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Mobile streaming applications for ADHD

Barriers, features, and design principles for neurodivergent accessibility

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Abstract: When discussing accessibility, neurodivergent individuals, such as people with attention deficit hyperactivity disorder (ADHD), are often not considered. Existing research suggests that the needs of users with ADHD differ from those of neurotypical users. However, research in this field is sparse, and often results in design implications that are not thoroughly validated with users.
This research aims to find accessibility barriers faced by adults with ADHD when using mobile applications, and which design elements can help mitigate these barriers. To answer these questions, an exploratory approach was chosen, including structured interviews, the development of a prototype, and testing the prototype.
The results of this research show that adults with ADHD are hindered by various barriers such as nested layouts, too much irrelevant content, features that require too much effort from the user, navigation issues, and lack of user control. These barriers can be minimized by reducing the number of animations and videos, utilizing more colours, and incorporating minimalist design principles when designing a mobile application.

Keywords: ADHD, neurodivergence, software accessibility, accessible mobile design, mobile streaming applications

1. Introduction

Following the EU directive on the accessibility requirements for products and services (Publications Office of the European Union, 2019), mobile applications must be accessible for everyone from 28 June 2025 on. This is to remove barriers for people with various kinds of disabilities, and therefore to enhance inclusion in the European society (Publications Office of the European Union, 2019). But how does accessibility look like for people with different disabilities, and what qualities do applications need to have to be considered as accessible, or even inclusive? Currently, applications lack accessibility for neurodivergent groups. An example of this is Google Maps, which conveys information in a way that does not allow users with ADHD to extract important pieces of information about their route, while users without ADHD can understand the displayed information without becoming overwhelmed (Smits, 2022). This is because user interface (UI) design principles are developed for neurotypical people and it is not clear to which extent they can be applied to neurodivergent individuals such as people with ADHD. In the past, it was believed that ADHD only existed in children, and not in adults (Barkley, 2019), which would lead to the conclusion that additional research on adults with ADHD is unnecessary. However, the belief of ADHD being a condition only present in children has been proven to be a myth (Barkley, 2019). Furthermore, ADHD differs in children and adults (CDC, 2024), so additional research is needed on adults with ADHD. Thus, this research aims to understand the needs of adults with

ADHD, and to identify guidelines for design principles in respect to mobile applications that are suitable to make those apps more accessible to people with ADHD. This could help developers avoid exclusion and discrimination in the future.

In previous interviews regarding the user experience of adults with ADHD (Smits, 2022), users repeatedly reported facing problems such as navigational issues when trying to understand where they came from and where to go next, when using the music streaming application Spotify[1]. Furthermore, existing research on accessibility for users with ADHD by Santos (2022) and Turner (2023) also focused on the use case of video streaming applications. Therefore, streaming applications could be suspected as posing more challenges than other types of applications to people with ADHD and are considered as suitable for exploring these challenges more. Thus, the use case of a mobile music streaming application is used as an example domain to define and discover design principles for users with ADHD. The scope of this research is defined as accessibility in mobile music streaming applications, and the target group is scoped to adults with ADHD.

This leads to two main research questions (RQ) and their sub-questions (SRQ):

- RQ1: What are the accessibility barriers adults with ADHD face when *accessing mobile streaming applications?*
  - SRQ1.1: What is the most prominent barrier?
  - SRQ1.2: What features do users with ADHD want in their mobile streaming apps?
- RQ2: Which design principles minimize or remove the accessibility *barriers?*
  - SRQ2.1: How do these principles relate to existing general UI design principles?

2. Related Work

In UI design, a popular set of principles that is commonly used and referred to, e.g., by Smits (2022), are the Nielsen Heuristics. These heuristics are ten principles for improving the usability of applications which were developed by Nielsen in 1994. They include giving the user appropriate feedback to actions, incorporating error prevention measures and showing clear error messages to the user to help figuring out the next steps, and reducing cognitive load by making important options visible, while avoiding showing irrelevant pieces of information (Nielsen, 1994).

To find complementary work regarding UI design for adults with ADHD, a scholarly keyword search with the search terms *UI design for ADHD* and *ui design guidelines for ADHD* was carried out in January 2025 and March 2026, using Google Scholar[2]. The results were filtered for articles that were published in 2020 or later to get more recent results.

2.1. Traditional UI Design for adults with ADHD

Building on the Nielsen Heuristics, Smits (2022) investigated usability adaptations of mobile applications for adults with ADHD. To investigate barriers faced by users with ADHD, Smits conducted interviews and surveys. Afterwards, two minimal user interfaces for a navigation application were designed, tested and compared to an existing navigation application (Smits, 2022).

[1] https://open.spotify.com
[2] https://scholar.google.nl

Smits found that it was necessary for participants with ADHD to have important pieces of information highlighted by colour, removing elements from the interface and limiting the overall amount of information presented to the user eased the application usage. Furthermore, people with ADHD were enabled to achieve their goals inside the application by applying these design principles, while neurotypical people preferred the accessible design, but did not need it to carry out their tasks (Smits, 2022). These results are relevant for this work, as they present barriers such as not being able to identify relevant information due to a high density of (textual) elements on the screen, or being distracted by moving content such as videos (Smits, 2022). However, these barriers and the respective approaches to remove them have never been validated in another way than by designing exemplary mock-ups (Smits, 2022).

The importance of colour for users with ADHD, and the barriers posed by interfaces which are densely filled with information are also recurring in Turner's research (Turner, 2023). Turner identified issues when designing for an audience with ADHD by doing interviews, tests and workshops with participants with ADHD, as well as trained professionals in the domain of UI design. Based on these barriers, Turner developed guidelines for designing interfaces for users with ADHD. These guidelines were validated by testing simple principles like whether icons are easier to understand than text. The problems identified through the interviews were finding the balance between not overloading interfaces, and therefore overstimulating users with ADHD, versus designing too minimalist interfaces, which are not suitable for grabbing the focus of users with ADHD, the choice of colours which can also influence how users with ADHD perceive information, and a lack of feedback in case of errors, leaving users with ADHD with a greater feeling of self-doubt. Furthermore, participants with ADHD reported on facing navigational issues connected to nested menus, and understimulation or overstimulation caused by either a lack of personalization, too many elements on a single page, or auto-playing contents (Turner, 2023).

Guidelines to mitigate these barriers include principles such as conveying information in multiple forms, providing possibilities for personalization, highlighting important information with colour or contrast, preferring short texts, and not sending too many notifications to the user (Turner, 2023).

Additional design principles were collected by Kletenik et al. (2024) in a literature review of resources that teach about software accessibility for users with ADHD, autism or dyslexia. In these principles, guidelines that have also been presented in Smits' (2022) and Turner's (2023) work reoccur, such as applications being easier to use for people with ADHD when a neat layout without too many elements on the same page is given, the page's content is organized clearly, and important information is highlighted by colour or a bolder font weight. However, there is no additional explanation provided about what it means to have page content clearly organized or how much information is too much information. Furthermore, they advise using a 12-14pt sized font without serifs, give clear instructions about what the user must do, allow for user customization of an application's appearance and show information long enough for users to process the information (Kletenik, Minkowitz, Peric, Sahin, & Adler, 2024).

