Assistive Technologies for People with Cognitive Impairments – Which Factors Influence Technology Acceptance?

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Abstract. While in the general field of acceptance research convincing and empirically well-tested models for the acceptance of technical systems exist, only a few studies have been carried out in the area of acceptance of assistive software systems. Appropriate acceptance models play an important role, especially for user-centered and participative software development and quality assurance. In this article, the most important models from general acceptance research are briefly introduced. Based on the results of an acceptance study of an app for independent media access for users with cognitive impairments, a proposal for an acceptance model of assistive technology was developed, in which personal and environmental factors are considered more strongly than in the classical acceptance models.

Keywords: Assistive technology · Cognitive accessibility
Technology acceptance · Acquired brain injury · Participation
Independent media use

1 Introduction

Since the mid-1980s, technology acceptance models have been an essential part of sociological, economic and media research. Technology acceptance models describe the subject-, object- and context-related factors that influence the acceptance of technology in general. Although technology acceptance research is nowadays an important part of economic research, it is still not very widespread in the field of assistive technologies. Based on the theoretical models of acceptance research, only a few empirical studies have been carried with different user groups and for different areas of application, e.g. for users with cognitive impairments, with multiple sclerosis, for students with frequently occurring impairments, users with traumatic brain damage and dementia [1–3]. Particularly for complex aids, e.g. software to support cognitive functions, inadequate instruction and training in the use of the aid constitute major barriers to successful use. Often the training does not only fail due to time and financial resources, but also due to the lack of technical competence of the experts involved in the supply process [4].

While motor and sensory impairments can usually be well compensated for by the use of assistive technologies, cognitive impairments often negatively influence the

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possibilities for participation and a self-determined lifestyle. People with cognitive impairments after acquired brain damage are usually affected by disorders of memory, attention, action and affect control. As a result, such persons are dependent on the support and care of family members and nursing staff in many aspects of their lives.

The UN Convention on the Rights of Persons with Disabilities, which came into power in 2008, provides for all people to have full participation in public and social life and the right to a self-determined lifestyle. The availability of suitable assistive devices is an important mean to enable people to participate as fully as possible in public and social life after having suffered from brain damage. As part of the rehabilitation process, the supply of aids, which also includes demand-oriented access to assistive computer technologies, is of particular importance.

In the subsequent sections, the most important models of acceptance research will be presented and their applicability to the acceptance of assistive technologies for people with cognitive impairments will be discussed. Based on the results of a user acceptance study for a cognitive support app for the use of web applications, a proposal for an extended model of assistive technology acceptance will be developed.

1.1 Technology Acceptance Research

Technology acceptance is generally defined as the 'positive adoption or transfer of an idea, an issue or a product, in the sense of active willingness and not only in the sense of reactive acquiescence' [5, 6].

Over the last 30 years, many different models have been developed that have aimed at describing and correlating the subject-, object- and context-related factors that influence technology acceptance. The following section presents the most influential models for the acceptance of IT technologies that are considered relevant for the acceptance of assistive software systems.

TAM, TAM3. The Technology Acceptance Model (TAM) was first developed by Davis [7] and is regarded as the initial model of technology acceptance in international research. Davis defines acceptance as the actual use of the respective technology by its (potential) users based on perceived usefulness (PU) and perceived ease of use (PEOU). Perceived usefulness (PU) refers to a user's estimation of how the use of a specific IT application improves the completion of work tasks within a specific organizational (acceptance) context. Perceived ease of use (PEOU) refers to the estimation of the user whether the use of the IT system can be learned and handled effortlessly. In Davis' model, the interaction of these two factors results in an intention to use the technology in question (intention of use, BI). This intention of use may then lead to an actual use of the respective technology (actual use). Figure 2 illustrates the relationships between the mentioned factors of the TAM model.

In various empirical studies it has been shown that the factors PU and PEOU postulated by Davis are valid indicators for the acceptance (intention to use) and actual use of a technical systems [8, 9] (Fig. 1).

