DOCTORAL (PhD) DISSERTATION

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

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1. GENERAL INTRODUCTION WITH BIBLIOGRAPHY

“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)

1.1. Mobile-Health

Electronic health belongs to the area of medical informatics, which is an emerging field. It can be defined as the delivering of health services, using the internet and related technologies (Eysenbach, 2001). Mobile-Health is a subset of this and uses mobile devices to deliver these services to the patients (Mechael, 2009). Generally it can be stated that the use of these technologies is increasing and offers benefits like an enhanced patient-doctor engagement, improved service quality and patient-centered

care (Aljasir & Alghamdi, 2010; Chae et al., 2001; Paglialonga et al., 2019; Patrick et al., 2008). However, when considering these studies, it is important to mention in a limiting manner that the mobile-health technologies used were used as an adjunct to conservative in-person care (Lee et al., 2018). A 2018 study directly compared the face-to-face variant of treatment with the mobile-health variant in the area of mental illness. Good treatment results were observed in both groups, as well as a high level of patient satisfaction. The use of mobile-health technologies also resulted in high levels of patient engagement (Ben-Zeev et al., 2018). These high satisfaction rates are also found on the side of healthcare providers from various medical fields (Dobrusin et al., 2020; Fieux et al., 2020; Layfield et al., 2020). At this point, it should be mentioned that the data collected was gathered during the Corona pandemic and may have been the only viable form of intervention

1.2. Hearing Aid Fitting

Due to the increasingly noisy environment and the aging of society, the number of people with hearing loss is increasing. As mentioned, it is anticipated that approximately 30% of men and 20% of women will have a hearing loss by the age of 70 that indicates the need for hearing aids. By age 80, this is already the case for 55% of men and 45% of women (Roth et al., 2011). The impact of unaddressed hearing loss at this level of severity is greater than initially thought. Problems understanding speech, especially in challenging acoustic situations, is one of the biggest issues for patients. In addition, the hearing and localization of sounds is significantly limited. However, these limitations in audiological terms have far-reaching negative consequences for patients in psychological and social aspects, leading to a reduction in quality of life due to isolation,

reduced social activities, the feeling of being excluded and the resulting increase in depression symptoms (Arlinger, 2003). Apart from pathological causes that can be surgically corrected, fitting hearing aids is usually the only way to compensate for this deficit. This fitting is performed in a clinic by a hearing care professional. In the first step, audiological measurements are taken to determine the type and severity of hearing loss. In the next step, hearing aids are fitted on this basis. A review of the setting, patient satisfaction, and minor readjustments to the settings are made at short intervals until a final setting is achieved (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998).

Just like fitting methods, hearing aids have changed over the past few decades. Starting with the ear trumpet, which merely amplified the acoustics by focusing the sound and directing it into the ear, technology has evolved with the help of transistors and microprocessors, enabling clear transmission across all relevant frequencies due to digital signal processors (Mudry & Dodelé, 2000). The American Food and Drug Administration (FDA) defines hearing aids as sound amplifying devices, designed to aid people who have a hearing impairment. The essential components are specified as at least one microphone to pick up sound, an amplifier to amplify the sound, and a loudspeaker for the purpose of directing the sound to the ear canal (Health, 2019).

1.3. Tele-Audiology

Apart from traditional hearing aid fitting in the clinic, patient care exists via tele-audiology. The early form can be seen as a precursor of modern tele-medical applications. According to Northern, tele- audiology can be defined as the use of electronic information and telecommunication technologies to support remote and distance clinical hearing healthcare

(Northern, 2012). In the early 1960s, this technology was used the first time due to a maldistribution of hearing care professionals in depressed areas of the United States (Gladden et al., 2015). Thus, the onset of use of tele- audiology is relatively identical to many other telemedicine procedures from other disciplines of medicine (Ashley, 2002). Results from other areas show the potential that telemedicine offers. For example, the Medical Center of Central Massachusetts conducted a comparative study in the field of psychiatric medicine, in which it compared the results between the traditional clinic variant with that of telemedicine. The results correlated with each other, which corresponded to an equivalent treatment method (Bear et al., 1997). A recent study from 2018 in the field of mental illness, which can be considered as a related field, confirms these results (Ben-Zeev et al., 2018). Similar results in terms of hearing aid outcomes and patient satisfaction have also been demonstrated through the use of tele-audiology. A cohort of n=197 veterans received tele-audiology care over a three-month period. At the conclusion of these studies, it was found that nearly all areas were rated as excellent. Here, from the equipment used, the technical infrastructure and quality, the subjective satisfaction with this form of intervention was also taken into account. In addition, participants indicated a score of 4.85 on a 5-point Lickert scale that they would prefer this form of care over traditional. Compared to the face to face variant, another study by the Veterans Health Administration found that using the IOI-HA (International Outcomes Investor for Hearing Aids), the tele-audiology form of intervention provided good or even better results (Gladden et al., 2015).

In hearing healthcare, as in other fields of telemedicine, there are asynchronous and synchronous procedures. Asynchronous data transfer is used, for example, for the transmission of audiograms, tympanograms or brain wave measurements via e-mail or fax. Synchronous procedures are defined when the hearing care professional delivers services to the patient in real time. In the classic form of tele-audiology in the era without smartphones, this was realized via webcam or laptop. In addition, the synchronous variant is divided into pure consultation, as well as the implementation of concrete audiological activities such as hearing measurements or hearing aid programming. For this model to work, in addition to the hearing care professional and the patient, a facilitator was needed to carry out the instructions received from the professional which can be seen in Figure 1 (Krumm & Syms, 2011).

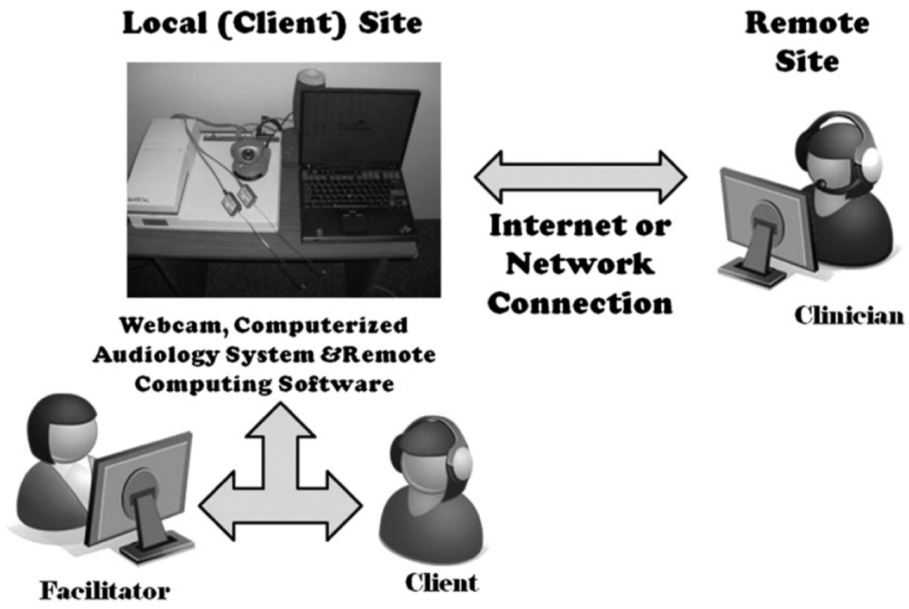

Figure 1: Procedure Tele- Audiology (Krumm & Syms, 2011)

Telehealth applications can be divided into three categories in the field of hearing healthcare. Screening, diagnosis and audiological interventions (Swanepoel & Hall III, 2010). Up to the present day and the associated use of the smartphone, including the apps that accompany hearing aids, the main focus has been on audiological intervention, i.e. changing hearing aid settings remotely (Ross, 2020b).

1.4. Smartphone Apps

With the possibility of connectivity via Bluetooth between the hearing aids and the smartphone, a lot of new possibilities emerged and also changed the processes of the classic tele-audiology. The resulting procedures and services can be assigned to the field of electronic health, which is in the context of applied medical informatics strongly emerging, characterized by the delivery of health services through the Internet or similar technologies (Eysenbach, 2001). The use of mobile devices such as the smartphone in this area, defines processes of this type as mobile-health, which is a subset of electronic-health (Mechael, 2009). In this context, the use of hearing aid accompanying smartphone apps plays a major role in hearing healthcare.

The first records of this already existed in 2014, when researchers investigated the technical aspects of the connection between hearing aids and smartphone apps. It was possible to conclude that the three hearing aid manufacturer apps tested, still had some weaknesses and offered potential for optimization (Offiah et al., 2014). Since these were the first steps in mobile smartphone apps in hearing healthcare, these results are also less surprising. In the same year, researchers searched all relevant app stores for hearing healthcare apps and grouped them into different categories a) education and information b) hearing testing c) rehabilitation

d) sound enhancement e) assistive tools. With the apps found from the hearing aid manufacturers, settings on the hearing aids could be changed by the patients and the operation of the devices could be adjusted to personal preferences. This intervention by patients and the more active role they play is described as part of the paradigm shift away from traditional clinic centered- towards a more patient centered care (Paglialonga et al., 2015a). In a further study analyzing apps in this area, the authors concluded that the use of manufacturer apps improves the mutual interactions between hearing care professionals and patients, which has positive effects on satisfaction with the hearing aids. However, in the negative case, this increase in patient autonomy could lead to a neglect of contact with the professionals (Paglialonga et al., 2015c).

To account for the paradigm shift and the changes taking place, an e-health 4 Hearing model was developed in which mobile smartphone applications play an essential role. In this model, target groups of hearing-impaired people were defined, as well as their different needs in the context of better hearing. Here, it could be proven that the majority of patients consider it positive when personal wishes regarding hearing can be realized even through the use of the smartphone app. Through the possibilities offered by the apps, the patient becomes an active participant in the hearing aid fitting process and thus achieves a high level of patient engagement (Paglialonga et al., 2017).

To explore how hearing aids are worn under real-world conditions, Johnsen et. al. conducted a study with six experienced hearing aid wearers. They were equipped with Bluetooth-enabled hearing aids and a smartphone including the corresponding app. Over the course of the week, the patients' adjustments were evaluated in terms of days of the

week and times of day. It was shown that the preferred hearing aid settings are time-dependent and that these behavioral patterns must be taken into account in the hearing aid fitting process. The use of smartphone apps is key to this and is also considered by the authors to be part of the paradigm shift (Johansen et al., 2017).

To determine the functionality of hearing aid accompanying smartphone apps, Habib et. al conducted a study with a cohort size of n=30 over a period of six weeks. Specifically, subjects were asked to rate the use, as well as the personal benefits, of smartphone apps in the context of hearing aid use. It was found that the apps fully met the needs of the users and that access to the settings of the devices created a higher level of trust towards the technology, especially in challenging hearing situations. A variety of benefits were demonstrated to accrue to the patient through app use. In particular, when understanding speech in noise, device settings were noticeably optimized which led to an increase in the wearing time of the devices (Habib et al., 2019).

In order to compare the actual hearing aid settings from the clinic with the additional settings modified by the app, a study with seven subjects was conducted in real listening situations. The test subjects were given the option via app to change noise reductions, directionality of the microphones, brightness and soft gain in four different levels. In addition, the listening situations they were in, their emotional state and what they wanted to achieve audiological were recorded in detail. These aspects were then finally incorporated into a personalized device fitting and compared with the clinic's regular fitting. Six out of seven of the subjects opted for the personalized settings derived from real-life listening situations (Pasta et al., 2019). At this point, however, it should be

questioned a bit critically whether the subjective change in the hearing aid´s settings also generates objective advantages or at least no disadvantages, such as the reduction of required amplification in the speech area.

As mentioned in the introduction, many hearing aid manufacturers offer a subset in their apps that enables smartphone-based tele-audiology. This remote fitting option, in which the hearing care professional has full access to the settings of the devices, was investigated in another study with 30 subjects. This again involved a comparison to the traditional workflow in the clinic. After an initial fitting of hearing aids, 15 subjects were followed up via app, while the control group regularly visited the clinic for this purpose. It was clearly established that the results of the intervention group showed no significant differences to the control group in terms of hearing aid outcomes, satisfaction and benefit (Convery et al., 2020). This is in line with the mentioned studies from the classical - analog - form of tele-audiology (Gladden et al., 2015). It should be mentioned here that the initial adjustment was performed in person and that the study results only refer to the follow-up appointments.

