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THE APPLICATION OF MOBILE HEALTH TECHNOLOGIES IN HEARING HEALTHCARE AND ITS EFFECTS ON SERVICE QUALITY

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Background and Objectives

Background

"Not seeing separates us from things, not hearing separates us from people." This maxim by Immanuel Kant describes in one sentence very precisely the effects of bad hearing on interpersonal relationships and thus on one of the most important aspects in our lives. How essential good hearing is, you usually notice only when your hearing begins to deteriorate. The causes for this are manifold, but mostly a wear and tear effect that occurs with increasing years of life. Due to our increasingly aging society in Europe in conjunction with increasing noise conditions it is estimated that about 30% of men and 20% of women by 70 years have a hearing loss < 30 dB SL. By the age of 80 it is assumed that 55% of men and 45% of women are already impaired by hearing loss of this type (Roth et al., 2011). Apart from some pathological causes of hearing loss that may be solved surgically, fitting hearing aids by a hearing care professional is usually the only way to compensate the hearing impairment (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). These devices have an incredible history behind them, which once began with an ear trumpet and have evolved into small, nearly invisible high-tech devices to this day that work automatically, can distinguish noise from speech, and can be paired with the patient's smartphone due to Bluetooth capability (Florian, 2003; Health, 2019; Mudry & Dodelé, 2000). This technology offers the possibility to make phone calls via the hearing instruments, stream music or use the accompanying app, where the patient has various options to change the hearing aid settings according to the situation. Not only this aspect, but

also the possibility of conducting an online video session between the hearing care professional and the patient, in which the professional has full access to the hearing aid setting - equivalent to the clinic - define this application as m-health technologies (Mechael, 2009; Weaver, 2014). These m-health technologies are covered under the classification of gerontology-technologies, as it is mainly applied to an older generation of patients (Rogers & Fisk, 2010). Since the 65+ age group is the fastest growing market for smartphones, it can be assumed that the use of these technologies will continue to increase (Rogers & Fisk, 2010; Schulz et al., 2015).

The integration of the smartphone, or the associated apps, in the fitting and use of hearing aids can be done unilaterally by the patient or bilaterally between the patient and the Hearing Care Professional (Weaver, 2014). The successful application and thus technology acceptance depends on various factors and is described in the Technology Acceptance Model according to Davis (1989). It can be defined as generic, since the effects are identical in various application areas like banking or e- learning (Al-Adwan et al., 2013; Pikkarainen et al., 2004). In Hearing Healthcare, ease of use seems to be one of the most challenging factors, as the older user group is characterized by low literacy in smartphone use, which negatively affects the mentioned variable (Wildenbos et al., 2015).

Research Gap and Contributions

The use of mobile health technologies in Hearing Healthcare is, in the broadest sense, still a fairly under-researched area. On the one hand, this is probably due to the fact that the widespread use of these technologies such as mobile apps is still quite new and the main focus is on the actual

main benefit of hearing aids, i.e. an improvement in hearing ability. This is also reflected in the current state of research. There are various publications that deal with the audiological effects of using mobile health applications. Patient use of smartphone apps was found to increase satisfaction and perceived usefulness, which led to an increase in the wearing time of the devices (Habib et al., 2019; Johansen et al., 2017; Pasta et al., 2019). In addition, the use of smartphone-based tele-audiology led to the same results as when care was provided in the clinic (Convery et al., 2020). These results are in line with results of classical tele-audiology from the last century, but the research does not go beyond the boundaries of audiology. This raises questions about the impact that the use of this technology will have on the various divisions of a clinic, particularly in the relationship between the Hearing Care Professional and the patient. This aspect can clearly be classified as a research gap of the knowledge gap type (Jacobs, 2011; Müller - Bloch & Kranz, 2015). This thesis fills this gap by taking a closer look at the effects on the service quality of a clinic through the use of smartphone-based tele-audiology.

In order for this technology to be used at all, a positive attitude towards its use by hearing care professionals, as well as patients, is essential. There are a few studies in the field of classical - analog - tele-audiology on this topic, which also deal with the barriers against its use among practitioners (Eikelboom & Atlas, 2005; Eikelboom & Swanepoel, 2016; Singh et al., 2014). In general, a fundamental openness to this procedure could be observed here. This is also consistent with a recent study of 258 Hearing Care Professionals who reported a similar level of willingness to integrate the smartphone into the hearing aid fitting process (Kimball et al., 2018). These studies point the way for broader and deeper research that

addresses the willingness to use smartphone-based tele- audiology among Hearing Care Professionals while discussing their role also in the technology uptake of patients in this context. This also has the character of a research gap, which can be further classified as a practical knowledge gap (Jacobs, 2011; Müller - Bloch & Kranz, 2015). Therefore, the thesis also focuses on this point and further explores the acceptance of this technology on the part of professionals and patients.

