related and organizational issues that are expected to change the influence of benefits on technology usage, '*personal variables*' are the third group of moderator variables. Research has shown a complex influence of personal variables on technology acceptance [6], and found that the effect of benefits on usage will be stronger for men, and particularly younger men [6], with more computer experience. The personal variables that are expected to influence the causal relationship between benefits and technology usage are thus: gender, age, experience with technology, computer experience, and self-efficacy. Our model to be tested is given in Fig. 4.

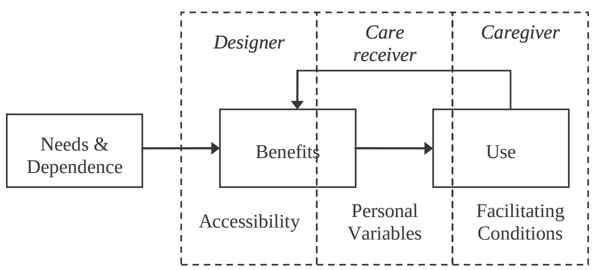

Fig. 4. The Technology Use Model to be tested.

Most personal variables will also have an effect on people's needs, as the personal situation is expected to determine the dependence of the person. Additionally, the personal variables also influence the accessibility of the technology. Self-efficacy, for example, positively influences ease of use [35], and according to [6] gender, age, and experience have an influence on intentional behavior, through accessibility. However, to keep the model as simple and concrete as possible, we have decided to leave out the smaller side effects that the variables may have on each other, and study the direct effects of the variables on 'Benefits', 'Use' and the interaction between these variables.

D. Social Influence

The social context seems to be a key issue, that can be helpful in convincing (end) users to use new technology [36], by involving opinions, information, and behaviors of the people whom end-users communicate with. Other models have considered 'social influence' as a determinant for (intentional) technology use [8] described as 'subjective norm' [1], [3], [6], [23], 'social factors' [7], and 'image' [24] respectively. However, the effect of social peers and other social influences on attitudes or needs are hard to categorize under *solely* one of the variables described in our model. The effect may involve increased perceived benefits ("My peers use it, so it will probably be useful to me too"), as well as increased accessibility and facilitating conditions ("My children want me to use it, so they will probably help me with it" or "If they can use it, I can use it too"). For now, we believe that the social influence can be considered as an element of the "gulf of evaluation" ((B) in Fig. 3), in which social influence is one of indirect experience.

IV. Conclusion

Many research has been conducted in order to find relevant external factors that affect technology acceptance (e.g. [6], [15], [37]). We believe that the many external variables – like system characteristics, individual differences, facilitating conditions, and social influences – can be categorized under the driver 'needs', under 'benefits', or under one of the moderators 'accessibility', 'facilitating conditions', and 'personal variables'. Therefore, we introduce a 'Technology Use Model' (Fig. 4) that includes relevant determinants and moderator variables to explain smart home and telecare technology acceptance in home care settings. Benefits are considered as key predictor for technology use, while the variables 'accessibility', 'facilitating conditions', and 'personal variables' are expected to influence this causal relationship. As the moderator variables cover 'designer', 'organizational' and 'personal' elements, our model underlines the necessity of *tuning* the perceptions of the stakeholders involved in smart home technology implementation [20]. Before the model can be tested, an operationalization of variables is needed. After operationalization, the model will be tested by means of field tests, involving older participants. Utilizing the iterative process of our model, may result in advisory steps for smart home and telecare technology acceptance.

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