Technology Acceptance Models in Gerontechnology

Don G. Bouwhuis, Lydia M. J. Meesters and Jelle Berentsen, *Member, ISG*

Abstract— **Successful introduction of IT technology is usually described by the Technology Acceptance Model (TAM) which consists of four latent variables with specified interrelations. Measurement takes place by means of subjective rating scales. Though many extensions of the basic model have been proposed, almost none of them can successfully predict actual usage in daily life of IT products. Based on a range of empirical studies, making use of triangulation measurement, it is shown that there are a multitude of phenomena in the design and operation of telemedicine applications that escape measurement according to the TAM methodology. An outline of the design trajectory of telemedicine applications is given, together with recommendations for design procedures that may considerable improve the chances of success for telemedicine.**

I. Introduction

THE arrival of a new technology invariably gives rise to social questions where it might be applied beyond the area it was originally designed for. Education is one such example, which is usually seen as refractory to change; care is another, more recent one. Inasmuch as traditional care is largely based on physical activity, it is not immediately clear how a new technology as IT could be employed effectively in care provision. In the first place, care has been considerably diversified and extended in the past decades, and currently there is a large number of well being activities that does not require actions of professionals. Second, there is a tendency, especially among older people to remain independent as long as possible, for which some IT provisions might be suitable or necessary. Third, IT can be provided with sufficient intelligence to carry out a range of monitoring and sensing activities, which can obviate the presence of dedicated caring staff.

The rise of the terms "user-friendliness" and "usability" indicate that the introduction of IT in society has been accompanied by multiple difficulties, and bearing in mind the characteristics of 'technology generations' [1], substantial difficulties in the uptake of care technology by older people must be foreseen. Difficulties in the acceptance of technology had already motivated the development of the Technology Acceptance Model (TAM) [2] and its successor TAM2 [3] that give a theoretical description of how and why people come to accept IT products in their daily life. A schematic overview of the basic TAM model is shown in figure 1. The theory states that prospective users are basing their attitude to use a specified product is formed by the usefulness they perceive and by the perceived Ease of Use. This attitude, in turn leads to the behavioral intention to use that product, or choose a competing product. The TAM model has been applied for a very broad range of IT products and services, for which often other components, affecting the four basic ones were considered necessary. 'Individual characteristics' can be taken to affect Perceived Usefulness as well as Perceived Ease of use. 'Support' is supposed to increase ease of use, whereas 'Social Influence' may be thought of as affecting the Intention to use [4]. In [5] 'direct stress' and 'indirect stress' were proposed as important factors affecting Perceived Ease of Use and Perceived Usefulness, whereas [7] introduced 'Trust' as a powerful factor. TAM2 in [3] investigated the roles of 'Subjective Norm', 'Image', 'Job Relevance', 'Output Quality', 'Result Demonstrability' 'Experience' and 'Voluntariness' and found that social influence processes also significantly influenced user acceptance. It should be noted, however, that 'User Acceptance' is not part of the schematic diagram in Fig. 1. Strictly speaking
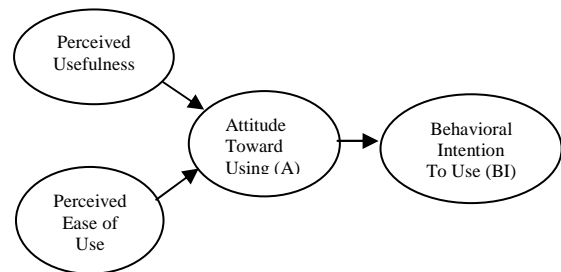

Fig. 1. Technology Acceptance Model (TAM) with the four basic components. Many other components have been proposed in the literature that supposedly influence one or more of the four components.

there should be a fifth concept, 'User Acceptance' to the right of the concept 'Behavioral Intention to Use'. Sometimes it is indicated there by the name of 'User Acceptance'. In fact, User Acceptance is a somewhat ambiguous term, as it might refer to actual uptake of an IT product, or to just acceptance

without real usage. It is exactly this issue that highlights the inherent limits of the TAM model. Considering the wide impact it has on predictions of user acceptance it is useful to study the area of applicability of TAM and to find a methodology to measure user acceptance, and specifically adoption in Activities of Daily Life (ADL) in more, and different detail.

