Mobile app for the remote control of a bone conduction hearing aid considering customer and other stakeholder requirements

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***Abstract*—The purpose of this study is to evaluate and analyze the user requirements of a remote-control app for a bone conduction hearing aid called *ADHEAR*, and to demonstrate how these can be addressed in the software.**
An online survey identified and evaluated the needs and wishes of all stakeholders involved including end-users, supervisors of the users (e.g., parents and caretakers), and hearing acousticians. As usability techniques, the *ten heuristics for user interfaces* by Nielsen and the guidelines of *Material Design Components* were applied in the programming of a demonstrator app. A usability test was conducted to evaluate and provide proof of the concept. Although the user survey confirmed most of the requirements, some aspects like the significant interest in streaming were surprising. The usability test could identify one major issue in the design and functionality of the demo app, which will be solved before the market release. This paper concludes that the outcome of the future *ADHEAR* system was benefited by involving users and other stakeholders in the development process of the remote-control app.

***Index Terms*—Mobile application, Usability, Remote-control app, bone conduction**

I. INTRODUCTION

WITH its cochlear and bone conduction implants, *MED-EL* has been a global player in the field of hearing solutions since 1977. Next to implantable bone conduction hearing solutions, *MED-EL* also offers a non-implantable adhesive hearing aid called *ADHEAR* [1]. Currently, the system will be revised and upgraded in terms of design and software. Also, the introduction of a remote-control app is under consideration. For a successful implementation of a mobile application for the *ADHEAR* system, first user and stakeholder requirements must be analyzed and evaluated. A user-centered approach for the development process will be chosen for the project process which includes the implementation of usability techniques in the concept development as well as the usability testing of the programmed demonstrator app.

It is well known that mobile medical application became a trend in recent years [2]. This trend is also recognizable in the hearing aid industry [3]. According to [4] and [5], mobile applications of the hearing device have multiple benefits including patients' empowerment to self-manage their hearing loss. Hence, involving the users of the hearing aids in the development process of the remote-control app might also be beneficial. Nowadays, not only the functionality of a mobile application is important but also non-functional requirements like user-friendliness and intuitiveness [6]. This especially applies to elderly persons.

After analyzing current trends, technological background, and the market situation, the requirements of users and stakeholders will be evaluated. Based on the finding of the requirement analysis and usability techniques a demonstrator app will be designed and programmed. This paper will be concluded with a usability test to show proof of concept and design.

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II. MARKET AND TECHNOLOGY ANALYSIS

This section of the paper summarizes the emerging trends of mobile applications, technological possibilities, and the direct comparison of the *ADHEAR* system to its competitors.

Although there is no clear definition of mHealth, it has been broadly described as the use of mobile and wireless technology in the medical environment to enhance the health system and outcomes [7]. The emerging trend of mHealth applications can be proven by the increasing number of mobile medical applications, which peaked at over 653,000 in 2021 [8]. This trend can be further confirmed by the FDA releasing additional guidelines on mobile medical apps in 2013 due to the emerging numbers of approved mHealth applications since 1997 [9]. The trend of mHealth applications is not restricted to the United States; since 2008, the EU has found over 45 projects for the development of mobile medical applications. A study by Koumpouros and Georgoulas [10] evaluated these projects and showed that most medical apps targeted patients with a number of 37 projects. However, the study also notes that research in that area is dominated by the private sector. As part of the medical healthcare application, the topic of remote care is also becoming more important. According to [11], more evidence is given that remote care positively influences the health of the patients, especially since the COVID-19 pandemic. More relevant for this thesis is the emerging section of mobile applications for remote fitting. A published research study from 2020 [12] showed that by including mobile applications in the hearing aid fitting procedure, the quality of the outcome of hearing aids can be improved. Additionally, the study demonstrated an increase in wearing time because users felt more involved in the hearing aid fitting process.

The introduction and availability of *Bluetooth low energy (LE)* is one of the most recent technical achievements that will support the development of the next generation of *ADHEAR* especially the remote-control app. *Bluetooth LE* provides significant advantages in terms of high connectivity and low battery consumption [13]. The issue with hearing aids and ordinary *Bluetooth* in recent years has been the excessive battery consumption and poor audio streaming capabilities [14]. The release of *Bluetooth 5.2* in 2020 [15] included the next generation of *Bluetooth Audio LE*. The technology provides high-quality audio sound transmission in combination with low power consumption by integrating isochronous channels [16]. Lastly, the findings of the competitor analysis are summarized. A review paper by Ellsperman et al. [17] compared multiple bone conduction devices available on the market, including the availability of mobile applications and streaming methods. Generally, bone conduction systems can be divided into surgical implanted and extrinsic devices. Surgically implantable devices are further classified as percutaneous (skin penetrating) and transcutaneous (non-skin penetrating) devices which are further categorized as passive and active products. Table I demonstrates the market availability of bone conduction devices in each category class.

TABLE I: Currently available bone conduction hearing devices on the market including their basic characteristics [17].