2.2. Features for adults with ADHD

In the article by Santos (2022), it was explored how people with ADHD and dyslexia experience video streaming platforms, and how they think about the issues they are facing when navigating these platforms by conducting interviews and co-design sessions (Santos, 2022).

Santos (2022) found that the participants disliked the automatic recommendations of shows to watch, as they felt like the algorithm for creating recommendations would leave them out and

did not represent their interests well. Another finding was that even if categories can be helpful, they pose challenges to participants with ADHD when sub-categories are introduced. Features liked by the participants were the functionality of going back to where the user was when using the application, the previous time, and the direct search, as it allows them to avoid diving into categories. They also underlined the importance of sufficient search algorithms (Santos, 2022). Santos' findings inform this research, because she identified challenges for users with ADHD, such as nested categories adding cognitive load, and dynamic content like auto-played media, which can also be transferred to the domain of music streaming applications.

3. Methodology

This research is positioned in the research field of user experience design and followed an exploratory mixed-methods approach including structured interviews, developing a prototype, and conducting experiments with users to validate the findings. The qualitative part of the research can be found in different phases of the methodology: The structured interviews, and the prototype evaluation, as users were asked for their opinion in an interview setting. The quantitative part of the research lies within the prototype evaluation, as participants had to fulfil tasks while their actions and task completion times were recorded and was added for indicative, preliminary results that can be used as an introduction for further research.

3.1. Ethical Considerations

Various ethical challenges can be encountered when working on inclusive software projects (Dirks, 2022). According to Susanne Dirks (2022), these problems could concern the group of researchers themselves, and the participants of the study. As this research was not conducted in a team, but by a single person, the challenges regarding researchers will not be discussed further.

One possible obstacle regarding study participants is that they must give informed consent. The participants must be informed about their tasks and the research goal in a way that is easy to understand before they begin to participate (Dirks, 2022). This is an issue that could be encountered when conducting interviews with people with ADHD, as well as when testing the prototype with users. Therefore, an information and consent sheet was handed out to potential participants which they had to read and sign before the interviews and experiments were done. Furthermore, the researcher was available in person and via email for giving additional information before the interviews and user tests.

3.2. Structured Interviews

For the qualitative part of this research, structured interviews were chosen to find common barriers faced by adults with ADHD when using mobile music streaming applications, and to derive requirements for a prototype.

Other interview settings would have been possible, too, but structured interviews were preferred. During structured interviews, a fixed script is followed, which was favoured over semi-structured interviews, to get a higher consistency across participants to make comparison easier. This script is grounded in data gathered from semi-structured interviews previously done by Smits (2022), and it aims to test against the findings from these previous interviews. The interviews consisted of 14 questions, starting by gathering demographic information, covering the participant's smartphone and music streaming usage, and ending with detailed questions about the participants likes, dislikes, wishes and expectations regarding their music streaming applications.

The full list of questions can be found in Appendix A. The aim of these questions was to gather a list of barriers that adults with ADHD face while using those applications, discover how these barriers might connect to ADHD, and get insights into what could make their experience more pleasant. These findings formed the basis of the prototype requirements.

The participants for the interviews were recruited through convenience sampling on social media platforms like LinkedIn, Instagram, Whatsapp and Signal. This method of sampling is a biased method, but it has been chosen due to difficulties in getting access to adults with ADHD in a non-clinical setting, and convenience sampling is a way to connect to this population. With this approach, 15 participants were recruited.

From these 15 participants, 14 used Spotify as their main music streaming application, and one person used YouTube. Other streaming apps mentioned but not mainly used were SoundCloud, Apple Music, and Audible. Despite the biased sampling method, the group showed diverse features such as different genders and an age range from 20 to 47. Still, a bias towards younger women could be detected, as the average age was 28.6, and 73.33% of the participants identified as female.

This study focuses on adults with ADHD in a Western culture, since all participants were residing in Germany and the Netherlands. This sample is valuable, as it enabled finding common barriers faced by people with ADHD and was suitable for finding common wishes the participants expressed regarding mobile music streaming applications. It could be verified by comparing the results from the interviews to related research by Smits (2022) and Santos (2022).

3.3. Prototype

Based on the interview transcripts, the responses were analysed for common themes and issues with music streaming applications mentioned by multiple participants. The themes and issues were then used to collect requirements for a prototype that is more accessible to people with ADHD. Moreover, the requirements for the prototype were matched to existing UI design principles to explore the suitability of general UI design principles for people with ADHD and, therefore, to answer SRQ2.1. This prototype was developed with NextJS[3] and used the Spotify API[4] as the backend to be able to play music when interacting with the prototype. This has been done to make the prototype resemble a real music streaming application, which makes the tests simulate a real everyday scenario for the participants, and therefore, enable a better comparison between the prototype and real music streaming applications.

3.4. Validation

To improve the internal validity of the prototype, it was tested utilizing qualitative and quantitative methodology. The tests were done with 14 participants which were split into two groups: A test group, consisting of 7 adults with ADHD, and a control group with 7 adults without ADHD. The average age of the test group was 27.7 years, ranging from 22 to 43 years, while the control group featured an average age of 33 years, ranging from 23 to 54 years. In addition, the test group consisted of 4 female participants, 2 male participants, and one participant who did not identify within binary gender categories. In the control group, there were 5 female and 2 male participants. In the test group, 2 of the participants were taking ADHD medication. The participants were acquired using convenience sampling. During the tests, the participants had to

[3] https://nextjs.org
[4] https://developer.spotify.com/documentation/web-api

perform tasks using an iPhone 13 Pro provided by the researcher. The tasks were defined based on the findings from the interviews, so they are listed in the results section. The time to complete the tasks was measured with a stopwatch and timestamps in the application logs, and the areas on which the participants focused were recorded using the built-in eye tracking using the front-facing camera and screen recording functionality in iOS 18, so no third-party tooling was utilised. The participants had to give their own opinion on the prototype as well, to be able to connect the subjective experiences of participants with the measurements. The goal of this procedure was to ensure the internal validity of this research, as well as to investigate the elements of the prototype that posed barriers or removed barriers for users with ADHD. Additionally, the overall results of this research were being validated by triangulating these results with related work by Smits (2022) and Santos (2022). The goal of comparing the findings of this research with other findings is to improve the external validity, as this research's results could either fit in with previous results, which confirms and strengthens previous research, or they could challenge existing research. In the second case, the differences between the studies would be investigated to explain the varying results.

4. Results

The results of the interviews and the prototype validation are presented in the following.

4.1. Structured Interviews

Common themes that were coming back throughout the interviews were presentation issues, issues regarding the ratio between cost and benefit of the streaming applications' functions, consistency issues, and the reinforcement of problems regarding the users' self-esteem. Additionally, participants mentioned features they liked or would like to have.

4.1.1. Barriers

The barriers that users with ADHD faced when using their music streaming apps can be divided into categories of problems.

First, there are presentation issues: confusing nested layouts leading to mis-clicks, an overload of (irrelevant or auto-generated) content, and videos which are seen as a distraction. Other concerns in this category are cluttered home screens, especially when filled with irrelevant material. Also, participants described their app interface as chaotic due to a lack of categorization. One participant also found the dark colour scheme not engaging enough.

Another category of barriers are issues regarding the effort of using the application. There are user actions which require too much cost and lead to too few benefits for the users, e.g., creating and managing playlists, as users mentioned the process being too complicated, and not having enough patience to keep up with maintaining playlists over time. Furthermore, long texts and instructions are usually not being read.