Research Questions and Objectives

Derived from the identified research gaps, two overarching main objectives emerge. The first objective is to find out what impact the use of mobile health technologies, in this case smartphone apps including the subset of tele-audiology, has on the quality of services and the resulting patient satisfaction. The second objective is to find out which factors are decisive for hearing care professionals and patients for the successful application of mobile health technologies in hearing healthcare and what significance different influencing factors have for this. These objectives raise certain questions that need to be answered in order to fulfill the research objectives. Thus, the following research questions arise from the objective definition:

RQ1: What effect does the use of smartphone apps have on hearing aid outcomes and patient satisfaction?

To address this research question, the application of smartphone apps in other disciplines of medicine was considered. It was found that good results could be achieved in the treatment of depression, for example. This was able to significantly improve the state of mind, especially in advanced forms of this disease (Arean et al., 2016). But also in the

treatment of speech disorders of children, which is a closely related field to hearing healthcare, it was found that smartphone apps can provide quick access to treatments and therapies that can improve the level of communication (Furlong et al., 2018). Smartphone apps are also used to assist in the treatment of tinnitus. There are a large number of publications that demonstrate positive results regarding the treatment and patient satisfaction (Mehdi et al., 2020). Therefore, hypothesis H1 can be formulated.

H1: The use of hearing aid accompanying smartphone apps have a positive impact on patient satisfaction.

RQ2: What factors have a positive impact on the hearing care professional's willingness to use mobile health technologies?

In previous publications related to traditional tele-audiology, it was found that hearing care professionals are generally open to using this form of intervention (Eikelboom & Atlas, 2005; Kimball et al., 2018a; Ravi et al., 2018). In addition, it was found that professionals have a positive attitude towards the use of smartphones and their apps in the context of hearing aid fitting. Interestingly, the professionals with longer work experience were more willing to use this technology than their colleagues with comparable less experience. The conscious perception of advantages could be taken from this. (Kimball et al., 2018). Therefore, H2 can be derived.

H2: The successful use of smartphone-based tele-audiology by professionals depends largely on the training level and the perceived benefits of the technology.

RQ3: What is the role of the hearing care professional among other key factors in patient side uptake of mobile-health technologies?

To examine the successful application of technologies, Davis' Technology Acceptance Model can be applied. Here, the aspects of perceived meaningfulness and ease of use play a decisive role in the willingness to use a technology (Davis, 1989). Above all, the aspect of ease of use must be prioritized in the application of geronto technologies, which includes hearing aid accompanying smartphone apps, and it must be emphasized that age plays a key role in the interaction with technologies (Charness & Boot, 2009; Wagner et al., 2010). In this regard, the hearing care professional can help to break down the technical barriers and facilitate the use of this technology through successful instruction. Similar effects through face to face support could be observed in other technological fields between elderly and healthcare providers (Forman et al., 2014; Varnfield et al., 2014). These facts lead to H 3.

H3: The attitude towards the use of smartphone-based tele-audiology by patients depends on the ease of use and is positively influence by the assistance of the hearing care professional.

RQ4: What impact does the use of smartphone-based tele-audiology have on the quality of services?

It has been proven that the application of mobile health technologies leads to benefit like the promotion of preventive behaviors and health monitoring, enhanced patient – doctor engagement improved service quality and patient centered care (Paglialonga et al., 2019). Several studies confirmed the positive impact on service quality and patient

satisfaction from other fields of medicine (Aljasir & Alghamdi, 2010; Chae et al., 2001; Patrick et al., 2008). These data lead to H4.

H4: The use of smartphone-based tele-audiology has a positive impact on the service quality of a clinic.

The corresponding publications that answer the research questions can be found in Figure 1for a better overview.

