Institute of Parallel and Distributed Systems

University of Stuttgart
Universitätsstraße 38
D–70569 Stuttgart

Masterarbeit

User-Centred Development of the VitaBeat App for Linking Smartwatch Sensor Data with Spotify Songs

Benjamin Tunc

Course of Study:	Software Engineering
Examiner:	Prof. Dr. Dirk Pflüger
Supervisor:	Jonathan Stumber, M.Sc., Dr. Tanja Blascheck (VIS)
Commenced:	October 11, 2024
Completed:	April 11, 2025

Abstract

The adoption of wearable technologies, particularly smartwatches, is rapidly increasing, offering new opportunities for collecting and analyzing health data. Music streaming has also become integral to daily life, creating potential for linking music with physiological signals like heart rate. The VitaBeat app was developed as part of a student research project to provide a tool for analyzing the relationship between music and heart rate. Connects music to heart rate measurements, collecting data from smartwatch and smartphone sensors and Spotify playback via the Spotify SDK, which is transmitted to a central back-end for analysis. A requirements analysis was conducted using an online survey to gather insights from potential users. The survey aimed to identify user needs and preferences for the app's features and usability. Based on the survey findings, several new features were implemented, including heart rate diagrams for individual songs, heart rate overviews, and gamified micro-breaks to enhance engagement. The user interface was also redesigned for better usability and clearer data presentation.

This thesis outlines the methodology and results of the survey, the new features developed from those insights, and recommendations for future improvements.

Kurzfassung

Die Verbreitung von Wearable-Technologien, insbesondere Smartwatches, nimmt rasant zu und eröffnet neue Möglichkeiten zur Erfassung und Analyse von Gesundheitsdaten. Auch Musikstreaming ist ein fester Bestandteil des Alltags geworden, wodurch sich Potenziale für die Verknüpfung von Musik mit physiologischen Signalen wie der Herzfrequenz ergeben. Die VitaBeat-App wurde im Rahmen eines studentischen Forschungsprojekts entwickelt, um ein Tool zur Analyse der Beziehung zwischen Musik und Herzfrequenz bereitzustellen. Sie verbindet Musik mit Herzfrequenzmessungen, indem sie Daten von Sensoren der Smartwatch und des Smartphones sowie von der Spotify-Wiedergabe über das Spotify SDK sammelt und diese zur Analyse an ein zentrales Backend überträgt. Im Rahmen einer Bedarfsanalyse wurde eine Online-Umfrage durchgeführt, um Einblicke von potenziellen Nutzer*innen zu gewinnen. Ziel der Umfrage war es, Bedürfnisse und Präferenzen hinsichtlich der Funktionen und Benutzerfreundlichkeit der App zu identifizieren. Auf Basis der Umfrageergebnisse wurden mehrere neue Funktionen implementiert, darunter Herzfrequenzdiagramme zu einzelnen Songs, Herzfrequenzübersichten sowie gamifizierte Mikro-Pausen zur Steigerung der Nutzerinteraktion. Zudem wurde die Benutzeroberfläche neu gestaltet, um die Bedienbarkeit zu verbessern und die Daten klarer darzustellen.

Diese Arbeit beschreibt die Methodik und Ergebnisse der Umfrage, die daraus abgeleiteten neuen Funktionen sowie Empfehlungen für zukünftige Verbesserungen.

Contents

List of Figures

1 Introduction

The global adoption of wearable technologies, particularly smartwatches, is steadily increasing and opening up new opportunities for the collection and analysis of health data. According to a forecast [Dep25], the number of users in the smartwatch segment is expected to increase by 285.8 million (+62.86 %) between 2024 and 2029, reaching a projected peak of 740.53 million users in 2029. At the same time, music streaming has become an integral part of daily life for many people: in the fourth quarter of 2024, the music streaming service Spotify reached a record high of 675 million active monthly users around the world [Spo25]. The widespread adoption of both technologies presents significant potential for linking music with vital parameters such as heart rate, offering new insights into their interrelation.

The VitaBeat [BJT+24] app was developed as a student research project. Since collecting sleep data using traditional methods like EEG is complex and difficult to scale, an alternative approach was adopted: connecting music listened to while awake with physiological signals such as heart rate. To enable this, a first functional prototype was developed that collects data using smartwatch sensors and Spotify playback information, transmitting it to a central back-end for further analysis. Researchers can configure various parameters, including measurement frequency, selection of active sensors, and desired endpoints, and distribute these settings to participants via QR code.

The project was implemented in 2024 at the Institute of Parallel and Distributed Systems (IPVS) at the University of Stuttgart, involving contributions from five bachelor's and three master's students over a period of six months. The initial development focused primarily on reliable data collection, while user-centered aspects such as direct user benefit had to be deferred due to time constraints. As a result, the user interface (UI) was deliberately kept minimal and focused on the live display of sensor data collected from the smartwatch and smartphone, offering limited direct value to end users.

As part of this master's thesis, a requirements analysis was performed using an online survey built with an open source survey tool. Participants were asked to answer questions based on their personal experiences and preferences. The responses collected were analyzed to identify patterns and potential features that could improve the app and increase its value to users. Building on these insights, VitaBeat was extended with several new features aimed at supporting both the original research goals and enhancing the user experience.

The UI was completely redesigned and expanded. A new feature was introduced to display the history of the songs listened to and related details, allowing users to view the progression of their heart rate as a diagram for individual songs. In addition, daily and weekly heart rate overviews were implemented to provide users with a more comprehensive view of their data. Some sensor values that were difficult for users to interpret were moved to a separate screen to maintain a clear focus on the most relevant information and improve usability.

With the introduction of micro-Breaks in VitaBeat [Bau25], a new use case supported by gamification was added to enhance user engagement: Users can now build a streak by taking daily micro-breaks, adding a motivational element to encourage regular use.

In this master's thesis, the architecture and implementation of the VitaBeat app will first be briefly presented, followed by a discussion of its current limitations. Next, the methods and results of the requirements analysis will be outlined, highlighting the findings that influenced the further development of the app. The changes and new features added to VitaBeat will be described in detail. Finally, the thesis will offer recommendations for future improvements and possible extensions.

2 Related Work and Background

To support the further development of VitaBeat, this chapter outlines key theoretical foundations and related research.

2.0.1 User-Centered Design

The work by Abras et al. [AMP+04] offers a comprehensive overview of the concept of User-Centered Design (UCD), which has become a foundational methodology in the development of user-oriented systems since the 1980s. UCD refers to a design philosophy and a set of methods in which end-users are actively involved throughout the development process, from requirements analysis to evaluation. The degree of user involvement can vary, ranging from consultation and usability testing to full partnership with designers throughout the design process.

2.0.2 Enhancing User Engagement by Gamification

Groh [Gro12] analyzes the state-of-the-art definition of gamification in his work as „the use of game design elements in non-game contexts“[p. 39].

Bitrián et al. [BBC21] explored in their work how different categories of game elements influence user engagement in mobile applications, using the Self-System Model of Motivational Development (SSMMD) as a theoretical framework. Bitrián et al. [BBC21] study shows that performance-oriented elements such as challenges and progress bars address all three basic psychological needs: competence, autonomy, and relatedness, thus increasing engagement. In contrast, immersive elements, such as avatars, primarily foster relatedness. In addition, participation mediates the relationship between the use of game elements and positive outcomes such as satisfaction and continued use. This research highlights the importance of carefully selecting game mechanics to support motivational needs and improve user experience in mobile applications.

2.0.3 Visualization on Smartwatch and Smartphone

Grioui and Blascheck [GB23] explored micro-visualizations of heart rate data on a virtual smartwatch in a Virtual Reality (VR) environment during a physically active task. Participants played a tennis-like game in VR and were prompted to adjust their intensity based on real-time HR feedback. The study compared three visualization types: one without summary and two with additional bar or radial summaries of the time spent in the heart rate zones. Although no significant differences in task completion time or accuracy were found, visualizations with summaries, especially bar charts, were subjectively preferred and slightly more effective. Despite the limited sample size (N=5), the findings suggest that summary-enhanced micro-visualizations may support in situ self-regulation of physical activity, even in dynamic contexts like VR.

Brehmer et al. [BLIC18] conducted the first crowdsourced visualization experiment exclusively on mobile phones, focusing on how to effectively visualize ranges over time on small displays. They compared two approaches: a conventional linear layout and a radial layout, with the former offering faster task completion times while maintaining similar accuracy.

2.0.4 VitaBeat

VitaBeat [BJT+24] is a student research project at the Institute of Parallel and Distributed Systems (IPVS) at the University of Stuttgart. The app focuses on collecting and analyzing data from music playback, smartwatches, and smartphones. It is designed for Android devices and supports Wear OS-based [Wea] smartwatches. The app integrates with Spotify[Spob] via its SDK to access music data. VitaBeat records sensor data from both the smartwatch and the smartphone, visualizes the information for users, and securely stores it in a backend.

Requirements of the smartphone application:

- Android Version: 8.0+
- Minimum Android SDK: 26
- Target Android SDK: 34
- Compile Android SDK: 35

Requirements of the smartwatch application:

- Android Version: 12.0+
- Minimum Android SDK: 31
- Target Android SDK: 34
- Compile Android SDK: 35

Figure 2.1: The logo of the VitaBeat application.[BJT+24]

3 System Overview and Initial State of VitaBeat

This chapter outlines the technical structure and initial capabilities of VitaBeat. It is divided into two main parts: the first describes the modular system architecture, the technologies used, and the deployment infrastructure; the second provides an overview of the initial functional state of the app, highlighting the limitations and challenges identified during early development.

3.1 System Overview

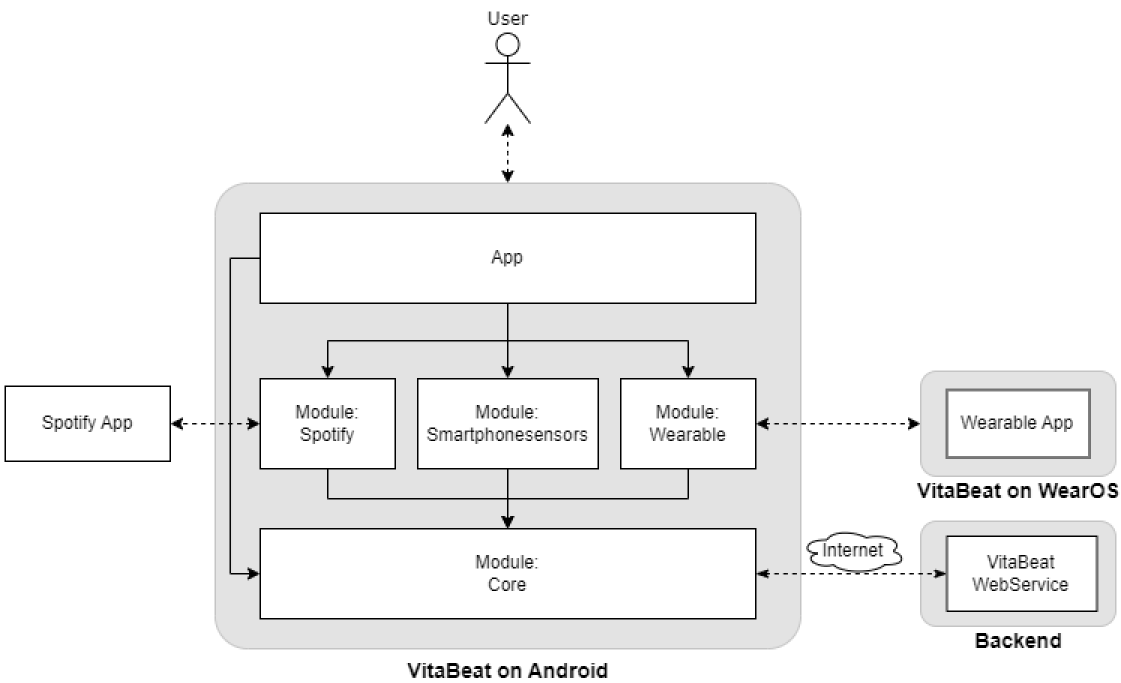


Figure 3.1: Modularisation and Components of VitaBeat. [BJT+24]

The VitaBeat system follows a modular and hierarchical architecture that enables scalable, extensible, and efficient data collection and processing. At the top level, the **App Component** integrates various modules and coordinates data flow through activities, UI components, and view models. It can access features of lower-level modules, but these modules cannot access the app directly.

The **Core Module** provides foundational abstractions for data collectors, storage mechanisms, and configurable settings. It includes essential components such as a foreground service to start data collection and notify users, and background services using Android Workers [Andj] to handle tasks such as data packaging, uploading to the server, and exporting to local storage.