However, other empirical studies revealed that the factors postulated by Davis are not sufficient to explain the acceptance and subsequent use of technical systems completely. In subsequent research, Davis' original technology acceptance model was

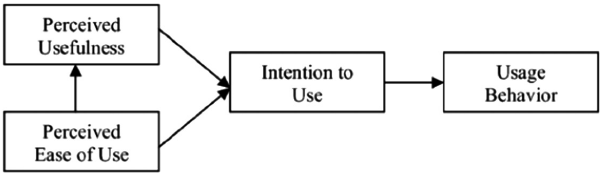


Fig. 1. TAM – technology acceptance model [7]

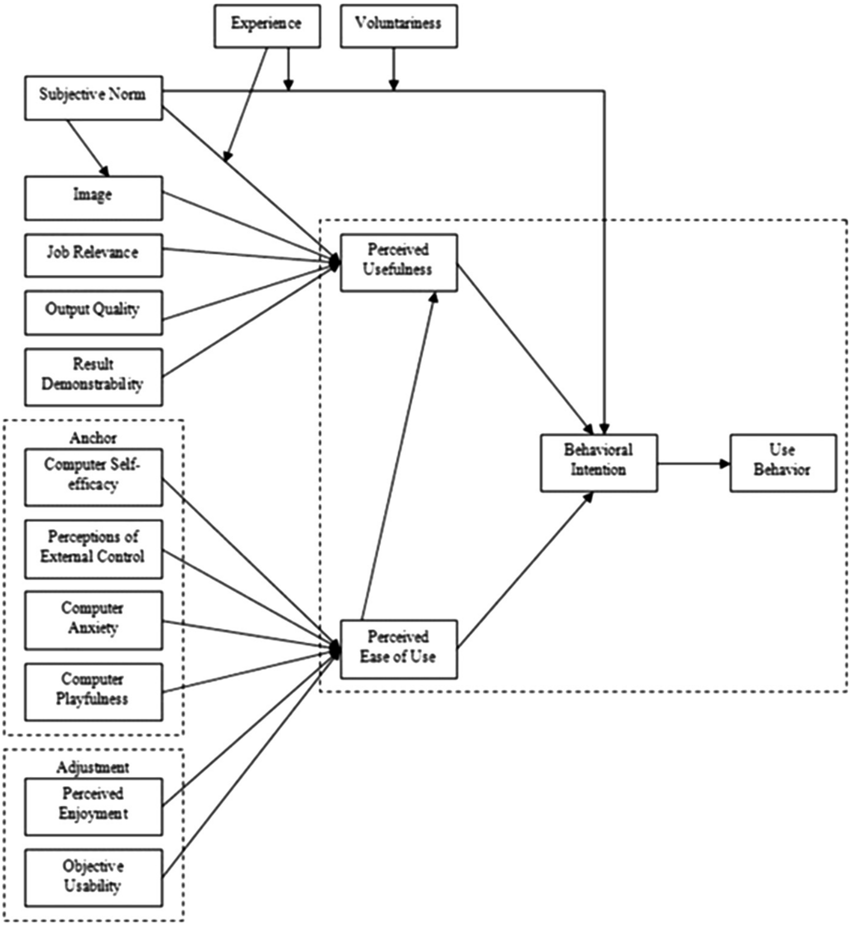


Fig. 2. TAM 3 [11]

modified in numerous adaptations. In particular, the influence of external variables such as demographic factors or personality traits of the potential user, as well as the influence of subjective norms on the acceptance of technical systems, have been taken into account in different models, e.g. in the extended technology acceptance model of

Davis and Venkatesh [10]. In their research on changes in acceptance of technical systems over a longer period of use, the authors found that, in addition to the known factors ‘perceived usefulness’ and ‘perceived ease of use’, social influences such as the subjective norm, voluntariness and self-image significantly influence the acceptance of technical systems. Further important factors for acceptance are the importance of the tool for the professional development and the quality and visibility of the achieved results. In a further revision of the original model, TAM3 [11], some intrinsic factors, like computer self-efficacy and playfulness of use and extrinsic factors, like objective usefulness and their influence on the acceptance of technical systems were taken into account. The applicability of TAM3 has been demonstrated in several longitudinal studies. Figure 3 shows an overview of the influence factors considered in TAM3 and their interdependencies.