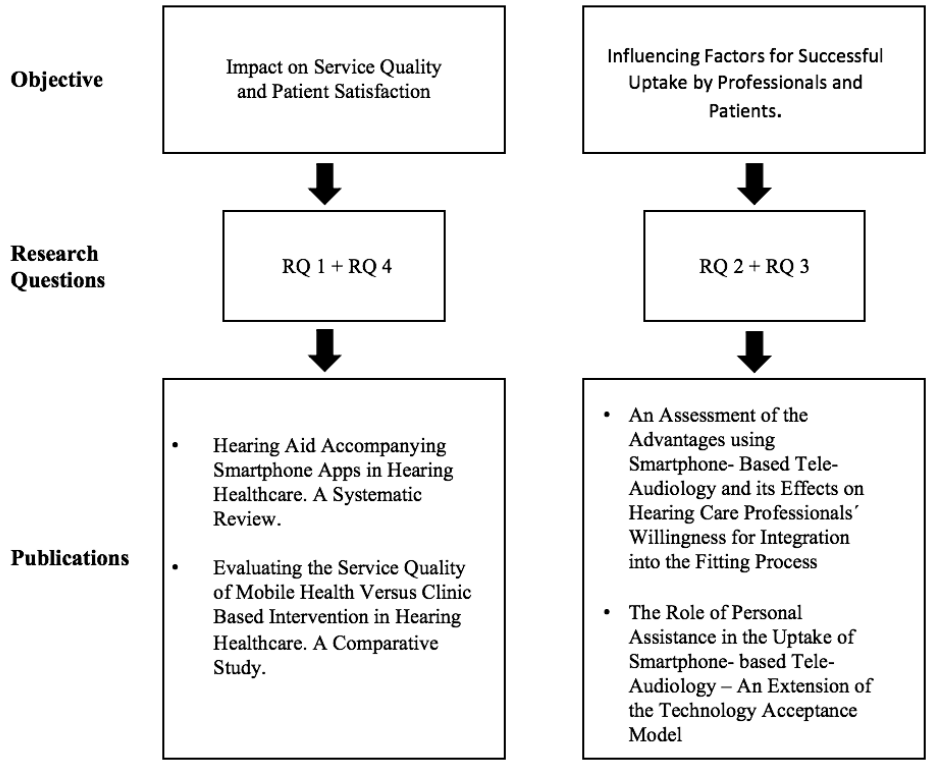

Figure 1:Research Overview

In the Systematic Review it was clearly established that the use of hearing aids generates benefits in the audiological aspects, which in a subsequent step has a positive effect on patient satisfaction, the benefit of the hearing

aids, as well as the wearing time (Habib et al., 2019; Johansen et al., 2017; Pasta et al., 2019). In addition, it was found that the use of the app by the patient leads to more active role in the entire fitting process, and that this higher level of commitment also has positive effects on the wearing behavior and consequently on satisfaction (Tognola et al., 2015).

In the following publication, the influence of the use of mobile health applications on the quality of services was investigated. For this purpose, a comparative study with 30 participants was conducted to highlight the differences to the traditional variant in the clinic. It was found that the use of these technologies creates advantages in various service dimensions and, in a meaningful combination with the traditional variant, results in the highest possible level of service quality.

To address the issue of successful application by the hearing care professional, the third publication deals with factors that have a positive influence on the willingness to use smartphone-based tele-audiology. A survey of 156 German hearing care professionals showed that factors related to training and experience with the technology had a positive influence on its use. In addition, it was found that the conscious perception of benefits outside audiological aspects also had a positive effect.

The fourth publication focused on patient application of mobile health technologies. Here, the focus was placed on the factors that lead to successful acceptance of these technologies in a survey. In addition, the role of the hearing care professional in the context of personal assistance in the instruction of the technologies was examined in more detail. Existing hypotheses could be confirmed, and it could be concluded that

with an increase in technical affinity the relevance of personal assistance decreases.

Materials and Methods

The purpose of this chapter is to provide an overview of the research methodology.

The first step was to conduct a systematic review to identify publications in the field of hearing aid-accompanying smartphone apps. For this purpose, the Prisma Flow Chart was chosen as a method (Liberati et al., 2009).

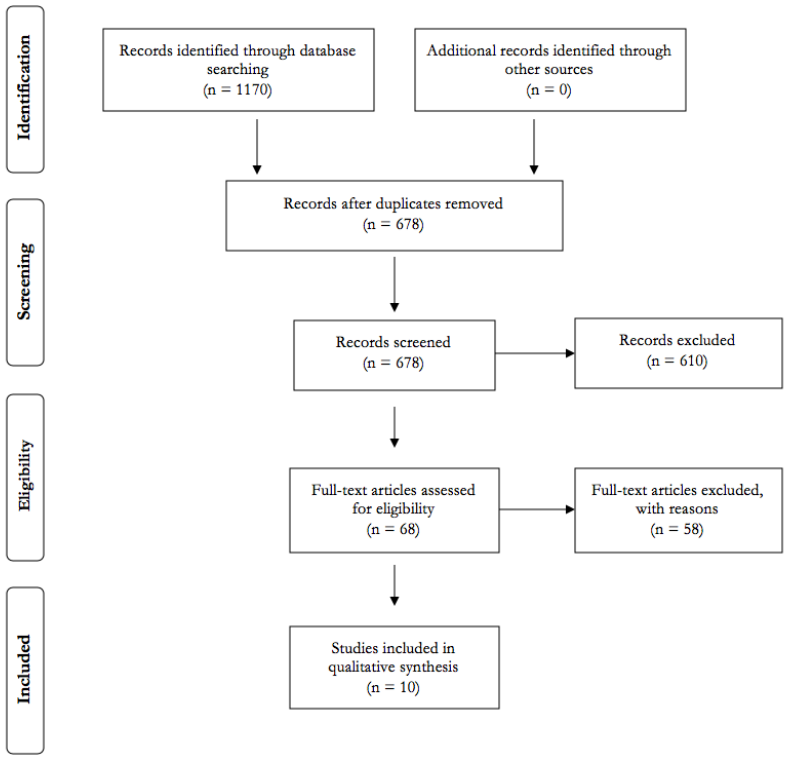

Figure 2: Prisma Flow Chart according to Liberati et. al. (2009)