The **Smartphone Sensors Module** builds on core abstractions to access onboard smartphone sensors. Collect sensor data according to configurable settings and store it locally. Additionally, it includes functionality to monitor VitaBeat's battery consumption.

The **Wearable Module** consists of two parts: a Wear OS [Wea] app installed directly on the smartwatch, and a companion module integrated into the Android app. The smartphone module handles communication with the wearable, configuration via repository classes, and data synchronization using key-value pairs. If no connection is available, the data is buffered on the smartwatch until it can be synchronized.

The **Spotify Module** enables the tracking and collection of music playback data by integrating with the Spotify SDK. To ensure secure communication, the app must be registered via the Spotify Developer Dashboard and requires user permission to receive Spotify broadcasts.

VitaBeat on Wear OS was developed to address inconsistent sensor sampling rates in smartwatches. By deploying a custom Wear OS app, the team ensured consistent and high-quality data acquisition.

3.1.1 Backend System

The backend supports automated and scalable data upload and processing. Key components include:

- **VitaBeat WebService**: A REST API built with Spring [Spr] for data upload, feedback exchange, and configuration retrieval.
- **MinIO** [Min]: An S3-compatible storage abstraction that supports integration with tools such as Apache Spark [Apa], enabling flexible and distributed data storage.

3.1.2 Deployment Architecture

The system is deployed using a modern GitOps. The lightweight Kubernetes distribution **K3s** [K3s] manages deployments, while **FluxCD** [Flu] and GitLab Runner enable Continuous Integration and Continuous Deployment (CI/CD). The configuration is stored in Git repositories to ensure a separation of code and deployment logic.

3.1.3 Technology Stack Overview

The following table provides an overview of the main technologies and libraries used in the initial development of VitaBeat.

Table 3.1: Overview of used Android libraries and technologies.

Category	**Libraries / Technologies**
UI Compoenents	Jetpack AndroidX Activity [Anda], Jetpack AndroidX Appcompat [Andb], Jetpack Compose [Jet], AndroidX Pager [Andg], AndroidX Navigation [Andf], AndroidX Lifecycle [Ande], JourneyApps ZXing [Jou]
Data Collection & Storage	AndroidX Room [Andh], Jetpack DataStore Preferences [Dat], Jetpack WorkManager [Andj]
Web Service	Retrofit [Ret], Moshi [Mos]
Wearable Integration	AndroidX Wear Compose [Andi], Google Play Services Wearable [Goob]
Dependency Injection	AndroidX Hilt [Andd] Dagger [Gooa],
Code Generation	Kotlin Symbol Processing (KSP) [Kot]
Code Quality	ktlint [Pin]

3.2 Initial State

At this stage, VitaBeat was a functioning prototype designed to collect and display data from multiple sources, including smartwatch sensors, smartphone sensors, and Spotify SDK. The live data was displayed on the overview screen, allowing real-time tracking of the participants' metrics. However, all available data were recorded without assessing their relevance or significance. The system was primarily focused on collecting as much data as possible, without considering whether the data were meaningful, useful for further analysis, or interesting to the user. A screenshot of the overview screen can be seen in Figure 3.2. Raw sensor data from sources such as gyroscopes and accelerometers are often difficult for most users to interpret. These values, typically represented as axis data or angular velocities, require a deeper understanding of movement analysis. As a result, they can distract from more essential health-related metrics, such as heart rate. In contrast, heart rate data are more intuitive and widely understood.

One of the key limitations of this version was the lack of historical data visualization. Although live data was displayed in real time, the application did not include any functionality to allow users to review past data. However, the collected data were also stored locally on the smartphone in the form of SQLite tables [Hip]. In addition, users had the option to export their data as tables.

Another major issue was the lack of user-friendly features and a coherent interface. The current prototype displayed all data as raw text without any form of organization or visual structure. This made it difficult for users to get an overview of their data and hindered user interaction with the app. There were no graphical representations, charts, or visual cues to help users quickly interpret their data or identify patterns. The app design was minimalistic, but this resulted in an unintuitive and cluttered experience.

Furthermore, the prototype lacked tools or features to help users or researchers analyze the collected data. Without data processing or visualization capabilities, users were unable to identify patterns or correlations between different data points, such as linking heart rate data to specific music playback periods. This limitation meant that while data was being collected, it could not be used for meaningful analysis or insights within the app.

Although researchers could access raw data through the back-end, this was only possible if the user had set it as an endpoint. However, the collected data was not properly mapped or correlated between the different data sources, making it difficult to draw connections between participants' vital parameters and their music listening behaviors. All data collected were packaged into ZIP files and sent to the back-end for further processing or analysis.

At this stage, the prototype offered limited value to users or researchers. The lack of analytical features meant that, despite the data being collected, users could not derive meaningful insights or identify potential trends, preventing VitaBeat from providing any significant value beyond the mere collection of data.

Furthermore, the absence of advanced visualization tools, interactive elements, and a clear UI made it difficult for users to engage meaningfully with the data. Without graphical representations or visual structure, the application presented a highly technical, text-based view that was overwhelming and uninformative. Although the system collected a wide range of data, as summarized in Table 3.2, there was no meaningful analysis or correlation between the data sources. This revealed the limitations of the prototype and highlighted the need for improved data processing and a more intuitive user interface.

Table 3.2: Overview of collected data in the VitaBeat prototype.

Data Source	Collected Data
Smartwatch Sensors	heart rate, battery monitoring, battery level, ambient temperature, pressure
Smartphone Sensors	step count, accelerometer data, gyroscope data, ambient temperature, light, pressure, relative humidity
Spotify SDK	Currently playing song, artist, album, playback timestamp

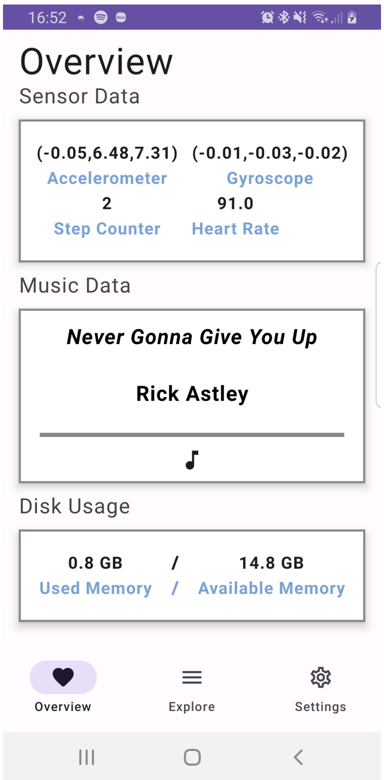


Figure 3.2: Screenshot of the original VitaBeat overview screen. [BJT+24]

4 Requirements Analysis Survey

This chapter offers a detailed explanation of the requirements analysis survey, outlining its objectives, methodology, and structure. It describes the purpose of the survey to collect information on user needs and expectations and details the design of the questions and distribution channels. In addition, the chapter discusses how the collected data will be analyzed to inform the development of the application.

4.1 Methods and Goals

This section presents the approach taken to design and conduct the survey. It outlines the main objectives, the structure of the questionnaire, and the methods used for data collection and analysis.

4.1.1 Goals

To ensure that VitaBeat development is aligned with user needs and expectations, a survey was conducted to analyze the demographics of potential users, music listening behavior, and their expectations about the functionality and usability of the app. The primary objectives of this survey were:

- Understand the demographic characteristics of potential users, including age, education, and profession.
- Investigate music listening habits, including frequency, context (e.g., commuting, sports), and motivations (e.g., relaxation, entertainment).
- Assess current smartwatch ownership, specifically regarding Wear OS
- Evaluate users' interest in features related to vitalparameter monitoring and music data integration, such as linking vital parameters with music.
- Collect feedback on the preferred app features, such as music controls, gamification and data visualization preferences.
- Analyze users' opinions about the current VitaBeat UI, focusing on aspects such as data presentation, usability, and perceived relevance of specific metrics.
- Generate additional use cases for VitaBeat based on user feedback and preferences for expanding the app's functionality.

4.1.2 Survey Design

The survey consisted of multiple thematic question groups, each covering a specific area relevant to VitaBeat's development. These groups were designed to provide information on various aspects of user behavior and expectations. The questionnaire was structured as follows:

- **Demography**: Basic user information such as age, gender, and highest educational degree.
- **Music Listening Behavior**: Insights into participants' music listening habits, preferences music genre[1], and motivations.
- **Usage Behavior**: Exploration of the use of music streaming services, smartwatches, health apps and gamification features by participants, including their motivations and interaction patterns.
- **Evaluation of App Function**: Expectations about the features and functionality of VitaBeat.
- **VitaBeat – Functionality**: Questions about the integration of music playback and heart rate tracking from a user's perspective.
- **VitaBeat – Design and Usability**: Preferences related to the app's interface design and ease of use, based on custom mockups created specifically for the survey.
- **VitaBeat – Research**: User perception of the value of the app for scientific research purposes.

A detailed overview of the individual questions within each thematic group is provided in Appendinx A.

4.1.3 Data Collection and Participants

The survey was conducted using LimeSurvey [Gmb], an open source online survey tool that allows structured data collection and analysis. It was distributed online through various channels, including social networks, academic networks, and personal outreach. The survey was available in both German and English, in line with the languages supported by the VitaBeat app. Participants were asked to provide responses based on their personal experiences and preferences. The data collected was then analyzed to identify trends and insights that will contribute to the further development of VitaBeat.

The survey received responses from a diverse group of participants, predominantly from the University of Stuttgart and the Stuttgart metropolitan area, providing valuable information for further analysis. All results of this survey are presented in the Appendix B and are further detailed in Section 4.2.

[1]Music genre were based on the 14 music genres [RG03].

4.2 Results

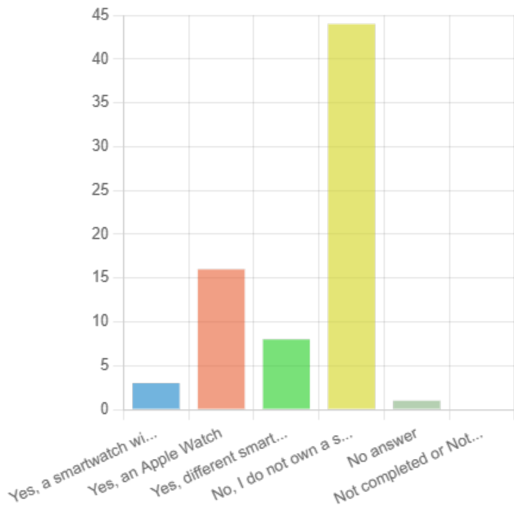
In total, 72 participants participated in the online study and completed it in full. The demographic analysis reveals that the majority of the respondents (66 responds, 84.72 %) were between 24 and 44 years old, with most holding at least a high school diploma or its equivalent (66 responds, 84.72 %). A significant proportion of the participants (42 responds, 58.33 %) are employed in the field of software engineering. This can be attributed to recruitment through university channels at Faculty 5 – Computer Science, Electrical Engineering, and Information Technology at the University of Stuttgart (e.g., mailing lists, social media, and personal contacts). The gender distribution was 41.67 % (30 responds) female and 58.33 % (42 responds) male.

Regarding music listening behavior, 68 participants (94.44 %) stated that they listen to music several times a week, with 48 (66.67 %) of them doing so daily. The most common contexts for listening were commuting (49 responds, 68.06 %), engaging in sports (36 responds, 50.00 %), and working (25 responds, 34.72 %). The primary motivations for listening to music were entertainment (50 responds, 69.44 %), relaxation (46 responds, 63.89 %), and motivation enhancement (38 responds, 52.78 %). Furthermore, 47 respondents (65.28 %) use Spotify for music playback.

Only 3 participants (4.17 %) indicated that they own a Wear OS smartwatch or plan to purchase one within the next three months. The most popular smartwatch was the Apple Watch, with 16 mentions (22.22 %). More than half of the participants (44 responds, 61.11 %) do not own a smartwatch and do not plan to purchase one in the near future (see Figure 4.1b).

Response	Count	Percentage
Wear OS Smartwatch	3	4.17 %
Apple Watch	16	22.22 %
Other Smartwatch	8	11.11 %
No smartwatch, no plans	44	61.11 %
No answer	1	1.39 %
Total	**72**	100.00 %

(a) Smartwatch ownership or purchase intention.



(b) Smartwatch ownership or purchase intention as bar chart.

Figure 4.1: Comparison of smartwatch ownership in table and chart.

Almost half of the respondents use health apps (35 responds, 48.61 %) for fitness improvement (27 responds, 37.50 %), to enhance general health awareness (22 responds, 30.56 %), or to pursue personal goals (18 responds, 25.00 %). Some also mentioned using these apps purely out of interest in technology. A total of 23 participants (31.94 %) already use applications to monitor vital parameters on their smartphone or smartwatch.