Category	Device	Manufacturer
Percutaneous	Ponto	Oticon Medical [18]
	Baha Connect	Cochlear [19]
Transcutaneous Passive	Alpha 2 MPO	Medtronic [20]
	Baha Attract	Cochlear [19]
Transcutaneous Active	Osia	Cochlear [21]
	Bonebridge	MED-EL [22]
Adhesive	ADHEAR	MED-EL [23]

The fact that the *ADHEAR* system is the only adhesive bone conduction hearing aid stands out in Table I. Also mentioned in [17] is that the anchoring method provides multiple advantages like no pressure-induced discomfort and no need for surgery. Furthermore, bone-anchored devices have the potential for skin infections. However, as shown in Table II, the *ADHEAR* system does not include a mobile application.

TABLE II: Bone conduction hearing devices including mobile applications and streaming options for *Android* and *iPhone* [17].

Device	Mobile Application	Direct iPhone streaming	Direct Android Streaming
Ponto	OTICON ON App	X	
Baha Connect	Baha Smart App	X	X
Alpha 2 MPO	None		
BAHA Attract	Baha Smart App	X	X
Osia	Osia Smart App	X	
Bonebridge	Samba 2 Remote		
ADHEAR	None		

III. Methods

A. *Identification and evaluation of user and other stakeholder requirements*

The structure of the methodology of identifying and evaluating user and other stakeholder requirements is divided into objectives, procedures, and analysis of the survey.
The survey's objective is the determination of the requirements of users and stakeholders. The three main stakeholders of the *ADHEAR* product are:

- Direct users of the device
- Supervisors of users (e.g., parents and caretakers)
- Hearing acousticians

Three key requirements were established by product managers as well as research and development engineers before the survey. The new app should provide all of the features the old *ADHEAR* audio processor offered via its buttons. The project's minimum requirements were set to those two functions and include volume adjustment and program switching. As the old audio processor could give the user acoustic feedback when the battery was low, this feature was added to the minimum requirements. In addition to the auditory signal, the app should also include a display of the current battery status. Nonetheless, the three main features of the *ADHEAR* will still be implemented into the new audio processor. The purpose of the study is to assess the needs and requirements of the users for these functions named above. Further features are evaluated and additional needs and wishes of *ADHEAR* users, supervisors of *ADHEAR* users, and hearing acousticians are identified.
As shown by [24], surveys are one of the best quantitative tools for determining user and stakeholder requirements. In this study, an online survey was conducted using *Microsoft Forms*. Over three months, the survey was carried out and included all stakeholders. The structure of the survey was split into users, supervisors, and hearing acousticians and was distributed in *Germany*, *Austria*, and *Great Britain* via the *MED-EL* newsletter. The target size of 50 people was set.
The survey's analysis and evaluation were divided into two parts. Only two supervisors participated in the survey, thus their feedback was united with the results of the users' section. Only the wording of those two parts differed, but not the content. The questions were just worded differently to better address the supervisors instead of the users. In this summary, only the overall participation distribution and the three key requirements were evaluated in the sections of *ADHEAR* users and hearing acousticians.

B. *Usability techniques in app programming*

For developing the app concept and designing the prototype, two usability techniques were used. First, the *usability heuristics for user interface design* are described and second, the *Android Studio Material Design Components* guidelines are summarized.
Although no precise instructions regarding the implementation of usability exist, a set of very basic guidelines should be taken into account, when developing an app. In the concept

development, the 10 usability heuristics for user interface design by Jacob Nielsen were applied [25]. The usability heuristics are:

1) Visibility of system status
2) Match between system and real world
3) User control and freedom
4) Consistency and standards
5) Error prevention
6) Recognition rather than recall
7) Flexibility and efficiency of use
8) Aesthetic and minimalistic design
9) Help users recognize, diagnose, and recover from errors
10) Help and documentation

Next to the usability heuristics, the Android Studio Material Design Components were used for the implementation of the demo app [26]. The following components were integrated. Most of them were utilized for navigation purposes.

- Launch Screen
- App bars top
- Bottom navigation
- Navigation drawer
- Menu

C. *Concept evaluation and usability testing*

Overall, the usability test intends to evaluate the concept of the app in form of an interview. The test focuses on the app's usability and the user experience. Thereby, the usability interview aims to identify issues and problems in the concept. Four *ADHEAR* users were interviewed for the usability tests. Generally, all tests were executed at the *MED-EL* headquarters in *Innsbruck* besides the one which was conducted online via *Microsoft Teams*. A *Samsung Galaxy S5* smartphone was used for the offline test. For the online interview, a *Google Pixel 3a* emulator device was installed.
The usability test started with reading out the process of the interview to guarantee all participants had the same information. To begin with, the *Affinity of technology interaction scale (ATI)* was determined [27]. This standardized test evaluates the users' affinity toward technological interactions. The main part of the interview consisted of a five minutes time frame for the users to familiarize themselves with the app as well as five different tasks. The time to successfully complete a task was measured. Afterward, the participants rated the intuitiveness of each task on a ten-point scale (one being worst and ten being best) and were asked to answer a few questions regarding its usability. The five tasks were:

1) General functionality
2) Renaming program title
3) Sending feedback
4) Delete notification
5) Statistics page

Directly after the tasks were completed, the participants were asked to perform a standardized usability test called the *User Experience Questionnaire (UEQ)* [28]. This test is often used to gain quantitative data regarding the usability of a product. Lastly, the participants were able to give feedback on the demo app via open questions. The last part of the usability interview aimed to capture an overall impression of the app.
For the evaluation of the usability test first, all data were collected, organized, and translated. The determination of the ATI scale was performed according to [29]. Table III shows the possible interpretation of the calculated ATI scale [30].