II. TAM's formal Model

Basically, TAM is a latent structure model, meaning that the concepts and the linkages between them are not

directly observable, but hypothesized. Measurement of the concepts is by rating scales, usually 7-point Likert scales, an example from [3] being "*My interaction with the system is clear and understandable*". This is typically an item of the 'Perceived Ease of Use' concept. The reliability of each of the scales is mostly high, with Cronbach's α varying from 0.80 -0.98. The relation between the concepts is expressed as correlations between the scales and from these correlations a structure of the concepts can be derived, however not in an unambiguous manner. Here is one of the main problems in interpreting the concept structure of the TAM model. By definition the linear structure of the TAM model does not allow to specify a causal structure, i.e. it cannot be decided whether A causes B, or B causes A. Moreover, as the concepts are latent variables, it is not possible to manipulate them independently. In some cases particular additional concepts have been found to act as moderator variables, meaning that depending on their value, a correlation between two other variables is high or low. This makes it even more difficult to decide on a best fitting structure. Moreover, the importance of the concepts that are variously introduced depend very much on the type of technology and its application. While anyone would agree that individual characteristics are important for technology acceptance, it is far less clear in the case of one specific individual which ones that would be. So, while measures of goodness of fit of TAM-like models have been reported of the order of 0.60 of explained variance [3], it is not sure whether different configurations of the model would have been higher or similar in other experimental contexts. It is somewhat disconcerting to find in the study of El-Gayar and Moran [7] that while the goodness of fit for the 'Behavioral Intention' was as high as 0.55, the predictive value for 'actual use' was very low at 0.075. But the latter is exactly the issue behavioral science, including gerontechnology is interested in. So, not only are the basic components of the TAM models statistically not uniquely identifiable, they also fall short in predicting actual product usage.

III. METHODOLOGY

One of the critical points of TAM is that 'actual use' is essentially beyond the scope of TAM. TAM restricts itself to predicting the 'Behavioral Intention to Use' and does not extend onto actual product adoption and use. Measurement takes place *exclusively* by subjective rating scales, the item reliability of which is maintained at a high level. The construct validity is usually assessed by means of factor analysis. It has to be realized, however, that factor analysis does not yield unique solutions, so there is no certainty concerning the inferred structure, just likelihood. However reliable and replicable a rating scale can be, it does not guarantee truthfulness. In studies [8] and [9] it was found that older people invariably gave relatively high ratings to the usability of newly installed domotic provisions in their homes, say 5.5 on a scale of 1-7. In quite a number of instances however, it appeared that the same people were unable to control those systems, or admitted never having done it before. In a few cases it turned out that the specified functionality had – mistakenly- not even been installed. Also perceived usefulness was rated highly, whereas in most cases the operation of the functionality had not been experienced. In developing a satisfaction scale for the usefulness of domotic systems Eyck found in [9] that the most important component of the rating scales was what might be called 'positivity', a tendency to give responses with a high social desirability, irrespective of the particular product or service that had been provided. As soon as usefulness and usability questions concerning specific products became more detailed and concrete ratings started to decrease significantly. When ultimately confronted with the request to operate a product itself, the rating often became negative. This suggests strongly that ratings are dependent on the demand characteristics, on participants' expectations or the instrumental situational context. What seems clear is that one measurement method is not sufficient to uncover with sufficient precision what makes people endorse IT technology, and certainly not such technology that impinges so much on sensitive properties like personal health. What is apparently needed is the use of different methods studying the same phenomenon, a procedure which is called triangulation. Triangulation is not about three methods, but it employs different, often complementary methodologies the results of which should ultimately converge. Jick [10] has given a clear overview of such procedures that intend to give a more holistic and complete view of the issue under investigation. Essentially the studies of Ebeli [8] and Eyck [9] already made use of two measurement methods, subjective ratings and direct observation. The study by Meesters, Berentsen and Vergouwen [4] of a diabetes telemedicine application may serve as another and more elaborated example. In this study rating scales, part of which consisting of the TAM items, were collected. Care clients were observed in using the telemedicine application at their homes. A questionnaire was taken in an interview style and elaborated answers were encouraged about their experiences with the telemedicine application. A lab study was performed to investigate the users' performance under strict experimental controls. In addition the specialist nurses were interviewed concerning their experience with the clients using the application as well as the care centre operators, who could answer questions concerning the telemedicine operation and the measurement outcomes. Finally, a follow-up study was performed two months after the first evaluation in order to study whether prolonged use changed the views of the participants about the application. One interesting point is that the diabetes nurses judge that the clients have fewer difficulties with the measurement devices than the clients indicate themselves. Another point is that while the majority of the clients indicate that the telemedicine application is very useful, they will not use it in the foreseeable future. Apparently, the usefulness criterion is not a sufficient requirement for actual adoption.