Fourty-six respondents (63.89 %) expressed interest in an app to monitor vital data, particularly if the information is presented in statistical formats (51 responds, 70.88 %). The ability to link vital parameters with music data was deemed relevant by 40 participants (55.56 %). Furthermore, 57 respondents (79.16 %) find it necessary that the app is available in the Google Play Store.

When asked about the preferred features of an app such as VitaBeat (with the option to choose up to three), the most desired feature was the notification of abnormal vital values (47 responds, 65.28 %), followed by the ability to compare vital data across different music genres (36 responds, 50.00 %) and a live data display during music playback (32 responds, 44.44 %). Moreover, 32 participants (44.44 %) wished for personalized tips based on the collected data, while 22 (30.56 %) considered a data export feature to be important.

The most frequently mentioned music control features were displaying the current song (including title, artist, album, and duration) (54 responds, 75.00 %) and basic music controls (play/pause) (53 responds, 73.61 %). Additionally, 35 respondents (48.61 %) found reminders for regular micro-breaks[2] for relaxation appealing.

The survey results present a nuanced view of the use and preferences regarding gamification elements. When asked which features they would most likely use to visualize their progress, participants most frequently selected daily challenges (45.83 %), followed by reward systems such as badges (43.06 %) and point-based rankings (38.89 %).

Regarding regular use of gamification in other apps, 47.22 % of respondents stated that they do not actively use such features. However, collecting points (33.33 %) and earning badges (27.78 %) were reported as fairly common. This suggests that certain game-like features are indeed used when they are well-integrated, even if users do not explicitly seek out gamified experiences.

Regarding measurement preferences, the majority of respondents (48 responds, 66.67 %) preferred a longer battery life, even if it meant less frequent and potentially less accurate measurements. In contrast, 24 responds (33.33 %) would opt for more frequent measurements for higher accuracy, even at the expense of reduced battery life.

The preferred type of data visualization was charts (61 responds, 84.72 %), followed by simple symbols or icons (28 responds, 38.89 %). Regarding design preferences, 41 (56.94 %) respondents preferred a dark theme, and 32 respondents (44.44 %) preferred a clear, minimalist design.

Participants were shown a screenshot of the current overview screen (see Figure 3.2) and asked to provide free text feedback. Much of the feedback highlighted that the accelerometer and gyroscope data were perceived as too technical, with suggestions to either present these data graphically or omit them altogether. In addition, respondents requested that essential vital data, such as heart rate, be displayed more prominently and visually appealingly. Information such as disk usage was considered irrelevant and should not be persistently displayed. Overall, there was a strong call for an optimized overview with clear diagrams and integrated music control elements.

60 participants (83.33 %) expressed their willingness to share fully anonymized data collected through the VitaBeat app for scientific research purposes.

[2]Micro-breaks are short breaks taken during work to aid stress recovery [Adi24], and in the case of VitaBeat, these breaks can be done while listening to music.

The complete results can be found in the Appendix B, including all responses presented both as bar charts and in tabular form.

4.3 Discussion

The results of this online study provide valuable insight into users' preferences and behaviors regarding health monitoring apps, particularly in the context of integrating vital data with music consumption. Several key findings emerged from the survey responses, which have implications for the design and future development of the VitaBeat app.

4.3.1 Music Listening Habits

A substantial portion of participants (68 out of 72) listen to music regularly, and many do so daily. motivations for listening to music, including relaxation, motivation enhancement, and entertainment. VitaBeat could further engage users by using their heart rate data to offer personalized music recommendations or playlists tailored to specific motivations.

Furthermore, the fact that 47 participants use Spotify, a widely adopted streaming platform, reinforces the relevance of the existing Spotify integration of VitaBeat.

4.3.2 Smartwatch Ownership and Usage Patterns

Interestingly, only three participants indicated that they own a Wear OS smartwatch or intend to purchase one soon. In contrast, a larger proportion of respondents (16 mentions) owned an Apple Watch or planned to purchase one soon. This finding highlights that while smartwatches have gained popularity, a significant number of participants (61.11 %) do not own a smartwatch and do not plan to purchase one in the near future. This suggests that VitaBeat should consider compatibility with both smartphones and wearables, to ensure that users who do not own a Wear OS smartwatch can still benefit from its functions.

4.3.3 Health and Fitness App Usage

Nearly half of the participants (48.61 %) reported using health apps to improve fitness or health awareness. Furthermore, 31.94 % already use apps to monitor vital signs on their smartphones or smartwatches, highlighting a substantial potential user base for VitaBeat. By integrating health monitoring with music data, VitaBeat could appeal to users seeking a more comprehensive approach to understanding their well-being, positioning itself as a valuable tool in this area.

4.3.4 App Features and Preferences

The participants expressed a strong preference for features that enhance the user experience, such as notifications for abnormal vital values (65.28 %), the ability to compare vital data with music data (50.00 %), and the display of live data during music playback (44.44 %). These results suggest that users are particularly interested in receiving actionable insights based on their health data, with the added context of their music experience. The offering of these features could significantly enhance the appeal of the application.

4.3.5 Battery Life and Measurement Preferences

The survey results show a clear preference for longer battery life (66.67 %), even at the cost of less frequent measurements. However, about one-third of participants (33.33 %) prefer more frequent measurements for higher accuracy, even if it means shorter battery life. This highlights the need to balance functionality with user convenience. To meet these varying preferences, VitaBeat should set a default value that optimizes battery life, while also offering the possibility for users to customize their settings and choose between longer battery life or more frequent, accurate measurements.

4.3.6 Data Visualization and Design Preferences

Participants overwhelmingly preferred data visualizations in the form of charts (84.67 %), indicating that graphical representations of health data are more engaging and informative than text-based information. This preference aligns with the desire for clear, concise, and aesthetically pleasing data displays. The dark theme (56.94 %) and minimalist design (44.44 %) preferences also suggest that users value a simple and easy-to-read interface that minimizes distractions.

4.3.7 User Feedback on the Current User Interface

Feedback from participants also shows the current weaknesses of the VitaBeat app's user interface. Many respondents felt that the accelerometer and gyroscope data were too technical and should either be presented graphically or omitted altogether. They also expressed a desire for vital data, such as heart rate, to be displayed more prominently in a visually appealing way. Moreover, information such as disk usage was considered irrelevant and should not be shown continuously. These insights are invaluable in refining the UI of the app to make it more user-friendly and intuitive.

4.3.8 Gamification

Gamification elements were generally well received by participants, especially those that offer a sense of achievement or progress tracking. In the context of VitaBeat, elements like daily challenges and badge systems present a low-friction way to engage users without requiring constant interaction or competition.

The popularity of daily challenges highlights users' interest in establishing healthy routines through manageable, bite-sized tasks. These features offer structure and continuity, which can be particularly valuable in the context of wellbeing and behavioral change. Interestingly, while many users reported not actively engaging with gamified elements in other apps, their preferences still leaned toward commonly used features such as point systems and badges. This suggests that while users may not label these mechanisms as gamification, they still appreciate the motivational aspects they provide, especially when seamlessly integrated into the app experience.

4.3.9 Willingness to Share Data

The willingness of 83.33 % of participants to share anonymized data for scientific research purposes is a promising sign of the potential of VitaBeat to contribute to research, as long as their privacy is respected.

4.4 Conclusion of the Survey

The survey results provide valuable information on the needs and expectations of users regarding the features and design of VitaBeat. With 72 fully completed questionnaires, a solid data base was established that exceeded expectations and allowed a well-founded evaluation.

Despite positive feedback on functionality, it became evident that the UI requires improvement in several areas. In particular, users frequently pointed out potential enhancements concerning usability and data presentation. They expressed a desire for a clearer display of key information to facilitate more efficient app usage. One concrete example is the visualization of health data, such as heart rate, which should be presented in a more intuitive and comprehensible way.

Further adjustments concern the extension of the navigation system to allow intuitive music control. This would enable users to pause or switch songs according to their preferences. The idea of integrating gamification elements was also positively received, as these could help increase user engagement. In addition, a question about preferred forms of data visualization revealed that the majority of participants prefer diagrams. This user request will also be taken into account in future development. The revision of the UI and the integration of these new features will therefore be central aspects of the next development phases.

A particularly encouraging result was the willingness of 83.33 % of the participants to share anonymized data for scientific research purposes.

The survey also revealed some weaknesses in the questionnaire design. Certain questions did not yield the expected insights, emphasizing the need to be more precise and focused in future studies. It became clear that some questions were too general or did not produce usable conclusions.

In summary, the survey has provided valuable information for the continued development of VitaBeat. The results provide not only a solid basis for optimizing existing features, but also key indications for new functions that could further improve the user experience.

5 Implementation

Based on the results of the user survey in Section 4.2, as well as additional technical and design considerations, the application was revised and expanded in several areas. The goal was to improve usability, improve visual presentation, and integrate new features to increase user engagement and provide deeper analysis of the collected data. All of the new UI screens can be seen in Figure 5.1.

5.1 Collaborative Enhancements

During the course of this master's thesis, additional contributions were made in parallel by a master's thesis [Bau25] and a bachelor's thesis [Mer25]. The following improvements were developed collaboratively or by others and contributed to improving the overall user experience and technical robustness of the application. These additions also aligned with results of the requirements analysis.

To move beyond the prototype stage and toward a publishable application, several known bugs were fixed, and the existing codebase was revised. For instance, one of the issues was that a view was not scrollable, causing content to be cut off. Additionally, a specific page was prone to crashing under certain conditions, which was addressed during this phase. A particularly important step was the improvement of back-end communication. In the initial version, collected data could not be uniquely assigned to users, which hindered meaningful analysis. This issue was resolved by introducing a unique identifier that is now transmitted with each data upload. As a result, heart rate data, playback periods, and sensor values can now be reliably linked to specific users, forming a foundation for further analysis.

In addition, a setup guide was developed, which includes instructions for linking a Spotify account. The guide appears the first time the app is opened and contains a general data protection regulation request, which can only be accepted if the user is of legal age, necessary for data collection. After accepting, the regulation can be declined, preventing the app from sending data. The setup guide can also be revisited later through the explore screen.

A further contribution came from a collaborating Master's thesis [Bau25], which introduced notification-based support for musical micro-breaks. This not only expands the use case of the application beyond passive monitoring but also promotes stress reduction [Adi24] and increases user engagement through prefiguration break reminders.

Additionally, steps were taken to prepare the app for publication. A Google Developer account was created for the university institute, although initial delays were encountered due to internal processes. Furthermore, access to the back-end was expanded beyond the university network, making it possible to use the app under real-world conditions outside of campus.

Together, these improvements significantly increased the technical maturity and usability of the application and form a key part of the transition from prototype to deployable application.

5.2 New Overview Screen

A central finding of the survey was the desire for a clearer and more streamlined presentation of the collected data. Participants criticized the previous overview for being overly technical and cluttered, with irrelevant elements such as disk usage and raw sensor data (e.g., accelerometer, gyroscope). In response to this feedback, the Overview screen was completely redesigned.

The new version follows a minimalist design approach and now automatically adapts to the light mode (see Figure 5.1b) or dark mode (see Figure 5.1a) of the system, both of which were the two most preferred design choices in the survey. The screen focuses on presenting the most relevant metrics, such as the current heart rate, the song that is currently playing and its playback state, and the newly introduced Heart Rate Zones[1], providing a more meaningful context for users. Additionally, all charts and diagrams now feature a consistent color coding, which makes it easier for users to distinguish different heart rate zones across different visualizations.

Each section of the overview is interactive and leads to a detailed subview.

- **Weekly Overview Screen**: Summarizes heart rate trends over the last seven days.
- **Song History Screen**: Displays the last 20 songs played and allows users to view a detailed heart rate graph for each listening session.
- **Daily Micro-Break Screen**: Leads to a calendar where users can track when micro-breaks were taken.
- **Sensor Data Overview Screen**: Provides detailed insights into additional sensor data.

This modular redesign directly reflects the survey results and aims to improve the usability and clarity of the application while still allowing users to explore detailed data when desired.

Furthermore, the smartwatch application received a new overview screen with a coherent visual design, ensuring a consistent user experience across platforms. The smartwatch overview screen can be seen in Figure 5.2

5.3 Sensor Data Overview

The detailed overview of sensor data, which was previously part of the original overview screen, has been moved to a separate section (Figure 5.1e). This allows users to focus on key information on the main overview screen without losing the ability to display other collected data. The new sensor data overview screen provides quick access to more technical data, such as accelerometer and gyroscope readings. This separation ensures a clearer distinction between high-level metrics and detailed sensor-level information.

[1] Heart rate zones based on calculation of the American Heart Association [Ass24].