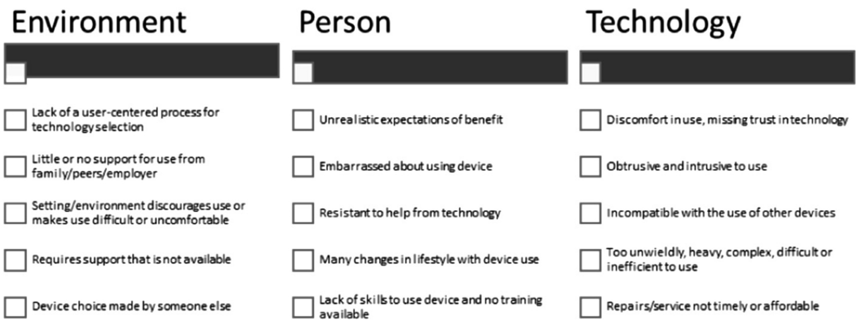


Fig. 3. Factors for non-use of assistive technology [24]

UTAUT. In 2003, Venkatesh, Morris, Davis and Davis developed the Unified Theory of Acceptance and Use of Technology (UTAUT) based on a comprehensive literature analysis of acceptance research [12]. The basic assumptions of the UTAUT model are closely based on the TAM model, again based on the premise that the actual use of technology is preceded by an intention to use it. That intention can be influenced positively or negatively by certain factors. As a result of the analysis and empirical comparison of different theoretical models for explaining and predicting individual user behaviour, the authors have identified the following four constructs as determining factors for user acceptance: performance expectancy, effort expectancy, social influence and facilitating conditions. Other factors, such as social gender, age, experience of use and the voluntary nature of use moderate the influence of the four determining factors. Various empirical studies have demonstrated that the four determining factors have a significant influence on the user’s intention to use a technical system in different contexts and for different user groups. Furthermore, a positive influence of behavioral intent on actual use could be empirically confirmed.

Additional Theories. In parallel to the development of the technology acceptance models described in the previous sections, user satisfaction research has been focusing on the levels of contentment among users of IT systems. In psychological research, user satisfaction is seen as an important prerequisite for performance in work and everyday situations. Important determinants of user satisfaction included the usefulness, simplicity of use, usage results, user expectations, operational factors, service quality, system quality and information quality [13].

Contrary to the technology acceptance models, which focus on the user with their characteristics and environmental impacts, the Technology Task-Fit Model (TTF) focuses on the nature of the task to be solved and the support the user receives from the technology used in the given task [14]. The more technology is used to support the user in solving the tasks, the more the IT system is used in real life and therefore contributes to an improvement of the work performance.

Limitations of Existing Models. All models and theoretical approaches of acceptance research presented so far have been tested to varying degrees in many empirical studies. Due to their great popularity and good applicability, the TAM-based models provide a highly utilized theoretical basis for empirical studies on user acceptance. Other approaches could also be validated for specific kinds of applications and user groups. Nevertheless, there are contradictory results for some of the proposed constructs. For example, the influence of social norm on the intention to use technology depends strongly on factors such as user experience, gender and type of task (obligatory or voluntary task) [12]. The influence of PEOU, which is a central construct of the TAM-based models, could be demonstrated in some empirical studies, but only for some user groups and task types [15].

A further relevant limitation for the applicability of the presented models for the general acceptance of technical systems lies in the prevailing limitation to the use of IT systems in work processes. Although there are some studies on the acceptance of eHealth and telemedicine systems, there is currently only one known publication available on the acceptance of assistive technologies based on the described acceptance models [16].

1.2 Acceptance of Assistive Technology

A closer look at resource directories for medical aids shows that there is no shortage of all types of technical aids. Nevertheless, in their regularly published reports the health insurance companies complain about an insufficient supply and use of these aids. International studies on acceptance of medical aids report that approx. 30% of the prescribed aids are insufficiently used or abandoned [17].