The following publication then aimed to investigate the willingness to use smartphone-based tele-audiology among German hearing care

professionals as well as several influencing factors. An online-based survey was conducted in the first half of 2021. For this purpose, a questionnaire was developed that asked for various data related to the topic. First, values were collected in relation to the HCP in order to be able to better classify the responses in the field of Tele- Audiology. The focus here was on values relating to the level of education and professional experience. Furthermore, the basic willingness as well as the experience - i.e. the actual use of smartphone-based Tele-Audiology - were asked.

The responses were analyzed descriptively first to get an overview of the data collected. Using multiple linear regression, the relationships of the hypotheses were examined (Cohen, 1977). Since there was no normal distribution of the variables in one hypotheses, proved with the Shapiro – Wilk Test (Shapiro & Wilk, 1965), this was checked using the Spearman correlation (Spearman, 1904).

The third publication aimed to investigate the patient-side prerequisites for successful use of smartphone-based tele-audiology. Davis' Technology Acceptance Model was used as a guideline. In addition, the relevance and thus the role of the hearing care professional in this process was to be considered more closely and the model was to be extended to include this variable.

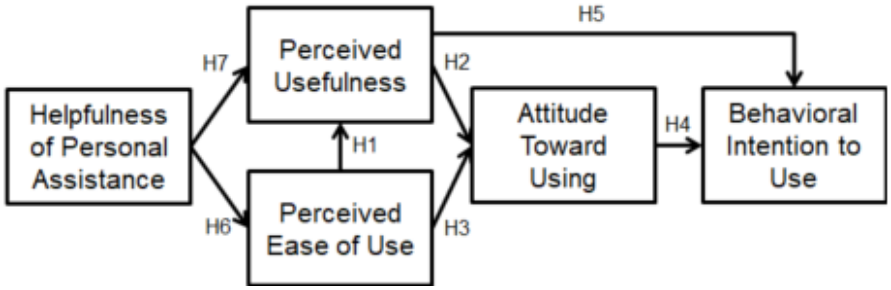

Figure 3: Technology Acceptance Model according to Davis (1989)

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 final publication was then to explore the effects of technology on service quality in the context of hearing aid fitting. For this purpose, a study was conducted with 30 subjects who were divided into two groups, a tele-audiology intervention group and a clinic-based control group. In order to measure the service quality, a 22-item questionnaire was developed according to the SERVQUAL method (Parasuraman et al., 1988). The subjects were interviewed two times, first at the beginning of the study to inquire the expectations on the service quality of a hearing care company and again at the end of the study to determine the actual perceived performance. The individual scores between the expected and actual perceived service were compared and the difference was determined. These gaps were finally checked statistically to make the results valid.

In Table 1, the individual methods, as well as the statistical calculations used, can be taken.

Table 1: Overview Materials and Methods

Publication	**Materials and Methods**
Hearing Aid Accompanying Smartphone Apps in Hearing Healthcare. A Systematic Review	• Systematic Review • PRISMA Flow Chart
An Assessment of the Advantages using Smartphone- Based Tele-Audiology and its Effects on Hearing Care Professionals´ Willingness for Integration into the Fitting Process	• Linear Regression • Shapiro Wilk Test • Spearman Correlation
The Role of Personal Assistance in the Uptake of Smartphone- Based Tele-Audiology – An Extension of the Technology Acceptance Model	• Cronbach Alpha Test • Linear Structural Equation Model
Evaluation the Service Quality of Mobile Health Versus Clinic Based Intervention in Hearing Healthcare. A Comparative Study	• Cronbach Alpha Test • Paired T - Test

Results

In the following, the contents of the qualitative synthesis of the Systematic Review are summarized and listed with the main features. In addition, the included articles have been grouped.

Table 2: Summary of the review´s results

Classification and Assessment

Author	Aim	Methods	Outcomes
1. Offiah et. al. 2014	Investigation of the connection between hearing aids and a smartphone app in terms of algorithms with the aim of a better differentiation of speech and noise.	Computer based app examination of ten different apps and evaluation with a Cost- Utility Analysis (CUA) as a general framework.	The tested three hearing aid accompanying apps leave a lot of room for improvement and aimed a relatively low score in the CUA. This is largely due to their low scoring in- and output support
2. Paglialonga et. al 2015	Review of available smartphone apps in Hearing Healthcare	Reviewing available apps in the field of hearing healthcare on the Apple Store, Google Play and the Windows Phone Store.	200 Hearing Healthcare related apps were found in the App Stores and grouped into five different categories.
3. Paglialonga et. al 2015	Evaluation of Apps in Hearing Healthcare in regarding of services, price and the need for additional external devices	Evaluation of available smartphone apps focused on service offered by the app, the apps price and the need for additional equipment or devices.	203 apps in hearing healthcare are available for HCPs and hearing impaired persons. Regarding to hearing aid accompanying smartphone apps it can be determined that they can increase mutual interactions between patients and audiologists and increase patient´s satisfaction.