5.4 Gamification and Micro-Breaks

To increase user engagement, a gamification element was implemented, focusing on the use of micro-breaks. For each day a micro break is successfully taken, the user earns an icon in the in-app calendar. When multiple days in a row are completed, a streak is built. This streak can be shared through social networks or instant messaging services, with a direct link to the app. This not only increases motivation for regular usage, but also increases the viral potential of the application. The new overview screen can be seen in Figure 5.1f.

5.5 Enhanced Statistical Features

Another central request from the survey was better visualization of long-term trends. To address this, a weekly overview was developed, displaying bar charts with the average heart rate values from the last seven days. A daily heart rate diagram was also implemented, which is interactive and zoomable to the 5-minute level, allowing both general patterns and finer fluctuations to be explored. The chart visualizations were created using the MPAndroidChart library [Phi]. Additionally, a tabular song history for the day was integrated, providing users with a detailed list of all songs played during the specified period. This screen can be seen in Figure 5.1d.

5.6 Song History and Song Details

The song history feature was expanded to include a new detail view. For each song played, a song details screen can now be opened, showing the heart rate curve during the listening session (Figure 5.1c). The visualization is zoomable down to five seconds, allowing for a detailed analysis of physiological responses to music. In addition to sensor data, the screen presents essential Spotify metadata, including song title, artist, album, playback time, and date.

5.7 Music Controls and Spotify Guidelines

Some of the originally planned music control functions could not be aligned with Spotify's official design and branding guidelines [Spoa]. Specifically, Spotify recommends that no play controls other than play/pause be provided in the app, as enabling or disabling controls like skip or back can lead to inconsistent and confusing behavior for users with a free account.

To provide seamless music interaction, a link to the respective Spotify song was integrated. This allows users to easily switch songs, pause, or skip directly through the official Spotify app.

The guidelines were fully followed to ensure that the app can be published later.

5.8 Limitations

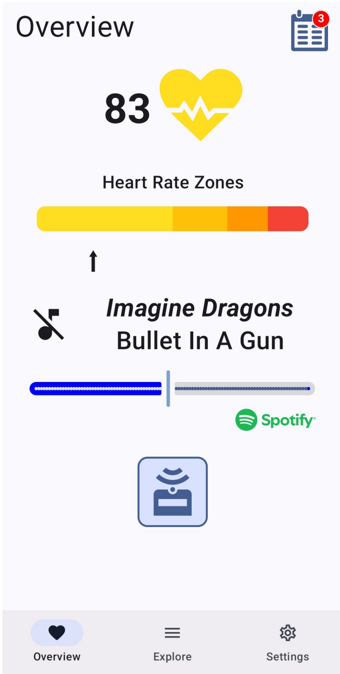
Several limitations of the current study and the VitaBeat application must be acknowledged.

First, due to restrictions of the Spotify SDK, the genre of a currently playing song cannot be retrieved. This limits the ability to analyze the relationship between specific music genres and physiological responses.

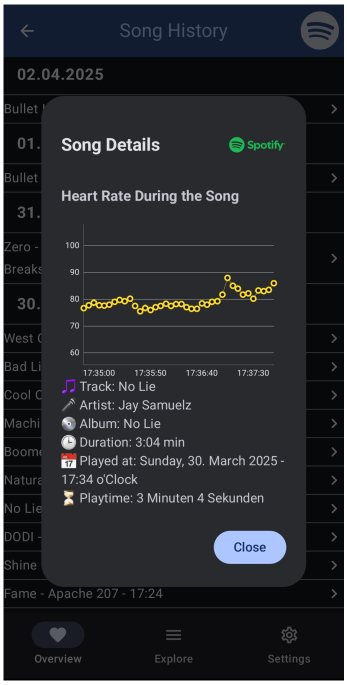
Second, the implementation of gamification elements was intentionally kept simple. While gamification is often used to increase user engagement, the primary goal in VitaBeat was to support stress reduction through micro breaks. Therefore, elements such as challenges or rewards were designed to encourage short recovery periods rather than competitive behavior or excessive screen time. More complex gamification strategies may be explored in future work.

Third, the application is currently only available for Android-based smartwatches. An extension to support Apple Watches would have significantly broadened the potential user base but was not feasible within the scope of this Master's thesis due to time and resource constraints.

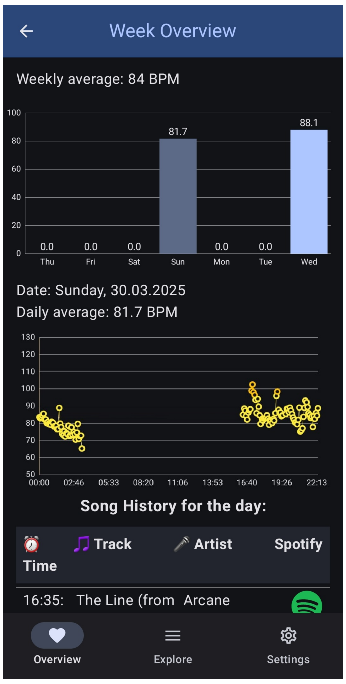
(a) Overview screen in dark mode showing heart rate and music data.



(b) Overview screen in light mode showing heart rate and music data.

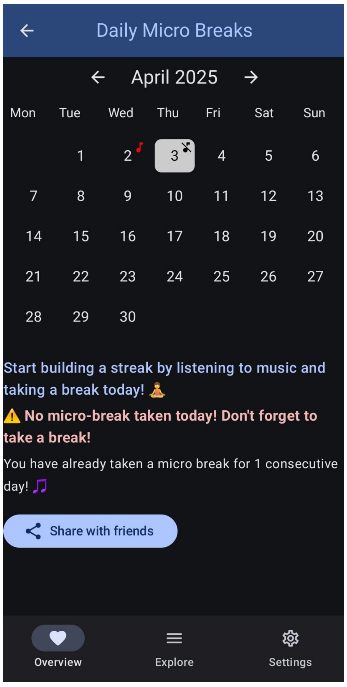


(c) Song detail view with heart rate progression and metadata.



(d) Weekly overview with bar chart, daily line graph, and song list.

(e) Sensor screen displaying additional raw data not shown in the main view.



(f) Calendar view of daily micro-breaks with icons indicating completion and share options.

Figure 5.1: New UI of VitaBeat smartphone application, displaying the main screen with heart rate and music data, along with navigation options for accessing different features.

Figure 5.2: New UI of VitaBeat smartwatch application.

6 Conclusion and Outlook

In this thesis, VitaBeat was further developed with a focus on the user. Through the extensive requirements analysis survey, many insights were gained regarding the implementation of features that address the needs and desires of potential users. A detailed conclusion of the survey can be found in Section 4.4. The collected data was directly incorporated into the design of new features, creating new use cases for the user. The ability to analyze personal data in histories with the corresponding charts and statistics provides the user with valuable information on their heart rate trends in combination with the data collected from the Spotify SDK.

Through the development of a more user-centric design, based on the results of this analysis, VitaBeat now offers a significantly more appealing and user-friendly interface that focuses on the most important collected data and makes the use of the app more intuitive. Additional new features, such as Spotify integration for music control, a new smartwatch overview screen, and the gamification approach to enhance user engagement, have been successfully integrated. These innovations not only improve the user experience, but also encourage regular use of the app and motivate users to continue using it.

During the further development of VitaBeat, several challenges arose that had to be overcome. One of the biggest challenges was the integration of the various data sources, ranging from heart rate measurements to music data and smartwatch sensor data. The correct synchronization of these data in real-time and their display across different overview screens with clear diagrams was time-consuming.

Additionally, there were limitations with the Spotify SDK that prevented us from integrating certain music control functions that were originally planned. These limitations required an adjustment of the functionalities to ensure that the user experience remained intact.

Thus, VitaBeat is evolving into a versatile app that offers added value to both researchers in studies and users in daily life. Notably, the app also continues to provide significant value to users even without an ongoing study. However, the continuous development of VitaBeat still reveals further potential for improvement, which could significantly expand its functionality and value. The following ideas outline possible directions for further enhancement:

1. **Enhancements in Backend:** Improving backend architecture and optimizing data processing capabilities could help accommodate a larger volume of user data. Furthermore, integrating tools such as Jupyter Lab [Jup] for data exploration and scripting would enable advanced analysis and visualization, primarily for research purposes.
2. **Integration with Health Connect:** Integration with Android's Health Connect [Andc] would enable the app to aggregate health data from various apps and wearables, creating new opportunities to connect physiological data with music data, offering richer insights for users and researchers.

3. **Intelligent music recommendations:** Based on collected heart rate data and listening habits, the app could suggest songs that support relaxation, enhancing the personal value of the app.
4. **Notifications for abnormal vital signs:** Real-time alerts could warn users if their heart rate exceeds or falls below certain thresholds, adding a preventive health monitoring feature.
5. **Expansion of gamification elements:** More advanced gamification features could be integrated to further enhance user engagement.
6. **Interpretation of activity:** Currently, VitaBeat collects sensor data such as accelerometer motion but does not interpret these signals beyond basic visualizations. Future versions could integrate activity recognition to classify types of physical activity (e.g., rest, walking, workout) based on data from smartwatches and smartphones. As demonstrated by Vaizman et al. [VEL17], the fusion of multimodal sensor data enables robust context recognition in real-life environments. This would help to connect heart rate data to user's activities.
7. **iOS and Apple Watch support:** Developing an iOS version of VitaBeat would make the app accessible to a broader audience and ensure compatibility with Apple Watches and iPhones. As indicated by the survey results (see Section 4.2), a significant portion of users rely on Apple smartwatches, underlining the importance of iOS and Apple Watch support in future development.

Bibliography

[Adi24] K. Adiasto. “Tuning in: A closer look at the effects of music listening on stress recovery”. PhD thesis. Sl: sn, 2024 (cit. on pp. 24, 29).

[AMP+04] C. Abras, D. Maloney-Krichmar, J. Preece, et al. “User-centered design”. In: *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications* 37.4 (2004), pp. 445–456 (cit. on p. 13).

[Anda] AndroidXActivity. *Android Developers Activity*. https://developer.android.com/jetpack/androidx/releases/activity (cit. on p. 17).

[Andb] AndroidXAppcompat. *Android Developers Appcompat*. https://developer.android.com/jetpack/androidx/releases/appcompat (cit. on p. 17).

[Andc] AndroidxHealthConnect. *Android Developers Health Connect*. https://developer.android.com/health-and-fitness/guides/health-connect (cit. on p. 35).

[Andd] AndroidxHilt. *Android Development Hilt*. https://developer.android.com/jetpack/androidx/releases/hilt (cit. on p. 17).

[Ande] AndroidxLifecycle. *Android Developers Lifecycle*. https://developer.android.com/jetpack/androidx/releases/lifecycle (cit. on p. 17).

[Andf] AndroidxNavigation. *Android Developers Navigation*. https://developer.android.com/jetpack/androidx/releases/navigation (cit. on p. 17).

[Andg] AndroidxPager. *Android Developers Pager*. https://developer.android.com/reference/kotlin/androidx/paging/Pager (cit. on p. 17).

[Andh] AndroidxRoom. *Android Developers Room*. https://developer.android.com/jetpack/androidx/releases/room (cit. on p. 17).

[Andi] AndroidxWearCompose. *Android Developers Wear Compose*. https://developer.android.com/jetpack/androidx/releases/wear-compose (cit. on p. 17).

[Andj] AndroidxWorkManager. *Android Developers WorkManager*. https://developer.android.com/jetpack/androidx/releases/work (cit. on pp. 16, 17).

[Apa] ApacheSpark. *Apache Spark Documentation*. https://spark.apache.org/documentation.html (cit. on p. 16).

[Ass24] A. H. Association. *Target Heart Rates Chart*. 2024. URL: https://www.heart.org/en/healthy-living/fitness/fitness-basics/target-heart-rates (cit. on p. 30).

[Bau25] R. Baumann. “Wearable-based Study on the Influence of Musical Micro-Breaks on Daily Stress Recovery”. M.S. thesis. Institute for Parallel and Distributed Systems (IPVS), University of Stuttgart, 2025 (cit. on pp. 12, 29).

[BBC21] P. Bitrián, I. Buil, S. Catalán. “Enhancing user engagement: The role of gamification in mobile apps”. In: *Journal of Business Research* 132 (2021), pp. 170–185 (cit. on p. 13).

[BJT+24] R. Baumann, F. Jerye, B. Tunc, L. Grams, I. Layer, L. Layer, S. Merkle, E. Rzadkowolski. “VitaBeat”. study project. Institute for Parallel and Distributed Systems (IPVS), University of Stuttgart, 2024 (cit. on pp. 11, 14, 15, 19).

[BLIC18] M. Brehmer, B. Lee, P. Isenberg, E. K. Choe. “Visualizing ranges over time on mobile phones: a task-based crowdsourced evaluation”. In: *IEEE transactions on visualization and computer graphics* 25.1 (2018), pp. 619–629 (cit. on p. 14).