However, in order for the apps to be regularly integrated into the fitting process, it is essential that hearing care professionals are open to them. In a study conducted in 2018 among 258 professionals in the USA, it was found that there is a high level of willingness to use towards this technology. This is also in line with the findings of classical tele-audiology (Eikelboom & Swanepoel, 2016; Singh et al., 2014). Interestingly, the higher the professional experience, the higher the willingness to use it (Kimball et al., 2018a).

Similar studies already existed in the field of classical tele-audiology. Singh et. al surveyed hearing care professionals regarding their attitudes toward the use of tele- audiology. The study was conducted in Canada and included responses from 202 professionals. For this purpose, a 46-item questionnaire was developed to address attitudes toward tele-audiology appointments, willingness to solve clinical tasks telemedically, and willingness to use tele-audiology in different patient populations. The majority of respondents indicated that the impact on the quality of hearing aid fitting and patient interaction was marginal. The authors concluded that the willingness to use tele- audiology depends on the medical field of application and the targeted patient population. These results provide a solid basis for further research in this area (Singh et al., 2014).

In 2016, there was a study conducted worldwide among hearing care professionals. The willingness to use telemedicine applications was surveyed among 269 participants in an online survey. The average work experience was 14.5 years, and the majority of questionnaire returns came from five countries. 15.5% of respondents reported previous experience with tele-audiology. 9.7% said they had used telemedicine for other medical fields, mainly in videoconferencing. Regardless of age and gender, most responses regarding positive attitudes toward the technology ranged from 3.2 to 4.7 on a 5 - point Lickert scale. This corresponds to a positive orientation towards the use and implementation of this form of intervention in the adaptation process (Eikelboom & Swanepoel, 2016).

1.5. Technology Acceptance

The willingness to use a technology depends on various factors. One of the best-known models of this kind is the Technology Acceptance Model developed by Davis, which states that the attitude toward using depends

on two variables. These are perceived usefulness and ease of use (Davis, 1989).

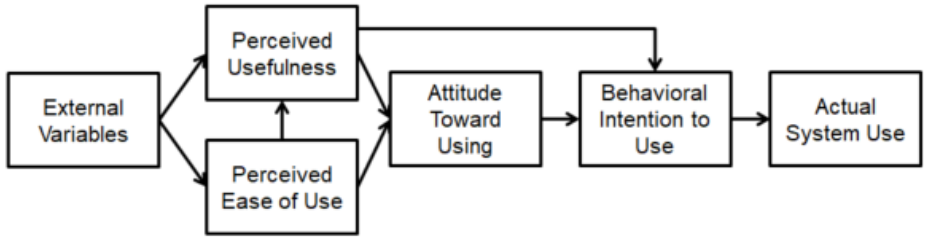

Figure 2: Technology Acceptance Model according to Davis (1989)

The origins of this model are based on psychological aspects that are supposed to provide insight into whether a technology is applied or rejected by the user. Two theories played a fundamental role in this. The social psychological theory of reasoned action (TRA) was developed by Fischbein and Ajzen. This assumes that a person's behavior is determined by his or her intention. This behavioral intention results from personal attitudes towards the behavior under consideration as well as from subjectively perceived norms from social and normative intentions, which have an influence on intentions to act (Ajzen & Fishbein, 1980; Leps, 2016). The theory of planned behavior was then further developed by Ajzen based on the TRA with the goal of improving predictions about the acceptance or rejection of a technology. The variance of actual behavior is to be derived from attitudes toward behavior, subjective norms, and perceived behavioral control (Ajzen, 1991).

Due to the generic nature of this model, this has found application in studies from a wide variety of industries. For this purpose, the model has been modified and developed several times to meet industry-specific

requirements. For example, in a study on consumer acceptance of online banking, it was found that while the variable perceived usefulness is a major factor in acceptance, the model can be supplemented by another latent variable, web-based information sharing, as this aspect also has a significant impact (Pikkarainen et al., 2004).

Another example is the further development of this model in the field of implementation of ERP software in a company. In a study conducted by Amoako- Gyampah and Salam, existing hypotheses were tested and confirmed and three additional latent variables ERP Project Communication, shared beliefs in the benefits of an ERP System and the Training on the ERP System were added to the system. The basis for this was a survey conducted, the values of which were statistically evaluated and validated with a factor analysis (Amoako-Gyampah & Salam, 2004).

In 2000, the basic Technology Acceptance Model was theoretically extended by Venkatesh and Davis. This involves explaining the latent variable perceived usefulness as well as the intentions to use by including social aspects and cognitive instrumental processes. To present a basis for the extension, data were collected in four organizations and n = 156 valid responses were evaluated. It was found in this study that the social influence processes (subjective norm, voluntariness and image), as well as the cognitive instrumental processes (job relevance, output quality, result demonstrability and perceived ease of use) significantly influence user acceptance. Due to the extension, the model was named Technology Acceptance Model 2 (Venkatesh & Davis, 2000).

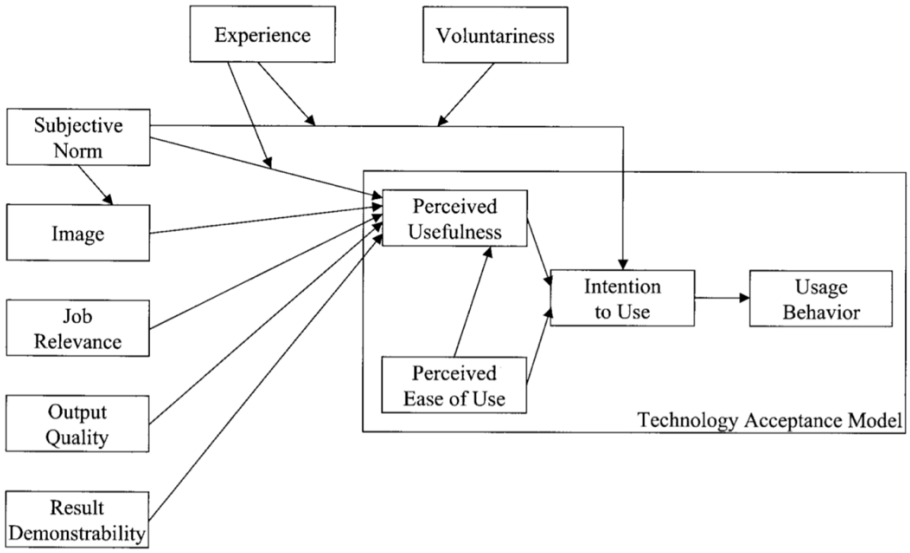

Figure 3: Technology Acceptance Model 2 according to Venkatesh and Davis (2000)

1.6. Servqual

The reasons for applying technologies can be many and varied, as can the impacts that result. For companies in particular, this offers opportunities to improve the status quo and derive benefits for the corporate environment. These benefits are reflected, among other things, in the area of services, which have a direct and indirect impact on business relationships and customer satisfaction (H.-H. (Sunny) Hu et al., 2009). Therefore, it is advisable for companies to control these aspects. There are various methods for measuring this service quality. One of the most widely used in science is the Servqual method, which was developed by Parasuraman et. al. in 1988. This procedure analyzes the quality of services by evaluating five different dimensions.

These are:

- Tangibles
- Reliability
- Responsiveness
- Assurance
- Empathy

Reliability includes the physical components such as the business facilities, the equipment used, or the outward appearance of the employees. Reliability measures the ability to deliver the promised services in a binding and reliable manner. The readiness to help customers and the prompt execution of this help is measured in the Responsiveness dimension. Assurance deals with the competence and expertise of employees and the extent to which they inspire trust in customers and generate reliability. In the empathy dimension, the individual attention of the company and its employees to customers, including the necessary empathy, is assessed. Two 22 item questionnaires with statements to be rated with a 7- point Lickert scale were developed for the measurement. One is used at the beginning of the measurement to ask about the expectations of the service quality of a service. The second questionnaire is applied at the end of the measurement period to assess the services actually received. The gaps can then be calculated from the differences between expectations and perceptions. The larger the gap, the worse the respective item is rated (Parasuraman et al., 1988).

This model is used in a wide variety of application areas from IT service evaluation to e-learning experiences (Kang & Bradley, 2002; Udo et al., 2011). Despite the fact that this model has become one of the leaders in

the field of service quality measurement, there are also approaches to criticism. On the one hand, this criticism refers to the theoretical component of the model, on the other hand, it also refers to practical aspects of the measurement process. In the area of theoretical conceptualization of the model, there is criticism that there is relatively little evidence for the validity that consumers evaluate service quality with gaps between Expectations and Perceptions and further, this model focuses on the process of service quality rather than the resulting outcomes. There is also cause for criticism in the area of dimensions which are not universal and involve a high degree of intercorrelation between themselves.

On the operational side, expectations are criticized because consumers use benchmarks of others instead of their own expectations and Servqual fails to capture them. Furthermore, the use of the same questionnaire twice is criticized, as it can cause boredom and confusion. The use of the 7-point Lickert scale to evaluate the items also shows weaknesses (Buttle, 1996).

Based on practical experience, the model was further developed and adapted several times. One of the best- known modifications is the Servperf model developed by Cronin and Taylor. The most striking difference to Servqual is probably the fact that this method uses only one questionnaire, which only deals with perceptions. The results are comparable to Servqual, but the procedure is much more efficient (Cronin & Taylor, 1992, 1994).

In response to criticism, particularly from Cronin and Taylor, the classic Servqual Model was re-evaluated by the authors in 2002 and re-validated

through a variety of applications, as well as resulting. In addition, a basis for further research in this field was created (Parasuraman et al., 1994)

With all the pros and cons, however, it can be stated that Servqual is probably the most complete approach to conceptualizing and measuring service quality. The practical application over several decades in all industries still underlines the relevance and actuality of this model (Nyeck et al., 2002).

2. CONCLUSIONS BASED ON THE LITERATURE

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 ((Convery et al., 2020; 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., 2018a). 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.

3. OBJECTIVES OF THE DISSERTATION

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., 2018b). 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., 2018a). 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 4 for a better overview.

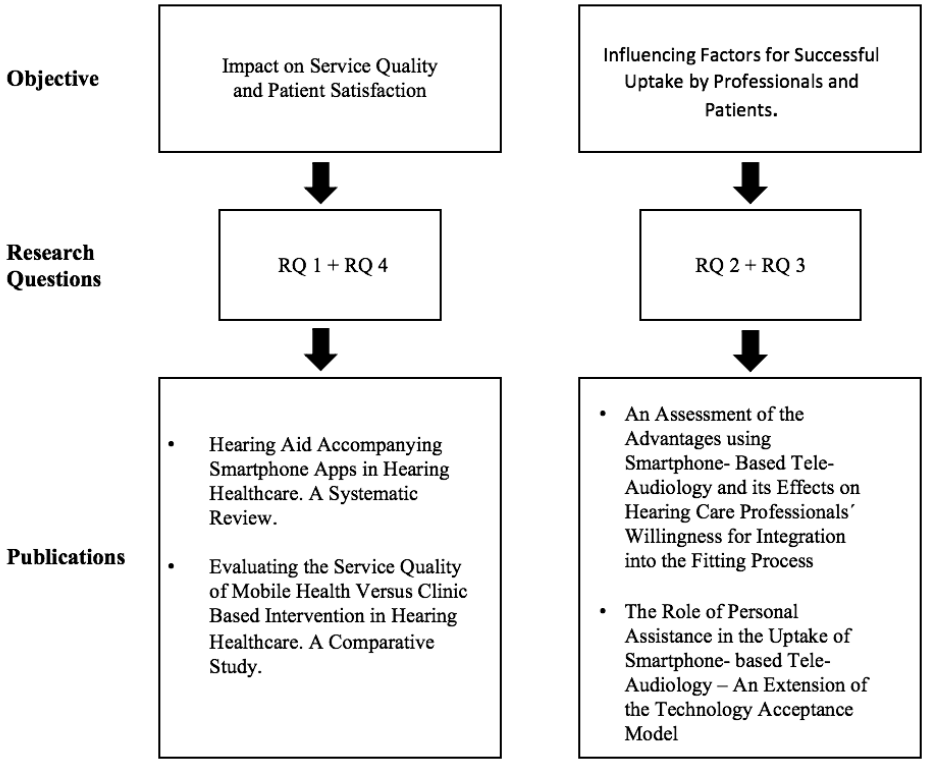

Figure 4: Research Overview

The first step was to prepare a systematic review that specifically addresses the use of hearing aid accompanying smartphone apps. In this study, 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.