4. Tognola et. al 2015	Developing of an e-health model for people with hearing loss, to take the digital transformation into account	Analysis of four target groups of people with hearing loss with several demands concerning hearing aid usage.	A ehealth4hearing paradigm was defined, which is delivering a new patient – centered model where people can use e-health tools in various steps of the patient journey in hearing healthcare. Due to the resulting higher engagement, they become an active participant in the fitting process.
5. Paglialonga et. al. 2017	Developing of a user support tool for a more informed adoption of health apps	The research was done in three steps from outlining a descriptive method to characterize hearing healthcare apps, visualizing it and proposing an automated approach, able to extract information about apps directly from the web.	Creation of the ALFA4hearing model, which classifies hearing aid apps in hearing healthcare in regarding of promoters, services, implementation, users and descriptive information.

Practical Application

Author	Aim	Methods	Patients Information	Outcomes
6. Johansen et. al. 2017	Inference of the optimal hearing aid settings, based on user adjustments in real life situations over an app.	The participants had the opportunity to change the hearing aid´s setting with the app. The setting´s changes were assessed depending of the day of the week.	N = 6, Ø Age: 61,8, Mild-severe hearing loss	Different hearing aid settings regarding to program changing and adjusted volume depending of the day of the week. The inclusion of individual behavior patterns in the settings can have a positive influence on the use of the devices.
7. Habib et. al. 2019	Identifying the user´s preferences and usability and the benefits of using an accompanying smartphone app	Participants were equipped binaurally with hearing aids and the accompanying smartphone app. After seven weeks, the app usage was evaluated and compared to a control group.	N = 30 Ø Age: 68 Ø Hearing loss: 38 dB HL	Subjects had significant improvements due to the usage of the smartphone app, especially in hearing aid benefit and satisfaction.

8. Pasta et. al 2019	Finding the optimal hearing aid settings in a defined context and situation.	Comparison of the individualized hearing aid settings created by the patient´s app usage with those from traditional clinic workflows.	N = 7 Ø Age: 58,3 Mild – moderately severe hearing loss	Five out of six participants preferred the self - adjusted settings with the app compared to the traditional clinic workflow.
9. Convery et. al 2020	Analysis of the effect of using an accompanying smartphone apps in regarding of patients / audiologist communication and hearing aid outcomes.	Participants were divided into a intervention and a control group. The intervention group used an app and was attended over it digitally. The control group was attended traditionally.	N = 30 Ø Age: 67 Ø Hearing Loss: 45dB HL	Using the app has no detrimental effect on hearing aid outcomes and can improve the communication between patient / audiologist

Integration into the Fitting Process

Author	Aim	Methods	Outcomes
10. Kimball et. al. 2018	Investigation of the willingness to integrate smartphones into the fitting process among audiologists.	Questionnaire based survey among 258 audiologists in the USA	A mayor part of the audiologists is open to integrate smartphones into the fitting process, especially those with more years of experience.

The results of the study conducted on the willingness to use smartphone-based tele-audiology confirmed some of the findings of the Systematic Review while creating new knowledge in this field.

The developed questionnaire was answered 156 times, of which 141 could be considered valid. Only five HCPs rejected the use of the technology in principle or stated that they were not willing to do so. Accordingly, 136 professionals were positive about its use. Most of the survey participants had a high level of education, i.e. that of master craftsman. The second relevant group was the journeymen. Apprentices and career changers were hardly represented here.

In order to test the hypotheses, a regression analysis is performed. The model is usable ((R^2 = .0485, $F(2,133)$ = 3.39, p = .0368) and can be applied accordingly.

Table 3: Influence of Experience on Willingness

Source	SS	df	MS	Number of obs	136
Model	.8935	2	.4467	F (2, 133)	3.39
Residual	17.5476	133	.1319	Prob > F	.0368
Total	18.4411	135	.1366	R-squared	.0485
				Adj R-squared	.0341

AttRF	Coef.	Std. Err.	t	P > |t|	[95% Conf.	Interval]
LevelRank	.1791	.0689	2.60	.010	.0427	.3155
ExpTotal	-.0550	.0400	-1.37	.172	-.1342	.0241
_cons	2.8582	.1460	19.56	.000	2.5693	3.1472

H1: A higher level of education (Level Rank) of the Hearing Care Professional leads to a higher willingness to use smartphone-based Tele-Audiology. Table 2 shows the results of the multiple regression and explains the positive effect of the level of education on the HCPs´ willingness (ß = .1791, t(133) = 2.60, p = .010.). H1 can be confirmed.