The third category of barriers is navigation issues. Participants reported not knowing how to go back when they reached certain places in the application, getting lost in their music streaming app, not knowing what buttons do, and accidentally clicking on elements like buttons or links, causing unintended actions. Two of the participants also talked about a lack of user control. Their music streaming app was showing them pop-ups that came back often, even if they did not want to see it. Functions inside their application (like downloading songs automatically) were started regularly without giving users the option to abort these processes.

Then, there are concerns, which were raised by various participants but did not fit into the previous categories. Users often faced the situation of being stuck in a certain set of songs because they thought it was too much effort or even overwhelming to discover new music. This problem was recently approached by Spotify, as the respondents also reported that new features were introduced which led to new, matching music being automatically added to the user's current playlist. This was liked by the participants and mitigates the matter of never discovering new music. The next point is the inflexible search functionality. Users often misspell song titles, which leads to the music streaming applications not finding the songs the users wanted to find, which is an even bigger problem for users who heavily rely on listening directly from the search results instead of discovering generated or recommended content. Throughout all interviews, the topics of having too many (distracting and irrelevant) elements on the home screen and actions requiring too much effort were mentioned most often, so they are considered the most important barriers.

4.1.2. Popular Features

One of the most popular features is the *liked songs* playlist in Spotify. This feature consists of a playlist that is created by default, which can be updated by clicking on a heart-shaped button when playing a song. This button serves as a shortcut to add songs to this playlist. Furthermore, participants reported to rather have one single playlist for their own music than managing music in different playlists. This also becomes relevant on the technical side, as one of the participants complained about their music streaming application not being designed for this use case, since their own playlist got large enough to cause the app to crash when scrolling through this playlist. Other features that were commonly used by the participants are searching for single songs using the search bar and playing them from there directly, looping songs, and listening to playlists curated by other people or organizations. Moreover, features like auto-play or getting a personal mix of songs were mentioned as helpful for finding new music without getting overwhelmed.

4.1.3. Most Wanted

The wishes that were expressed most often by the participants are having an easier workflow to add songs to the own music collection, getting exposed to less auto-generated or irrelevant content, and having a clearly structured interface with easily visible buttons. Regarding the question about what they would like to see when opening the music streaming app, half of the participants wanted to see their own music library, and half of them would like to see what they listened to most recently.

4.1.4. Change Management in Complex Systems

Another takeaway from the interviews was that users often find their own simplified routines through complex systems. These routines might differ heavily from what the designers and developers had in mind when creating the system. An example for that is the participant experiencing trouble with their music streaming application, because they stored all music in a single playlist, which is not intended by the developers, as the app starts to crash when scrolling to the playlist. This must be taken into consideration when introducing changes to the application, for example when removing or replacing features, because these changes might lead to the users' pathways to suddenly get blocked. In that case, users must spend effort again to try to find new routines. This can be seen in the interview answers, as one participant collected all their music by using a heart-shaped button in Spotify, until the button got (re-)moved. This change made it impossible for the user to navigate the application in the same manner as before, making the experience unpleasant.

4.1.5. Reinforcement of Self-Esteem Issues

The next finding from the interviews is a more general problem about the effects of inaccessible design on people with ADHD. As already stated by Dirks (2022), people with cognitive conditions might have lower levels of self-esteem and assertiveness. This phenomenon was also observed during the interviews, in which participants with ADHD referred to themselves as “not normal“. Furthermore, participants seemed to attribute ways in which their music streaming applications did not work well to their own disability instead of seeing them as failures in the application. One example for this is a participant who told about a process in which their app would download songs without giving them an option to abort the download process, but then added that this probably was their own fault, because maybe there was an option to stop this download, but they “just might have missed it“ as they “often miss things“. This shows how an insufficient design can reinforce existing issues with the user’s self-esteem: when applications are not working well, the user contributes this failure to their own disability, which might influence their self-esteem in a negative way again, consolidating existing assumptions the user already has about themselves.

4.2. Prototype

Based on the themes found in the interviews, requirements for a prototype were developed. These requirements were used to create a prototype for testing previous findings and validating design principles for users with ADHD.

4.2.1. Requirements

The requirements for the prototype were derived from the previously presented interview findings. They are based on the features the participants liked to use most, the expectations they had like seeing their own music collection and the music they listened to most recently on startup, and the barriers they faced. To overcome the matter of applications including too much functionality that the users do neither need nor like, the requirements were limited to the most important features that the application should have and did not include additional features. As most of the requirements either exist to help the users reach their main goal (listening to music) or are directly related to the interview outcomes, all requirements are considered user requirements. There are two exceptions in the category of non-functional requirements which are explained and justified below in more detail.

Functional Requirements (FR)

1. The application’s content must be minimized to the features listed in the following requirements.
2. The application must be able to play music.
3. The application must include the functionality of searching for music.
4. The application must provide a personal music collection for each user.
5. The application should enable the user to accomplish the following tasks in a minimal number of steps[5]: searching music, playing music, saving music
6. The application should include a short cut to save music to the user’s music collection.
7. The application’s startup page should not include more than the last listened music, the user’s music collection and a personalized recommendation.
8. The application could group music to categories.

[5] not more steps than required in Spotify, if applicable

The functional requirements specify that the application should be serving the purposes most of the participants used their music streaming applications for. Furthermore, the prototype should make the participants' workflows such as saving music to an own collection as efficient as possible, measured by the number of steps required to fulfil a certain task. To prevent overloading the prototype with unnecessary features that lead to the participants getting distracted again, FR1 specifies that the application's content should be limited to the features that are listed below, aiming for a minimalist design.

Non-Functional Requirements (NFR)

1. The application must be possible to access through a browser on iOS and Android-smartphones.
2. The application should not take longer than 1 second to load on user actions.
3. The application should contain only clear buttons highlighted by using contrasting colours. NFR 1 and NFR 2 are grounded in the methodology of this work: To properly test the prototype with users later, it is important to be able to access the prototype through a browser on common smartphones, as well as it is necessary for the prototype to offer sufficient response times to the users. Otherwise, the validation results might get influenced by users being irritated by a prototype that does not run smoothly. NFR 3, in turn, is based on users who reported accidentally clicking on the wrong elements in their app, getting confused on where to go back or abort actions, and facing trouble with dark colour schemes that often do not offer a lot of contrast.

4.2.2. Minimalist Design Principles

In a blog entry by Fessenden (2021) published by the Nielsen Norman Group, the concepts of signal and noise are introduced as important in minimalist design: Signals are elements holding a lot of information for the user, and noise are elements in an interface without much information, such as technical terms or irrelevant information. According to Fessenden, signal elements must be maximized while noise has to be reduced. This means, that all elements of an interface that are necessary to fulfil the user's tasks should be at hand, but any elements besides that distract from these necessary functions (Fessenden, 2021). These principles can be connected to the results of the interviews, as the participants disliked the cluttered homepage and the video-based features inside Spotify. Therefore, these principles were utilized when developing a prototypical music streaming application.

