The Role of Personal Assistance in the Uptake of Smartphone-Based Tele-Audiology—An Extension of the Technology Acceptance Model

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Abstract—The arrival of new technologies in Hearing Healthcare is evident. The ability to connect hearing aids to smartphones via Bluetooth has opened up a host of new possibilities. By using an associated app, it is possible, among other things, to make an appointment with the Hearing Care Professional remotely. This function is nothing other than a further development of the classic Tele-Audiology. However, since the user base is mostly older, the question arises about the importance of the personal assistant in the clinic in setting up and explaining the technology for successful use. For this reason, a study was conducted among 110 patients who had already received such a form of intervention. For this purpose, the existing Technology Acceptance Model was further developed to include the latent variable of personal assistance. Existing basic hypotheses from other areas of application were confirmed and an additional relevant variable was identified. It could be concluded that due to a further shift of the patient generation towards baby boomers, the need for personal assistance might decrease.

Keywords—hearing healthcare, tele-audiology, technology acceptance model, geronto technology, smartphone app, connectivity

1 Introduction

Poor hearing is one of the most progressive diseases in the Western world. By the age of 70, 30% of men and 20% of women already have hearing loss that significantly impacts their daily lives and their social relationships [1]. Except for some pathological conditions that can be surgically corrected, fitting a hearing aid by a hearing care professional is usually the only solution to compensate for this problem [2]. These devices evolved from a simple ear trumpet to a high-tech product which consists of several microphones, an amplifier and a loudspeaker and is able to detect all hearing situations automatically. Additionally, features beyond audiological aspects are available like music streaming or telephoning. These technological developments are now meeting patients, ready to use them in Hearing Healthcare [3], [4]. Much of the innovation is in the area of hearing aid connectivity. This means that the devices can be connected to the smartphone, as well as other devices, via Bluetooth [5]. This allows the hearing aids to be operated via a smartphone app which enables patients to make minor adjustments to

their settings. Furthermore using a sub-function of the app, an online session with the hearing care professional (HCP), who has the same options and access to the hearing aid settings from a distance as during a personal visit to the clinic, can be performed [4] and is conducted out of the clinic with the patient. Through the smartphone, the patient can hear and see the HCP and communicate with him this way [6]. This feature represents an evolution of classic tele-audiology, which has been around since the 1960s and found its way into rural areas due to insufficient availability of HCPs in the United States [7].

The use of this technology and mobile smartphone applications in general, is part of the paradigm shift that is taking place in the field of hearing healthcare, away from the classical clinic-centered model towards a more flexible model, where the patient is more engaged as an active participant in the whole fitting process [8]. The use of these small programs in the course of digital transformation can also be observed in other areas of medicine [9], as well as in many other industries such as retail, education and travel [10]–[13].

With regard to smartphone-based tele-audiology, no detrimental effects were found in audiological terms compared to traditional care in the clinic [6]. In the area of service quality, it was even determined that this form of care should be regularly integrated into the traditional process in order to achieve the greatest possible patient satisfaction [14]. HCPs stated that they are generally open to using tele-audiology, yet a variety of barriers still exist that severely limit its use [15]. However, it is worth noting that willingness to use depends not only on the part of professionals, but also on the part of patients. The majority of hearing aid users are of advanced age and not necessarily familiar with smartphone or app use. Thereby, the population of the over-65s is the fastest growing market for smartphones [16] and geronto technology, which means developing and delivering health technologies effectively to elderly adults, has become a highly emergent field [17]. Aspects like unclear interface elements or a lack of user feedback might be problematic for them and inconsistent navigation structures in combination with a low literacy regarding the smartphone use will negatively affect the ease and the actual use of this technology [18]. Since, as mentioned, the successful application of technology is occurring bilaterally in hearing healthcare, this raises the question of how far the HCP can compensate for the lack of familiarity among the vast majority of patients. This is based on study results that show that personal onboarding of geronto technologies, i.e. signing up, logging in or using an app for the first time, leads to elderly users being able to use the technology successfully [19]. To investigate this effect in more detail, a study was conducted among 106 patients in Germany who received smartphone-based tele-audiology treatment after a performed onboarding in the clinic. By means of a questionnaire, the relevance of this personal assistance is determined and put into context with the traditional Technology Acceptance Model (TAM) [20]. The purpose of the paper is to prove, if the TAM can be applied generically on the patients' side and to explore the role of the HCP in this process to support the successful application of this technology in practice. For this objective, existing hypotheses were tested through the analysis of the survey and further conclusions were drawn from it.