H2: Hearing Care Professionals with a higher level of work – experience, are more likely to use smartphone- based Tele- Audiology. It can be seen that the work experience has no significant effect on the positive attitude towards Tele- Audiology (ß = -.0550, t(133) = -1.37, p = .172). Therefore, H2 must be rejected.

H3: There is a correlation between the experience with remote fitting and the general attitude towards smartphone-based Tele- Audiology. To test the correlation of experience with Tele- Audiology and the actual willingness to use it, a Shapiro- Wilk test was first performed to test the normal distribution of the variables. Since these were not normally distributed (AttRF W = .9392, p = .0000; ExpRF W = .9767, p = .0196),

the Spearman correlation was used. Here, values of rs = .5017, p = .0000 could be determined, indicating a strong positive correlation. H3 can therefore be confirmed.

To test hypotheses H4a-h, another multiple regression analysis was performed.

Table 4: Perceived Advantages

Source	SS	df	MS	Number of obs	136
Model	2.8129	8	0.3516	F (8, 127)	2.86
Residual	15.6281	127	0.1230	Prob > F	0.0059
Total	18.4411	135	0.1366	R-squared	0.1525
				Adj R-squared	0.0992

AttRF	Coef.	Std. Err.	t	P > |t|	[95% Conf.	Interval]
MoAdjInit	-.0021	.0419	-.05	0.0960	-.0850	.0808
MoFlex	-.0299	.0637	-0.47	0.639	-.1560	.0961
MoService	.0172	.0586	0.29	0.769	-.0988	.1333
MoAdjCont	.0289	.0470	0.61	0.540	-.0642	.1220
MoAdjDirect	-.264	.0374	-0.71	0.481	-.1006	.0476
MoCompetition	.0555	.0575	0.97	0.336	-.0582	.1693
MoCustGen	-.979	.0634	-1.54	0.125	-.2235	.0276
MoCompetence	.1459	.0478	3.05	0.003	.0513	.2405
_cons	2.832	.3076	9.21	0.000	2.2242	3.4416

This model is also statistically useable (R^2 = .1525, F(8, 127) = 2.86, p = .0059) with a moderate R^2 (Cohen, 1977). Directly, only H4h can be confirmed (ß = .1460, t(127) = 3.05, p = .003). The remaining variables have no significant effect on willingness to use. Accordingly, hypotheses H4 a-g must be rejected. At any rate, this is the consequence of

considering the individual variables separately. If these variables are limited to the advantages outside of audiology, i.e. the more business-oriented ones – increasing the service quality of the clinic, creating competition advantages, addressing new customer generations and increasing level of expertise and competence - it can be seen that these together are very significant ($F(4, 128) = 5.00$, $p = .0009$) and thus have a positive effect on the willingness to use.

Table 5: Business Orientated Variables

(1) MoCompetence = 0
(2) Mo Competition = 0
(3) MoCustGen = 0
(4) MoService = 0

F(4, 128) = 5.00

Prob > F = 0.0009

Due to this, the rejection of the mentioned hypotheses must be considered in a differentiated and limited way.

After examining the influences on the use of technology on the part of the hearing care professional, the factors necessary for successful use on the part of the patient are examined. In addition, the hearing care professional and its role in this will be examined in more detail. For this purpose, the interaction of the individual variables in the Technology Acceptance Model (Davis, 1989) was examined and extended.

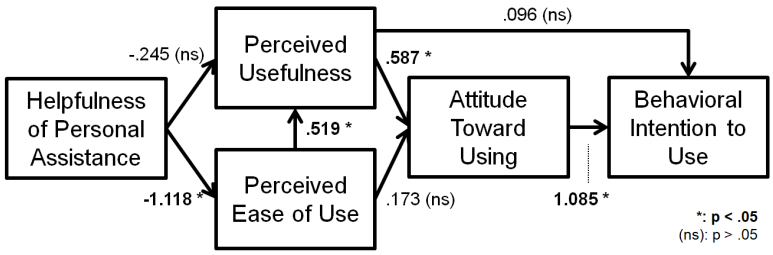

Figure 4: Final Estimated Model

The results of the individual hypotheses can be taken from Table 6.

Table 6: 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

The results of the model calculation can confirm the hypotheses H1, H2 and H4. For the hypotheses H3, H5 and H7 no significant results can be achieved.

Surprising is the result concerning the influence of helpfulness of personal assistance on perceived ease of use. 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 (β = -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 (β = 1.085).

After the factors for a successful application had been determined, the effects on the service quality of a clinic could now be examined and compared with the traditional variant. The results of the gap analysis across the individual dimensions can be found in Table 7.