4. METHODOLOGY

The purpose of this chapter is to provide an overview of the methodologies used by each publication. The approach and the statistical procedures used will be discussed. The practical calculation of the values was mostly done with R or with STATA.

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

To obtain an overview of existing publications in the field of hearing aid-accompanying smartphone apps, a Systematic Literature Review was

conducted. The Prisma Flow Chart method was used for this purpose. This well-known methodology divides the systematic literature review process into four steps. First, the publications stored in the database are identified with a key word search. After the duplicates are removed, the remaining ones are screened. This is done first by title, then by abstract. The remaining articles are then evaluated in detail during the full text analysis and irrelevant ones are sorted out. This step is called eligibility. The remaining relevant records are then included in the qualitative synthesis (Liberati et al., 2009).

The second publication then addressed the willingness to use smartphone-based tele- audiology by hearing care professionals and to what extent perceived benefits have an impact on willingness to use. For this purpose, quantitative data were collected by means of an online survey among professionals in Germany. Simple and multiple linear regressions were performed to evaluate and validate the responses. Because hypothesis 3, i.e., the relationship between experience with smartphone-based tele-audiology and general willingness to use it, had a variable distribution according to Shapiro Wilk that was not normally distributed (AttRF $W = .9392$, $p = .0000$; ExpRF $W = .9767$, $p = .0196$), the Spearman Correlation was used, which revealed a strong correlation between these two variables ($rs = .5017$, $p = .0000$).

The third publication dealt with the Technology Acceptance Model according to Davis as a basis (Davis, 1989). The aim is to investigate from the consumer's or patient's point of view to what extent the existing hypotheses apply to the use of smartphone-based tele-audiology and what role personal assistance plays in the installation and onboarding by the hearing care professional. For this purpose, quantitative data were also

collected through a survey among patients who have already had tele-audiological experiences using the smartphone. The values were validated using Cronbach's alpha, which indicates the internal consistency of a scale (Cortina, 1993). In the following, a linear structural equation model was calculated, which represents the correlative relationships and influences of the individual variables among each other (Steinmetz, 2015).

In the fourth publication, the impact of smartphone-based tele-audiology on the service quality of a clinic was investigated. As set as a research objective, the influences of these technologies are to be explored apart from audiological aspects. For this purpose, a comparative study was conducted in which 30 subjects participated. It should be analyzed how this form of intervention affects the service quality and how it differs from the traditional face to face treatment in the clinic. For this reason, the subjects were divided into two groups, each with n= 15 participants. Since the Servqual method was chosen as the basis of this study, questionnaires were created to elicit the expectations and perceptions of both cohorts. Using a 7-step Lickert scale, the values were then recorded and the gaps calculated using paired t-tests (Hsu & Lachenbruch, 2014).

Thus, across all publications, qualitative and quantitative data were collected - in addition to the Systematic Review. The quantitative data were collected with Sosciosurvey in the context of online surveys and the data sets were processed with the mentioned statistical programs.

5. PUBLICATIONS

5.1. Hearing Aid Accompanying Smartphone Apps in Hearing Healthcare. A Systematic Review.

This article was originally published as:

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

Abstract - Hearing Healthcare is in the midst of a paradigm shift due to increasing technologies and a changing patient generation. Hearing aids come up with more and more functions that have become possible due to the connection with smartphones and already a mayor part of the current patients is familiar using them via mobile applications. These apps are not only the interface between the hearing aids and the user, but also between the user and its Hearing Healthcare Professional. This Systematic Review, based on the PRISMA model, analyzed 1170 articles with the aim to filter them concerning to hearing aid accompanying smartphone apps. A total of ten articles were included in the qualitative synthesis because they contribute to the research field of those smartphone applications in terms of classification and assessment, practical application or implementation in the fitting process. It could be concluded, that engaging the patients more into the process of hearing aid fitting via smartphone apps, will lead to better hearing aid outcomes in terms of satisfaction and benefits, usage and hearing quality.

5.1.1 Introduction

Hearing loss affects the quality of life much more than initially assumed. The largest number of complaints are the problems in recognizing speech, especially in noisy areas. That communicative disability affects both, hearing impaired people and people in their environment. In addition, the ability to detect, locate and identify sounds quickly and reliably is also affected. This together leads to a reduction in the quality of life related to isolation, reduced social activity, a feeling of being excluded and increased symptoms of depression (Arlinger, 2003). It is estimated that in Europe, about 30% of men and 20% of women aged 70 years, have a hearing loss >30 dB HL. By the age of 80, this figure is already 55% of men and 45% of women (Roth et al., 2011). To compensate for these limitations, hearing aids can be fitted by an audiologist (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). These hearing aids have a long history. From the ear trumpet as a sound collector to transistors, microprocessors and digital signal processing (Mudry & Dodelé, 2000), the development of hearing aids has been impressive and has delivered more and more benefits to its users. According to the U.S. Food and Drug Administration, they are sound amplifying devices, designed to aid people who have a hearing impairment. The devices – independent of the model- share similar electronic components, including at least one microphone, an amplifier, that makes the sound louder and a loudspeaker, that delivers the amplified sound into the ear canal. They can be differentiated by the design, the technology or by special features (Health, 2019). Equipped with the latest Bluetooth technology (Florian, 2003), hearing aids can be connected with the user´s smartphone and fittings can be changed over mobile apps, which enable the Hearing Healthcare Professional access to the devices. These apps also allow the

user itself to use the smartphone as a remote control with several options to change the hearing aid´s fittings in a limited way (Roth et al., 2011). Especially the possibilities for hearing aid specialists bring the aspect of Tele – Audiology on a new level. Tele – Audiology is defined according to Northern, as the use of electronic information and telecommunications technologies to support remote and distance clinical hearing healthcare (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). Although this form of patient care was previously only intended to compensate the lack of audiologists in rural areas, it is now part of the paradigm shift that exists based on changing patient demographics and its different demands (Gladden et al., 2015). Due to the rapidly aging population and the increasing use of smartphones (Berenguer et al., 2017), it can be assumed that there will be much more research and development in the field of mobile applications for hearing aids in the future, which will take this paradigm shift into account. Away from Tele-Audiology or generational changes, the use of smartphone apps by the user and the associated higher level of engagement might offer more benefits. One of the biggest problems is that hearing aids are not worn as often as they should. Among the ten most frequently cited reasons for this behavior, negative experiences with sound, speech understanding, and annoying background noise are the most common (Kochkin, 2000). It is conceivable that these issues can be improved through the intervention of the user via an app. This paper therefor examines how hearing aid accompanying smartphone apps - thus that kind of apps that hearing aid manufacturers have developed specifically for use in combination with their hearing aids- affect hearing aid outcomes and which benefits they create for Hearing Care Professionals and Patients in the context of a systematic review. It aims to gap the bridge between academic and

corporate research and to encourage audiologists to integrate smartphone apps into the fitting process.

5.1.2 Materials and Methods

The PRISMA scheme was applied for the Systematic Review (Liberati et al., 2009), which is presented in Figure 5. An overview of the research framework can be found in Table 2.

Table 2:Review Protocol according to Wohllebe (2020)

Review question	"How does the Use of Hearing Aid accompanying Smartphone – Apps affect Hearing Aid Outcomes?"
Literature search	*Sources*: Science Direct, google scholar and PubMed
	Search Term: („hearing aid" OR „hearing healthcare") AND („app" OR „smartphone" OR „e-health" OR „m-health" OR „tele-audiology" OR „remote")
Filter criteria	*Type of work: All type of publications* *Years:* 2005 - 2020
Exclusions	*By title*: Examination of topics in a broader sense, exclusion of records especially related to traditional Tele-Audiology and remote issues
	By abstract: Exclusion of records not related to the combination hearing aid and mobile applications
Evaluation	*Full-text assessment*: Inclusion of those records which are engaged with hearing-aid accompanying smartphone-apps

The search for relevant records was conducted in the mentioned databases on May 20, 2020.

The keywords were intended to cover the combination of hearing aids and apps. Due to the fact that today's tele-audiology is almost exclusively app-based, the term was also included, as well as the key word remote, which stands in the broadest sense for all processes from a distance. This includes remote fittings of Hearing Healthcare Professionals, as well as the user´s possibility of changing the hearing aid´s settings in the context of a remote control.

The inclusion criteria were as follows:

Hearing aid accompanying smartphone apps, which are used in combination with the corresponding hearing aids

The exclusion criteria were as follows:

- Pediatric audiology
- Cochlear Implants and implants in general
- Results about stand - alone audiological mobile apps, without any hearing aid relation
- Over the Counter products or any kind of self – fitting devices

However, several records were excluded which, although they fitted the subject matter exactly, were not published in a scientific context. Explicitly mentioned examples of this are the following works:

- Signia TeleCare Facilitates Improvements in Hearing Aid Fitting Outcomes (Fröhlich et al., 2018)
- User Engagement with Signia TeleCare: A Way to Facilitate Hearing Aid Acceptance (Fröhlich et al., 2020)

In this Systematic Review there has been no type of publication excluded due to its type.

The following quantitative results were found in the various databases during the defined period.

Table 3: Initial Results of the Literature Search

Search Term	ScienceDirect	Google scholar	PubMed	Results after Removing duplicates
(„hearing aid“ OR „hearing healthcare“) AND („app“ OR „smartphone“ OR „e-health“ OR „m-health“ OR „tele-audiology“ OR „remote“)	485	604	81	678

According to the mentioned Prisma Flow Chart, the following search steps were conducted:

Identification

In that step, the duplicates where removed, with the result, that 678 of 1170 records remained in the review process.

Screening

The titles of these records were screened and 432 removed due to a missing relation to the research topic. Most of these removed records were in the field of traditional Tele – Audiology or in several hearing healthcare related sectors. Based on the overlap of audiology and

smartphone technologies, various records from the field of computer science were found. Those were also rejected due to the lack of connection to the research question. After this step in the review process, 246 publications remained in the database and advanced to the next stage. The abstracts of the records mentioned were read and 178 of them were also sorted out due to irrelevance to the research question.

Eligibility

Finally, the remaining 68 records were read in full and evaluated for their use in the Systematic Revue. The reason for excluding 58 of them were different. As in the screening phase, some had a wrong setting, i.e. the combination of apps and hearing aids was not given, or the paper focused on self-fitting devices. Afterwards, the references of the records were screened completely to identify additional records. No further ones were discovered and accordingly noted in the Identification step of the Prism Flow Chart.

Included

Ten of them were then assigned to the qualitative synthesis and consequently listed with their scientific results. They were grouped due to its characteristic into the following sections: i) Classification and Assessment ii) Practical Application iii) Integration into the fitting process and further chronologically listed. If several records appeared in the same year, they were arranged according to the first letter of the main author.