IV. VIEWS OF IT TECHNOLOGY

In line with the characteristics of Technology

generations the way people look at IT products may be very different. It may be easily underestimated how many different parties are confronted with the technology or are involved in its functionality. The following list is representative for many applications:

- Manufacturing industry
- System developer
- Installation and Maintenance firm
- Care providing Organization
  - management
  - communication operators
  - nurses
- Specialized Medical staff
- Relatives, Friends, Age Peers
- End users/clients

The first two parties see the application as a self-contained system that operates in accordance with formal specifications, for which a certain reliability can be guaranteed. As a rule the application consists of different products from different manufacturers that are integrated by the system developers. It often happens that the usability of a single product is considered to be adequate, or excellent by its manufacturer, but fails to be that when integrated in the composite system. One reason might be that the product was specifically intended for a small group of professionals, and now has to be used by naive users. It appears that frequently manufacturers are unwilling to improve, or even modify their product for usability purposes.

Unlike most products that are employed in TAM studies, like personal computers, health care applications are never simple self-contained single products that come out of a box with a manual and a warranty form. Yet, end users, unfamiliar as most are with rapidly evolving IT products, expect this to be the case. On the contrary, installing most applications requires more than one home visit by technicians, who carry out mysterious connection work, usually spread over many weeks, without giving an impression when what is going to work, and how. Also, unlike modern consumer products, the system does not always work first time as soon as it is switched on; frequently components are defective and have to be replaced, again requiring waiting time and causing uncertainty. None of these applications has attained the maturity of mass-produced consumer products that still are the standards to which the new application will be compared. Technologically the largely experimental health applications are all at the beginning of their learning curve. This state of affairs causes very divergent views of the same IT products.

While the care organization has usually been instrumental in co-developing the health care application the actual technological expertise is generally very limited. The most important issue for the care management is the application support by their staff, largely consisting of nurses with no or limited technological training. Whereas the bulk of the care provision consists of physical activities, IT applications require the deployment of operators with some basic training in technological systems, who do not need to carry out remote physical activities. This creates financial and scheduling problems which are at odds with the regular financial schemes of traditional care provision, and not sustainable in the long term without structural modification of the organization and its financing. This issue was already observed in [11] mentioning conflicts between management and nurses who had additional work responsibilities, but were not allotted more time. In fact, the time sheets indicated that actual productivity declined compared to the situation before telemedicine.

In the case of a diabetes application the health professionals may consist of a physician, but mostly they will be nurses specialized in diabetes care. In the study mentioned here [4] the nurses could deal well with the client questions concerning diabetes, however, technical questions could be answered less successfully.

It is interesting to note that some clients were more inclined to rely on their diabetes nurse than on the measurement system. This is striking as meetings with the diabetes nurse took place every three months, whereas the diabetes system was available at all times. During the evaluation trial the number of times the diabetes nurses were contacted increased slightly, unlike what was expected.

The necessary measurements that have to be taken by the diabetic client may pose problems of many kinds. Looking at the various devices, connections, operations and controls makes it obvious that many of those will *never* be uncovered by conventional rating scales. Inter-individual differences, for example, caused that the pressure band for measuring blood pressure was to wide for some participants preventing blood pressure measurement. Specific circumstances can be very subtle: the weighing scale should be level, but in one case was observed to stand partly on a carpet causing the measurement to fluctuate uncontrollably. Carrying out all measurements, -blood pressure, weight, glucose level-, is one thing, transmitting all data to the computer and sending it to the care centre is another, as this involves dealing with a software program. Despite all good efforts, this may not be equally transparent for all end users, and generally is not [4].

V. COVERAGE OF THE DESIGN TRAJECTORY

The deployment of IT can be seen as a trajectory with an underspecified length. In the case of an office computer the trajectory is of limited length. The kind of work for which the computer is needed has been defined, the type of computer is decided upon by the system support department, the user has a relatively clear idea how this computer works in the task he is to perform, and the output has to conform to a number of specifiable criteria. The computer is almost standard commodity, the software is at least partly a mass product with well-known standardization. The network connecting the computers is also a version of a standard solution, for which many