One reason for this unsatisfactory situation lies in the fact that, despite best efforts, there is often a one-sided view of patients' needs. The doctors and therapists involved in the care process have excellent specialist knowledge, but they often focus only on the functional aspects of the prescribed aids. The personal preferences of the user, the psychosocial conditions and the available support, which play an important role for the actual use of an aid, are often not sufficiently considered in the provision process. Another reason for the high proportion of unutilized devices is the lack of supervision and aftercare for the user. The standard regulatory processes usually include a verification of the sustainability of the provisions, but in reality, this step is often omitted due to a lack of time and financial resources. Furthermore, neither patients nor doctors are currently obliged to pass information about the success of treatment on to the insurance providers.

Looking at assistive technology more specifically, the concepts of environmental factors, accessibility and universal design [18–21] come into focus. This relates also to the process of development and service provision of assistive technology rather than the mere outcome of the provision. Participative processes in the provision of assistive technologies can be considered as one prospective avenue to better and more acceptable products and services.

Matching Person and Technology Model. There are few approaches in scientific research that deal with the acceptance and sustainable use of assistive computer technologies. Scherer's 'Matching Person and Technology Model' [22] is a theoretical framework for the application of assistive technologies, which can also be applied to software systems for cognitive support. The framework consists of a set of person-centered measures to assess the subjective judgements of the users' abilities, needs, goals, expectations, preferences and psychosocial characteristics. A good agreement between person and technology takes into account the interaction of the environmental conditions in which the technology is used, the needs and preferences of potential user and the functions and characteristics of the applied assistive technologies [23]. The proposed measures are grounded in the author's research on the underlying reasons for the abandonment of prescribed assistive technologies. These studies have shown that the abandonment of assistive technologies is generally based on a negative interaction of environmental factors, user characteristics and characteristics of the technology. Figure 5 gives an overview of the most important factors for non-use of assisted technologies [24].

Empirical Studies on the Acceptance of Assistive Technologies. Based on theoretical models of acceptance research, various empirical studies have been carried out with different user groups and for different areas of application, e.g. for users with cognitive impairments, with multiple sclerosis, for students with frequently occurring impairments, users with traumatic brain damage and dementia [1–4, 10]. These studies demonstrate that similar factors are relevant to the acceptance and use of assistive technologies for all investigated user groups and areas of use. The more individual needs and living conditions of potential users are integrated into the provision process, the better the individual counselling is in the provision process and the better the users are supported and advised during use, the greater are the acceptance, the intention to use and finally the actual use of a technical aid. Particularly for complex aids like software to support cognitive functions, inadequate instruction and training in the use of the aid constitute major barriers to successful use. Often the training does not only fail due to time and financial resources, but also due to the lack of technical competence of the experts involved in the supply process [4].

In relation to the acceptance concept PEOU the accessibility and user-friendly design of software, electronic documents and internet resources become important elements [25]. Unlimited accessibility is an essential prerequisite for the perceived ease of use and the acceptance of a technical aid, especially for handicapped users.

2 Study

Various empirical studies in the context of general technology acceptance research have shown that certain psychological constructs, in particular the constructs of 'perceived ease of use' (PEOU) and 'perceived usability' (PU), have a strong influence on technology acceptance. To date, there are only a few studies on the acceptance of assistive technologies. However, since acceptance is an important prerequisite for the continuous use of the provided aids, there is an ethical and economically motivated necessity to carry out further studies on this topic.

The acceptance study described here was carried out as part of the Mediata project. The goal of the media project was to develop an app that enables people with cognitive impairments or learning disabilities to use Internet and social media resources independently [26]. The developed app supports people with cognitive impairment through an easy and consistent interface design, a single sign-on approach, support for various input modalities, direct linking of popular apps and a configurable user profile. The functional scope and design of the user interface was determined in a user-centered requirements analysis in close cooperation with a group of users with cognitive impairments in order to ensure the development of an assistive device tailored to the needs of potential users [27]. Figure 5 shows an overview of the cognitively accessible login options in the app (Fig. 4).