[Dat] DataStorePreferences. *App Architecture:Data Layer*. https://developer.android.com/topic/libraries/architecture/datastore (cit. on p. 17).

[Dep25] S. R. Department. *Number of users of smartwatches worldwide 2020-2029*. 2025. URL: https://www.statista.com/forecasts/1314339/worldwide-users-of-smartwatches/ (cit. on p. 11).

[Flu] FluxCD. *Flux Documentation*. https://fluxcd.io/flux/ (cit. on p. 16).

[GB23] F. Grioui, T. Blascheck. “Heart Rate Visualizations on a Virtual Smartwatch to Monitor Physical Activity Intensity”. In: *Proceedings of the International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications*. SciTePress, 2023, pp. 101–114 (cit. on p. 13).

[Gmb] L. GmbH. *LimeSurvey - Free Online Survey Tool*. https://www.limesurvey.org/ (cit. on p. 22).

[Gooa] GoogleDagger. *Google Dagger*. https://github.com/google/dagger/releases (cit. on p. 17).

[Goob] GooglePlayServices. *Google Play Services*. https://developers.google.com/android (cit. on p. 17).

[Gro12] F. Groh. “Gamification: State of the art definition and utilization”. In: *Institute of Media Informatics Ulm University* 39 (2012), p. 31 (cit. on p. 13).

[Hip] R. D. Hipp. *SQLite*. URL: https://www.sqlite.org/index.html (cit. on p. 17).

[Jet] JetpackCompose. *Android Developers Get started with Jetpack Compose*. https://developer.android.com/develop/ui/compose/documentation (cit. on p. 17).

[Jou] JourneyAppsZxing. *GitHub - journeyapps zxing*. https://github.com/journeyapps/zxing-android-embedded (cit. on p. 17).

[Jup] Jupyter. *Project Jupyter Documentation*. https://docs.jupyter.org/en/latest/ (cit. on p. 35).

[K3s] K3s. *K3s - Lightweight Kubernetes*. https://docs.k3s.io/ (cit. on p. 16).

[Kot] KotlinSymbolProcessing. *Github - KSP*. https://github.com/google/ksp (cit. on p. 17).

[Mer25] S. Merkle. “Wearable-based Study on the Influence of Music Genre Preferences on Heart Rate”. B.S. thesis. Institute for Parallel and Distributed Systems (IPVS), University of Stuttgart, 2025 (cit. on p. 29).

[Min] MinIO. *MinIO Object Storage for Kubernetes*. https://min.io/docs/minio/kubernetes/upstream/ (cit. on p. 16).

[Mos] Moshi. *GitHub - moshi*. https://github.com/square/moshi (cit. on p. 17).

[Phi] PhilJay. *MPAndroidChart*. https://github.com/PhilJay/MPAndroidChart (cit. on p. 31).

[Pin] PintrestKtlint. *Github - ktlint*. https://github.com/pinterest/ktlint (cit. on p. 17).

[Ret] Retrofit. *GitHub - Retrofit*. https://github.com/square/retrofit (cit. on p. 17).

[RG03] P. J. Rentfrow, S. D. Gosling. "The do re mi's of everyday life: the structure and personality correlates of music preferences." In: *Journal of personality and social psychology* 84.6 (2003), p. 1236 (cit. on p. 22).

[Spoa] Spotify. *Design & Branding Guidelines*. https://developer.spotify.com/documentation/design (cit. on p. 31).

[Spob] Spotify. *Spotify Android SDK*. https://developer.spotify.com/documentation/android (cit. on p. 14).

[Spo25] Spotify. *Number of Spotify monthly active users (MAUs) worldwide from 1st quarter 2015 to 4th quarter 2024*. 2025. URL: https://www.statista.com/statistics/367739/spotify-global-mau/ (cit. on p. 11).

[Spr] Spring. *Spring Framework*. https://spring.io/projects/spring-framework (cit. on p. 16).

[VEL17] Y. Vaizman, K. Ellis, G. Lanckriet. "Recognizing detailed human context in the wild from smartphones and smartwatches". In: *IEEE pervasive computing* 16.4 (2017), pp. 62–74 (cit. on p. 36).

[Wea] WearOS. *Android Developer Wear OS*. https://developer.android.com/wear (cit. on pp. 14, 16).

All links were last followed on April 11, 2025.

A Survey Questionaire

This appendix contains all questions from the online survey, grouped according to the thematic sections presented in Section 4.1.2 of the thesis.

A.1 Demography

The first section of the survey focused on gathering demographic data to better understand the participant group. The questions included:

1. **Age**: Participants were asked to select their age group with the following options:
   - Under 18
   - 18 - 24
   - 25 - 34
   - 35 - 44
   - 45 - 54
   - 55 - 64
   - Over 64

   Note: Participants must be over 18 years old to take part in the survey.
2. **Gender**: The gender question provided the following choices:
   - Female
   - Male
   - Non-binary
   - No answer
3. **Highest Level of Education**: The education level question offered the following options:
   - No degree
   - Secondary school diploma
   - High school diploma
   - Bachelor's degree
   - Master's degree

- Doctorate (PhD)
- Other: (with an option to specify)
- No answer

4. **Usage of Health Apps**: Participants were asked whether they regularly use health apps on their smartphone or smartwatch to monitor vital parameters (e.g., heart rate).
5. **Professional Background**: Participants were asked to indicate if they work in any of the following fields (multiple selections possible):
    - Software Development
    - Healthcare & Medicine
    - Music

A.2 Music Listening Behavior

The second section of the survey focused on the music listening habits of the participants. The questions included:

1. **What music genres do you listen to most often?** Select all that apply:
    - Classical
    - Jazz
    - Blues
    - Folk
    - Alternative
    - Rock
    - Heavy metal
    - Country
    - Pop
    - Religious
    - Soundtracks
    - Rap / Hip-hop
    - Soul / Funk
    - Electronic
    - Other: (with an option to specify)
2. **At what times of the day do you usually listen to music?** Select all that apply:

- Morning
- Late morning
- Noon
- Afternoon
- Evening
- Night
- No specific time

3. **When do you most frequently listen to music?** Select all that apply:
    - While exercising
    - While working
    - While studying
    - While commuting
    - Other: (with an option to specify)
4. **What is your reason for listening to music?** Select all that apply:
    - For relaxation
    - For motivation
    - To improve concentration
    - For mood regulation
    - For entertainment
    - Other: (with an option to specify)
5. **How often do you listen to music?** Choose one of the following answers:
    - Daily
    - Several times a week
    - Once a week
    - Less often

A.3 Usage Behavior

The third section of the survey focused on the use behavior of participants related to music streaming services, smartwatches, health apps, and gamification elements. The questions included:

1. **Do you use Spotify[1] in your daily life?** *Spotify is a music streaming service for playing music and podcasts.*
    - Yes
    - No
2. **Do you currently own a smartwatch or plan to purchase one in the next 3 months? If yes, which one?** Choose one of the following answers:
    - Yes, a smartwatch with Wear OS (e.g., Samsung, Fossil)
    - Yes, an Apple Watch
    - Yes, different smartwatch (neither Wear OS, nor Apple)
    - No, I do not own a smartwatch and have no plans to purchase one
3. **What motivates you to regularly use a health app?** Select all that apply:
    - Health awareness
    - Improving fitness (e.g., weight loss)
    - Enjoyment of technology
    - Personal goals (e.g., better sleep quality)
    - I do not use health apps
    - Other: (with an option to specify)
4. **Which of the following gamification[1] elements do you regularly use in apps or digital applications?** *Gamification is the application of game-like elements such as points and challenges in a non-gaming context to enhance motivation, engagement, and user behavior.* Select all that apply:
    - None of these elements
    - Collecting points
    - Earning badges
    - Viewing rankings
    - Participating in competitions or challenges with others
    - I use the following: (with an option to specify)
5. **Do you share achievements or progress from apps on social media? If yes, which platforms?** Select all that apply:
    - Yes, via Facebook

- Yes, via Instagram
- Yes, via X (formerly Twitter)
- Yes, via an instant messaging service like WhatsApp
- No, I do not share achievements or progress
- Other: (with an option to specify)

A.4 Evaluation of App function

The fourth section of the survey focused on evaluating the potential features and functions of the app. The questions included:

1. **An app for tracking my vital parameters (e.g., heart rate) is interesting to me.**
2. **I would use an app that provides the ability to view statistics of my vital parameters (e.g., heart rate), such as average heart rate per day.**
3. **I would use an app that links music data (e.g., music genre) with my vital parameters (e.g., heart rate).**
4. **The availability of an app in app stores like Google Play Store is important to me.**

For all of the above questions, the following response options were provided:

- Does not apply
- Mostly does not apply
- Mostly applies
- Fully applies

A.5 VitaBeat - Functionality

The next section of the survey focused on the specific features that participants would appreciate in an app such as VitaBeat. The questions included:

1. **Which 3 features would you particularly appreciate in an app like VitaBeat? (Maximum 3)** *Please select at most 3 answers:*
    - Notifications for unusual vital values
    - Personalized tips based on vital data
    - Integration with other apps (e.g., Google Fit)
    - Data export in tabular form
    - Live data display (e.g., current heart rate during music playback)

- Comparison of vital parameters (e.g., heart rate) across different music genres
- Other: (with an option to specify)

2. **Which of the following features would you be most likely to use in an app like VitaBeat to visualize your progress or achievements? (Maximum 2)** *Please select at most 2 answers:*
   - Points and rankings
   - Challenges (e.g., daily tasks)
   - Rewards (e.g., badges)
   - Other: (with an option to specify)
3. **Which of the following features for linking music with your vital parameters (e.g., heart rate) would you be most likely to use in the VitaBeat app? (Select up to 2)** *Please select at most 2 answers:*
   - Visualization of my vital parameters in relation to preferred music genres
   - Display of average playback duration and its impact on my vital parameters
   - Music recommendations based on my preferences and vital parameters
   - Other: (with an option to specify)
4. **Which of the following music control features would you consider most necessary in the VitaBeat app? (Maximum 2)** *Please select at most 2 answers:*
   - General music control (e.g., play/pause)
   - Display of the current song (title, artist, album) along with song duration (elapsed and remaining time)
   - Music timer (automatic pause after a certain duration)
   - Other: (with an option to specify)
5. **I would find it helpful if VitaBeat regularly reminded me to take short relaxation breaks (micro-breaks) during work.** Choose one of the following answers:
   - Does not apply
   - Mostly does not apply
   - Mostly applies
   - Fully applies
6. **How important is the frequency of measurements (e.g., how often your vital data is recorded per second) compared to battery life in the VitaBeat app?** Choose one of the following answers:
   - I prefer more frequent measurements for more accurate data, even if it drains the battery faster.
   - I prefer a longer battery life, even if the measurements are less frequent and therefore less accurate.

A.6 VitaBeat - Design and usability

The following section of the survey focused on the design and data visualization preferences for the VitaBeat app. The questions included:

1. **Which two types of data visualization for VitaBeat appeal to you the most? (Maximum 2)** *Please select at most 2 answers:*
   - Charts (e.g., bar or line charts)
   - Tables
   - Simple symbols or icons
   - Text-based information
   - Other: (with an option to specify)
2. **Which colors or designs do you find appealing for an app like VitaBeat? Below you can see example images.** *Please select all that apply:*
   - Clear, minimalist designs
   - Vibrant, colorful designs
   - Dark designs (Dark Mode)
   - Other: (with an option to specify)

   Example images:

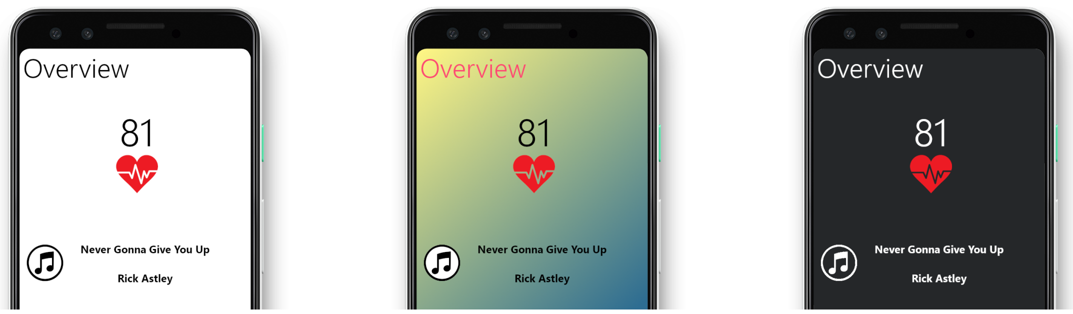


Figure A.1: Example images of different design styles.