5.1.3 Results

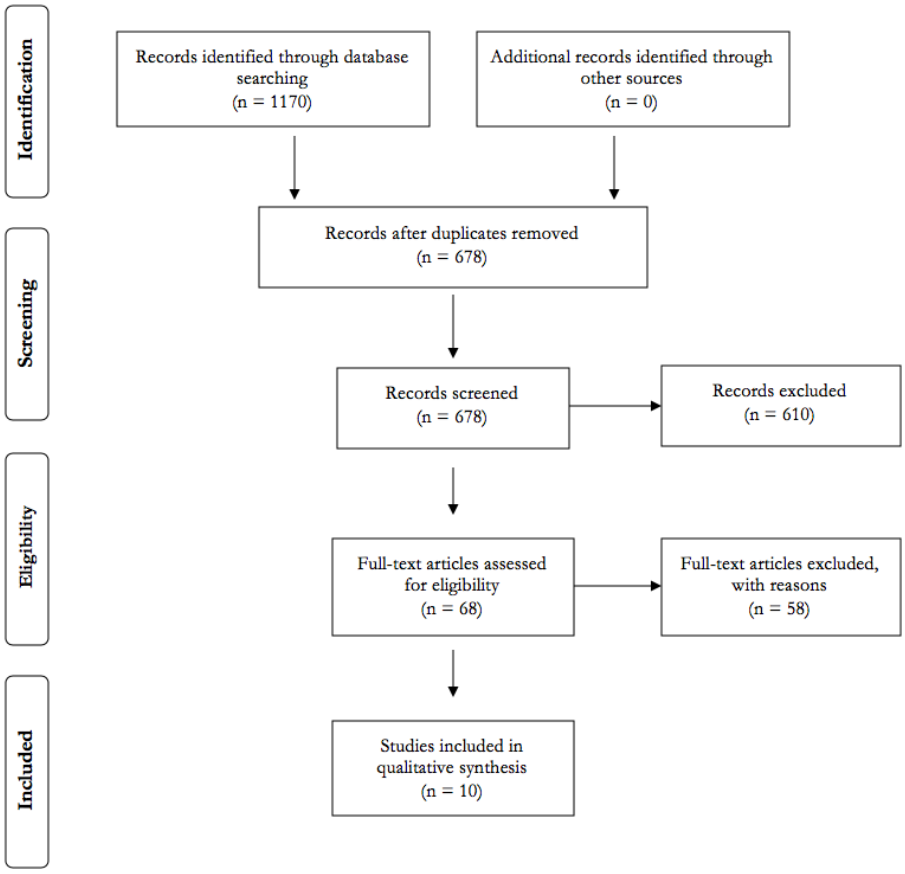

Figure 5: Prisma Flow Chart according to Liberati (2009)

Table 4: Summary of the Review´s Results

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 available apps in hearing healthcare are available for hearing professionals and people with hearing problems. 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.	An 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 finally proposing an automated approach, able to extract	Creation of the ALFA4hearing model, which classifies hearing aid apps in hearing healthcare in regarding of promoters, services, implementation, users and descriptive information.

		meaningful information about apps directly from the web.	

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	Participants were equipped binaurally with hearing aids and the accompanying smartphone app.	N = 30 Ø Age: 68	Subjects had significant improvements due to the usage of the smartphone app, especially in

	smartphone app	After seven weeks, the app usage was evaluated and compared to a control group.	Ø Hearing loss: 38 dB HL	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.

5.1.4 Discussion

Classification and Assessment

Offiah et. al.(2014) investigated the connection between hearing aid and smartphone mobile applications regarding to different algorithms with the aim of a better differentiation of speech and noise. The study is based on the assumption that due to the higher computing power and the more complex operating system of smartphones, better speech understanding with hearing aids can be achieved by using the smartphone as an external microphone. Using the app, the individual input signals are calculated or differentiated and then transmitted back to the hearing aids for output. In this study different hearing healthcare apps were tested, three of them from hearing aid manufacturers. These apps were evaluated for signal input and output, the possible hearing profiles, the settings per ear, the possibility of hearing measurements and the availability on the different platforms and finally weighted with a combined value. When evaluating

the study data, the authors came to the conclusion that although some manufacturers have smartphone apps, they still leave a lot of room for improvement, especially in the areas of signal input and binaural support (Offiah et al., 2014). It is noteworthy that this study focuses more on the electrotechnical than on the audiological component. As mentioned, the input and output values were analyzed on the smartphone., but since most of the signal processing takes place in the hearing aid and not on the smartphone, the relatively poor performance of the hearing aid accompanying apps is also understandable.

The aim of Paglialonga et. al.(2015) with their research was to review the available smartphone apps in Hearing Healthcare. Therefor they searched in the Apple Store, the Android Market in Google Play and the Windows Phone store for related applications. In November 2014 they found a total of 200 relevant apps in this search, which they divided into five different categories. These categories were i) education & information ii) hearing testing iii) rehabilitation iv) sound enhancement v) assistive tools.

The category "sound enhancement", which accounted for 28% of the relevant apps, includes the mobile applications of the hearing aid manufacturers. With that tools, it is possible to support the hearing aid use (e.g., system control, support to hearing aid selection, ratings of listening experience or consumer engagement services) as well as personal enhancement tools. Hearing aids users can use these tools to personalize the device´s settings in real time to limit the need for face to face appointments. The authors concluded that there is a paradigm shift in Hearing Healthcare from the traditional hospital-centric model to a more flexible model where the patient is more empowered and involved in the fitting process and the usage of mobile applications plays therefore a

major role (Paglialonga et al., 2015a). The importance in practice seems to be clear. In a large number of Hearing Healthcare related apps, it is difficult for users - especially older ones - to find their way around. A grouping of the available applications as suggested in record 2, could lead to a significant simplification and clarity in practical use.

With a similar approach, Paglialonga et.al. (2015) published another paper in the field of apps in hearing science and care. Their aim was to evaluate the available apps according to the services, or combination of services, the price and the need for additional external devices. In this study, they classified the 203 found apps in four categories, i) screening and assessment ii)intervention and rehabilitation iii) education and information and iii)assistive tools. The applications of the hearing aid manufacturers belong to the group of intervention and rehabilitation, which makes up 52% of the found apps. The 203 apps were analyzed according to the price and divided into five groups, from free to >15 euros. The hearing aid manufacturers' mobile applications were all free of charge. The authors concluded that the use of hearing aid manufacturer apps can improve mutual interactions between patients and audiologists and increase patient satisfaction and benefits. As a drawback they mentioned that the usage of this technology may temp patients to overlook or greatly reduce the contact and exchanges with their audiologist (Paglialonga et al., 2015c). In this argument, the actual use of apps is probably the decisive point. In particular, one of the main functions - modern tele-audiology - can be used to provide more up-to-date customer care. Preliminary studies from classic tele-audiology, such as the already mentioned by Gladden et. al (Gladden et al., 2015), show that this form of patient care has no disadvantages compared to face to

face treatments. Moreover, since the user himself has only limited access to the settings (Weaver, 2014), these concerns can be dispelled by clear workflows, such as frequent service appointments in the clinic.

Tognola et.al. (2015) described in their work the silent and disrupting revolution in hearing health care practice, based to the increasing usage of e - health methods and technologies, in particular mobile smartphone applications. Their goal was to develop a new "ehealth4hearing" model and to define the associated boundaries and rules. In this paper, they tried to give an answer, what could be envisaged with that model, how it would contribute to patient – centeredness, patient empowerment and patient – caregiver relationships. Further, they highlighted the differences between the traditional health care services and the “ehealth4hearing” model. A total of four target groups of people with hearing loss were defined, differentiated by the type of services needed to manage their impairment as well as the various perceived needs. They found that the target group, who already require amplification because of their hearing loss, has the demand to be able to change the settings of the hearing instruments quickly and flexibly to tailor them to their needs. The advantage of the "ehealth4hearing" model is that this target group can implement their wishes themselves via a mobile app, i.e. they can use their smartphone as a remote control. Remote consultations and individual engagement services, which are also conducted by the several apps, engage the patient to become an active participant in the hearing aid selection process. This is, so they concluded, a huge advantage compared to the traditional model (Tognola et al., 2015). Especially in the course of the generational changes of patients, this conclusion seems very plausible. Similar results about the advantages of remote treatments compared to the traditional

way can be observed in the field of general medicine and can be used for comparison to Hearing Healthcare (Hjelm, 2005).

Paglialonga et. al. (2017) investigated several hearing healthcare related smartphone applications. The aim of their work was the development of user support tools for a more informed adoption of health apps. They created the ALFA 4 hearing model, which characterizes apps for hearing healthcare by using 29 features, grouped into five components. With this model, it is possible to classify hearing aid manufacturer apps regarding to promoters, services, implementation, users or descriptive information. The study showed the value of characterizing health apps features by extracting its meaningful information based on the large amount of information that can be found in the web (Paglialonga et al., 2017). With this approach, the authors once again had the same goal as (Paglialonga et al., 2015b), namely to create a clear and informative basis from a large pool of apps and the associated multitude of information.

At the category Classification and Assessment, it is noteworthy that almost all relevant records were written with the participation of Paglialonga and Tognola. A number of commonalities could be identified among all publications. While Records 1 and 2 dealt with analyzing and categorizing the multitude of apps in hearing healthcare, Records 4 and 5 focused on the creation of models to simplify the use of the applications in terms of target groups and information. Another important conclusion of publications 2, 3 and 4 is that the active involvement of patients by using smartphone apps in the hearing aid fitting process, can lead to a higher customer satisfaction. It may make sense to perceive the hearing aid user less as a patient and more as a consumer, with the consequence to engage him much more in the treatment (Hibbard & Greene, 2013). The

records of that category determine the theoretical and therefore descriptive part in the field of hearing aid accompanying smartphone apps with the aim to provide a good theoretical basis for the practical use of the applications.

Practical Application

Johansen et.al. (2015) investigated in their study how a hearing aid is used throughout the day. Instead of simulating listening scenarios in a clinic, they had the aim to infer the optimal hearing aid settings based on how the user adjusts programs or volume in changing real life situations. For the study, they selected six experienced hearing aid users with mild to severe hearing loss. All of them used an iPhone 4s or newer with Bluetooth 4.0 and were fitted binaurally with two Oticon OPN hearing aids and the corresponding Oticon iPhone app. Four different hearing programs were set up and the use of those was examined according to the day of the week and the time of day. In addition, the user intervention on the amplification of the individual hearing programs was also analyzed. They found out, that volume and program interaction differed from Monday – Friday and the weekends and that the individual behavior patterns affected the usage of the devices. This outcome is of great relevance in the context of the frequency of use of hearing aids. As mentioned in the introduction, hearing aids are often not worn as often as they should be. The inclusion of these individual behavioral patterns in the hearing aid setting can therefore positively influence the use of hearing aids and thus reduce one of the biggest barriers in this area. The authors proposed, that rethinking hearing instruments as devices, that adaptively learn behavioral patterns based on user interaction, might provide a degree of personalization, that wouldn´t be possible due to a

lack of audiologist´s resources. They recommend a new way of hearing aid fitting, connecting the hearing aids with the smartphone and the Internet to make them cloud connected devices. Finally, a paradigm shift is proposed, where the audiological best practice includes decisions making from user generated data reflecting everyday usage (Johansen et al., 2017).

Due to technological and socio-demographic changes in Hearing Healthcare, Habib et. al. (2019) conducted a study to evaluate the benefits of smartphone connected hearing aids and to identify the user´s preferences and usability in regarding of functionality of an accompanying smartphone app. Over a period of seven weeks, the smartphone connected hearing aids + app were tested by 30 test persons and evaluated for their use and benefits. Subjects, whether they were experienced or first - time hearing aid users, indicated that they had significant improvements in terms of social participation, hearing-related fatigue, quality of listening and hearing aid benefit and satisfaction due to the usage of the smartphone app. The authors concluded, that the tested app meets the needs of a typical NHS clinical sample of hearing aid users and due to empowering them to self – manage their hearing loss, the app provides them with a greater confidence, especially in challenging listening situations (Habib et al., 2019). These study results also show that the use of smartphone apps in the context of hearing aid fitting offers great advantages for the user. Especially the optimization in the areas of speech understanding and sound - which are the most frequently cited reasons for not wearing hearing aids - can also have a positive effect on the wearing behavior.

Due to the fact, that hearing aids can potentially be complemented with smartphone apps, that model the sounding environment in order to find the optimal settings in a defined context and situation, Pasta et.al.(2019) recommended a rethinking of hearing aids as context – aware recommender systems. They aimed to analyze the challenges in this process and addressed them by gathering the preferences of seven participants in real world listening environments. They fitted Oticon hearing aids and installed the corresponding mobile app, which enabled collecting data about the audiological preferences and the corresponding context. The test persons were given the opportunity to optimize noise reduction and directionality, brightness and soft gain in four different levels. In addition, each time they reported on their preferences, they specified about the environment they were, their motion state and their audiological intent. They sequentially optimized the three mentioned audiological parameters, which subsequentially were combined in a personalized device configuration. Finally, this configuration was compared against a configuration personalized in a standard clinical workflow and six out of seven participants preferred the device settings learned in real world listening environments (Pasta et al., 2019). These study results clearly show that the inclusion of the daily hearing situation in the hearing aid settings is of great importance and therefore allows a more individualized fitting of the devices. The use of smartphone apps is the interface in this process.