providers will be available. All of this makes the user, using the computer, responsible for only a small part of the whole trajectory, otherwise stated, only a small part of the trajectory involves the user in a critical way. It is usually underestimated how much further the telemedicine trajectory extends in both ways, and how much more sensitive and vulnerable it is to external and internal influences. From the start there is nothing like a standard device with a well-known control procedure or standard interface like a hair dryer or a coffee maker. System integration means that heretofore there was no such system, no control procedure and no familiar interface. System integration also means that components of a very different technical construction will have to be put together, e.g. a weighing scale and a blood glucose meter, that obviously have no joint industrial history. Even while the formal technical specifications do not stand in the way, there may be numerous features that make integration difficult. One is reminded of the old fact that the default mono channel in stereo audio is the left channel. However, as the loudspeaker in TV sets used to be on the right, the default mono channel in video is the right channel. A good example of such an accidental feature conflict is that during calibration of a weighing scale the weight indicated can be preceded by a dash, e.g. -68, where 68 is expressed in kg. Upon sending this value to the computer, the dash is interpreted as a minus sign and the warning invalid measurement is produced, as weights cannot be negative. Of course, the weighing scale does not intentionally show a minus sign, and the computer's task is not to check basic facts about Newtonian physics, nevertheless both systems work exactly according to their specifications. Another problem was introduced by the short lead between the blood pressure meter and the computer. As the lead was so short the meter could be easily pulled from the table and fall. Upon touching the ground the batteries would fall out, and the clock would reset itself, leading to desynchronization with the computer. These are only two examples of many unexpected problems that may occur in the actual practice of telemedicine operation. Working with a telemedicine system need not in principle be difficult, but it can be, and it need not be equally easy for every individual. Background knowledge and computer anxiety play a much more important role in telemedicine than in the regular workplace. After sending the diabetes data to the care centre, the client involvement does not end. What is being sent may be vital for the patient: it is not just output with which the patient is not concerned anymore. The basic function of the telemedicine system is that its output determines what is needed for the health of the person who produced the data. In this sense the technology trajectory is much more extended than for the regular IT worker, and, consequently much more liable to disturbances, while the disturbances also seem more serious than in the normal work place.

VI. USER-CENTERED DESIGN

A number of observations among the framework programs of the European Commission in the area of People with Special Needs, Universal Access and Health Care reveals recurring issues that plague universal introduction of telemedicine and successful IT applications. One is that much effort is spent on diagnosis and network systems to requisition direct medical advice and treatment for the patient from medical institutions. It is highly questionable whether any hospital could cope with the sudden influx of consultation and treatment demand, many of which would inevitably be false alarms. From the experience in telemedicine projects it becomes clear that knowledge of the local situation, the situational context and the personal properties of the client is most important for a successful intervention.

A second observation is that after the end of a project the services rendered so far have to be stopped for lack of funding. This, of course, proves that the service in that form is certainly not cheaper than alternative forms of care, and also not self-sustaining. It appears that many forms of telemedicine are more technological feasibility studies than serious efforts to create cost-effective health solutions. This is stressed by the fact that telecare expenses are usually not covered by health insurance companies

A third observation is that system integration is usually the critical component of the research project. More often than not system integration fails, while there is no more time left in the duration of the project to do it right. Of course, system integration is not a discipline in its own right, and is a long way from a discipline considering the increasing hybridization of constituent parts of a system.

All of these considerations lead to the central question of how to design successful telemedicine systems, successful in the sense that they are really accepted, i.e. adopted in the regular daily activities of the prospective clients. Several design procedures have been suggested to cope with the difficulties of developing effective and robust products and systems that are accepted by their users. Design for All is one, and Universal Design another. Neither seems particularly opportune as they seem to imply that a well-designed product is suitable for everyone. User-Centered Design seems a better choice as it may imply that a design can be made for an individual, but still lacks detail about the structuring of the design process. In Human Factors Engineering User-Centered Design is usually defined as an iterative design cycle, where new design features are being evaluated, modified when needed and the new design further evaluated until finished. Even while this approach is widely advocated and claimed to be an industry standard, the full method is generally too costly and time consuming to implement as standard practice. This is not to say that user involvement in design is counter-productive; on the contrary, there is empirical evidence [13] that when end-users are involved early in the design process the design costs are significantly lower, and the development times shorter than without end-user involvement. In the case of telemedicine the development is spread over more than a single industry, which makes it not easy to involve the user in all stages, and to harmonize the results of part evaluations. An approach rather similar to the iterative design cycle is the action research approach, originally

coined by Lewin in 1946 [12]. Its basic organization, originally intended to effect changes in social groups, is as follows

- Identifying a general or initial idea
- Reconnaissance or fact finding
- Planning
- Take 1st Action step
- Evaluate
- Amended Plan
- Take 2nd Action step

The idea is that each action step contains a design of some sort, that is to have an intended affect on a population group. Dansky, Bowles and Britt [11] propose such an approach for telemedicine, which has been elaborated for nursing applications by Hart and Cert [14]. At any rate, considering the wide range of the telemedicine IT trajectory, participatory design seems obligatory; no way of subjective rating scales, of questionnaires or surveys will ever do justice to the actual events taking place at the location of the client.

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