3. **You see a screenshot of the home screen of VitaBeat. Do you think any important information is missing that should be presented more clearly or prominently? If yes, what?** *(Provide space for free-text answer)*
4. **How do you evaluate the balance between information content and clarity (e.g., a simple layout) in the VitaBeat app?** Choose one of the following answers:
   - The information content should be prioritized, even if it makes the layout slightly more complex.

  - Clarity should be the top priority, even if it means displaying less information.

5. **Do you have any additional comments or suggestions on how the VitaBeat app could be made more appealing or useful for you?** *(Provide space for free-text answer)*

A.7 VitaBeat - Research

The final section of the survey focused on the interest of the participants in research topics related to the VitaBeat app and their willingness to contribute to scientific research.

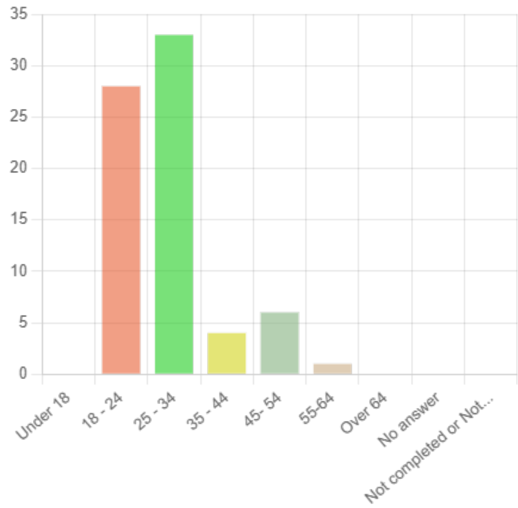
1. **Which of the following topics and questions would you find most interesting?** *Select all that apply:*
   - Influence of Music Genre Preference on Heart Rate
   - What role do personal preferences play in the effect of music on the body?
   - How can apps help enhance well-being through the analysis of vital data and music?
   - Influence of Musical Micro-Breaks on Daily Stress Recovery
   - Other: (with an option to specify)
2. **Would you be willing to share fully anonymized data collected through the VitaBeat application for scientific research purposes?**
   - Yes
   - No
3. **Are you interested in the current research questions we are investigating? If yes, please enter your email address to stay informed about our research findings.** *(Provide space for free-text answer, email address)*

B All Results of the Survey

B.1 Demography

Age Group	Count	Percentage
Under 18	0	0.00%
18 - 24	28	38.89%
25 - 34	33	45.83%
35 - 44	4	5.56%
45 - 54	6	8.33%
55 - 64	1	1.39%
Over 64	0	0.00%
No response	0	0.00%
Total	**72**	**100.00%**

(a) Age distribution of participants.

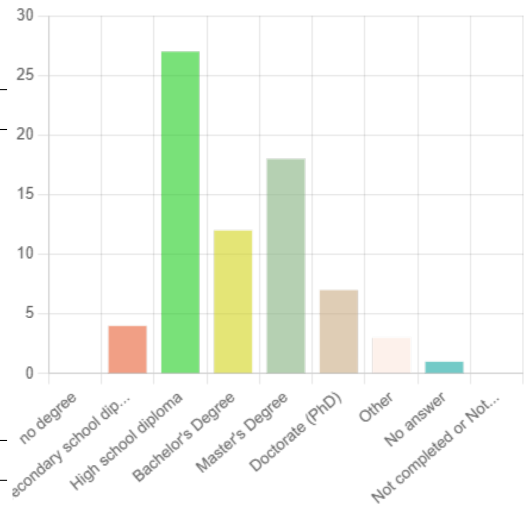


(b) Age distribution as bar chart.

Figure B.1: Comparison of age distribution in both a table and a bar chart.

Education Level	Count	Percentage
No degree	0	0.00%
Secondary school diploma	4	5.56%
High school diploma	27	37.50%
Bachelor's Degree	12	16.67%
Master's Degree	18	25.00%
Doctorate (PhD)	7	9.72%
Other	3	4.17%
No response	1	1.39%
Total	**72**	**100.00%**

(a) Highest level of education among the participants.

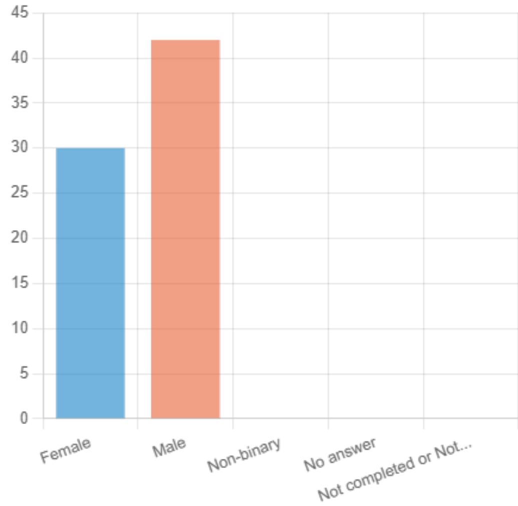


(b) Age distribution as bar chart

Figure B.2: Highest level of education in table and bar chart.

Gender	Count	Percentage
Female	30	41.67%
Male	42	58.33%
Non-binary	0	0.00%
No response	0	0.00%
Total	**72**	**100.00%**

(a) Gender distribution of participants.

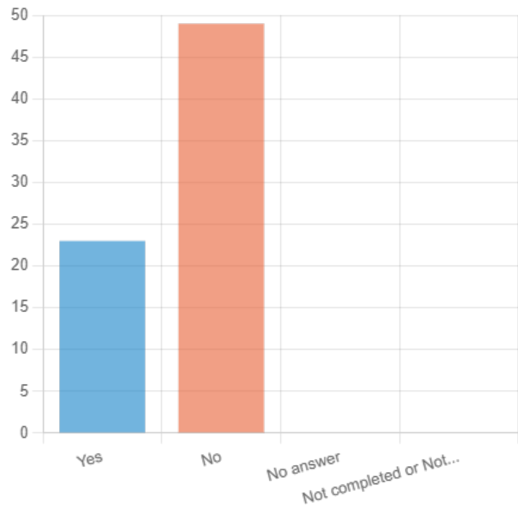


(b) Gender distribution as bar chart.

Figure B.3: Comparison of gender distribution in table and chart.

Response	Count	Percentage
Yes	23	31.94%
No	49	68.06%
No response	0	0.00%
Total	**72**	**100.00%**

(a) Regular use of health apps for monitoring vital parameters.

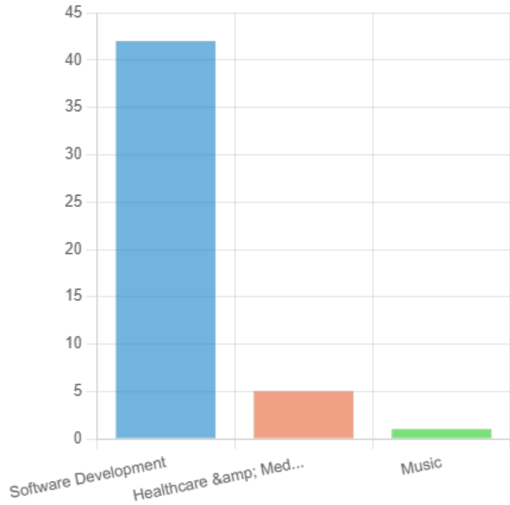


(b) Health app usage for monitoring vital parameters as bar chart.

Figure B.4: Comparison of health app usage for monitoring vital parameters in table and bar chart.

Field	Count	Percentage
Software Development	42	58.33%
Healthcare & Medicine	5	6.94%
Music	1	1.39%
Total	**48**	**100.00%**

(a) Employment in specific fields.



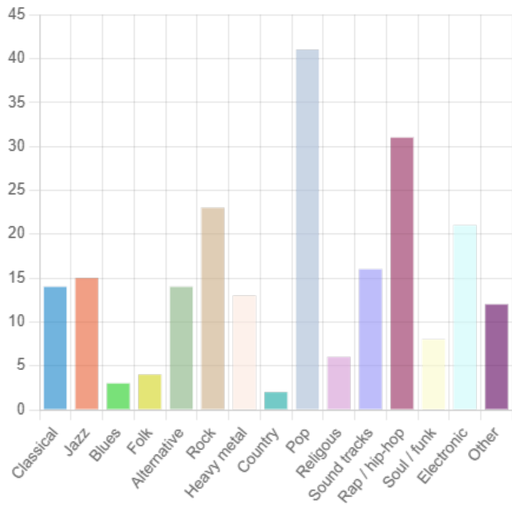
(b) Employment distribution in specific fields as bar chart.

Figure B.5: Comparison of employment in specific fields distribution in table and bar chart.

B.2 Music Listening Behavior

Music Genre	Count	Percentage
Classical	14	19.44%
Jazz	15	20.83%
Blues	3	4.17%
Folk	4	5.56%
Alternative	14	19.44%
Rock	23	31.94%
Heavy Metal	13	18.06%
Country	2	2.78%
Pop	41	56.94%
Religious	6	8.33%
Soundtracks	16	22.22%
Rap / Hip-Hop	31	43.06%
Soul / Funk	8	11.11%
Electronic	21	29.17%
Other	12	16.67%
Total	**223**	**100.00%**

(a) Preferred music genres among participants.

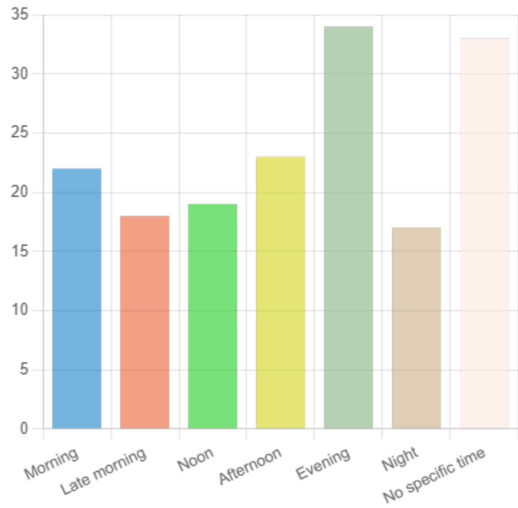


(b) Preferred music genres as bar chart.

Figure B.6: Comparison of preferred music genres in table and bar chart.

Time of Day	Count	Percentage
Morning	22	30.56%
Late morning	18	25.00%
Noon	19	26.39%
Afternoon	23	31.94%
Evening	34	47.22%
Night	17	23.61%
No specific time	33	45.83%
Total	**166**	**100.00%**

(a) Preferred times of the day for listening to music.

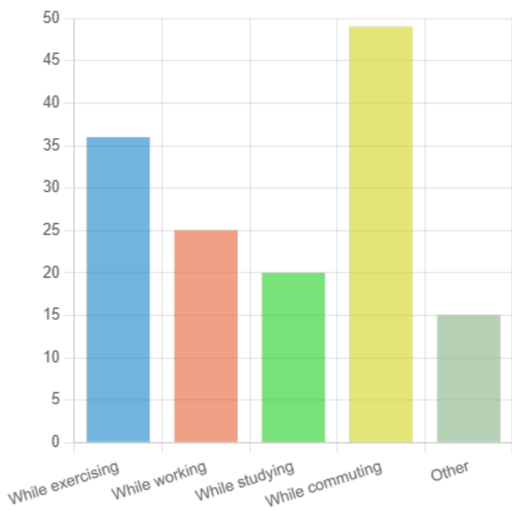


(b) Preferred times of the day for listening to music as bar chart.

Figure B.7: Comparison of preferred times of the day for listening to music in table and chart.

Listening Situation	Count	Percentage
While exercising	36	50.00%
While working	25	34.72%
While studying	20	27.78%
While commuting	49	68.06%
Other	15	20.83%
Total	**145**	**100.00%**

(a) Most frequent situations for listening to music.

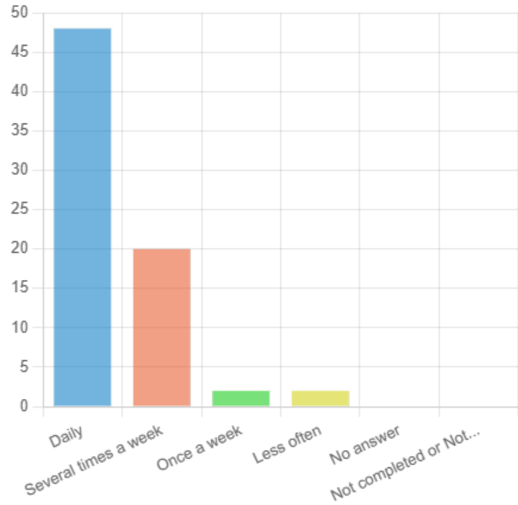


(b) Listening situations as bar chart.

Figure B.8: Comparison of music listening situations in table and chart.