Table 7: Service Quality Scores

	Tele-Audiology					Clinic				
	(E)	(P)	(P-E)	t-value	p-value	(E)	(P)	(P-E)	t-value	p-value
Tangibility	**6.02**	**5.10**	**-0.92**			**5.87**	**5.12**	**-0.75**		
1. The clinic works with Up to date equipment	6.46	6.13	-0.33	-2.09	0.0276	6.00	5.07	-0.93	-5.13	0.0001
2. The fitting environment is visually appealing	5.54	4.47	-1.07	-6.96	0.0000	5.87	5.20	-0.67	-3.57	0.0015
3. The HCP is visually appealing	5.60	4.67	-0.93	-4.09	0.0006	5.20	4.73	-0.47	-3.50	0.0018
4. The environment is appropriate for the fitting process	6.46	5.13	-1.33	-7.13	0.0000	6.40	5.47	-0.93	-5.13	0.0001
Reliability	**6,52**	**5,80**	**-0,72**			**6,15**	**5,44**	**-0,71**		
1. The technology used ist reliable	6.66	5.53	-1.13	-5.91	0.0000	6.40	6.00	-0.40	-3.06	0.0043
2. The HCP proceeds in a structured manner to solve a problem	6.67	6.00	-0.67	-3.57	0.0015	6.27	5.60	-0.67	-3.16	0.0035
3. Problems with the hearing aids are solved immediately	6.20	5.80	-0.40	-2.45	0.0140	5.93	4.60	-1.33	-7.14	0.0000
4. Services are executed at the promised time	6.67	6.27	-0.40	-2.10	0.0270	6.26	5.73	-0.53	-2.78	0.0074
5. Necessary information relating to the hearing aid fitting is provided	6.40	5.40	-1.00	-7.25	0.0000	5.87	5.27	-0.60	-3.67	0.0013
Responsiveness	**5.98**	**5.53**	**-0.45**			**5.83**	**5.23**	**-0.60**		
1. The information about follow-up appointments is precisely	5.87	5.20	-0.67	-5.29	0.0001	5.46	4.93	-0.53	-2.78	0.0074
2. The patients are treated immediately and without long waiting periods	6.20	5.87	-0.33	-2.65	0.0096	6.13	5.40	-0.73	-4.04	0.0006
3. The HCP is always ready to assist the patients	5.46	5.13	-0.33	-2.65	0.0096	6.00	5.27	-0.73	-4.04	0.0006
4. The HCP is never too busy to respond to patients´ requests	6.40	5.93	-0.47	-3.50	0.0018	5.73	5.33	-0.40	-2.10	0.0027
Assurance	**6.52**	**5.77**	**-0.75**			**6.32**	**5.72**	**-0.60**		
1. The HCP creates trust with the patients	6.40	5.80	-0.60	-4.58	0.0002	6.40	6.00	-0.40	-3.06	0.0043
2. The HCP conveys a sense of seriousness during the fitting process	6.67	5.80	-0.87	-6.50	0.0000	6.53	5.94	-0.60	-3.67	0.0013
3. The HCP is always friendly in contact with patients	6.20	5.40	-0.80	-5.53	0.0000	5.60	5.00	-0.60	-4.58	0.0002
4. The HCP has a high level of competence and expertise	6.80	6.07	-0.73	-4.78	0.0001	6.73	5.93	-0.80	-4.00	0.0007
Empathy	**5.70**	**4.96**	**-0.74**			**6.09**	**5.19**	**-0.90**		
1. The patients receive a high degree of individual attention	5.73	5.00	-0.73	-3.21	0.0031	6.00	5.40	-0.60	-4.58	0.0002
2. The services are convenient for disabled patients	5.47	4.87	-0.60	-4.58	0.0020	6.07	4.60	-1.47	-6.20	0.0000
3. The HCP understands the personal needs of the patients	5.93	4.87	-1.07	-9.03	0.0000	6.20	5.53	-0.67	-4.18	0.0005
4. The interests of the patients are the main focus for the HCP	5.27	4.47	-0.80	-4.58	0.0002	6.00	5.33	-0.67	-5.30	0.0001
5. The services are offered at times appropriate to the patients	5.93	5.60	-0.33	-2.09	0.0276	6.20	5.07	-1.13	-5.27	0.0001
Overall Service Quality	**6.14**	**5.43**	**-0.71**			**6.06**	**5.34**	**-0.72**		

Through the publications, the set Research Objectives could be achieved, and the Research Questions could be answered. The resulting hypotheses could also be evaluated. An overview can be found in Table 8Table 9

RO: Impact on Service Quality and Patient Satisfaction

Table 8: H1 + H4 Results

Hypothesis	**Result**
H1: The use of hearing aid accompanying smartphone apps have a positive impact on patient satisfaction.	supported
H4: The use of smartphone-based tele-audiology has a positive impact on the service quality of a clinic.	supported