TABLE III: Values of ATI scale and their corresponding level of technological affinity. [30]

ATI scale	Description
1-2	very low affinity of technology interaction
2-3	low affinity of technology interaction
3-4	medium affinity of technology interaction
4-5	high affinity of technology interaction
4-5	very high affinity of technology interaction

The general first impression of the app was evaluated and major critics were pointed out in the results. The section of the five tasks was analyzed using Nielsen's severity rating [31]. Following scale was applied to categorize the usability based on the intuitiveness rating. Table IV shows the classification used for the analysis of the tasks.

TABLE IV: Relation between the scale in usability test and Nielson's severity rating.

Test scale	Nielson's severity rating [31]
9-10	0 no problem
7-8	1 cosmetic problem
5-6	2 minor usability problem
3-4	3 major usability problem
1-2	4 usability catastrophe

With the UEQ as described in [31], the quality of a product can be measured by evaluating its attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. The six scales were determined by rating 26 items between -3 to 3, whereby -3 represents the most negative and +3 the most positive. For the analysis of the UEQ, the mean value of each item was calculated and evaluated. The results were visualized graphically. Between -0.8 to 0.8 the results were categorized as neutral, greater than 0.8 as positive, and smaller than -0.8 as negative. Lastly, the general feedback of the participants is summarized and the main positive and negative results are named.

IV. Results

A. *Identification and evaluation of user and other stakeholder requirements*

The results of the identification and evaluation of user and other stakeholder requirements include the overall participation and the three main features of the app.
Figure 1 displays the distribution of participants in the survey.

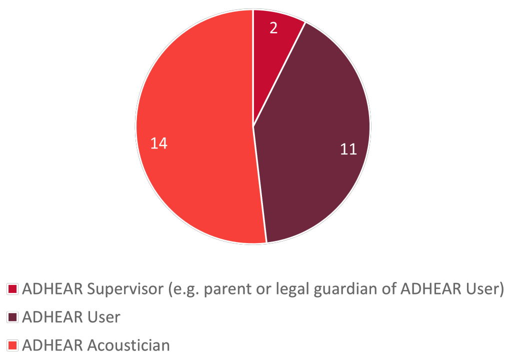


Fig. 1: Representation of participation of the survey.

Figure 1 shows 27 participants in total, including 14 hearing acousticians, eleven users, and two supervisors.
Next, the frequency of users changing the hearing program of their audio processor is displayed in Figure 2.

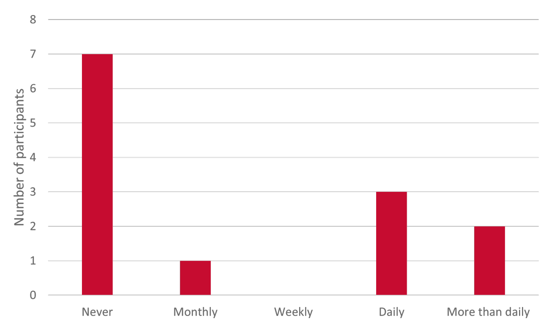


Fig. 2: Number of times participants change program.

Figure 2 shows that seven participants never change the program. In contrast, three *ADHEAR* users answered that question with daily and two with more than daily.
The other two main functions of the new remote-control app are described in Figure 3. Additionally, the interest in streaming is displayed.

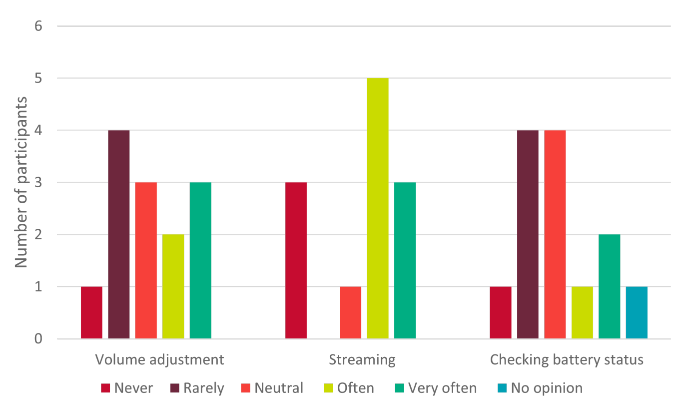


Fig. 3: Demonstration of the probability of using of the two main features: volume adjustment and display of battery status. Also, the interest of users in streaming is shown.