To analyze to what extent the use of smartphone apps in combination with hearing aids facilitates communication between audiologists and patients and influences hearing aid outcomes, Convery et al. (2020) conducted a study with 30 subjects. During the six-week study period,

one group received regular face-to-face care, while the second group received tele audiological care via the GN Resound smartphone app. The results of the study were evaluated in terms of hearing aid outcomes, satisfaction and use. The authors came to the conclusion that care via the smartphone app had no detrimental effect on fitting results - at least in the short term and could enable patients to communicate remotely with their audiologists to seek and receive help with their hearing aid problems (Convery et al., 2020) These study results also confirm the results of the traditional Tele-Audiology studies that there are no audiological disadvantages (Gladden et al., 2015).

The evaluation of the studies in this category yielded very relevant results for practice. Records 6,7 and 8 had partly similar study objectives and finally delivered similar conclusions. They set themselves the goal of individualizing the hearing aid settings by the patient using a smartphone app. These individualizations led to an increase in patient satisfaction in Records 7 and 8, in part also in direct comparison with the traditional clinic work- flow. It can be assumed that this increased patient satisfaction will also increase the wearing time of hearing aids. This conclusion is also confirmed by the results of record 6.

Integration into the fitting process

To investigate the willingness to integrate smartphones into hearing aid fitting, Kimball et. al. conducted a survey among 258 audiologists in the USA. This survey focused on the use of the Phonak smartphone app and analyzed in ten items the extent to which audiologists would involve patients in the fitting process via smartphone. The key finding of that study was, that the audiologists generally expressed a high willingness to

integrate the smartphone into patient care. Similar older papers in the context of traditional Tele – Audiology (Eikelboom & Swanepoel, 2016; Singh et al., 2014), confirmed that results years ago, using traditional Tele-Audiology tools. A surprising outcome was, that the audiologists with the least number of years of experience had more negative attitudes toward smartphone integration, than audiologists with comparatively more years of experience. The authors concluded, that due to further improvements of technologies, patients will take a greater role in hearing healthcare and audiologist will need to be prepared to adapt (Kimball et al., 2018a). This trend will accelerate, especially with regard to generational changes (LeRouge et al., 2014) and the new patient´s – the Babyboomer – demands (Coleman et al., 2006).

5.1.5 Conclusion

This Systematic Review showed very clearly that the use of smartphone apps as part in the hearing aid fitting process can positively influence Hearing Aid Outcomes. It can be concluded that the better outcomes and the resulting increased customer satisfaction lead to an increase in the wearing time of the devices. Especially with regard to further technical developments in the direction of artificial intelligence and a changing customer generation, the use of these applications will become even more important in the future. Furthermore, not only the audiological effects of using smartphone apps should be investigated, but also their influence on the relationship between Hearing Care Professional and patient.

5.2 An Assessment of the Advantages using Smartphone – Based Tele- Audiology and its Effects on Hearing Care Professionals' Willingness for Integration into the Fitting Process

This article was originally published as:

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. In: Auer, M.E., Tsiatsos, T. (eds) New Realities, Mobile Systems and Applications. IMCL 2021. Lecture Notes in Networks and Systems, vol 411. Springer, Cham. https://doi.org/10.1007/978-3-030-96296-8_66

Abstract - Hearing loss affects the patients´ quality of life far more than commonly known and can end in depression if left untreated. Fitting hearing aids can compensate for the hearing loss and counteract the negative effects. These devices have undergone a remarkable development and can now be connected with the users' smartphones. This technology enables a variety of options that can improve audiological quality and the relationship between the Hearing Care Professional and the patient. Especially the option of smartphone- based Tele - Audiology, i.e. a video call in which the Professional has full access to the hearing aid settings, shows the strong transformation of these technologies. Despite these advantages, this form of customization is only partially used in practice. The paper therefore aims to explore the preferences that need to be met in order for this form of intervention, to be integrated frequently into the fitting process. For this purpose, a survey was conducted among Hearing Care Professionals in Germany. These results were evaluated and

statistically validated. It could be concluded that barriers still exist, mainly due to lack of knowledge about the benefits of this tool, as well as its impact on patient relationships.

5.2.1 Introduction

The increase in people with hearing loss is a dramatic development in the industrialized world. It is estimated that by age 70 years, 30% of men and 20% of women in Europe have a significant hearing loss. This number increases sharply with further increase in years of life (Roth et al., 2011). In most cases, fitting hearing aids can solve the resulting problems (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). This technology transformed from an ear trumpet in the last century to today's High – Tec devices, which can be connected over Bluetooth with the users´ smartphones (Florian, 2003; Mudry & Dodelé, 2000). Mobile apps act as the interface between the devices and the relevance in Hearing Healthcare is constantly increasing (Ross, 2020b), just like in many other industries (Wohllebe, Dirrler, et al., 2020b). These small programs enable a remote online fitting session between the Hearing Care Professional and the patient, with full access to the devices´ settings (Weaver, 2014). This is part of the digital transformation that is finding its way more and more into medicine (Diez, 2020).

Even though the use of smartphone-based Tele- Audiology brings various benefits and opportunities for patient care, the use of this technology is still quite different among Hearing Care Professionals, even if they are generally open to integrate this form of intervention into the hearing aid fitting process (Kimball et al., 2018b). Nevertheless, there are still various barriers towards the uptake of Tele- Audiology. The main reasons for this

are a lack of technical infrastructure for HCPs and patients, lack of training, and knowledge levels of HCPs (Ravi et al., 2018b).

The paper therefore aims to find out whether there is a correlation between professional related factors as well as perceived benefits of smartphone-based Tele- Audiology and the actual usage. The aim is to distinguish if there are factors beyond the audiological component that have a positive influence towards the uptake of this technology. For this purpose, a survey was conducted among 141 HCPs in Germany. The results were processed descriptively and statistically and compared with existing hypotheses. The purpose of this study is to identify further approaches to reduce existing barriers to acceptance of the technology and to expand training content for HCPs.

5.2.2 Literature Review

According to Northern, Tele- Audiology is the use of electronic information and telecommunication technologies to support remote and distance clinical Hearing – Healthcare (Northern, 2012). The classical - analog - Tele- Audiology has its origin in the late 60s of the last century and was able to show comparable results in audiological aspects, such as Hearing Aid Outcomes, as the classical on-site intervention in the clinic. The reason for the use was due to the lack of audiologists in rural areas (Gladden et al., 2015). Today, the reasons for its use have changed somewhat. Certainly there are still areas with inadequate distribution of HCPs, but it is also part of a paradigm shift that is happening, away from the clinic centered toward a patient centered model (Tognola et al., 2015). Studies have already determined that although HCPs have the technical infrastructure to use Tele-Audiology, only 25% actually used it (Eikelboom & Swanepoel, 2016). This is noteworthy because another

study of 258 HCPs in the U.S. found that the majority were open to integrating smartphone apps into the fitting process, and thus, in the broadest sense, the function of Tele- Audiology as well (Kimball et al., 2018b). In recent publications, it was also found that the use of smartphone-based Tele-Audiology does not result in any disadvantages in the audiological context (Convery et al., 2019), and that in the area of perceived service quality, individual aspects of patient care were even rated more favorably compared to traditional treatment in the clinic (Ross & Wohllebe, 2021).

Most of the articles in the field of Tele- Audiology section have an audiological background. However, since the acceptance of technologies and the associated regular use is significantly influenced by the perceived benefits (Schenk et al., 2008), there are also references in the publication mentioned to explore the effects outside the medical field (Ross, 2020b).

5.2.3 Hypotheses

Based on existing findings related to the use and the general willingness of Hearing- Care Professionals towards Tele- Audiology (Eikelboom & Swanepoel, 2016; Kimball et al., 2018b; Ravi et al., 2018b; Saunders & Roughley, 2021), the following Hypotheses H1 – H3 could be formulated, taking into account the level of education and professional experience:

H1: A higher level of education (Level Rank) of the Hearing Care Professional leads to a higher willingness to use smartphone-based Tele-Audiology.

H2: Hearing Care Professionals with a higher level of work – experience, are more likely to use smartphone- based Tele- Audiology.

H3: There is a correlation between the experience with remote fitting and the general attitude towards smartphone-based Tele- Audiology.

Within this framework, it will be examined the extent to which the conscious perception of various benefits affects the willingness to use smartphone-based Tele- Audiology. Even though the individual motives are partly exploratory in nature, they are examined on the basis of existing findings (Ross & Wohllebe, 2021; Saunders & Roughley, 2021):

H4a: With the acceptance of the assumption that smartphone-based Tele-Audiology can reduce fitting times, the willingness to use this technology increases.

H4b: With the acceptance of the assumption that smartphone-based Tele-Audiology can ensure a higher degree of flexibility in customer requests, the willingness to use this technology increases.

H4c: With the acceptance of the assumption that smartphone-based Tele-Audiology can increase the service quality of the clinic, the willingness to use this technology increases.

H4d: With the acceptance of the assumption that smartphone-based Tele-Audiology can shorten follow-up appointments in terms of time, the willingness to use this technology increases.

H4e: With the acceptance of the assumption that smartphone-based Tele-Audiology can be used to adjust hearing aids better directly in certain problem situations, the willingness to use this technology increases.

H4f: With the acceptance of the assumption that smartphone-based Tele-Audiology creates competitive advantages over competitors, the willingness to use this technology increases.

H4g: With the acceptance of the assumption that smartphone-based Tele-Audiology can better address future generations of customers, the willingness to use this technology is increasing.

H4h: With the acceptance of the assumption that smartphone-based Tele-Audiology can be used to convey a high level of personal competence and expertise to patients, the willingness to use this technology is increasing.

5.2.4 Methodology

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. In terms of willingness, a split question was built in. If a fundamental rejection of the technology was indicated, the reasons, i.e. the barriers against its use, became the focus of the research. In the opposite case of basic openness, participants were directed to assess the benefits of Tele- Audiology. In the main part of the survey, i.e., the perceived benefits of the technology, participants could rate statements using a seven-point Lickert scale from 1 = no agreement, to 7 = full agreement.

The responses were analyzed descriptively first to get an overview of the data collected. Using multiple linear regression, the above relationships of Hypotheses H1, H2, H4 a-h, were examined (Cohen, 1977). Since there was no normal distribution of the variables in H3, proved with the

Shapiro – Wilk Test (Shapiro & Wilk, 1965), this was checked using the Spearman correlation (Spearman, 1904).

5.2.5 Results

The 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.

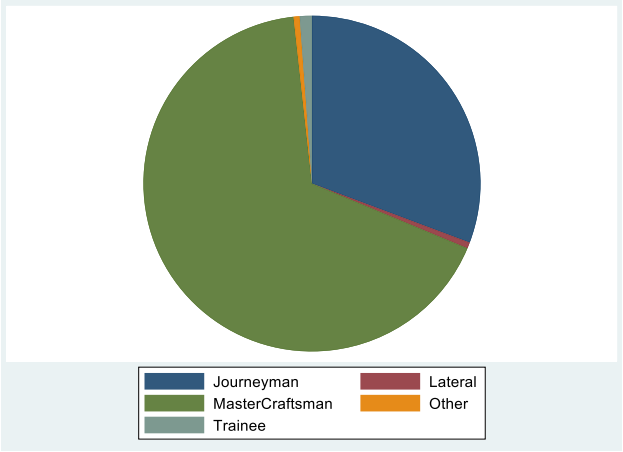

Figure 6: Distribution of Training Levels

Since work experience (ExpTotal), experience with smartphone-based Tele- Audiology (ExpRF), and willingness to use (AttRF) are of central importance in this study, the individual values were processed descriptively.