2 Literature review

2.1 Smartphone-based tele-audiology

Beginning in the last century, tele-audiology is the use of electronic information and telecommunication technologies to support remote and distance clinical hearing healthcare [21]. This form of intervention has a long history and was first used in the U.S. several decades ago because of the insufficient number of HCPs available, especially in structurally weak counterparts. Via telephone, or later via videoconference, an HCP remotely instructed a trained practitioner on how to fit the patient's hearing aid [7], [21]. As analog technologies evolve, the internet and smartphones are replacing the circumstantial process with the practitioner and are now used to conduct an online video session directly between the HCP and the patient using an app, where the professional has full access to the hearing aid's settings. In a comparative study, it was found that from an audiological point of view, there was no difference between in-person care in the clinic and remote care via smartphone [6]. On the contrary, it could even be proven that smartphone-based tele-audiology generates benefits in the area of patient engagement and service quality, especially aspects such as a more competent perception of the professional and his equipment could be clearly demonstrated beyond the expected assumptions. [14], [22]. Audiologists are generally open to use this intervention [23], even there still exist a lot of barriers which prevent a regular use in daily practice [24]. The most named barriers are a lack of technical infrastructure, lack of training and knowledge levels of the professionals [15]. It can be assumed that the usage of mobile apps in hearing healthcare and thus the subset of tele-audiology will become more important in the future in the course of a paradigm shift, away from the clinic centered model to a patient centered one [25].

2.2 Geronto technology acceptance

To describe the acceptance of a technology by its users, Davis' TAM is probably one of the best known. As shown in Figure 1, the model states that the perceived usefulness and perceived ease of use influence on the attitude toward using resulting in the behavioral intention to use [20]. The origin of TAM is based on psychological aspects. These theories tried to explain or predict whether a technology would be applied or rejected by the user [26]. The theory of reasoned action (TRA) and the theory of planned behavior (TRB) are explicitly mentioned here [27], [28]. This model has been extended over the decades to various applications with additional latent variables. These range, for example, from online banking to e-learning [29], [30].

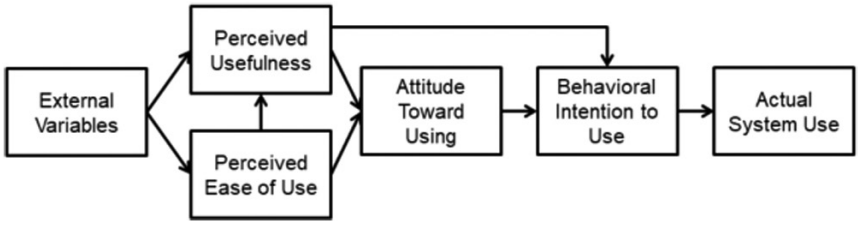

Fig. 1. Technology acceptance model according to Davis [20]

Marangunić and Granić identified the target population of older adults as one of the four most important directions for future TAM research [26]. The reason therefor is that various studies found out that age plays a key role in the interaction with technologies [31], [32]. In this context it is noteworthy to mention that cognitive abilities are strong predictors of age-related reduction in performance, perceived usefulness and perceived ease of use [33]. These facts also and especially apply to the use of tele-medicine, which is a modern form of treatment in which patient and practitioner are in different locations [34]. Since this definition also applies to smartphone-based tele-audiology, it can be seen as a subset of telemedicine. The demand for these new technologies will increase due to demographic trends. The benefits of this form of intervention are tremendous. Regardless of their limitations, older persons can live largely independently at home for longer periods of time, yet still have contact with their healthcare providers at all times and thus also get the opportunity to conveniently attend treatments and consultations [35]. In addition, it was possible to determine that patients with higher social welfare and health condition who use this technology regularly, exhibit higher quality of life and accepted use of technology [36].

As stated in [17], the usage of these new technologies of older adults counts to the field of geronto technology. Above all, these technologies are used in the areas of health, housing, mobility, communication, leisure and work of the older generations [37]. A study conducted in 2014 identified that a variety of aspects play a significant role in the successful uptake of geronto technologies. Beyond the known variables of Davis' TAM, additional latent variables were identified. Thus, geronto technology self-efficiency and anxiety, facilitating conditions, cognitive ability, social relationships, attitude of life and satisfaction and physical functioning significantly influence the perceived usefulness, usage behavior and the perceived ease of use [38]. Another study found that successful adoption of geronto technologies in mobile health applications depends significantly on the hardware used. Thus, if the application is used via a device that is used on a daily basis, such as the smartphone, the barriers on the part of the patients are greatly reduced [39]. Gell et al. determined socioeconomic and health statuses are the most significant issues for an successful technology adoption by the elderly population, followed by physical capacity and disability [40].