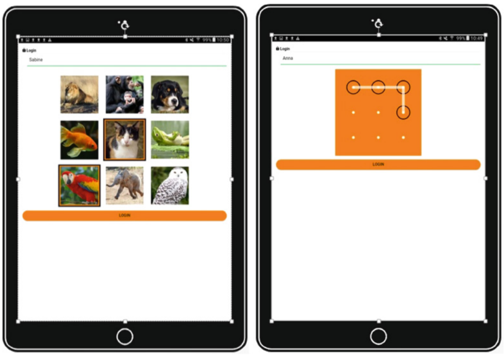
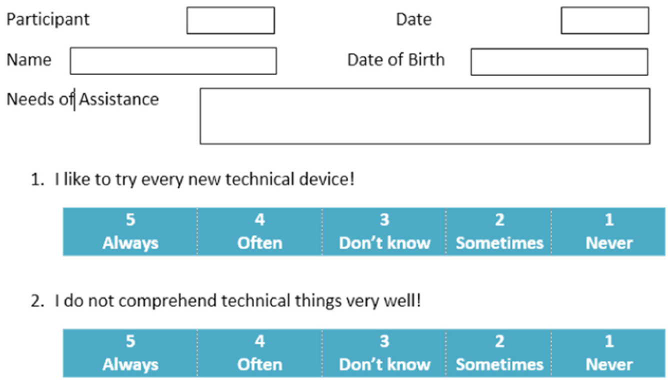


Fig. 4. Picture based and pattern based login into the Mediata-App


Participant
Date
Name
Date of Birth
Needs of Assistance

1. I like to try every new technical device!

5 Always	4 Often	3 Don't know	2 Sometimes	1 Never

2. I do not comprehend technical things very well!

5 Always	4 Often	3 Don't know	2 Sometimes	1 Never

Fig. 5. Starting section of acceptance questionnaire

2.1 Method

In order to continuously monitor the usability of the app, intensive test phases were already carried out during the development phase. Once the development was completed so far that a stable prototype of the app was available, a final usability test and an acceptance test were carried out. The results of the usability tests can be found in Dirks and Bühler [27, 28] here the focus of the presentation is on the results of the acceptance test.

The items of the acceptance questionnaire have been adapted to the structure of the 'Matching Person and Technology Assessment' form and have been formulated according to the rules of easy language. Due to their cognitive limitations, the user of the respective user group have specific requirements to formal and verbal design of questionnaires. Therefore, the study did not use a standardized questionnaire but developed a proprietary format. In addition to the personal contentment in different areas of life, various questions were asked about the satisfaction with the application. Acceptance was evaluated using a 5-step Likert questionnaire. Figure 6 shows the starting section of the acceptance questionnaire.

The following hypotheses have been formulated to examine the acceptance of the Mediata App:

- Hypothesis 1: Perceived Usefulness (PU)
  – The Mediata app helps users with cognitive impairments to use Internet and social media services independently.

- Hypothesis 2: Perceived Ease of Use (PEOU)
  – The user interfaces are easy to use for users with cognitive impairments.

- Hypothesis 3: Behavioural Intention (BI)
  – Users with cognitive impairments want to use the Mediata app because it increases their sense of participation and independence.

2.2 Participants

Altogether 17 people participated in the acceptance test. Of the 17 persons, 13 people suffered from acquired damage and four persons had cognitive impairments of different origins. As part of the participatory requirements analysis for the Mediata app, the preferences of potential users were assessed. The functional requirements for the Mediata app were compiled based on the indicated user preferences. Table 1 shows an exemplified overview of the gathered user information.

2.3 Results

For reliability analysis, a Cronbach's alpha was calculated to assess the internal consistency of the subscale for positive affect, which consists of ten questions. The internal consistency of the questionnaire is satisfying, with Cronbach's alpha for positive affect = .95.