Listening Frequency	Count	Percentage
Daily	48	66.67%
Several times a week	20	27.78%
Once a week	2	2.78%
Less often	2	2.78%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) Frequency of music listening among participants.



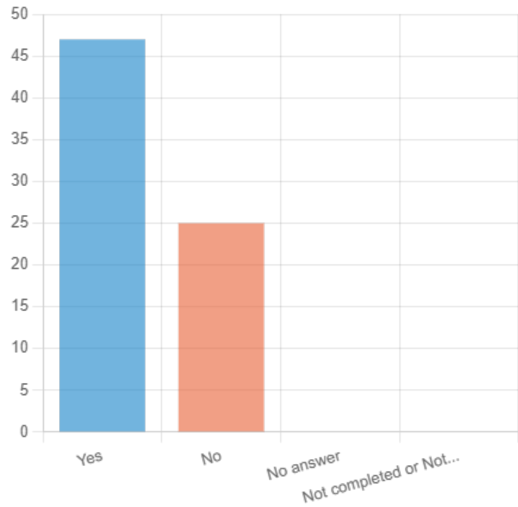
(b) Music listening frequency as bar chart.

Figure B.9: Comparison of music listening frequency in table and chart.

B.3 Usage Behavior

Response	Count	Percentage
Yes	47	65.28%
No	25	34.72%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) Spotify usage in daily life.

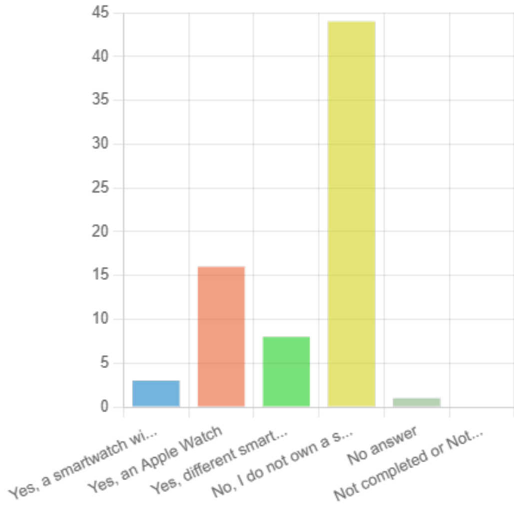


(b) Spotify usage as bar chart.

Figure B.10: Comparison of Spotify usage in table and chart.

Response	Count	Percentage
Wear OS Smartwatch	3	4.17%
Apple Watch	16	22.22%
Other Smartwatch	8	11.11%
No smartwatch, no plans	44	61.11%
No answer	1	1.39%
Total	**72**	**100.00%**

(a) Smartwatch ownership or purchase intention.

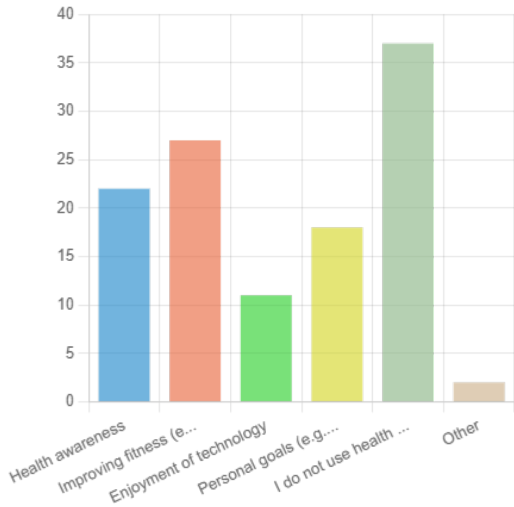


(b) Smartwatch ownership as bar chart.

Figure B.11: Comparison of smartwatch ownership in table and chart.

Motivation	Count	Percentage
Health awareness	22	30.56%
Improving fitness	27	37.50%
Enjoyment of technology	11	15.28%
Personal goals	18	25.00%
No health app usage	37	51.39%
Other	2	2.78%
Total	**117**	**100.00%**

(a) Motivations for using health apps.

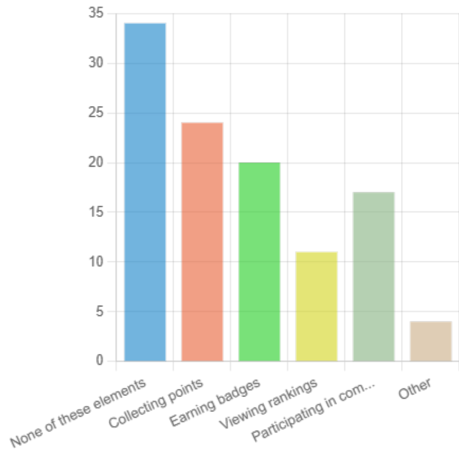


(b) Motivation for health app usage as bar chart.

Figure B.12: Comparison of motivations for health app usage in table and chart.

Gamification Element	Count	Percentage
None of these elements	34	47.22%
Collecting points	24	33.33%
Earning badges	20	27.78%
Viewing rankings	11	15.28%
Participating in competitions	17	23.61%
Other	4	5.56%
Total	**110**	**100.00%**

(a) Regular use of gamification elements.

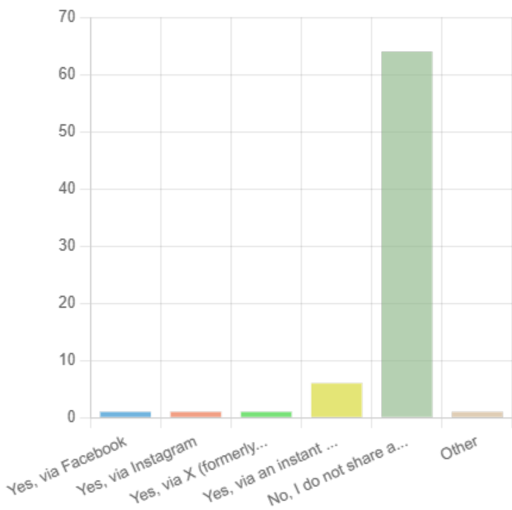


(b) Gamification elements usage as bar chart.

Figure B.13: Comparison of gamification elements usage in table and chart.

Platform	Count	Percentage
Facebook	1	1.39%
Instagram	1	1.39%
X (formerly Twitter)	1	1.39%
Instant messaging	6	8.33%
No sharing	64	88.89%
Other	1	1.39%
Total	**74**	**100.00%**

(a) social media sharing.



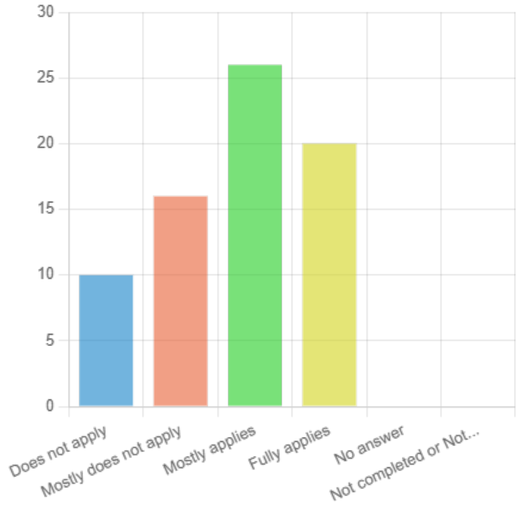
(b) social media sharing as bar chart.

Figure B.14: Comparison of social media sharing in table and chart.

B.4 Evaluation of app functions and properties

Response	Count	Percentage
Does not apply	10	13.89%
Mostly does not apply	16	22.22%
Mostly applies	26	36.11%
Fully applies	20	27.78%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) Interest in a vital parameter tracking app.

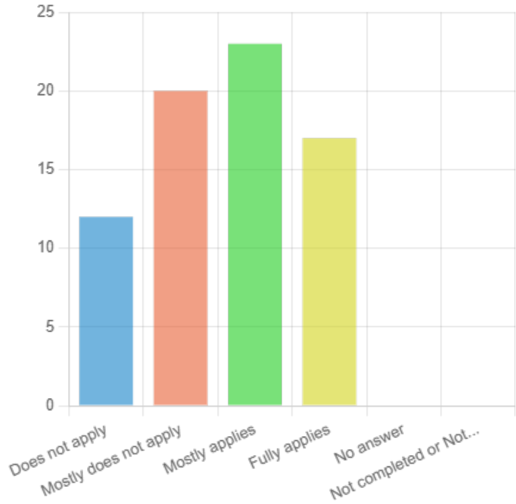


(b) Vital parameter tracking interest as bar chart.

Figure B.15: The interest in a vital tracking app in table and chart.

Response	Count	Percentage
Does not apply	9	12.50%
Mostly does not apply	12	16.67%
Mostly applies	27	37.50%
Fully applies	24	33.33%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) Interest in viewing statistics for vital parameters.

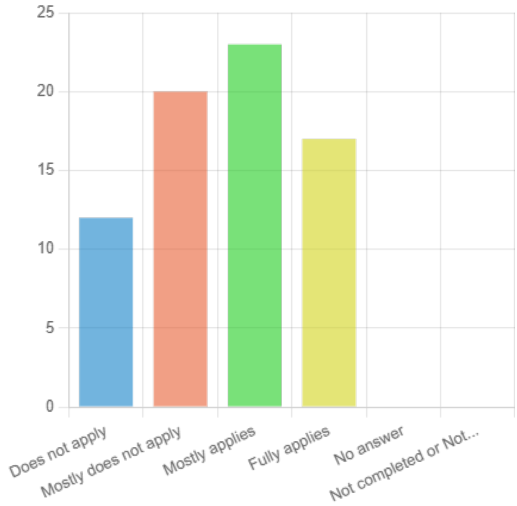


(b) Interest in viewing statistics for vital parameters as bar chart.

Figure B.16: The interest in statistics for vital parameters in table and chart.

Response	Count	Percentage
Does not apply	12	16.67%
Mostly does not apply	20	27.78%
Mostly applies	23	31.94%
Fully applies	17	23.61%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) Interest in linking music data with vital parameters.

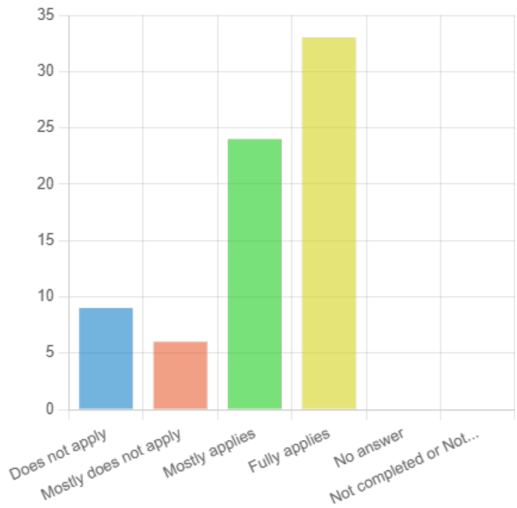


(b) Interest in linking music data with vital parameters as bar chart.

Figure B.17: The interest in linking music data with vital parameters in table and chart.

Response	Count	Percentage
Does not apply	9	12.50%
Mostly does not apply	6	8.33%
Mostly applies	24	33.33%
Fully applies	33	45.83%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) The importance of the availability of an app in app stores like Google Play Store.



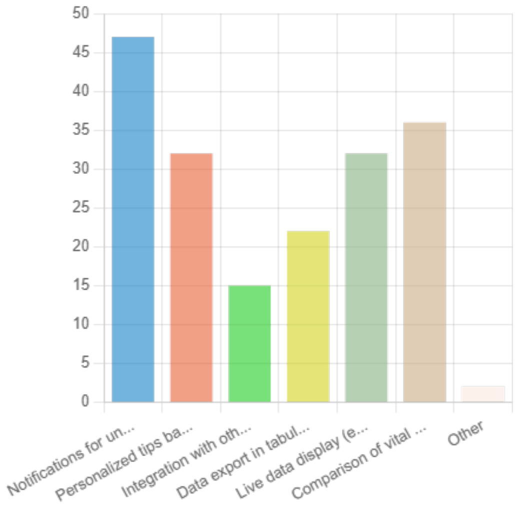
(b) Importance of the availability of an app store as bar chart.

Figure B.18: The importance of app availability in app stores like Google Play Store in table and chart.

B.5 VitaBeat - Functionality

Feature	Count	Percentage
Notifications for unusual vital values	47	65.28%
Personalized tips based on vital data	32	44.44%
Integration with other apps (e.g., Google Fit)	15	20.83%
Data export in tabular form	22	30.56%
Live data display (e.g., current heart rate during music playback)	32	44.44%
Comparison of vital parameters across different music genres	36	50.00%
Other	2	2.78%
Total	**72**	**100.00%**

(a) Features particularly appreciated in an app like VitaBeat.