It can be seen in Figure 3 that the interest in volume adjustment is moderate with four participants stating rarely and one participant stating never wanting to change the volume. Two participants noted often using this function and three very often. The answers to the probability of using the display of the battery status vary from one never, four rarely, four neutral, and two very often want to use this feature. The feedback on streaming is more positive compared to the interest in two of the three main functions. The streaming option would be used by five participants often and by three very often. One individual has a neutral opinion about the function and three users would not use a streaming option. The affinity of *ADHEAR* users towards the main features can be directly compared to the feedback of hearing acousticians in Figure 4.

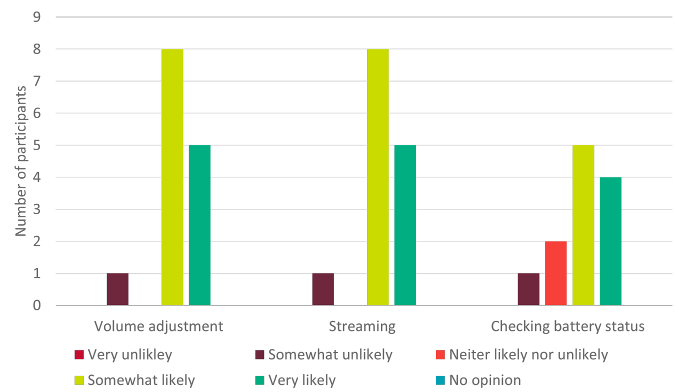


Fig. 4: Demonstration of the probability of use of the two main features volume adjustment and display of battery status out of the hearing acoustician perspective. Also, the interest of users in streaming is shown.

The two features - volume control and streaming - had a strong resonance. Eight hearing acousticians stated that those two features would be very likely used. According to one participant, the two features are unlikely to be used. Also, the battery status is popular among the hearing acousticians as six answered with a somewhat likely use and four with a very likely use.

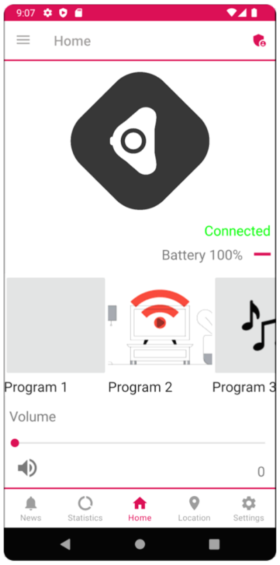
B. Implementation of usability techniques in app programming

The general workflow of the app is attached in the appendix A. The user will automatically be guided to the start screen after the app is launched. The user will either be guided into the login procedure of the app or in case of no existing *MED-EL* account, into the registration. The demo app can also be started directly on the start screen. If no device is connected the pairing process will be starts. Later, when the user is logged in and a device is connected all intermediate steps will be skipped and the user will be directly navigated to the home screen.
Next, the implementation of the usability heuristics and *Android Studio Material Design Components* guidelines into the prototype is summarized. In the scope of this work only the features and function of the app are described which will later

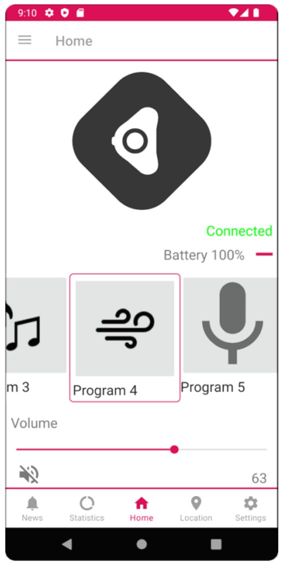
be evaluated in the usability test.

1. Home Screen and main functionality

The three main features of the app are displayed in Figure 5.



(a) Home screen in admin mode



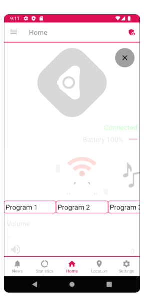
(b) Home screen in user mode

Fig. 5: Display of home screen with navigation components, title, battery and connection status, program switching, and volume adjustment. Also, the admin mode and user mode are displayed.

The volume adjustment is placed at the bottom of the screen as can be seen in Figure 5a and Figure 5b. In the middle of the screen, the battery display and the selection of the five different hearing programs are implemented. In Figure 5b the muting of the device and the selection of program four are demonstrated. The various programs can be selected by swiping to the left and the right. As of right now, only placeholders are used as icons. The activated admin mode is illustrated in Figure 5a by an icon on the top right of the top app bar. The admin mode enables further functionality for the user.

2. Renaming of a program title

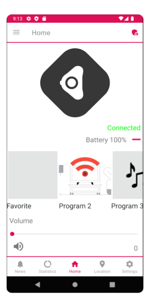
For the personalization of the app, the user can rename program titles. Figure 6 shows the process.