Table 1. User profile examples

User	Age	Diagnosis	Deficits	ICT interests
1	54	Cerebral haemorrhage	Memory deficits, reduced attention span, mood swings	YouTube, email, messenger
2	56	Cerebral haemorrhage	Hemiparesis, short term memory deficits, reduced drive	Games, news, reading, google search
3	36	Alcohol intoxocation	Dysarthria, reduced attention span	Office, facebook, google search
4	57	Traumatic Brain Injury	Memory deficits, reduced impulse control	YouTube, games, travel, languages

In order to check whether the psychological constructs PU, PEOU and BI have an influence on the acceptance of assistive technologies, the questionnaire items were assigned to the corresponding acceptance constructs of TAM3. Table 2 shows the assignments of the questionnaire items to the TAM3 constructs.

Table 2. Mappings of questionnaire items to TAM3 constructs

TAM3 construct	Questionnaire items
Experience	newTech_like, newTech_knowGood, newTechSeldom_insecure
Output Quality	appUse_quicker, appUse_feelGood, appUse_withoutHelp
Result Demonstrability	appUse_independence, appUse_likeOthers, appUse_ownAfraid
Perception of External Control	friends_help
Image	friends_interest, friends_disapprove
Computer Anxiety	newTech_diff, newTech_insecure, newTech_afraidToBreak
Computer Playfulness	newTech_likeToPlay, appUse_fun
Perceived Usefulness	appUse_important
Perceived Ease of Use	appUse_easy

Correlations between the items were calculated and high positive correlations were found between items that influence the constructs PU and PEOU in the TAM3 model, e.g. experience, computer playfulness, result demonstrability. The influence of the PU and PEOU constructs on the BI construct postulated in the TAM3 model could also be demonstrated for the examined app. Table 3 shows the most important results of the descriptive data analysis.

As can be seen in the data in Table 3, the questionnaire items that correspond to the TAM3 constructs' Computer Playfulness',' Result Demonstrability',' Perceptions of External Control' and' Output Quality' have been consistently rated as highly beneficial.

Table 3. Descriptive data analysis

Item	N	$\bar{x}$	σ^2	σ
newTech_like	17	3,18	3,15	1,78
newTech_difficulties	17	2,76	2,69	1,64
newTech_likeToPlay	17	3,88	2,36	1,54
newTech_knowGood	17	4,00	2,62	1,62
newTech_insecure	17	3,06	3,31	1,82
appUse_fun	17	4,47	1,64	1,28
appUse_independence	17	3,70	3,10	1,76
appUse_likeOthers	17	4,00	2,25	1,50
appUse_feelGood	17	4,41	1,51	1,23
appUse_withoutHelp	17	3,82	2,53	1,59
appUse_easy	17	4,35	1,62	1,27
appUse_important	17	3,94	2,68	1,64
appUse_quicker	17	3,47	4,02	2,00
appUse_likeToUse	17	4,29	1,60	1,26
newTech_afraidToBreak	17	4,06	2,43	1,56
newTechSeldom_insecure	17	3,71	2,97	1,72
appUseOwn_afraid	17	3,59	4,13	2,03
friends_help	17	4,35	1,87	1,37
friends_interest	17	3,18	2,78	1,67
friends_noInterest	17	3,00	6,12	2,48

In order to determine the influence of the constructs 'Perceived Ease of Use', 'Perceived Usefulness' and 'Behavioural Intention to Use' postulated in the acceptance models, correlations between the questionnaire items were calculated. For an overview of the calculated values, see Table 4.

High positive correlations could be found between the item' appUse_important' (Perceived Usefulness) and the following items: newTech_knowGood (Experience), friends_interest (Image), appUse_likeOthers (Result Demonstrability), newTechLikeToPlay (Computer Playfulness), appUse_fun (Computer Playfulness) and appUse_wantToUse (Behavioural Intention).

For the item 'appUse_easy' (Perceived Ease of Use) positive correlations to the following items could be found: appUse_feelGood (Output Quality), appUse_likeOthers (Result Demonstrability), friends_help (Perception of External Control), newTech_afraidToBreak (Computer Anxiety), newTech_liketoPlay (Computer Playfulness) and appUse_fun (Computer Playfulness).