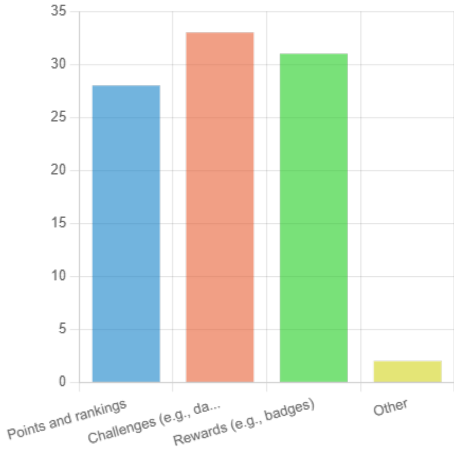


(b) Appreciated features in VitaBeat as bar chart.

Figure B.19: Features particularly appreciated in an app like VitaBeat in table and chart.

Feature	Count	Percentage
Points and rankings	28	38.89%
Challenges (e.g., daily tasks)	33	45.83%
Rewards (e.g., badges)	31	43.06%
Other	2	2.78%
Total	**94**	**100.00%**

(a) Preferred gamification features.

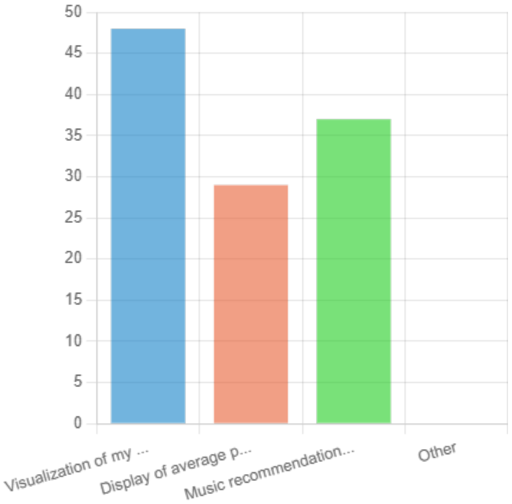


(b) Preferred gamification features as bar chart.

Figure B.20: Comparison of the preffered gamification features in VitaBeat.

Feature	Count	Percentage
Visualization of vital parameters in relation to preferred music genres	48	66.67%
Display of average playback duration and its impact on vital parameters	29	40.28%
Music recommendations based on preferences and vital parameters	37	51.39%
Other	0	0.00%
Total	**114**	**100.00%**

(a) Preferred features for linking music with vital parameters.

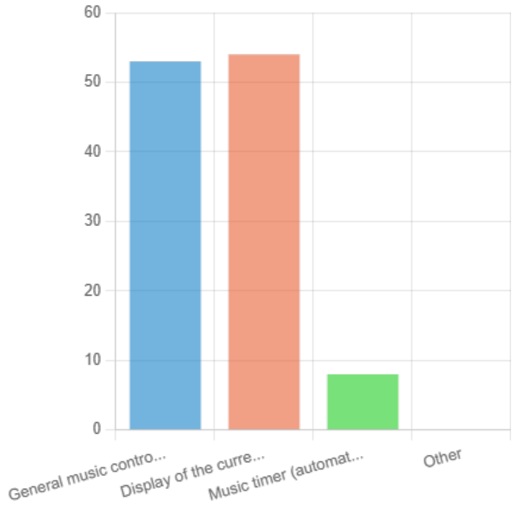


(b) Graphical representation of preferred features.

Figure B.21: Comparison of the most preferred features for linking music with vital parameters in VitaBeat in table and chart.

Feature	Count	Percentage
General music control (e.g., play/pause)	53	73.61%
Display of the current song (title, artist, album, elapsed and remaining time)	54	75.00%
Music timer (automatic pause after a certain duration)	8	11.11%
Other	0	0.00%
Total	**115**	**100.00%**

(a) Most necessary music control features in VitaBeat.

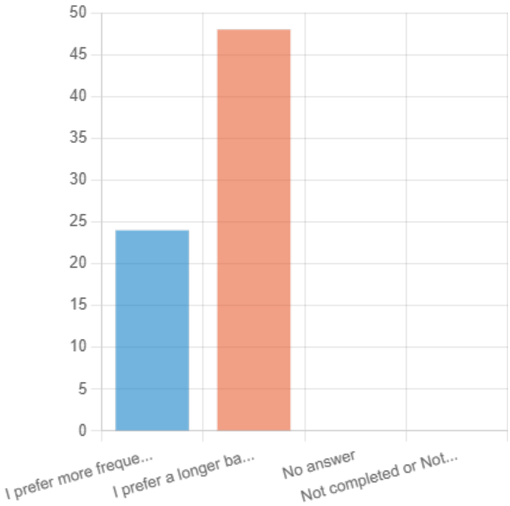


(b) Graphical representation of necessary music control features.

Figure B.22: Comparison of the most necessary music control features in VitaBeat as table and chart.

Response	Count	Percentage
More frequent measurements (even with faster battery drain)	24	33.33%
Longer battery life (even with less frequent measurements)	48	66.67%
No answer	0	0.00%
Total	**72**	**100.00%**

(a) Tabular representation of measurement frequency vs. battery life.



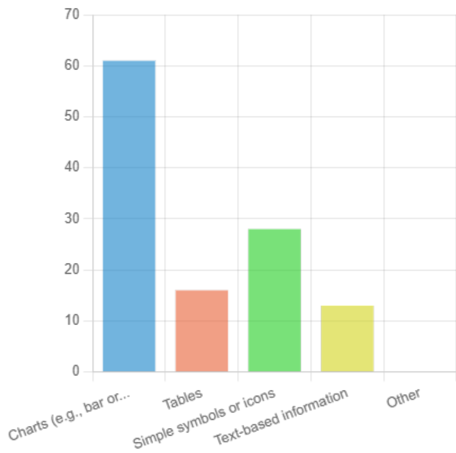
(b) Graphical representation of measurement frequency vs. battery life.

Figure B.23: Comparison of user preferences regarding measurement frequency versus battery life in table and chart.

B.6 VitaBeat - Design and Usability

Response	Count	Percentage
Charts (e.g., bar or line charts)	61	84.72%
Tables	16	22.22%
Simple symbols or icons	28	38.89%
Text-based information	13	18.06%
Other	0	0.00%
Total	**118**	**100.00%**

(a) Preferred types of data visualization for VitaBeat.

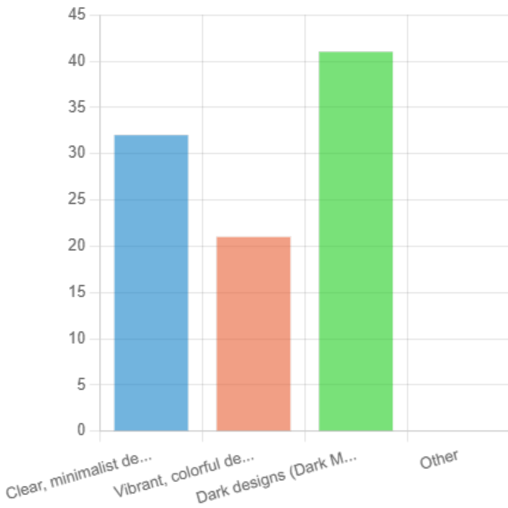


(b) Preferred data visualization types as bar chart.

Figure B.24: Comparison of user preferences for data visualization in VitaBeat in table and chart.

Response	Count	Percentage
Clear, minimalist designs	32	44.44%
Vibrant, colorful designs	21	29.17%
Dark designs (Dark Mode)	41	56.94%
Other	0	0.00%
Total	**94**	**100.00%**

(a) Preferred colors and designs for VitaBeat.

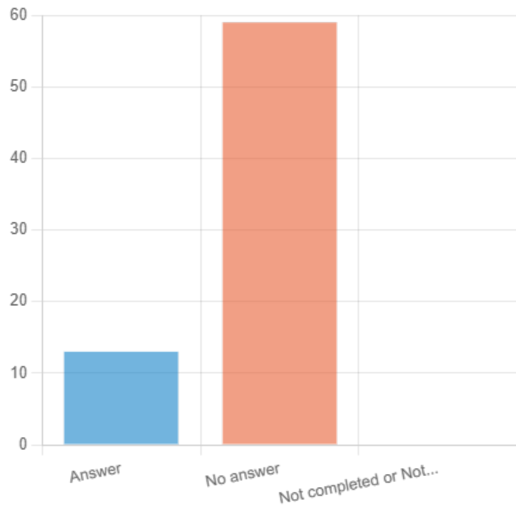


(b) Design preferences as bar chart.

Figure B.25: Comparison of user preferences for app design in VitaBeat.

Response	Count	Percentage
Answer	37	51.39%
No answer	35	48.61%
Total	**72**	**100.00%**

(a) Number of feedback given on the VitaBeat overviewscreen.



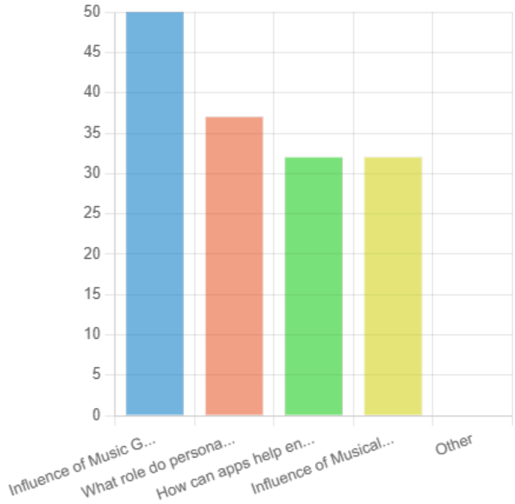
(b) Number of feedback given on the VitaBeat overviewscreen as bar chart.

Figure B.26: Number of feedback given on the VitaBeat overviewscreen in table and chart.

B.7 Research

Topic	Count	Percentage
Influence of Music Genre Preference on Heart Rate	50	69.44%
Role of personal preferences in music effects	37	51.39%
Apps enhancing well-being via vital data	32	44.44%
Influence of Musical Micro-Breaks on Stress Recovery	32	44.44%
Other	0	0.00%
Total	**151**	**100.00%**

(a) Interest in research topics related to music and vital data.

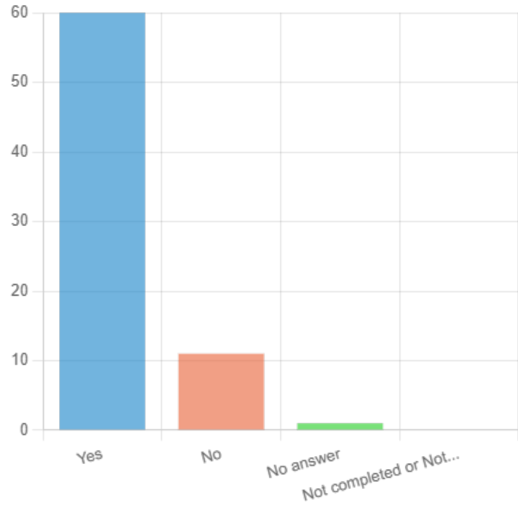


(b) Interest in research topics related to music and vital data as bar chart.

Figure B.27: Comparison of responses regarding interest in research topics on music and vital data in table and chart.

Response	Count	Percentage
Yes	60	83.33%
No	11	15.28%
No answer	1	1.39%
Total	**72**	**100.00%**

(a) Willingness to share anonymized VitaBeat data for research.

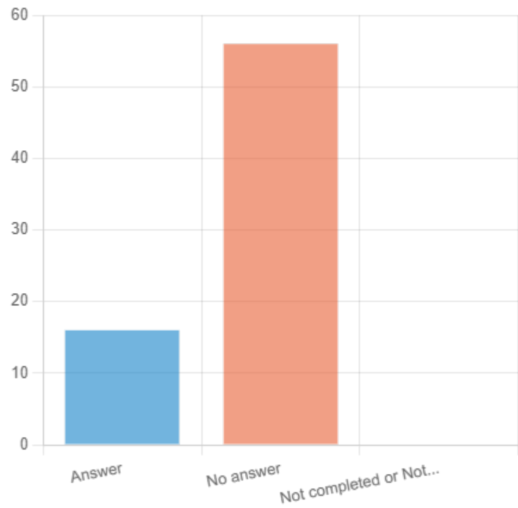


(b) Willingness to share anonymized VitaBeat data for research as bar chart.

Figure B.28: Willingness to share anonymized data collected by VitaBeat for research in table and chart.

Response	Count	Percentage
Answer provided	13	18.06%
No answer	59	81.94%
Total	**72**	**100.00%**

(a) Interest in research updates via email.



(b) Interest in research updates via email as bar chart.

Figure B.29: Interest in research updates via email in table and chart.

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

place, date, signature