Table 5: Descriptive Variable Overview

Variable	Obs.	Mean	Std. dev.	Min	Max
ExpTotal	136	2.74	0.96	1	5
ExpRF	136	2.95	1.31	1	5
AttRF	136	3.16	0.37	3	4

Work experience was mainly indicated between 2 (5 - 10 years) and 3 (10 - 20 years). When asked about the previous use of smartphone-based tele-Audiology, the interquartile range was found to be between 3 (now and then), 4 (regularly) and 5 (use whenever possible). The median attitude towards use was found to be 3, which was listed in the questionnaire as basically positive towards the technology.

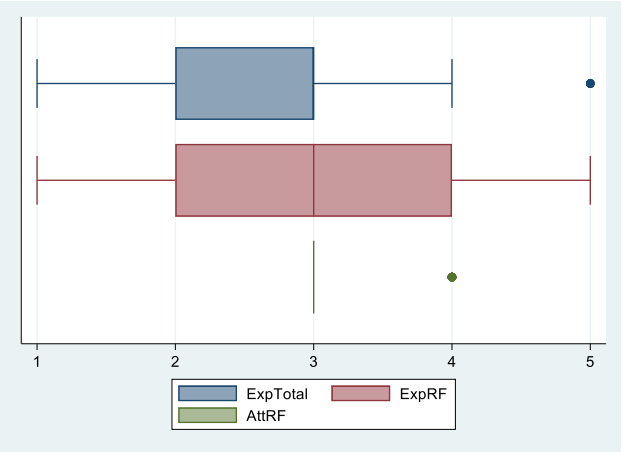

Figure 7: Data Range

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 6: 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 7: 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 8: 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.

5.2.6 Discussion

The conducted study showed clearly that there are, after all, some factors that positively influence the willingness of Hearing Care Professionals to use smartphone-based Tele-Audiology. The level of training and the associated knowledge play a decisive role here. Surprisingly, this positive effect could not be demonstrated in relation to professional experience. This is somewhat in contrast to the publication by Kimball et. al. (2018), who showed audiologists with high professional experience to be more open to the integration of apps compared to colleagues with less experience (Kimball et al., 2018b). Overall, only five HCPs indicated a general rejection of the technology. The reasons for this were focused on a lack of technical infrastructure, but above all on uncertainties in application, as well as in the proper integration into the fitting process.

When examining the extent to which the various benefits positively influence the willingness to use them, only the aspect of subjectively perceived improved expertise and competence on the part of the patient could be shown to be significant. A study published in 2021 has already established that the use of this technology leads to this effect. In addition, the equipment used was assessed as more modern than in traditional treatment in the clinic (Ross & Wohllebe, 2021). However, it is doubtful that the majority of HCPs are aware of this characteristic. It is obvious, of course, that the communication of benefits tends to be focused on the audiological aspect but runs the risk of overlooking benefits outside the classical field of application - i.e. the patient treatment. Interestingly, a joint significance was demonstrated in the collaborative consideration of these benefits. This was not the case in the collaborative consideration of the audiological benefits. The reason for the strong audiological focus in

the use of technology may be historical, when Tele- Audiology had to be used to restore good hearing to patients in less structured areas. With the change in technology, as well as the user generation, this form of intervention is experiencing a renaissance and should be perceived as such.

5.2.7 Conclusion

Hearing Healthcare is changing, and the application of new technologies is part of it. However, in order for technologies to be applied, a clear perception of the benefits is essential. The study clearly showed that while the level of education significantly influences the use of smartphone-based Tele-Audiology, there are additional factors that reinforce its use. In this case, these factors were more likely to be found in the area of business management. It can be concluded that knowledge of the benefits should be extended outside audiology so that the technology is used more regularly in the fitting process. Initiators for this should first be the hearing aid manufacturers, who should emphasize these advantages significantly more in their training courses for HCPs.

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

This article was originally published as:

Ross, F., Wohllebe, A., Diez, E. (2022). The Role of Personal Assistance in the Uptake of Smartphone-Based Tele-Audiology – An Extension of the Technology Acceptance Model. International Journal of Interactive Mobile Technologies. 16(12), pp. 18-31. https://doi.org/ijim.v16i12.30133

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 decreases.

5.3.1 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 (Roth et al., 2011). 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 (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). 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 (Mudry & Dodelé, 2000; Weaver, 2014). 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 (Florian, 2003). 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 (Weaver, 2014) 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 (Convery et al., 2019). 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 (Gladden et al., 2015). 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 (Paglialonga et al., 2015b). The use of these small programs in the course of digital transformation can also be observed in other areas of medicine (Diez, 2020), as well as in many other industries such as retail, education and travel (Papadakis et al., 2018; Saare et al., 2019; Wohllebe, Stoyke, et al., 2020; Wohllebe, Dirrler, et al., 2020b).

With regard to smartphone-based tele-audiology, no detrimental effects were found in audiological terms compared to traditional care in the clinic (Convery et al., 2019). 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 (Ross & Wohllebe, 2021). HCPs stated that they are generally open to using tele-audiology, yet a variety of barriers still exist that severely limit its use (Ravi et al., 2018a). 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 (Schulz et al., 2015) and geronto technology, which means developing and delivering health technologies effectively to elderly adults, has become a highly emergent field (Rogers & Fisk, 2010). 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 (Wildenbos et al., 2015). 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 (Miller et al., 2016). 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) (Davis, 1989). 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.

5.3.2 Literature Review

5.3.2.1 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 (Northern, 2012). 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 (Gladden et al., 2015; Northern, 2012). 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 (Convery et al., 2019). On 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 (Ross, 2020b; Ross & Wohllebe, 2021). Audiologists are generally open to use this intervention (Kimball et al., 2018a), even there still exist a lot of barriers which prevent a regular use in daily practice (Eikelboom & Swanepoel, 2016). The most named barriers are a lack of technical infrastructure, lack of training and knowledge levels of the professionals (Ravi et al., 2018a). 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 (Tognola et al., 2015).

5.3.2.2 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 (Davis, 1989). 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 (Marangunić & Granić, 2015). The theory of reasoned action (TRA) and the theory of planned behavior (TRB) are explicitly mentioned here (Ajzen, 1985; Ajzen & Fishbein, 1980). 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 (Al-Adwan et al., 2013; Pikkarainen et al., 2004).

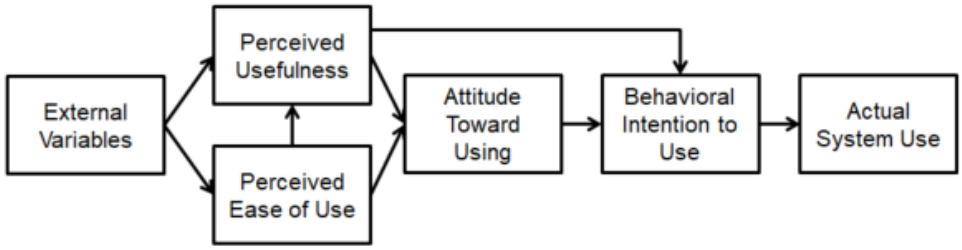

Figure 8:Technology Acceptance Model According to Davis (1989)

Marangunić and Granić identified the target population of older adults as one of the four most important directions for future TAM research (Marangunić & Granić, 2015). The reason therefor is that various studies found out that age plays a key role in the interaction with technologies (Charness & Boot, 2009; Wagner et al., 2010). 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 (Arning & Ziefle, 2007). 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 (Bashshur et al., 2000). 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 (Bashshur et al., 2009). 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 (Chou et al., 2013).

As stated in (Rogers & Fisk, 2010), 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 (Micera et al., 2008). 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 (Chen & Chan, 2014). 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 (Bastawrous & Armstrong, 2013). 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 (Gell et al., 2015).

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 (Forman et al., 2014). 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 (Varnfield et al., 2014).

5.3.3 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. (Chen & Chan, 2014) and (Varnfield et al., 2014) , 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 9.

Table 9: 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 9 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.

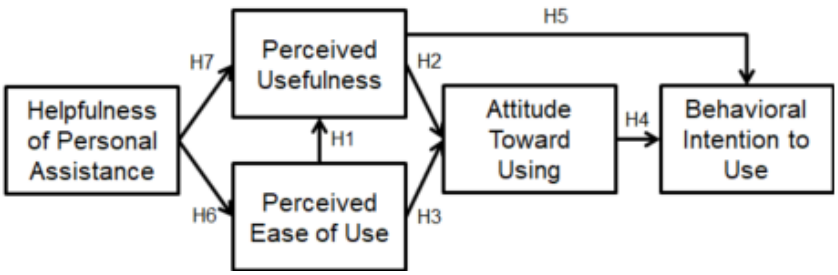

Figure 9: Proposed Model Based on Hypotheses

5.3.4 Empirical Analysis

5.3.4.1 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.

5.3.4.2 Descriptive Statistics

First, the data are described descriptively. Cronbach's alpha is used to test the reliability. Table 10 shows the underlying variables for each factor, their mean and standard deviation, and the value for Cronbach's alpha for each factor.

Table 10: 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 (Bortz & Döring, 1995).

5.3.5 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(Steinmetz, 2015). To check the goodness of fit of the model, different model fit indices are used as proposed in different places in the literature (GATIGNON, 2010; L. Hu & Bentler, 1999; Shneif, 2015). Due to the equally chosen scales across all variables, a standardization of the coefficients is not necessary(Steinmetz, 2015).

Table 11: 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, Salavei 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 11 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 9 are shown in Figure 10. 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 *.

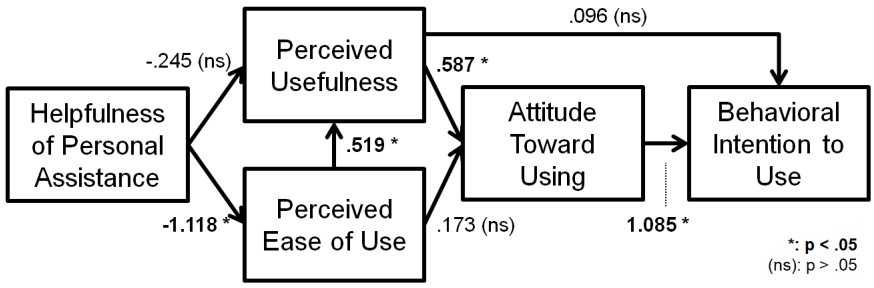

Figure 10: Final Estimated Model

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 12.

Table 12: 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. 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 (β = 1.085).

5.3.6 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 (Chen & Chan, 2014). 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 (Ross & Wohllebe, 2021). 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 (Schmidt et al., 2013). 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.

5.3.7 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.

5.4. Evaluating the Service Quality of Mobile Health Versus Clinic Based Intervention in Hearing Healthcare. A Comparative Study

This article was originally published as:

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Abstract- Hearing Healthcare is in midst of a paradigm shift and the use of mobile health technologies plays therefore a major role. Through the Bluetooth connectivity between the hearing aids and the smartphone with an accompanying app, the Hearing Care Professional can remotely access hearing aid settings during an online video session. In this study, 30 subjects were divided into a Tele-Audiology intervention and a Clinic-Based control group and followed up after an initial fitting for four weeks. At the beginning, structured interviews were used to determine the expectations on the service quality of a Hearing Aid Company, and these were compared with the actual perceived performances at the end of the study using the SERVQUAL model. Various advantages and disadvantages of both forms of intervention were identified. It could be concluded that a combination of both variants ensures the greatest possible perception of service quality.