Moreover, positive correlations for the item' appUse_wantToUse' (Behavioural Intention) could be found to the following items: newTech_knowGood (Experience), appUse_feelGood (Output Quality), friends_help (Perception of External Control), appUse_fun (Computer Playfulness), appUse_easy (Perceived Ease of Use) and appUse_important (Perceived Usefulness).

Table 4. Correlations between questionnaire items

Variablen	newTech_ likeToPlay	newTech_ knowGood	appUse_ fun	appUse_like Others	appUse_ feelGood	appUse_ easy	appUse_ important	appUse_ wantToUse	newTech_ afraidToBreak	friends_ help	friends_ interest
newTech_like	0,70	0,65	0,48	0,77	0,42	0,41	0,58	0,42	0,45	0,36	0,37
newTech_difficulties	0,46	0,24	0,35	0,51	0,36	0,43	0,27	0,28	0,13	0,29	0,06
newTech_likeToPlay	1,00	0,80	0,54	0,76	0,52	0,63	0,67	0,57	0,37	0,47	0,64
newTech_knowGood	0,80	1,00	0,54	0,69	0,57	0,58	0,80	0,64	0,54	0,48	0,60
newTech_insecure	0,63	0,68	0,36	0,48	0,35	0,40	0,59	0,40	0,46	0,32	0,43
appUse_fun	0,54	0,54	1,00	0,59	0,94	0,81	0,64	0,88	0,55	0,76	0,57
appUse_independence	0,75	0,79	0,43	0,73	0,44	0,44	0,51	0,46	0,58	0,36	0,36
appUse_likeOthers	0,76	0,69	0,59	1,00	0,58	0,66	0,71	0,59	0,48	0,49	0,27
appUse_feelGood	0,52	0,57	0,94	0,58	1,00	0,86	0,60	0,96	0,61	0,88	0,54
appUse_withoutHelp	0,71	0,70	0,50	0,79	0,55	0,47	0,57	0,59	0,58	0,49	0,34
appUse_easy	**0,63**	0,58	**0,81**	**0,66**	**0,86**	**1,00**	0,46	**0,79**	**0,68**	**0,71**	0,41
appUse_important	**0,67**	**0,80**	**0,64**	**0,71**	0,60	0,46	**1,00**	**0,70**	0,32	0,51	**0,62**
appUse_quicker	0,38	0,37	0,54	0,48	0,55	0,40	0,35	0,51	0,23	0,30	0,42
appUse_WantToUse	0,57	**0,64**	**0,88**	0,59	**0,96**	**0,79**	**0,70**	**1,00**	0,53	**0,91**	0,60
newTech_afraidTo Break	0,37	0,54	0,55	0,48	0,61	0,68	0,32	0,53	1,00	0,46	0,26
newTechSeldom_ insecure	0,69	0,85	0,49	0,65	0,53	0,54	0,57	0,56	0,68	0,39	0,39
appUseOwn_afraid	0,80	0,68	0,44	0,45	0,42	0,47	0,57	0,46	0,11	0,44	0,71
friends_help	0,47	0,48	0,76	0,49	0,88	0,71	0,51	0,91	0,46	1,00	0,46
friends_interest	0,64	0,60	0,57	0,27	0,54	0,41	0,62	0,60	0,26	0,46	1,00
friends_noInterest	0,43	0,55	0,34	0,35	0,31	0,16	0,37	0,32	0,37	0,13	0,53

Values in red bold are different from zero with a significance level of alpha=0.01

2.4 Discussion

Based on the three postulated research hypotheses, it can be stated that the Mediata app helps users with cognitive impairments to use Internet and social media services independently (hypothesis 1). Moreover, the user interfaces are easy to use for the user group (hypothesis 2) and users with cognitive impairments want to use the Mediata app because it increases their sense of participation and independence (hypothesis 3).