4.2.3. Development

A prototype of a mobile music streaming application was developed as a progressive web app (PWA). This is an application running in a browser which can be accessed via a smartphone in the same way as any native app. It was developed using NextJS and the Spotify API and then deployed on Vercel[6]. The aim of the prototype was to implement the previously listed requirements and create a tool to assess the usefulness of different design principles in terms of improving usability for people with ADHD. Screenshots of the prototype can be found in figures 1 to 6 in Appendix C. As can be seen there, a minimalist design was created by using large simple buttons, a flat interface without many animations or auto-playing videos. The pages of the application were limited to a homepage to fulfil FR7, a search page for searching and saving music (FR3, FR5, FR6), and a page for the user's own music collection (FR2, FR4). The only requirement that was

[6] https://vercel.com

dismissed is grouping music into categories (FR8), as this was the least important requirement and bloated the prototype, interfering with other requirements regarding minimization (FR1).

4.3. Validation

For validating whether the prototype adheres to the previously identified needs of people with ADHD, it was tested with a group of participants with ADHD and a group of participants without ADHD, which all had to fulfil a set of four tasks.

4.3.1. Tasks

The tasks used to validate the prototype were defined based on the features that were identified as most important and most used by the participants in the interviews. Common usage patterns identified throughout the interviews were that users liked to have a single place in which they can quickly and easily save the music they like, and that users wished to see what music they last recently listened to as well as their own music collection when opening the application.

Therefore, the following four tasks were defined:

1. Tell what songs were played last.
2. Go to a recommended playlist and then go back to the previous screen.
3. Search for a song of your choice and save it to your music collection.
4. Go to your music collection and play a song from there.

4.3.2. Evaluation

In Table 1, the task completion times of the ADHD group (test group) and the non-ADHD group (control group) are displayed. A more detailed comparison of the task completion times in the form of box-plot charts can be found in the appendix in figures 7 to 10. Table 2 shows how many steps the participants needed on average to fulfil the given tasks, together with the minimal number of steps that is required for completing each task.

Table 1. Average Task Completion Times per Group (Ranges of Task Completion Times in Brackets)

Task Number	ADHD Group (n=7)	Non-ADHD Group (n=7)
1	9.34s (1.7s – 28s)	14.62s (3.55s – 36.6s)
2	4.92s (1.79s – 9.1s)	5.12s (2.6s – 11s)
3	13.17s (6.8s – 27.4s)	19.36s (8s-52s)
4	4.67s (1.6s – 9.5s)	4.27s (1s – 13s)

Table 2. Average Number of Steps for Task Completion per Group, compared to minimal number of steps required

Task Number	ADHD Group (n=7)	Non-ADHD Group (n=7)	Min. Required
1	1.71	2.43	1
2	2.29	2.29	2
3	3.57	3.29	3
4	2.29	2.29	2

The results suggest that the group of participants with ADHD completed the first and the third tasks faster on average than the group of participants without ADHD. For tasks 2 and 4, marginal differences regarding the average task completion times could be observed between both groups. Due to the sample size, Mann-Whitney U tests were applied to each task. And even if the

plain averages show faster task completion times for the ADHD group, none of the comparisons between the two groups reached statistical significance (all $p > 0.05$). So, these findings are not describing a definitive performance, but an indicative trend, and should be interpreted with caution.

When analysing the eye tracking data, certain patterns of eye movement could be identified in the ADHD group (n=7): Randomly looking at different points on the screen, looking at interesting (e.g. moving or colourful) elements first, and scanning the page from top to bottom and left to right (like reading a book). Two participants were looking around the page in seemingly random patterns, but one of them, who was also taking medication, was slowing down when they came across interesting elements. Two other participants fitted into the category of interesting elements first, and two more participants were scanning the screen from top to bottom and left to right.

Lastly, there was one participant who fitted in both categories, as they also scanned the page from left to right, but stopped more often at moving and colourful elements.

In the non-ADHD group (n=6, due to missing eye-tracking data for one participant), the following patterns of eye movement were observed: Looking at areas where elements were expected first and scanning from top to bottom. Three participants looked at the location on the screen where they expected the elements they were searching for first, while three people looked at the entire page from top to bottom. One person could not be classified due to missing eye-tracking data. Furthermore, it was noticeable that the participants without ADHD moved their eyes much slower when scanning the interface than the ADHD group did.

After performing the tasks, all participants were asked four questions regarding challenges they faced when interacting with the prototype, aspects they liked and disliked, and improvements they would like to see in the prototype. Challenges faced by the ADHD and non-ADHD group are presented in Table 3. These challenges are ordered by their relevance (amount of being mentioned by single participants). The non-ADHD group did not face common challenges besides technical questions due to the application being in the state of a prototype, as all the listed challenges were reported just once. One participant in the non-ADHD group also stated to not have faced any challenges.

The aspects liked most by the participants are displayed in Table 4, also sorted by relevance. One of the participants with ADHD took her own phone out to present to the researcher how the workflow in her regular music streaming application would be and expressed preferring the interface of the prototype to the one she is used to.

Table 3. Challenges faced by the participants when fulfilling prototype validation tasks (number of mentions in brackets)

ADHD Group (n=7)	Non-ADHD Group (n=7)
• Being distracted by the eye-tracking (3) • Understanding the tasks given by the researcher (2) • Navigating a different interface than they were used to (2) • Not finding the interface intuitive (2) • Looking at wrong parts of the screen (1) • Using a type of device they are not used to (1)	• Feeling stressed (“Like in an exam”) (1) • Expecting the recently listened songs at another page (1) • Thinking of a song to add to the music collection (1) • Understanding the difference between the two most recently played songs on the homepage (1) • “None” (1)

Table 4. Aspects the participants liked about the prototype (number of mentions in brackets)

ADHD Group (n=7)	Non-ADHD Group (n=7)
• The clear and simple structure of the application (5) • The functionality for adding a song to the user's own collection (2) • The button for going back from nested pages (1)	• The clear and simple structure of the application (5) • The navigation (2) • The large buttons (1) • The similarity to known apps (1)

Aspects that were disliked by the participants were shown in Table 5, ordered by relevance. As the wrong page that was opening on startup was mentioned by a participant who faced a technical bug in the beginning, leading to seeing another page on application startup than intended, this aspect can be disregarded.

Table 5. Aspects the participants disliked about the prototype (number of mentions in brackets)

ADHD Group (n=7)	Non-ADHD Group (n=7)
• The prototypical state of the application in general (3) • No dark mode available (2) • The animation of recently listened to songs (1) • Having too many things on the home page (1) • Seeing too much text and too few icons (1) • Missing quick actions like swiping (1)	• Being used to another app (1) • Not finding the recently listened to songs (1) • Not understanding how the own music collection and the recommended playlist are distinguished (1) • Not being able to add and view more albums (1) • Too few colour (1) • Having only one playlist and not more nesting (1) • Not seeing enough images (such as album covers when searching for songs) (1) • The prototypical state of the application in general (1) • The wrong page opening on startup (1)

Suggested improvements can be found in Table 6 and are ordered by relevance (with one person from the ADHD group not suggesting any improvements).

One common theme that was brought up by different participants in both groups and appeared in all questions was the comparison to already known applications and devices, even if the participants were not asked to do that. However, there were more common themes in the answers by the participants with ADHD than in the group without ADHD, as participants in the non-ADHD group mostly gave responses that were not repeated by other participants. Furthermore, the group with ADHD expressed having challenges when using the application more clearly than the group without ADHD, even if they performed better in terms of task completion times. Lastly, there was a more direct expression of feelings and preferences (such as "I love it" or "Sorry, but it is just not beautiful") by participants in the ADHD group than in the group without ADHD.