The relationship between the healthcare provider and the patient appears to be another key factor in technology adoption by those over 65. Forman et al. found out that the study's participants demonstrated a higher user satisfaction with an app when using

a direct messenger system with the healthcare workers [41]. Similar findings were made in another study that examined the useful addition of a face-to-face component to app use. After a study phase of several weeks, the points registration, adherence and completion were evaluated as more optimal compared to the conservative form of intervention [42].

2.3 Hypotheses development

The hypotheses essentially derive from the contexts as postulated by the TAM (H1–H5).

In addition to the hypotheses derived from the TAM, this research aims to explain the role of helpfulness of personal assistance in the context of tele-audiology. Based on Ref. [38] and [42] , it can be hypothesized that the helpfulness of personal assistance in the initial configuration of the hearing aid and tele-audiology functions has a positive effect on how ease of use of the tele-audiology application is perceived (H6).

It can be assumed that the helpfulness of personal assistance has a direct influence on the perceived usefulness of the tele-audiology subset of the app (H7).

The hypotheses are summarized in Table 1.

Table 1. Hypotheses overview

#	Hypothesis
H1	+ EASE → + USE
H2	+ USE → + ATT
H3	+ EASE → + ATT
H4	+ ATT → + BEH
H5	+ USE → + BEH
H6	+ HELP → + EASE
H7	+ HELP → + USE

Figure 2 shows the proposed model based on the TAM together with the extension to include the relevance of personal assistance in the context of tele-audiology.

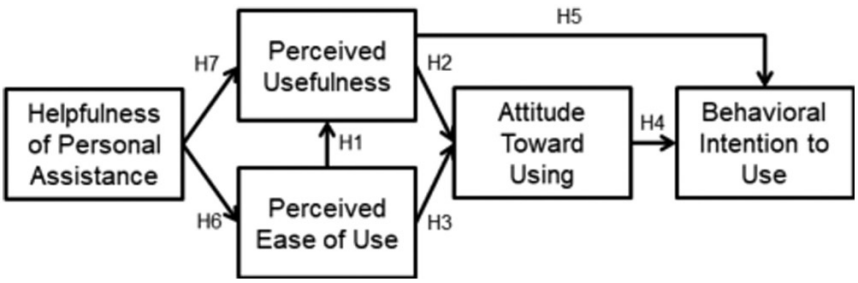

Fig. 2. Proposed model based on hypotheses

3 Empirical analysis

3.1 Data collection

To explore the relevance of personal assistance in smartphone app instruction-particularly the tele-audiology subset-an online survey was conducted among patients who have had tele-audiology experiences in the context of a hearing aid fitting. This survey was conducted among patients in clinics distributed throughout Germany. The foundation was a 13-item questionnaire, in form and content adapted to the TAM. In total, the questionnaire was answered 110 times, of which 104 returns could be considered valid.

3.2 Descriptive statistics

First, the data are described descriptively. Cronbach's alpha is used to test the reliability. Table 2 shows the underlying variables for each factor, their mean and standard deviation, and the value for Cronbach's alpha for each factor.

Table 2. Descriptive statistics overview

Factor	Variable	Mean	SD	Cronbach's Alpha
HELPfulness of Personal Assistance	01_01	4.43	.55	.71
	01_02	4.49	.61	
Perceived EASE of Use	02_01	3.62	.80	.85
	02_02	3.84	.71	
	02_03	3.43	.83	
Perceived USEfulness	03_01	3.47	.71	.81
	03_02	4.06	.60	
	03_03	4.23	.71	
ATTitude Toward Using	04_01	4.28	.57	.72
	04_02	3.92	.75	
BEHavioral Intention to Use	05_01	4.22	.61	.77
	05_02	3.92	.96	

For all factors, Cronbach's alpha is in the good range (> .80) or at least above the minimum value of .70 [43].

3.3 Results

To test the established hypotheses, a linear structural equation model is used, which is calculated with R and the R package "lavaan". Since a deviation from the condition of multivariate normal distribution of the variables is to be assumed, the model is calculated with Satorra-Bentler correction [44]. To check the goodness of fit of the model, different model fit indices are used as proposed in different places in the

literature [45]–[49]. Due to the equally chosen scales across all variables, a standardization of the coefficients is not necessary [44].