It can further be assumed, that the psychological constructs of 'Perceived Usefulness' (PU) and 'Perceived Ease of Use' (PEOU) postulated in the TAM models also play an essential role for the acceptance of assistive technologies. There is evidence that they are influenced by the same intrinsic and extrinsic factors as described in the TAM3 model for general acceptance of technology. Similarly, an influence of 'Perceived Usefulness' (PU) and 'Perceived Ease of Use' (PEOU) on the 'Behavioral Intention' (BI) to use the Mediata app as an example for assistive technology for cognition could be found in the data.

3 Conclusions

The influencing factors PU and PEOU postulated in the TAM models also seem to apply to the acceptance of assistive technologies for cognitive support and are mediated by at least some of the psychological constructs postulated in the TAM3 model.

Experience, result demonstrability, computer playfulness and perception of external control play an important role in the technical acceptance of assistive technologies for people with cognitive impairments. From the results of the presented study, it can be deduced that the TAM 3 model seems to be suitable for the assessment of the acceptance of assistive technologies for cognitive support. Figure 6 shows the factors of the TAM3 model that seem to be particularly relevant for the acceptance of assistive technology for cognition and their relationships to each other. However, more focus need to be given to the relevance of accessibility and environmental factors in the context of TAM3. While accessibility seems to be closely connected to 'perceived ease of use' environmental factors relate to social and other external facilitation factors.

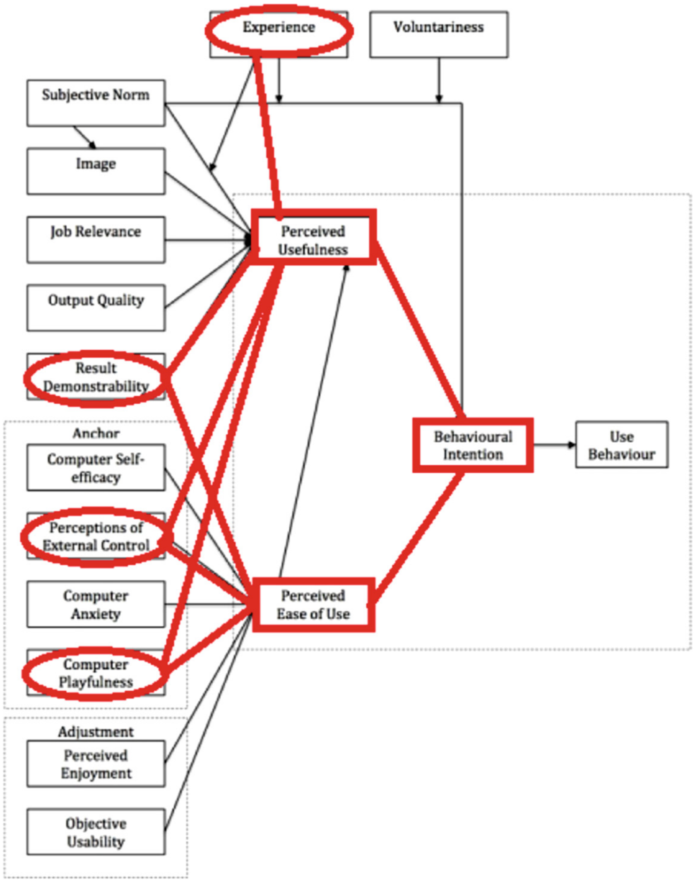


Fig. 6. TAM3 model with marked factors relevant for the acceptance of assistive technologies

Since only a small group of users was analyzed in the presented study, the results can be generalized only to a limited extent. It is intended to conduct further studies to investigate the acceptance of assistive technologies for cognitive support in various fields and to explore the relation of technology acceptance to accessibility and environmental factors in this context. In times of increasing need for support in the use of internet and media services by various user groups (seniors, immigrants with limited language skills), the development of highly acceptable and cognitively accessible support technology is of particular importance and requires special social and scientific attention.

As there is still limited research on the acceptance of assistive technologies, the relationship between accessibility, ICF-based context factors and technology acceptance has not been clarified yet. There is still much to be done in this area of research.

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