5.4.1 Introduction

It is estimated that about 30% of men and 20% of women have a hearing loss >30dB by age 70. At 80, this figure rises up to 55% for men and 45% for women (Roth et al., 2011). Poor hearing and understanding leads to a

decrease in quality of life due to a reduction in social activities, the feeling of being excluded, and an increase in symptoms of depression (Arlinger, 2003). In most cases, the provision of hearing aids by a Hearing Care Professional is the only way to compensate the hearing loss (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). These devices have undergone an impressive development. Starting with an ear trumpet, which amplified the acoustic signals in the simplest way, to today's high-tech system that automatically detects the most diverse hearing situations and adjusts the hearing aid setting accordingly (Mudry & Dodelé, 2000). The current generation of hearing aids is already equipped with Bluetooth (Florian, 2003), which enables the connection to a smartphone. Using the associated apps, the patient then has access in a limited way to the hearing aid´s settings. Over the mentioned applications, Hearing Care Professionals can invite the patients to a tele-audiology online video session and can change the hearing aid settings remotely from the clinic (Weaver, 2014). The significance of hearing aid accompanying smartphone apps increased in Hearing Healthcare in the last years (Ross, 2020b) and the rapidly advancing digital transformation poses new challenges for medicine in general (Diez, 2020). To take these challenges into account, the quantity of the small programs is also increasing in the field of telemedicine (Luna-Perejon et al., 2019; Smith et al., 2017). The same trend can be seen in other sectors outside of medicine, such as tourism, education and retail. Here, too, companies are increasingly turning to mobile smartphone apps (Kalogiannakis & Papadakis, 2019; Prakasa et al., 2020; Wohllebe, Dirrler, et al., 2020b). On the one hand, socio-economic reasons are central to user acceptance and the associated actual use (Papadakis et al., 2019); on the other hand, perceived added value, such as time or money savings, play an important

role (Rojas-Osorio & Alvarez-Risco, 2019; Wohllebe, Stoyke, et al., 2020) which should be noticed by app developers (Papadakis et al., 2018).

Several publications already addressed the audiological context of using smartphone-based Tele-Audiology (Ross, 2020b). The purpose of this article is to examine in more detail the perceived service quality and patient´s satisfaction when using the tele - audiology subset of Hearing Aid Accompanying Smartphone Apps. An exploratory study was therefore conducted, and the participants divided into a Tele- Audiology intervention and a Clinic Based control group. Follow-up appointments for the intervention group were realized via smartphone based tele-audiology, while the control group received traditional face to face care in the clinic. The results were collected and compared within the SERVQUAL method.

This paper aims to complete the research in smartphone-based Tele-Audiology beyond the boundaries of audiological aspects and to encourage Hearing Care Professionals to integrate this form of patient care into the fitting process.

5.4.2 Literature Review

5.4.2.1 Tele- Audiological Background

The traditional route to hearing care is through visiting a clinic and fitting of hearing aids by a Hearing Care Professional (ASHA Ad Hoc Committee on Hearing Aid Selection and Fitting, 1998). Due to the maldistribution of clinics in rural areas and the associated time required for a clinic visit, the need for Tele-Audiology grew constantly (Swanepoel et al., 2010). This type of service started very simple in the

early 1960s , using a practitioner in a surgery who adjusted hearing aids under the instruction of a Hearing Care Professional he received on the phone or later via video session. The results were from the audiological aspect comparable to traditional care in the clinic (Gladden et al., 2015). Today, this technology has evolved, and synchronous fitting sessions can be conducted via smartphone apps during an online session (Weaver, 2014). It could be concluded that this method does not have any detrimental effects on hearing aid outcomes and can increase the patient´s engagement with the Hearing Care Professional (Convery et al., 2019). This issue may be part of a paradigm shift in Hearing Healthcare, away from the traditional clinic centric model to a more flexible one, where the patient is more empowered in the whole fitting process and the use of mobile apps plays therefor a major role (Paglialonga et al., 2015a). Tognola et. al. described this paradigm shift as a silent and disrupting revolution in hearing healthcare due to the increasing use of e – health methods and technologies, in particular mobile smartphone applications (Tognola et al., 2015).

A study among 258 audiologists in the USA found out that Hearing Care Professionals are generally open to the use of smartphone-based Tele-Audiology as it can generate benefits for the clinic as well as for patients (Kimball et al., 2018a). A similar willingness regarding the use of tele-audiological practices could be confirmed in several older publications in the context of traditional non- smartphone based Tele-Audiology (Eikelboom & Atlas, 2005; Singh et al., 2014).

5.4.2.2 Mobile Health Technologies – User Satisfaction and Service Quality

In the intersection of medical informatics, public health and business, e-health is an emerging field, referring to health services and information delivered or enhanced through the internet and related technologies (Eysenbach, 2001). M-health can be defined as a subset of this, using mobile devices to deliver health services to the customers (Mechael, 2009). The use of this technologies is increasing, due to benefits like the promotion of preventive behaviors and health monitoring, enhanced patient-doctor engagement, improved service quality and patient centered care (Paglialonga et al., 2019). That aspects have an impact in patient satisfaction, which is one of the most important measures in healthcare provision (Fitzpatrick, 1991). Several studies have been conducted to evaluate user satisfaction from m-health, which demonstrated high satisfaction rates among patients (Aljasir & Alghamdi, 2010; Chae et al., 2001; Patrick et al., 2008). However, it must be mentioned limiting that in these studies the m-health technologies were used as an adjunct to conventional clinic treatment and not as the sole medical intervention (Lee et al., 2018). In a direct comparison between mobile health and clinic-based intervention for Serious Mental Illness, it was found that both variants were able to achieve good results in treatment. The level of satisfaction was comparable in both groups and the m-health treatment showed superior level of patient engagement (Ben-Zeev et al., 2018).

In terms of user satisfaction, the application of mobile health technologies, especially in the field of telemedicine, must also pay attention to the practitioner side. Various studies from 2020 during the Covid-19 pandemic could confirm that there is a high degree of user

satisfaction among Healthcare workers as well (Dobrusin et al., 2020; Fieux et al., 2020; Layfield et al., 2020).

Especially with regard to the patient side, service quality plays a decisive role to achieve a high degree of satisfaction (H.-H. (Sunny) Hu et al., 2009). It can be defined as the difference between the actual consumers´ perceptions of services and their expectations placed on them (Parasuraman et al., 1985). For companies it is significant to measure those expectations because it leads to an increase of the overall long-term quality (Grönroos, 2007). Especially in healthcare, where Hearing Healthcare is a part of it, the quality is highly important due to the aspect that the service affects directly the well-being and expectation of life (Sabahi-Bidgoli et al., 2011). In literature, several models with the purpose to measure the service quality can be found. In this study, the SERVQUAL model was applied, as it considers the dimensions Tangibility, Reliability, Responsiveness, Assurance and Empathy. It measures the differences between expectations and perceptions along every dimension with totally 22 items using a GAP analysis (Parasuraman et al., 1985). The model is based on existing and tested psychological processes and was initially designed to measure customer perceptions of service quality in retail businesses (Parasuraman et al., 1988), to which the distribution of hearing aids belong as well (Ross, 2020a).

5.4.3 Materials and Methods

5.4.3.1 Research Methodology

The hearing aids were fitted to all participants in both groups under laboratory conditions at a neutral location by the study director. Based on the hearing loss, the hearing aids were fitted to the target gain. The

handling of the hearing aids was explained in detail. The hearing aids of the intervention group were connected to the prepared smartphones and the subjects were instructed in the navigation of the app. Further, four follow-up appointments were arranged at intervals of one week each for subjects of both groups. The Tele- Audiology intervention group was followed up via online sessions from the clinic, while the control group visited the clinic in person. The supervising hearing care professional was always the same in both groups. After the last session, an appointment was made with the study director again at a neutral location to finalize the study.

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. To assess the participant´s level of agreement with the statements regarding expectations and perceptions, a 7-point Likert scale, from 1 = strongly disagree to 7 = strongly agree, was applied to all 22 items. 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.

Participants

The study was conducted with 30 participants (17 male, 13 female). They were divided into a tele-audiology intervention and a clinic-based control group of 15 subjects each. The inclusion criteria were as follows: ≤ 75 years, average air conduction hearing loss in the frequencies 0.5 , 1, 2 and 4 kHZ between 25dB and 75 dB across both ears. Experience with

hearing aids ≥ 2 years. In addition, care was taken in the selection of participants to ensure that they were familiar with smartphone use. The median age was 64 in the intervention and 63 in the control group.

5.4.3.2 Hearing Aids and Smartphone App

The hearing aid model used in this study was the Signia, Pure Charge & Go 7X, a RIC (Receiver in Channel) hearing aid which counts to the premium segment of hearing aid technologies. It is equipped with 2,4 GHz Bluetooth technology that enables the communication with the patient´s smartphone. The hearing aid accompanying smartphone App, SIGNIA APP, was used. With this app, an online video session can be realized between the patient and the Hearing Care Professional. This sub-section of the app named Telecare, allows the Professional a complete access to the hearing aid´s settings and fitting values, without any bigger limitations compared to traditional care in the clinic. To ensure a consistent study design, all subjects of the intervention group were provided with Apple iPhone 8 smartphones.

5.4.4 Results

In the first step, the questionnaire setup was validated using the Cronbach Alpha Test. In a pretest, the scale reliability of alpha = 0.79 for the expectations and alpha = 0.82 for the perceptions could be determined. Accordingly, the reliability results from this test were supported.

5.4.4.1 Descriptive Statistics

Table 13 provides an overview about the items used in this study, as well as the means of expectations and perceptions of the tele-audiology intervention and the clinic based control group. T-Tests were used to confirm that the gaps are statistically significant. Further, the results were

calculated for every dimension with the aim to improve the comparability. The means of expectations were high in both groups and ranged in the tele-audiology intervention group from 6,8 (Item: The HCP has a high level of competence and expertise) to 5,27 (Item: The interests of the patients are the main focus for the HCP). The range in the clinic-based control group was from 6,73 (Item: The HCP has a high level of competence and expertise) to 5,2 (Item: The HCP is visually appealing). In the tele-audiology intervention group, the mean scores of the perceived service quality reached from 6,27 (Item: Services are executed in the promised time) to 4,47 (Item: The fitting environment is visually appealing) and in the clinic based control group from 5,94 (Item: The HCP conveys a sense of seriousness during the fitting process) to 4,6 (Item: The services are convenient for disabled patients). The biggest gaps between expectations and perceptions could be observed for the intervention group in the dimension Tangibility and for the control group in the dimension Empathy.

Table 13: 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**		

The several gaps between expectations and perceptions can be taken from Figure 11 along all dimensions.

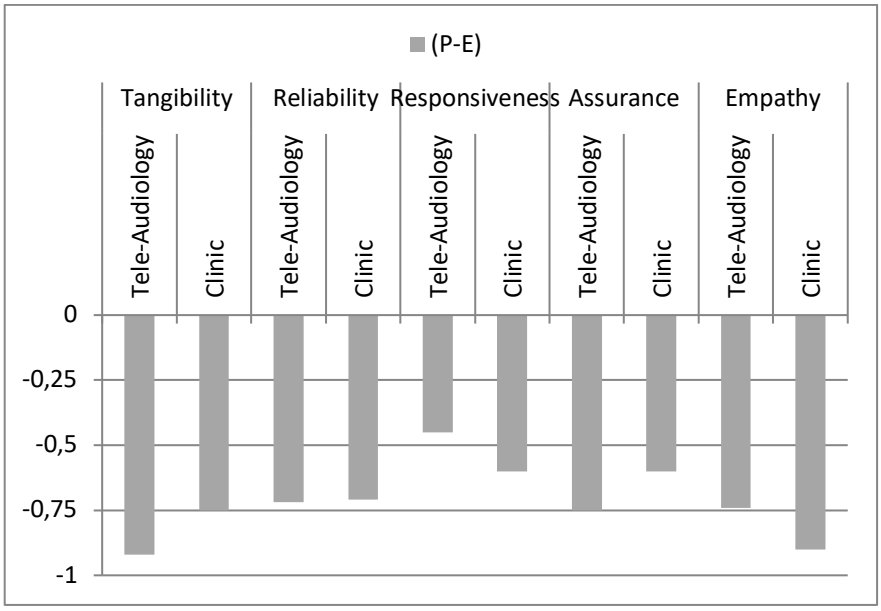

Figure 11: Gaps along Dimensions

5.4.5 Discussion

The study assessed the perceived service quality of the two intervention forms on a stand-alone basis. Care was taken in the setup to ensure that there was a clear delineation between the two forms and that they were not mixed. Analyzing the average gaps of the two variants across all 22 items, it is noteworthy that the overall service quality differs only slightly. Accordingly, the overall expectations and perceptions were also on a similar level. However, a closer look at the several dimensions, as well as the several items, reveals various significant differences that play a major role in interpreting the results.