Table 6. Improvements for the prototype, suggested by the participants (number of mentions in brackets)

ADHD Group (n=7)	Non-ADHD Group (n=7)
• Avoiding song titles that are running through (3) • Adding more colours (2) • The possibility to use dark mode (1) • Buttons that are easier to recognize (1) • A more responsive interface with more visual response to user action (1) • Having "a less horizontal layout" (1) • Adding quick actions (1) • More personalisation regarding the colours (1)	• Adding more icons and images (2) • Changing the placement of the recently listened song (2) • Further development of the prototype (1) • Adding more features (1) • Adding more colours (1) • Fixing a bug regarding the application's scroll behaviour (1) • More personalisation regarding creating and pinning playlists (1)

5. Discussion

In this study, barriers faced by users of music streaming applications with ADHD were identified through structured interviews and ways to remove these barriers were tested by developing a prototype and evaluating it with those users.

5.1. Findings

The analysis of the interviews yielded three categories of barriers: Presentation issues, actions in an application requiring too much effort, and navigation issues. The most important barriers identified were the display of too many elements on one screen and functions that require too much effort and are not used consequently. Another noticeable finding is related to the change management in applications, as sudden changes of an interface can lead to routines of the users being destroyed. Furthermore, ADHD users referred to themselves as "the problem" when their applications did not work properly, which shows how inaccessible systems can reinforce existing self-esteem issues. During the prototype validation, the group of users with ADHD managed to complete half of the tasks on average in less time, and the other tasks as quickly as the group without ADHD. There were cases of ADHD participants who were able to complete the tasks faster than the non-ADHD participants, even though they reported that they disliked the prototype or did not find it intuitive. What could also be observed (see Table 2 in comparison to Table 1) is that participants with ADHD often did not require fewer steps to complete the tasks, but they were able to follow these steps faster. 7 One observation that stuck after conducting the questionnaire with all participants was that people with ADHD gave more general feedback like "I love it!" or "It's just not beautiful", whereas participants without ADHD commented more on little details, but stated that they thought the application in general was satisfactory enough. There was also the same number of participants with ADHD as without ADHD saying that they did not face any specific issues when completing the tasks, even if the group without ADHD required a longer time to solve the tasks. Task 3 of the prototype validation required creativity, because the participants had to think of a song to add to their music collection. When working on this task, the group of people with ADHD required less time to spontaneously think of a song they liked. One person of the group without ADHD did not even think of a specific song and just searched the word song in the search bar. As described in the results section, three patterns of eye movement could be identified within the group of participants with ADHD. One of these patterns is scanning the page from top to bottom and left to right. One question that arises when examining this pattern is to

what extent the participants' eye movement patterns are influenced by the UI design of the prototype, as one participant also complained about a "too horizontal" layout. Additionally, the group of people with ADHD moved their eyes faster than the people without ADHD, resting on elements for shorter periods of time. Also, the group of people with ADHD did not look at the full screen before taking actions but instead turned their attention directly to elements that seemed interesting, such as moving song titles or album covers. The participants without ADHD got less distracted by moving content and stopped less at images with their eyes. However, when answering the open questions, they also expressed finding symbols and images more interesting. Moreover, participants with ADHD partly thought that there are too many elements in the prototype already, especially when looking at the homepage, while participants without ADHD would like to have more features, more content, and more images. Lastly, it occurred that explicit wishes of the users collide with existing design principles. For example, one participant with ADHD wished for having only one way to go to the music collection, because they thought having two possible ways of completing this task was confusing. This conflicts with the Nielsen heuristics (Nielsen, 1994), as they advise offering multiple ways for achieving one goal, so users can decide on what works best for them and create their own workflow. In conclusion, it can be said that design features like providing a minimalist design and marking functionality with colours and symbols seem to be a nice-to-have for neurotypical people and get appreciated by them, but present crucial support for people with ADHD.

5.2. Relation to existing work

This research's setting differs from the work of Smits (2022), Santos (2022), and Turner (2023), as design principles to mitigate barriers faced by people with ADHD were integrated into a prototype that was tested with users on a mobile device. In other studies, barriers were identified in interviews and surveys (Smits, 2022), and simple wireframes were designed (Turner, 2023), partly also in co-design sessions with users (Santos, 2022), but there was no further validation of the proposed designs. Despite the different methodologies, the outcomes of this work are in line with the findings present in another research. For instance, participants with ADHD felt distracted by a moving song title in the prototype developed for this research, which fits the aspect of users with ADHD disliking moving content, as described by Smits (2022). And users with ADHD being overwhelmed by interfaces with many elements in it confirms to the results by Smits (2022) and Turner (2023). Further, during the interviews, participants reported not liking the recommendations and thinking that the auto-generated content was too much, which has also been found by Santos (2022). The issue of nested categories of content inside an application adding mental load for users with ADHD was previously described by Santos (2022) and Turner (2023) and could also be observed in the answers to the interview questions in this work. Furthermore, Turner also found indications for inaccessible design increasing self-doubt of neurodivergent users (Turner, 2023), which is also reflected in this work's results. Other aspects like the importance of colour usage and rewarding the user to extend the user's attention span were repeatedly brought up during this research and have also been described by Smits (2022).

5.3. Strengths

The internal validity of the research is ensured, because different measures like using test and control groups for the same prototype validation tasks, and formatting the results against former research are employed. The construct validity is also given, as multiple indicators are combined. using interviews, numerical measurements and supplementary qualitative data. This approach allowed to measure the concept of accessibility in a more precise way, as qualitative

data that shows what users like was connected to numerical indicative data which approximates how fast users can do certain tasks in the prototype.

5.4. Limitations

However, there are limitations to this study. As a biased sampling method has been chosen for interviews as well as for user testing, the resulting samples are also biased. In addition, the sample size of the different user testing groups was 7 participants per group, which is not enough to reach statistical saturation (Hennink & Kaiser, 2022) and resulted in outcomes that do not reach statistical significance according to an inferential analysis using the Mann-Whitney U test. This limits the generalizability of the results. Furthermore, most of the participants came from central Europe, which means that it is not clear to what extent the results of this research can be applied to people who were not socialized in western society. Lastly, for the prototype validation, there are age differences between the control and test group with the group with ADHD participants being on average 5.3 years younger than the group of non-ADHD participants. This could mean that the ADHD group was more experienced with using mobile applications which would also partly explain why this group was faster in accomplishing the tasks. This could be clarified by conducting further similar studies with larger sample sizes and more similar demographics. Suggestions for experimental controls to mitigate this limitation can be found in the future work section.

5.5. Ethical Concerns

One question in the set of structured interview questions might have contributed to the phenomenon of self-esteem issues being reinforced. In question 10b in the Appendix B, participants are asked how ADHD could play a role in the challenges they are experiencing when using mobile music streaming applications. Thus, they are getting nudged to connect their ADHD to features that do not work properly in their preferred music streaming app. This might give them the impression that unintuitive interfaces would be their fault and could have led to the results of this work in which persons with ADHD talk more about their disability to achieve certain tasks on their own, instead of focusing on poorly designed user interactions. In further research, this question should be rephrased or completely left out. Approaches for more inclusive software design will be discussed in the future work section.