(a) Start rename process

(b) Program Selection

(c) Renaming



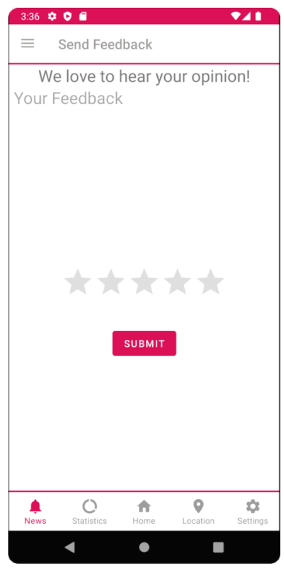
(d) Saving

Fig. 6: Workflow of the program renaming process (a)-(d)

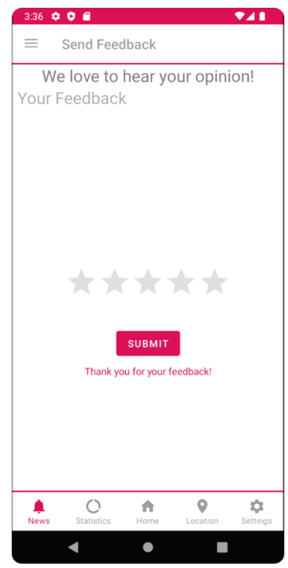
By clicking on the admin mode icon (see Figure 5a) the options menu will be opened and the renaming process can be started. In Figure 6a it can be seen that the to-be-renamed program titles are highlighted with a red border. The surrounding screen appears blurry. The keyboard gets activated by clicking on the program name (see Figure 6b). In Figure 6c the new named *Favorite* is typed in and the cancel icon on the top right (see Figure 6a and Figure 6b) switches to a save icon. After clicking the save icon, the new name appears on the home screen (see Figure 6d) and the renaming process will be closed.

3. Sending feedback

The demonstrative functionality of the *Send Feedback* screen is displayed in Figure 7.



(a) Representation of feedback screen



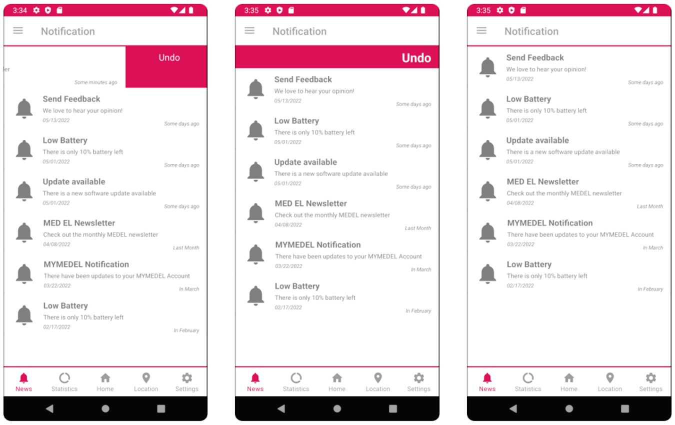
(b) Illustration after feedback was sent

Fig. 7: Display of feedback screen and its implemented demonstrative functionality.

Figure 7a shows the feedback input field and a five stars rating scale. The user can rate the app from zero to five stars in half-point steps and easily send feedback. After the feedback has been submitted a *thank you note* is displayed on the screen (see Figure 7b).

4. Deleting of notification

A function to delete single notifications was integrated into the app and is demonstrated in Figure 8.



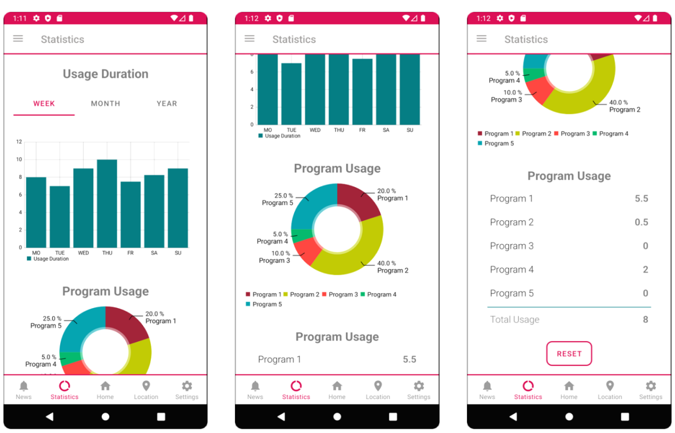
(a) Starting of deleting process (b) Undo functionality (c) Deleted notification

Fig. 8: Illustration of deleting notifications process (a)-(c).

The notification items can be deleted by swiping to the left which is indicated in Figure 8a. As this action might be done accidentally, the user can undo his action by clicking *Undo* (see Figure 8b). After three seconds the exit strategy disappears and the notification is gone (see Figure 8c).

5. Statistics

The main purpose of the statistics page is to provide the users an overview of their daily usage of the audio processor and the program usage. The statistics screen is displayed in Figure 9.



(a) Usage duration (b) Program usage (c) Program usage per day

Fig. 9: Display of usage statistic screen of demo app (a)-(c).

As seen in Figure 9a, the page starts with usage duration per week, month, and year. The program usage is displayed in a pie chart with the percentage use of each program (see Figure 9b). In Figure 9c the daily usage per program is illustrated. Furthermore, a reset button is shown. The data displayed is exemplary and the reset option is not implemented yet.