In the area of Tangibility it may be assumed that the advantages in terms of service quality are in favor of the Clinic-Based control group. This can also be determined in most items. For example, due to an appealing clinic design and the positive appearance of the HCP, the visual aspects were rated better compared to the Tele-Audiology intervention group. Very remarkable was the aspect that through the smartphone based tele - audiological intervention, the equipment used was perceived as more modern. Here, the conclusion can be drawn that through this form of treatment, the hearing care company is considered as more up to date than others who do not use this variant.

In the dimension of Reliability, too, the differences between the two variants only become apparent when the individual items are analyzed in more detail. For the technique reliability, a smaller gap was found for the Clinic Based control group. It should be mentioned limiting here that three subjects of the tele-audiology group had connectivity problems between the smartphone and the hearing aids due to Bluetooth issues which made scheduled online follow ups not feasible. Accordingly, this point was rated lower. Regarding the necessary information related to the fitting process, an advantage for the clinical group could be determined, which may be because of more extensive communication during face-to-face appointments. On the other side, the tele-audiology variant had a clear advantage in the area of speed of problem solving, as well as in the punctual implementation of planned service. These conditions can also be observed in the dimension of Responsiveness. The patients were treated without longer waiting periods, the HCP was always ready to assist and never too busy to respond to patients´ requests. The explanation here is simple. It just took less time to respond over the app or to perform a short

follow up in between whenever it was necessary. Compared to the clinic-based control group, the HCP was much more flexible, and the patients received a fast and uncomplicated service. In terms of information about follow-up appointments, smaller gaps were determined for the face-to-face variant. Here again and based on the interviews it can be assumed that the communication is more extensive.

In the dimension of Assurance, a higher degree of the perceived service quality was found in interpersonal aspects such as trust, seriousness, and friendliness in the clinic-based control group. In contrast, however, it must be emphasized that the perception of the HCP's competence and expertise tended to be more positive in the intervention group. This aspect coincides with the result from the Tangibility dimension that the equipment of the intervention group was evaluated as more modern. Thus, the study shows that the use of modern tele-audiology technologies has a positive influence on professional and technical conditions. In the dimension of Empathy, the items relating to the level of individual attention, understanding of the patient's personal needs, and attention to the patient's interests were rated better in the Clinic Based control group. Lower gaps and thus a higher level of perceived service quality was determined here. These values confirm the results from the previous dimension. It can therefore be concluded that there are advantages at the communication and interpersonal level in the area of face-to-face communication.

5.4.6 Conclusion

The study demonstrated very clearly the strengths and weaknesses of both intervention forms in the area of perceived service quality. Across dimensions, it can be stated that the intervention via smartphone-based

tele-audiology has clear advantages in the area of speed in the implementation of processes compared to the traditional clinic variant. In addition it has a positive impact on professional competence, as the expertise of the HCP is perceived to be higher and the equipment used more modern. On the other hand, a higher level of perceived service quality was found in the face - to - face intervention in other aspects. There were clear advantages in the interpersonal area as well as in the provision of information, indicating more extensive communication compared to the tele-audiology variant.

It can therefore be concluded that the highest possible service quality is achieved when the two forms are combined in a meaningful way. The personal appointments in the clinic are the foundation of the patient relationship in the hearing aid fitting process, which can be noticeably optimized by the digital accompaniment of smartphone-based tele-audiology. The demand for this service will certainly increase significantly in the coming years due to demographic changes. Further research is therefore indicated to investigate the expectations of future patient generations on the application of mobile health technologies in hearing healthcare as well as the requirements from the practitioner side.

Abbreviation
HCP – Hearing Care Professional

6. GENERAL DISCUSSION

This chapter is intended to summarize the results from the publications, to link them together, and to provide a retrospective on the research objectives and questions listed in the introduction.

The research focused on the application of mobile health technologies, which in the field of Hearing Healthcare is mainly associated with the use of the smartphone and the associated apps. The Systematic Review clearly showed that the use of these technologies not only has a positive effect on audiological aspects such as satisfaction with the hearing aids and the resulting benefits, but that the conscious interaction by the patients noticeably integrates them into the overall fitting process. Increasing the wearing time is another logical consequence of this. It was also found that this development is part of a paradigm shift in the entire healthcare system, away from clinic-based, towards patient-centered care (Barrett et al., 2019). The reason for this is certainly on the one hand the constant further development of technologies, but on the other hand also a change in the generation of patients who can and want to use these technologies. It can therefore be assumed that research and development in the field of mobile health applications will continue to gain relevance and that the use of these technologies will expand significantly. Clinics should keep an eye on these developments and incorporate the use of mobile-health applications into their processes or business models, as competitive advantages from the use of these technologies have already been demonstrated in other facets of healthcare (Ngumi, 2013).

However, these competitive advantages were also specifically demonstrated for Hearing Healthcare as part of the publication on service quality. The aim was not only to investigate the perceived service quality

resulting from the use of smartphone-based tele-audiology, but also how this relates to the traditional face-to-face variant. By applying the Servqual method, a comparable study setup was created, which brought to light essential findings for science, but also for practical application. Here, it was clearly demonstrated that each form of intervention provided roughly the same level of overall service quality and that smartphone-based tele- audiology was a comparable alternative to in-clinic care. However, it could be concluded that the two variants should not be considered as an either- or decision. In order to generate the highest possible level of service quality between the clinic and the patient, both forms of intervention should be used together, each variant in the areas where it has an advantage over the other.

Based on these findings resulting from these two publications, the goal of exploring the influences of mobile- health technology use on patient satisfaction and service quality can be considered complete. Thus, Research Questions 1 and 4 could also be clearly answered and the corresponding hypotheses 1 and 4 can also be assessed.

Table 14: 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

Since technologies must also be applied by the target group, the focus was placed on this in the further course. First, the user group of hearing care professionals was examined in more detail. Based on existing studies from North America and England among hearing care professionals, which investigated the willingness to use tele-audiology (Eikelboom & Swanepoel, 2016; Singh et al., 2014) or to integrate smartphone apps into the fitting process (Kimball et al., 2018b), these aspects were also investigated among German professionals. In this context, it was possible to demonstrate the extent to which factors such as the level of education, professional experience or previous experience with smartphone-based tele- audiology affect the willingness to use it. Overall, a consistently positive attitude towards the use of smartphones was found. These hypotheses based on the studies mentioned above could be confirmed and new findings could be derived. Here, the main focus is on the conscious perception of factors that increase the willingness to use. Interestingly, benefits outside of actual audiological use contributed positively. These were mainly factors located in the business-oriented area. As the survey was able to generate 141 validated responses, it should be mentioned in a limiting manner that while this is a representative amount, 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. Hearing aid manufacturers should keep this aspect in mind when introducing and further developing these technologies and emphasize it significantly more in order to support successful use by professionals.

The final aim was to find out what factors exist for successful use by patients and what role the hearing care professional plays in this. The

Technology Acceptance Model by Davis was used as a basis and confirmed the importance of the ease of use of the technology for a successful application. The influence of the professional on the variable Ease of Use was to be examined more closely. It was confirmed that the influence was significant, but negative. On further examination, however, this circumstance was understandable, since the personal assistance was rated higher in the evaluation by the patients with little affinity for technology, but the Ease of Use variable was rated lower. For this reason, it was concluded in the publication that the variable of technical affinity should be examined more closely for further research. For this further research, the results represent a solid basis.

With these two publications, the second research objective can be considered completed, the research questions 2 and 3 can be defined as answered and the stated hypotheses 2 and 3 can accordingly be assessed.

Table 15: 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

7. CONCLUSIONS

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 who can also use these technologies, a lot of opportunities are revealed for hearing care professionals. The managerial implications are summarized again in Table 16.

Table 16: Managerial Implications

Managerial Implication	**Publication**
Hearing aid accompanying smartphone apps should be frequently integrated in the fitting process by Hearing Care Professionals.	(Ross, 2020b)
The use of smartphone-based tele-audiology should be applied in combination with the traditional form of intervention.	(Ross & Wohllebe, 2021)
Clinics should work on education and training of hearing care professionals to increase the use mobile-health technologies.	(Ross, 2022)
Hearing aid manufacturers should more highlight benefits outside the audiological field of mobile-health technologies.	(Ross, 2022)
The design of hearing aid-accompanying smartphone apps by patients should be kept as simple as possible.	(Ross et. al, 2022)
Future generations of patients with higher levels of technical affinity will become more autonomous in their use of mobile health technologies.	(Ross et. al, 2022)

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.

8. NEW SCIENTIFIC RESULTS

Table 17: Overview of new scientific 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, 2020b)
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.

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.

9. SUMMARY

The goal of this cumulative dissertation was to address the application of mobile- health technologies in Hearing Healthcare. This includes not only the application itself, but also the effects that arise from its use.

For this reason, the first step was to conduct a systematic literature review that focused on the use of smartphone apps that accompany hearing aids. This research clearly showed that the use of this technology has positive influences on hearing aid outcomes. Increased levels of patient engagement, in which the patient plays a central role in the overall fitting process, were shown to result in higher satisfaction with the hearing aids and consequently increased wearing time.

Furthermore, it could be concluded that the use of smartphone apps with all their possibilities is part of the paradigm shift away from clinic-based care towards patient centered care.

To address this trend, the factors that positively influence the willingness to use smartphone-based tele- audiology were also investigated. Therefore, the user side of the hearing care professionals was considered first. It was found that there is a fundamentally positive attitude towards the use of this technology, which is positively affected by the level of training of the hearing care professionals and their previous experience with smartphone-based tele-audiology. It was also found that audiological benefits provided by the technology did not influence the willingness to use it. However, effects that generate business benefits for the hearing care professional or clinic have a positive impact on this.

Then the focus was put on the patients' side and a survey was conducted among them who have already had tele- audiological experiences with the

smartphone. This showed that factors such as the ease of use of this technology, i.e. the app, the smartphone and the hearing aids, are decisive for the willingness to use it. The role of the hearing care professional was also analyzed. In developing a new model, it was possible to assume that as technical affinity increases, the relevance of personal assistance in the use of the technology decreases. The mentioned model created a basis for further research in this direction.

To finally then investigate the effects of smartphone-based tele-audiology on aspects outside the audiological components, a study was conducted with 30 subjects to investigate the impact of this technology on the service quality of the clinic. In addition, this was compared to the traditional option. The Servqual model was used as the framework for this study. It was clearly shown that this form of intervention is comparable to the face-to-face variant, but a mixture of these two forms provides a maximum level of perceived service quality.

These results should provide a basis for hearing care professionals and clinics to integrate these technologies into their existing processes and, due to the positive effects, motivate them to use them regularly.

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11. RELATED PUBLICATIONS OF THE AUTHOR

11.1. Papers

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

Ross, F., & Wohllebe, A. (2021). Evaluating the Service Quality of Mobile Health Versus Clinic Based Intervention in Hearing Healthcare. A Comparative Study. *International Journal of Interactive Mobile Technologies (IJIM)*, *15*(10), pp. 21-32. https://doi.org/10.3991/ijim.v15i10.21725

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11.2. Books

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12.1. Papers

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Wohllebe, A., Ross, F., & Podruzsik, S. (2020). Influence of the Net Promoter Score of Retailers on the Willingness of Consumers to Install Their Mobile App. *International Journal of Interactive Mobile Technologies (iJIM)*, *14*(19), pp. 124–139. https://doi.org/10.3991/ijim.v14i19.17027

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12.2. Books and Book Chapters

Ross, F. (2022), Ambidextrous Leadership as a Success Factor in the Process of Digital Transformation. An Example on Hearing Healthcare. *Organizational Behaviour and Leadership Theory in Practice.* 109-114, MATE – Kaposvár Campus

13. SHORT PROFESSIONAL CV

Time period	Company	Professional Activity
2001 - 2007	Hörgeräte Reichel	Hearing Care Professional
2007 - 2011	Hörgeräte Reichel	Hearing Care Professional Master
2011 - 2016	Hörgeräte Reichel II	Owner and Managing Director
2016 - today	Das Hörhaus	Owner and Managing Director
2020 - today	Wohllebe & Ross Publishing	Owner and Managing director
2019 - today	Hamburger Fern Hochschule	Lecturer

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