5.6. Future Work

This research has implications for both, the tech industry and scientific research. In industry settings, for example at music streaming companies, the question of how users with ADHD could get most value out of their applications could become relevant. How could users with ADHD get to experience the same feature richness as users without ADHD without getting overwhelmed by packed screens? Also, music streaming providers could introduce minimalist noise-reduction modes for their apps, so users could get the opportunity to access basic features without distractions. Moreover, there could be more options for personalization offered in music streaming apps, so users would be enabled to remove elements they consider irrelevant or pick colours on their own.

Regarding scientific fields, this research managed to find noteworthy aspects that present potential for further investigation. One intriguing question is how design and evaluation processes involving people with ADHD could be designed to avoid making the participants self-conscious and causing negative feelings. For further research on this requestion, the interviews

should be designed without questions about an individual's neurological condition to prevent establishing a connection between barriers in handling the application and their own condition. It would also be valuable to create and validate a framework for ethically interviewing neurodivergent persons. Additionally, there should be more focus on neuro-reflexive methods like (more fine-granular) eye-tracking or measuring other biometrics while users are testing a system. Another limitation of this research that could be addressed in future work is the age gap between the test and control group, leading to results that are potentially influenced by a different baseline familiarity with using mobile devices. For expanding research on this, the experiments could get repeated with larger sample sizes. Further, there could be either more restrictions in recruiting participants, for example by requiring participants to be in a certain age range, or the groups could get split up into more detailed categories to not only compare between ADHD and Non-ADHD, but also within groups with similar technological knowledge or age.

6. Conclusion

This research aimed to find accessibility barriers faced by adults with ADHD when using mobile applications and to find design elements that can help mitigate these barriers. To answer these questions, an exploratory mixed-method approach was chosen, including structured interviews, the development of a prototype, and testing the prototype by giving four tasks to users with and without ADHD, measuring task completion times, tracking the participants eyes, and asking four questions about their experience when using the prototype. The interviews showed that adults with ADHD are hindered by different barriers such as nested layouts, too much irrelevant content, features that require too much effort from the user, navigation issues, and lack of user control. The results of the prototype testing indicated that these barriers can be effectively minimized by reducing the number of animations and videos within an application, using more colours, and incorporating minimalist design principles.

Regarding SRQ1.1, the most prominent barriers are getting overwhelmed by having too much content displayed and actions that require too much effort (e.g., too many steps). Features that are liked by users with ADHD in mobile streaming applications are central collections and short-cuts, for example, for saving items to the collection in one click, clear and simple structures in the UI layout, and having a back-button which also indicates the previous location.

The different kinds of elements liked by participants with ADHD are also the elements that are in line with minimalist design and benefit general usability: Making information implicit, for example, by showing a button that indicates which page it leads to instead of a generic back button, using bright colours and connection colour to specific functionality, having a flat information organization, and avoiding showing moving content or content that is not relevant to the user. Thus, principles for removing accessibility barriers for people with ADHD can be linked to minimalist design principles, as they also recommend the reduction of noise and only presenting important information in a clear way.

Despite the results of this study being limited by the sample size and biased sampling method, these results agree with other related work, such as the research by Santos (2022) and Turner (2023).

One finding that arose from the interview responses was how self-esteem issues can be reinforced. Regarding future work, it is relevant to research on how design and evaluation processes can be designed to prevent making neurodivergent people feel self-conscious.

7. Acknowledgements and Conflict of Interest

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AI Disclosure. For this research, generative AI was used in two ways:

First, the tool DeepL (https://www.deepl.com) was utilized to help with translating interviews that were not conducted in English initially.The structured interviews were partly done in English, but also partly in German. After administering the interviews, the transcripts were translated manually by the researcher, but for single phrases that stem from specific German dialects and do not have a literal English translation, DeepL was used to find the most appropriate English term.

Secondly, ChatGPT (https://chatgpt.com) was used to enhance the writing style, mainly to find synonyms for words that were repeatedly used to make the text more appealing. Usually, a regular thesaurus or dictionary was used first, but if these methods did not yield sufficient results, ChatGPT was asked for alternative terms. However, this AI tool never contributed whole sections of text, but only single expressions.

After using both tools, the author reviewed and edited the content as needed and assumes full responsibility for the publication's content.

Furthermore, data collected as part of this work has never been inserted into an AI model of any kind, since this research handles medical data, which should not be given away without consent of the participants.

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9. Appendices

9.1. Appendix A: Interview Questions

(1) How old are you?

(2) What is your gender?

(3) In case it was included in your diagnosis, what type of ADHD do you have?

(4) What is your current level of education?

(5) What job do you have?

(6) What else do you do in your daily life?

(7) What ADHD symptoms are affecting you most in your daily life?

(8) How much time do you spend on average using your smartphone per day?

(9) Which music streaming app do you mainly use?

(10) Do you face any specific challenges when using this app?

(a) If yes: Please describe these challenges further.

(b) If yes: How do you think ADHD plays a role in these challenges?

(11) What do you think could be improved or would make your experience easier when using this app?

(12) What is the first thing you would like to see or do when opening your music streaming app?

(13) What functions of your music streaming app do you use most often?

(a) Can you show me how you do that? While presenting this to me, could you comment on what you are doing and what you are trying to achieve?

(14) Do you use your music streaming app only for listening to music or also for other things, such as watching videos or listening to audio books?

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9.2. Appendix B: Screenshots of prototype