C. Concept evaluation and usability testing

The usability test started with the evaluation of the ATI scale for each participant. The results are described in Table V.

TABLE V: Results from the *Affinity for technology Interaction Scale* - Test.

Test person	Scale	Description
1	3.89	Medium affinity for technology interaction
2	5.78	Very high affinity for technology interaction
3	5.22	Very high affinity for technology interaction
4	3.33	Medium affinity for technology interaction

Before starting the task section, the participants had five minutes to familiarize themselves with the app. The users were allowed to stop as soon as they felt familiar. The average time for checking out the app was 2:25:15 min. Generally, there were no misunderstandings but test person two noted that one program does not have an icon. Features named likable after the first impression by the participants were location features, battery status, and statistics. The overall impression was positive. Dislikeable aspects of the app were layout design, colors, and bulky appearance. The navigation and menu were rated positively by the test persons besides test person two who suggested merging the two menus. The design (colors, symbols, and readability) was not rated positive but everything detail of the app was readable to the test persons. Lastly, the participants were asked if the expression is clear and if interactive elements are identifiable which everybody affirmed.

Task 1 about the general functionality of the app was completed successfully by every participant with an average time of 00:36:33 min. The average intuitiveness rating was nine out of ten. The main features were rated easy and straightforward. Only the volume adjustment was difficult for two participants. Test person two noted that it is hard to exactly set the volume with the slider. The covering of the volume display by the thumb in the higher ranges of the volume control was mentioned by test person three.

The only task that was not performed successfully by any participants without hints, was the renaming of the program titles. This resulted in an average completing time of 01:54:25 min and an average intuitiveness rating of 5.25. The identification of the admin icon and the closing of the keyboard were named as reasons for the negative rating.

In the third task, participants were asked to send short feedback within the app. The average time to complete the task was 00:22:12 min. Within an average of ten, the task was rated the most intuitive. Thus, the feedback was very positive and only the probability of using this feature was questioned.

Task 4 was performed the fastest with an average of 00:19:22 min. The average intuitiveness rating was 7.75. Test persons one and two did not have any issues deleting a notification. However, the other two test persons expected that by clicking on the notification the option to delete the item would be shown.

The last task included finding information on the statistics page. The time to successfully complete the task was 00:28:22 on average. Task 5 was rated with average intuitiveness of 8.85. The feedback on this function was positive. Test person three stated that the unit at the daily program usage is missing. Generally, the benefit of the statistics page was questioned by the test persons. However, the feature was rated as a nice add-on.

After the task section, the participants were asked to perform the UEQ test. The results are displayed in Table VI.

TABLE VI: Results of the User Experience Questionnaire with mean and variance of each scale.

UEQ Scale	Mean	Variance
Attractiveness	2.125	0.95
Perspicuity	2.500	0.71
Efficiency	2.625	0.19
Dependability	2.125	1.27
Stimulation	1.375	2.52
Novelty	1.188	3.02

The efficiency and perspicuity of the app were rated the highest with a mean of 2.625 and 2.5. In contrast, with a mean of 1.188 and 1.375, novelty and stimulation were rated the poorest. The results are graphically visualized in Figure 10.

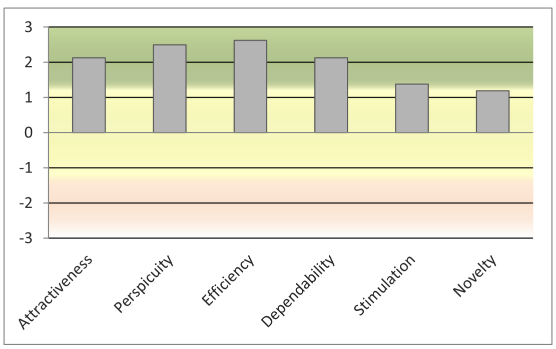


Fig. 10: Graphical representation of mean and variance of each UEQ scale.

The overall feedback on the app was positive. Only minor aspects were named dislikeable including design, issues with volume adjustment, and the benefit of usage statistics.

V. Discussion

The evaluation of the user and stakeholder requirements was one of the main objectives of this work. To begin with, participation in the online survey is discussed. With 27 participants the target sample size of 50 could not be met. According to [32] the number of participants is important for the outcome of a survey. Nonetheless, the results of the study provided interesting insights into the opinions of *ADHEAR* users and hearing acousticians about remote-control functions. The short period of only three months could be one reason for the low participation. Therefore, extending the survey time could both confirm already detected results and uncover new requirements.

The most important research results of the study are highlighted in the following section along with their implications for the development of the app concept. The finding of the low frequency of program changes is already known to *MED-EL* and was expected. Thus, the expectations of this question of the survey could be confirmed. The interest in adjusting the volume of the audio processor and the affinity towards displaying the battery status was moderate. In contrast, most hearing acousticians stated those two features will be utilized often or even very often. Both functions will still be implemented in the app as both of them are part of the main requirements. As the use of the remote-control app will not be mandatory, the basic control functions will also be implemented in the new audio processor. In addition, this will also simplify the approval of the new *ADHEAR* system by the *FDA* as the app is part of the medical device [33] [34].