Table 3. Fit indices overview

Measure	Value	Interpretation	Literature References
Chi-square	42.305	Predicted model matches observed data	Value should be low (Gatignon, 2010, Singh 2009)
p(Chi-square)	.667	Null hypothesis is not rejected	Should be above .05 (Gatignon, 2010)
CFI (robust)	1.000	High correlation between variables	Minimum: .90; Good: .95 (Hu & Bentler, 1999, Singh 2009, Savalei 2020)
TLI (robust)	1.013	Good non-normed model fit	Minimum: .90; Good: .95 (Hu & Bentler, 1999)
RMSEA (robust)	.000	Good model fit considering model complexity	Good: <.05; Acceptable: <.06; Bad: >.08 (Hu & Bentler, 1999, Singh 2009, Savalei 2020)
p(RMSEA)	.939	Null hypothesis is not rejected	Should be above .05 (Hu & Bentler, 1999)
SRMR	.034	Strong absolute fit	Acceptable: <.08 (Hu & Bentler, 1999)

Table 3 shows an overview of the fit indices for the calculated model. The chi-square test tests the null hypothesis that the predicted model fits the observed data. The null hypothesis is not rejected (p = .667). The values for the CFI (Comparative Fit Index) and TLI (Trucker – Lewis Index) are strong and indicate a very good model fit. The model also has high significance in light of model complexity (RMSEA = .000). Overall, all values are clearly within the acceptable and satisfactory ranges according to the literature. The validity of the calculated overall model can therefore be judged as given.

The results for the model proposed in Figure 2 are shown in Figure 3. The results show that four of the paths postulated in the hypotheses have significant results (p < .05). Significant results are in bold and marked with an *.

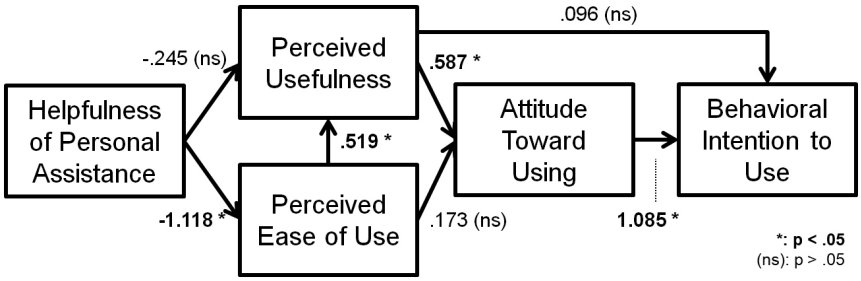

Fig. 3. Final estimated model

The results of the model calculation can confirm the hypotheses H1, H2 and H4. Perceived ease of use has a significant positive influence on perceived usefulness. Perceived usefulness has a direct positive influence on attitude toward using,

which in turn has a significant positive influence on behavioral intention to use. These results correspond to the generic hypotheses of the Technology Acceptance Model.

For the hypotheses H3, H5 and H7 no significant results can be achieved. Perceived ease of use does not seem to have a significant positive effect on attitude toward using (H3), but only indirectly via perceived usefulness. Also a direct influence of perceived usefulness on behavioral intention to use cannot be shown (H5). This influence also seems to be indirect, i.e. via attitude toward using. For perceived helpfulness of personal assistance also no significant influence on perceived usefulness can be shown (H7). The results of the hypothesis testing are summarized in Table 4.

Table 4. Hypotheses results overview

#	Hypothesis	Result
H1	+ EASE → + USE	Supported
H2	+ USE → + ATT	Supported
H3	+ EASE → + ATT	Not supported
H4	+ ATT → + BEH	Supported
H5	+ USE → + BEH	Not supported
H6	+ HELP → + EASE	Not supported, but negatively significant
H7	+ HELP → + USE	Not Supported

Surprising is the result concerning the influence of helpfulness of personal assistance on perceived ease of use (H6). Contrary to the expectations based on the literature that a perceived helpfulness of personal assistance by an audiologist has a positive effect on perceived ease of use, the model even shows a negative effect ($\beta = -1.118$). This is the strongest effect in the entire model and is even stronger than the postulated positive effect of attitude toward using on behavioral intention to use ($\beta = 1.085$).