Figure 1. Home page

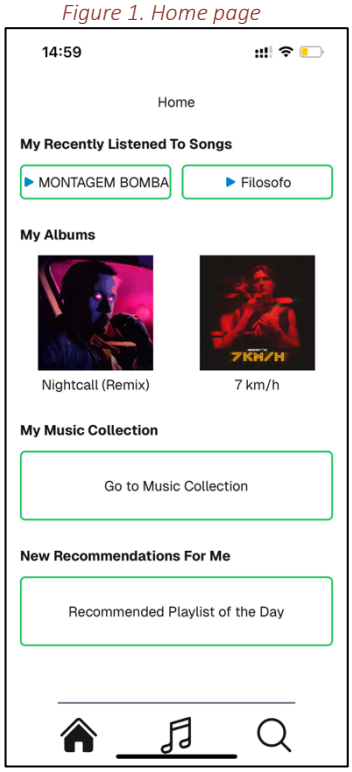


Figure 2. Album view

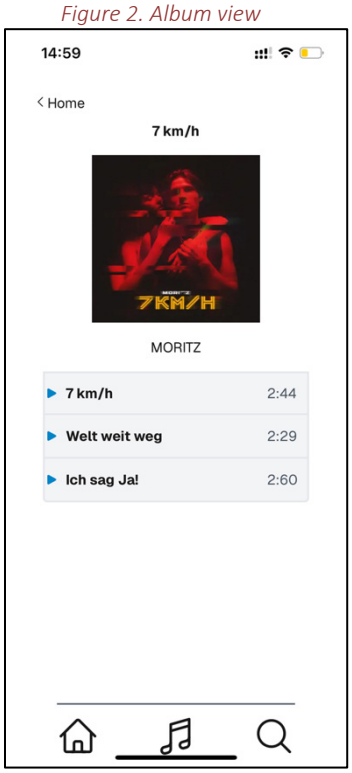


Figure 3. Playlist view

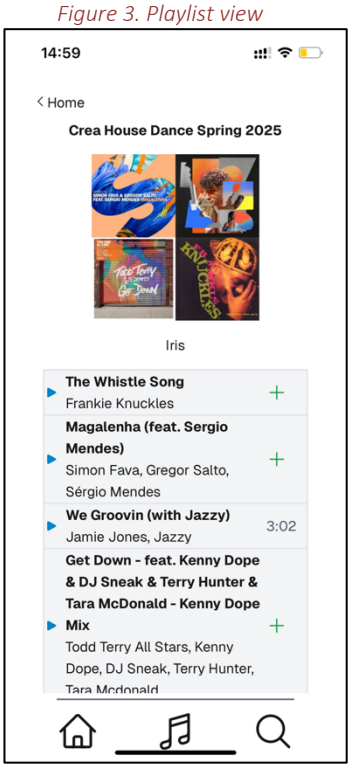


Figure 4. user's own music collection page

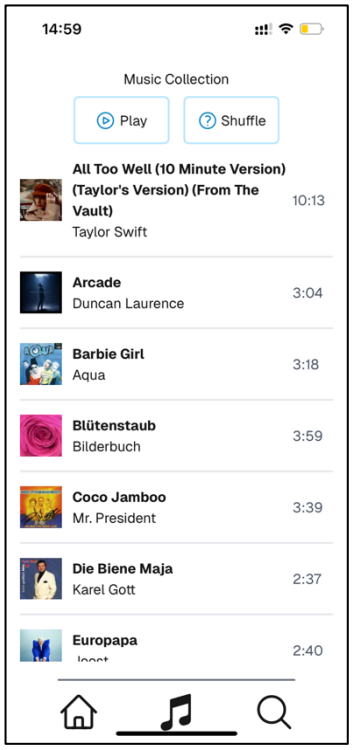


Figure 5.Ssearch page

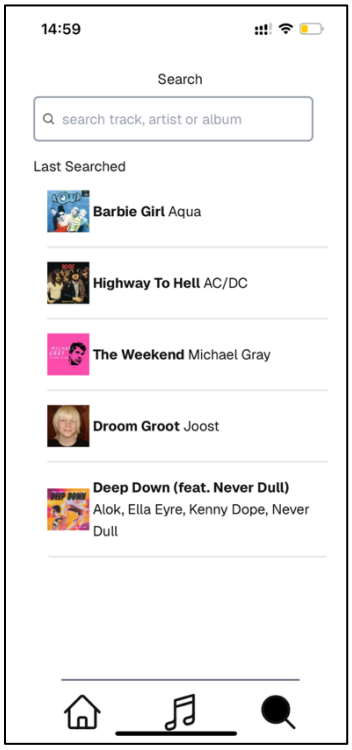
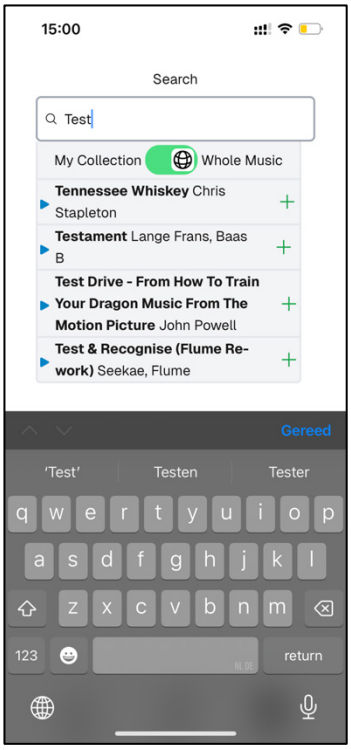


Figure 6. Search Page with activated search bar



9.3. Appendix C: Prototype Validation – Protocol

Demographics

1. Age
2. Gender
3. Experience with music streaming apps
4. ADHD or No ADHD
5. If ADHD: Is the participant currently taking any ADHD-related medication (such as Methylphenidate, also known as "Ritalin")

Tasks

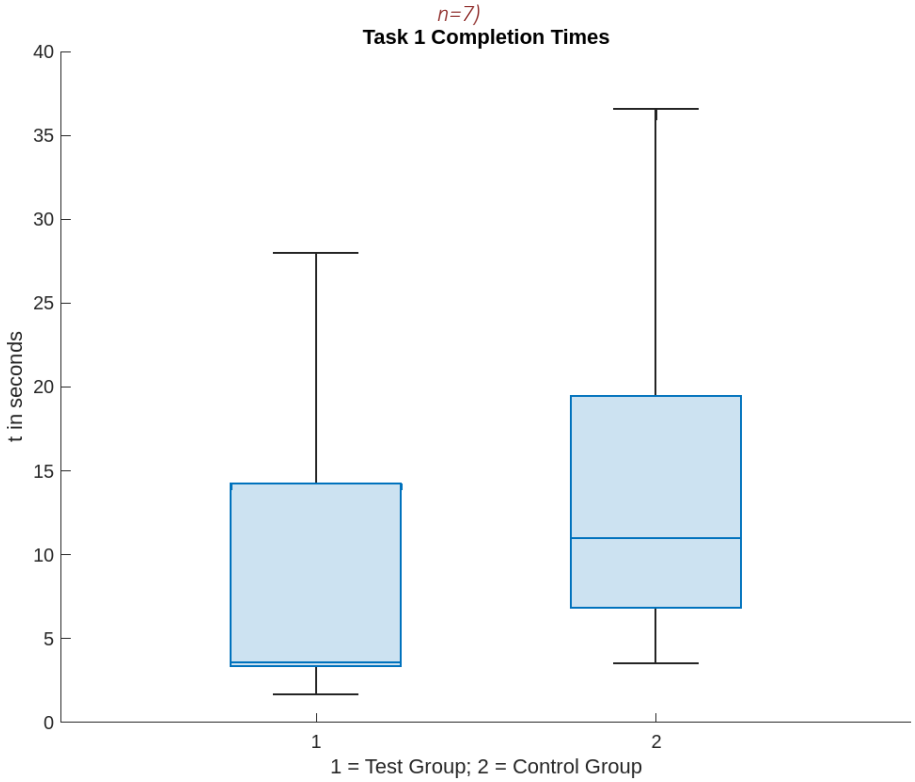
1. Tell me the songs that were played last.
2. Go to a playlist that is recommended for you and go back to the screen you looked at before.
3. Search for a song of your choice and save it to the music collection.
4. Go to your music collection and play a song from there.

Open Questions

1. Did you face any specific challenges when fulfilling the tasks given to you by the researcher?
2. Name at least one thing you liked about the prototype.
3. Name at least one thing you disliked about the prototype.
4. What do you think could be improved or would make your experience easier when interacting with this application?