An interesting finding of the survey was the very high interest in streaming. Although *MED-EL* is aware that streaming nowadays is popular and plays a crucial role in peoples' life [35], the resonance was still surprising. The same applies to the opinion of hearing acousticians regarding that topic. As an implication of this finding, streaming will be integrated as a separate program. However, they must be aware of this feature's downsides as extensive streaming will reduce the audio processor's battery life [36]. High streaming quality and low power consumption can only be provided by *Bluetooth LE* [16], which availability depends on the users' devices.

The second part of the thesis included integrating usability techniques into the design of a demo app. To show proof of concept a usability test was performed. The interview started with the determination of the ATI scale. Test persons two and three had a very high affinity for technology interaction which resulted in very detailed feedback. The value of the other two participants' opinions is also significant as not all *ADHEAR* users are very affine with technology. At the beginning of the main section of the usability test, the participants had five minutes to familiarize themselves with the app. The first impression of the test persons was overall positive. However, a few minor aspects were already named before starting the functionality tasks. The color theme and the design layout do not seem to be very attractive according to some test persons. Therefore, the design of the app should be reworked. The support of the *MED-EL* design department should be considered. While using the app for the first time some aspects were rated negatively, but generally, the first impression of the usability test was positive. Next, each task will be analyzed with the help of the Nielsen severity scale of usability [31]. The following Table VII included average time and average intuitiveness rating per task and the resulting categorization according to the severity scale.

TABLE VII: Representation of summary of results of each task and its classification according to the severity scale.

Task	Average time [min]	Average score	Category
1	00:36:33	9.00	cosmetic problem
2	01:54:25	5.25	usability catastrophe
3	00:22:12	10.00	no problem at all
4	00:19:22	7.75	cosmetic problem
5	00:28:22	8.85	cosmetic problem

The first task was rated as *no problem at all* based on average time and intuitiveness (see Table VII). It can be implied that the key requirements - changing programs, adjusting volume, and showing the battery level - were implemented effectively in the app. However, classifying the task's severity impact only in terms of quantitative aspects might compromise its validity. Despite the positive feedback of task one, further work is required to optimize the volume adjustment as it was considered challenging to set the volume precisely. Participants thus suggested adding + and - buttons for more accurate adjustment and repositioning of the volume display. Hence, the rating of the first task as *no problem at all* will be changed to *cosmetic problem* which suggests considering those findings when updating the demo app (see Table VII).
Usability testing has the benefit of identifying significant user interface issues before market release [37]. The perfect example of that statement is task two. The task was rated with an average of 5.25 on the intuitiveness scale, which would imply a categorization as a *minor usability problem*. However, looking at Table VII the usability of the second task was classified as a *usability catastrophe*. This categorization is appropriate given that no participant was able to perform the task without any help or support. Two main reasons were named as issues for the renaming process. First, the icon to open the options menu was not identifiable, and second, participants named trouble closing the keyboard. Therefore, it is clear that this function has to be reworked as soon as possible before the app is released onto the market. For that, the provided suggestions and ideas of the participants will be considered.
Only the third task, as shown in Table VII, was classified as *no problem at all* in the severity rating. As no negative comments regarding the functionality were made by the test persons, it can be said that the quantitative analysis matches their feedback. However, the likelihood of using this function was questioned. To increase the chance of sending feedback, a quarterly reminder will be sent out to the users.
Table VII shows that the last two tasks were categorized as a cosmetic problem. Normally this would imply no need in optimizing the delete function and the statistic page unless time is given in the project phase. Since the demo app is still being developed and the main development phase has not started yet, plenty of time is left for improvement. The fourth task received criticism for the non-interactive behavior of the notifications, which made it difficult to understand how to delete an item at first sight. The future version of the app will contain real interactable notifications and will be tested again before the market release. Hence, there is no need to create exemplary notifications. The same applies to the statistics page where exemplary data is also used to illustrate its purpose. However, in the future, the software will be connected to an audio processor with actual usage data. Nonetheless, the missing unit will be added to the program usage diagrams.
The last part of the usability test began with the usability questionnaire [28] to evaluate the general feedback of the whole app. The UEQ results showed a very positive impression of the *MyADHEAR* app. Generally, all scales were rated outstanding, especially efficiency and perspicuity. However, novelty and stimulation show potential for optimization.
Looking at the final section of the general feedback, it is possible to conclude that the overall response to the app was very positive. Furthermore, the key user requirements were named as likable functions. This demonstrates that the app's focus should be on the primary functionality rather than on playful add-ons. The participants were very engaging during the usability test and provided good suggestions on how to improve the app. The recommendation to combine the two menus, in particular, will be considered and analyzed in further studies. Although there are several methods to modify and optimize the app, the primary objective of developing a remote-control app should not be overlooked. The main purpose of the *MyADHEAR* app is to assist and help users in their daily lives.
Both, online survey and usability testing revealed that including users in the early phases of the development process was beneficial. The survey results were addressed in the demo app's software. In addition, the usability test evaluated the integration of usability techniques and user requirements. The next steps in the product development process will be to update and implement the findings of the master thesis into a new version of the demo app. Later, the basic functionality of the new *ADHEAR* system should be implemented by connecting the demo app to the prototype of the audio processor via *Bluetooth*.