RO: Influencing Factors for Successful Application by Professionals and Patients

Table 9: H2 + H3 Results

Hypothesis	**Result**
H2: The successful use of smartphone-based tele-audiology by professionals depends largely on the training level and the perceived benefits of the technology.	Supported
H3: The attitude towards the use of smartphone-based tele-audiology by patients depends on the ease of use and is positively influence by the assistance of the hearing care professional.	Supported with limitations

New Scientific Results

Table 10: Overview of New Scientifc Results

Result	**Novelty**	**Publication**
The use of smartphone apps that accompany hearing aids leads to audiological benefits, as well as higher patient satisfaction through patient engagement.	The first Systematic Review of hearing aid accompanying smartphone apps in hearing healthcare.	(Ross, 2020)
Through smartphone-based tele-audiology, an equal level of service quality can be generated compared to the traditional face-to-face variant.	The first examination of effects of smartphone-based tele- audiology outside of audiological aspects AND comparison to the traditional form of intervention.	(Ross & Wohllebe, 2021)
Level of education and experience with smartphone - based tele-audiology of the hearing care professional have a positive influence on the willingness to use.	The first investigation of the influence of education and experience on the willingness to use smartphone-based tele-audiology.	(Ross, 2022)
Perceived business-oriented benefits from smartphone-based tele- audiology have a positive impact on the willingness to use on hearing care professionals.	The first study to examine the effects of perceptions of audiology and non-audiology benefits on hearing care professionals.	(Ross, 2022)
The ease of use of smartphone-based tele-audiology has a positive effect on the actual use by patients.	The first investigations of the conditions for the application of smartphone-based tele- audiology by patients using the Technology Acceptance Model	(Ross et. al., 2022)

Negative correlation between Personal Assistance and Ease of use in patient use of smartphone-based tele - audiology.	Development of an extended Technology Acceptance Model for the purpose of laying the foundation for further research in the area of technical affinity of changing patient generations on new business models.	(Ross et. al., 2022)

The Systematic Review was the first to summarize the use of apps that accompany hearing aids. It was found that the use of these small programs not only has a positive impact on hearing aid outcomes, but that patient involvement leads to a higher level of satisfaction with the devices.

In addition, the service quality study addressed for the first time the effects outside the audiology fields of using mobile-health technologies. It could be shown that the perceived service quality, compared to the conservative form of the intervention, achieved similar results.

To analyze the area of technology use, for the first time, the willingness of Hearing Care Professionals to use the technologies depending on their education and experience was investigated. It could be shown that the level of education and experience with this technology have positive effects on the willingness to use it. Furthermore, individual advantages of the technology were evaluated to determine how far these positively change the willingness to use the technology. It was found that advantages in the business-oriented area had a positive influence. Due to 141 validated answers, it should be mentioned limiting that another survey with a larger number of respondents would provide a more

accurate picture. This should be conducted in a few years when a larger number of professionals have experience with these technologies

There were also new scientific findings in patient use. It was possible to verify that the ease of use of the app for smartphone-based tele- audiology has a positive influence on the actual use of the technology. With the aim of creating a basis for further research in the area of the influence of technical affinity, an extended Technology Acceptance Model for the use of smartphone-based tele- audiology was developed that also considers the role of personal assistance by the professional. This provides direction for more in-depth research in this area.

Conclusions and Suggestions

The research has focused intensively on the application of mobile health technologies in hearing healthcare and has identified the factors for successful application. In addition, the effects that arise from the use of the technology could also be demonstrated outside of the purely audiological component.

Across publications, it can be concluded that the use of mobile health technologies generates clear benefits at different levels - audiological as well as business. Especially with regard to further developments in the field of hearing aid technology in combination with a changing generation of patients, a lot of opportunities are revealed for hearing care professionals.

The achievement of the set research objectives or the answering of the posed research questions by the publications leads to an indication of further research in these areas based on the available results. Especially the publication The Role of Personal Assistance in the Uptake of

Smartphone-Based Tele-Audiology – An Extension of the Technology Acceptance Model, had the goal to create a basis for the investigation of the component of the technical affinity of future patient generations on the use of mobile health technologies, as well as in the further step on a change or amendment of business models. This aspect in particular raises the question of how far online-based business models can gain relevance in the distribution of devices and thus points the way for further research.

Papers of the Cumulative Dissertation

Ross, F. (2020). Hearing Aid Accompanying Smartphone Apps in Hearing Healthcare. A Systematic Review. *Applied Medical Informatics.*, *42*(4), 189–199.

Ross, F. (2022). An Assessment of the Advantages using Smartphone-Based Tele- Audiology and its Effects on Hearing Care Professionals´Willingness for Integration into the Fitting Process. *Proceedings of International Conference on Interactive Mobile Communication, Technologies and Learning IMCL 2021*.

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