9.4. Appendix D: Prototype Validation – Task Completion Times

Figure 7. Completion Times in Seconds for Task 1 (Finding Most Recently Played Songs) in Prototype Validation – ADHD Group (Test Group, n=7) and Non-ADHD Group (Control Group, n=7)



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Figure 8. Completion Times in Seconds for Task 2 (Opening Recommended Playlist and going back to Homepage) in Prototype Validation – ADHD Group (Test Group, n=7) and Non-ADHD Group (Control Group, n=7)

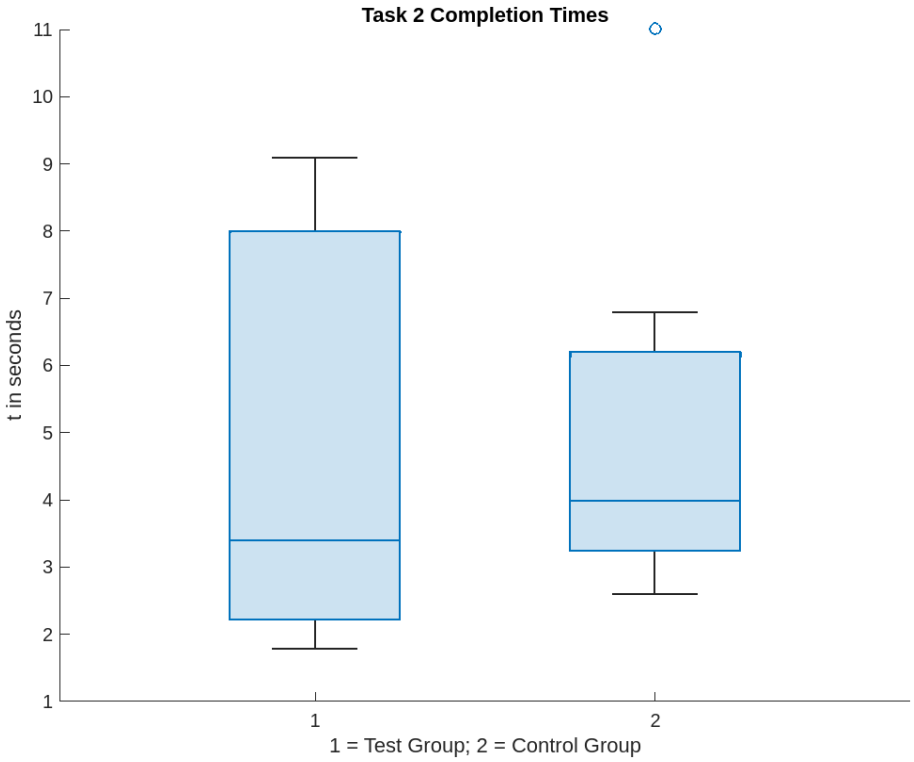
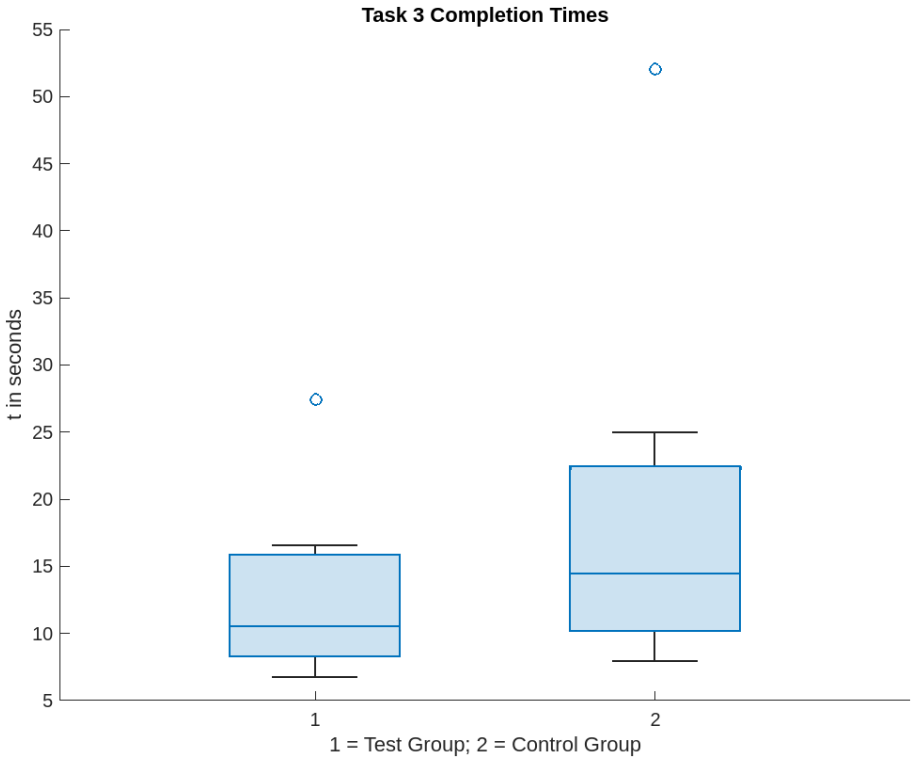
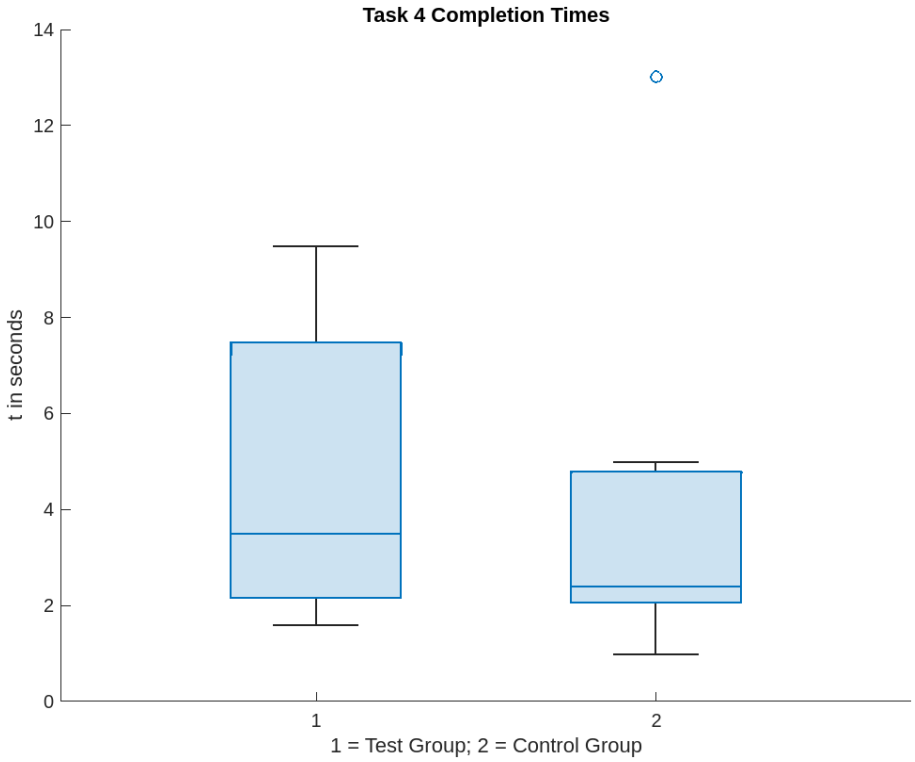


Figure 9. Completion Times in Seconds for Task 3 (Searching and Saving a Song of the Participant's Choice) in Prototype Validation – ADHD Group (Test Group, n=7) and Non-ADHD Group (Control Group, n=7)



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Figure 10. Completion Times in Seconds for Task 4 (Playing a Song from the Music Collection) in Prototype Validation – ADHD Group (Test Group, n=7) and Non-ADHD Group (Control Group, n=7)



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