4 Discussion

The approach of this manuscript is to examine to what extent the Technology Acceptance Model can be generically applied to uptake smartphone-based tele-audiology and how the personal assistance of the HCP affects this model. The results confirmed existing assumptions on the one hand and showed some new aspects on the other. As already described in the classic TAM, the positive influence of ease of use on perceived usefulness was demonstrated. These findings are consistent with existing studies in the field of geronto technology, which include the use of hearing aid accompanying apps including smartphone-based tele-audiology [38]. This is hardly surprising, especially with regard to the user group of older age and should be taken into account when developing smartphone apps and the associated subsets and workflows. Several study participants indicated that they had moderate difficulties pairing the hearing aids with their smartphones and navigating within the apps, and therefore they would prefer the traditional visit to the clinic instead of the smartphone-based variant. Furthermore, it was

also shown that the resulting perceived usefulness has a positive effect on the attitude towards using. With regard to this latent variable, the study found that participants rated the remote fitting option as helpful primarily because it saved them considerable time, as well as allowing them to have the hearing aids adjusted directly by the Hearing Care Professional in certain problem situations, such as understanding in noise. This effect has been scientifically proven several times and is also reflected in practice. One example in this context is the study by Ross and Wohllebe (2020), in which all subjects who received care using smartphone-based tele-audiology stated that they would also use this technology frequently in the future [14]. With regard to this statement, the survey was also able to determine that smartphone-based tele-audiology is seen as a positive trend and that participants would like to continue using this technology in the future. In addition, it was stated that this form of intervention is seen as an integral part of a new hearing aid fitting. The reasons for this were again the advantages and associated benefits of this form of intervention. All these points were unsurprising and the hypotheses arising from the literature could be confirmed accordingly.

Furthermore, this study aimed to shed light on the relevance of personal assistance in setting up in the clinic and to what extent this has an influence on the successful adaptation of the technology. Therefore, it was queried how helpful the introduction of the Hearing Care Professional was for the successful pairing of the devices with the smartphone, to what extent a personal conversation facilitated the introduction or how useful the practical introduction to the app with all its subsets was. Based on various studies in the literature, it was assumed that this form of assistance has a positive effect on the latent variable Ease of Use. This hypothesis could not be confirmed. On the contrary, it was shown that there is a negative correlation between these variables. Even though this was surprising at first, there is a plausible assumption for this phenomenon. It can be assumed that people who are not very tech-savvy anyway and therefore have difficulties with the installation and handling of the hearing aids in combination with the smartphone will particularly appreciate the personal assistance provided by the Hearing Care Professional. This circumstance is reflected with a high rating of the Help variable and a low rating of the Ease of Use variable. Thus, the relationship can be assumed to start from a third – not considered – variable, the technical affinity. Accordingly, it can be assumed that an increase in the unknown variable of technical affinity has a positive effect on Ease of Use and a negative effect on the Help variable. This aspect should be given more attention, especially in practice, as not only technologies are evolving, but also patient generations are changing, away from less technically savvy traditionalists towards the generation of baby boomers who have long been familiar with these technologies. This generation, aged 65–75, will already represent a population of 10.3 million people in 2025, or about 13.11% of the total population in Germany. The current generation of traditionalists will be 75 years and older at that time and will represent a population of only 9.72 million, or 12.3% of the total population [50]. Of course, this also means that the role of personal assistance in this field will continue to lose relevance and advanced technologies will meet users who can use them independently.

5 Conclusion

The study showed results that are relevant for research, as well as for practice. Existing hypotheses, derived from other fields of application, could also be confirmed and that certain structures of the classical Technology Acceptance Model are also relevant for the patient-side application of smartphone-based tele-audiology. In summary, it can be stated that the expectations were largely fulfilled. Only the result of the negative correlation between personal assistance and Ease of Use was surprising. The variable of technical affinity could be suspected as the cause for this. On the one hand, this circumstance limits the results somewhat, but on the other hand it shows the need for further studies that take the component of technical affinity into account. With regard to this variable, the role of personal assistance by the HCP in the clinic in performing connective processes, such as the use of hearing aid-accompanying smartphone apps, artificial intelligence, or tele-audiology sessions should be explored in particular. This aspect plays a major role, especially due to a changing generation of patients who are much more adept at using current technologies and thus have a high level of technical understanding. It can be an indication for practitioners to consider the aspect of higher autonomy of this future patient generation in their business models. Especially with regard to emerging online distribution channels in the field of hearing healthcare, where providers target autonomous, tech savvy patients, it can be concluded that the use of these online services may increase. This approach also provides a basis for further research in the area of market analysis to find out, which part of services in the context of a hearing aid fitting patients would wish to receive online or offline in the future.

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