VI. Conclusion

The primary objectives of this work were to identify and evaluate user and stakeholder requirements for a mobile application to remote-control a bone conduction hearing aid. A survey was conducted to analyze the basic requirements. The study provided interesting findings and gave a valuable insight into the mindset of *ADHEAR* users and hearing acousticians regarding a remote-control app. The user-centered strategy in the development process positively influenced the design of the demo app. Based on usability heuristics and Material Design Components, an appealing and functioning prototype was programmed. The key finding of the usability test shows that the developers' ideas do not always match the users' mindset. This once points out the significance of usability testing before the market release. With the introduction of a remote-control app for the *ADHEAR* bone conduction system, *MED-EL* follows the trend of mobile applications in the hearing aid industry.

APPENDIX A
WORKFLOW OF THE APP CONCEPT

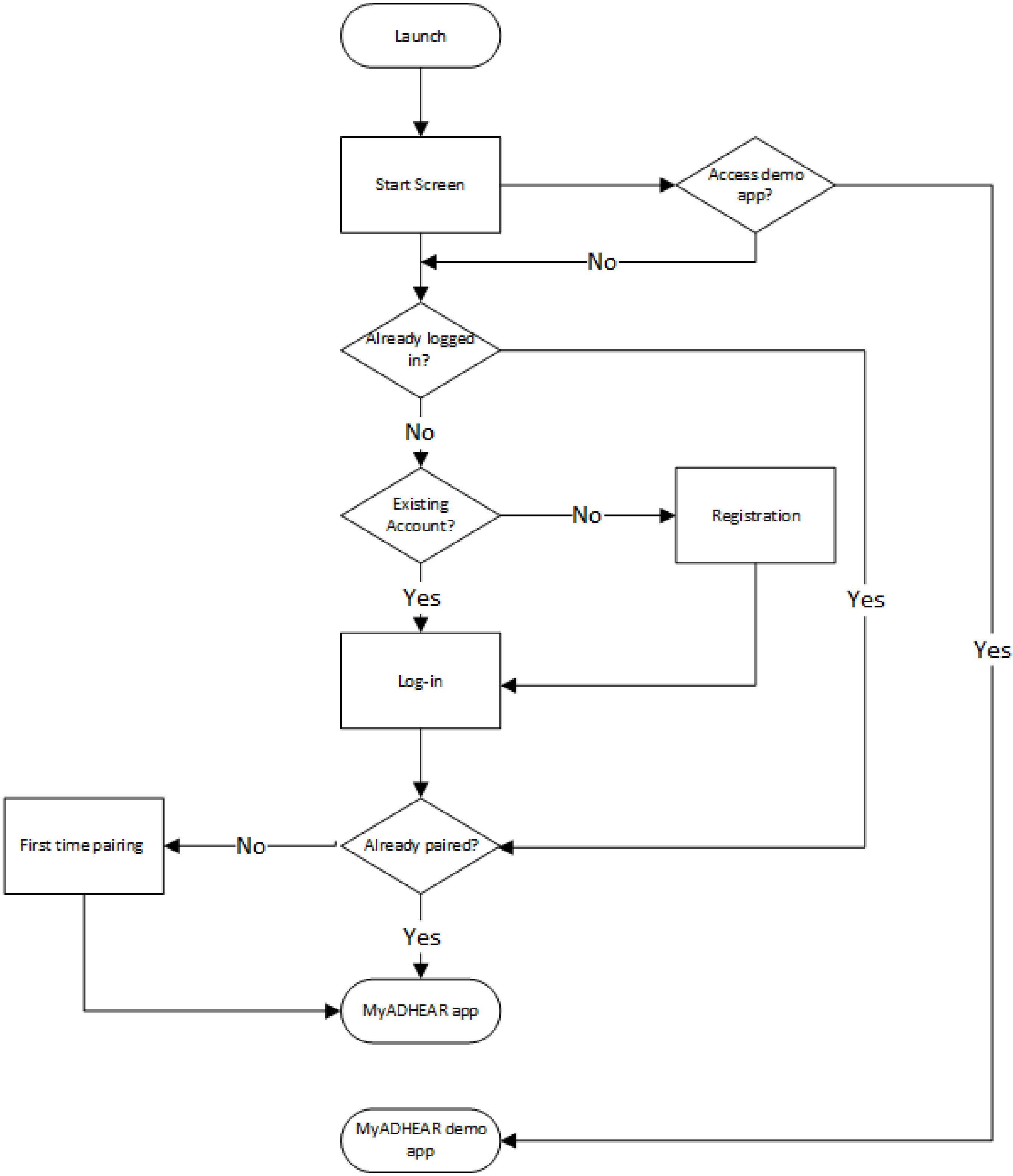


Fig. 11: Representation of the workflow of the app.

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