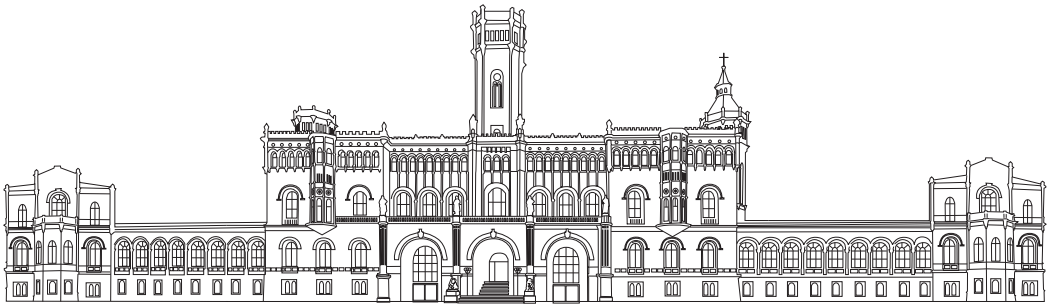

LEIBNIZ UNIVERSITÄT HANNOVER

Faculty of Electrical Engineering and Computer Science

Human-Computer Interaction Group

CASUAL INTERACTION WITH A SMARTWATCH

A Thesis presented for the degree of Master of Science

by

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July 2016

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Hannover, July 2016

Sven Röttering

ABSTRACT

This thesis investigates which and how user interfaces allowing for *casual interaction* should be implemented. A mobile music player as a representative application is implemented on an android handheld device, which is fully controllable by an android smartwatch. Interactions between user and music player can happen via touch input, speech commands or arm gestures. Subsequently a case study investigates which interaction techniques are preferred by users depending on task and context. For this purpose the participants are put in 6 different scenarios in which they have to follow predefined actions regarding the music player. The results show, that speech commands are highly versatile and the use of touch or gesture input depends on the current context of the user.

ZUSAMMENFASSUNG

Diese Arbeit untersucht welche und auf welche Weise Benutzerschnittstellen, die *casual interaction* unterstützen, implementiert werden sollten. Als Beispielanwendung wird ein mobiler Musikplayer auf einem Android Smartphone implementiert, der vollständig per Smartwatch gesteuert werden kann. Touch-Eingabe, Sprachbefehle und Armgesten stehen dem Benutzer dabei als Interaktionsmöglichkeiten zur Verfügung. In einer Studie wird anschließend untersucht, welche Interaktionsmöglichkeiten, abhängig von Aufgabe und Kontext, von den Benutzern bevorzugt werden. Dazu werden die Teilnehmer in 6 verschiedene alltägliche Situationen versetzt, in denen sie Vorgaben erhalten, welche Funktionen des Musikplayer sie steuern sollen. Die Resultate zeigen, dass die Sprachsteuerung vielseitig einsetzbar ist und der Einsatz von Touch- bzw. Gesteneingabe vom aktuellen Kontext des Benutzers abhängt.

CONTENTS

1 MOTIVATION

Electronic devices connected to the internet play a big role in almost everyone's life. According to a survey[1] two thirds of the global population have access to the internet and almost every third human owns a smartphone in 2016. People not being bound to stationary computers anymore has numerous advantages and opens up for manifold possibilites of applications. However most applications are exclusively touch based and hence draw a user's attention from her environment to the screen in a large extent. Depending on the context, this inobservance can have various levels of adverse impact – one merely could have to reread a passage of a book or in fact cause a serious car accident with lethal consequences. Furthermore, a user is not always able to interact with a handheld device as intended due to physical or mental barriers.

Casual Interaction addresses this issue by introducing additional input techniques and interactions which offer the required flexibility in terms of control over an application, such that the user can limit the required amount of focus to a minimum [9]. The H-metaphor [7] explains this idea by looking at a horse rider. Whenever high amount of control is needed, the rider can steer the horse precisely with the reins. However, riding straightly requires nearly no effort from the rider.

As a representative everyday life application a music player is chosen and implemented in this thesis which offers a speech and armgesture interface for input in addition to the typical touch based user interface. This enables the user to leave her handheld device in the pocket and interact with it even when her hands or fingers are not available. A typical daily life scenario involving the music player might be the following:

> Programmer Bob is a passionate music listener. At work he starts the day with his favorite playlist with shuffle mode enabled to boost his coding efficiency. Occasionally some songs hit his ears that he heard enough of in the last days so he performs a short arm swing to the right to skip to the next song without loosing track of his current programming task.
>
> After work he rides his bike home, still listening to music, to have a physical compensation for sitting in a chair half the day. In order to hear other traffic participants and emergency sirens he decides to turn the vol-

> ume of the music down a bit by raising his smartwatch to his mouth and saying "*volume down, please*". Arriving at home he switches from listening with headphones to his brand new sound system that is spread around his entire house. During dinner preparations he gets a phone call from a friend. His phone resides on the table, however Bob's hands are still dirty from cooking so he tells his watch to pause the music and answer the call. They arrange on having dinner together at Bob's place today. It strikes Bob that his music library is not prepared for such a dinner but he is able to delegate the creation of a playlist to his music player by simply specifying suitable audio features. Not having to bother about finding the right music enables Bob to finish cooking just before his guest arrives.

This scenario reveals the advantages of an always accessible device with alternative input techniques to perform casual interactions in situations where users are physically or mentally obstructed. In order to decide which additional input techniques an application should provide and how the corresponding user interfaces should be designed one has to consider the possibilities these techniques offer as well as how users approach them. The last aspect particularly depends on the user's preferences and perception performing the interactions. On the one hand, the perceived amount of control for a particular level of engagement is important. *Is she able to achieve the desired reaction of the application or does it feel like the application has developed it's own life?*

On the other hand, users often times get influenced by how interactions appear to the environment. *Can I perform an arm gesture right now or will people stare at me if i suddenly wave my arm through the air?* These and related concerns need to be kept in mind in order to be able to develop useful and effective casual user interfaces.

However, devices require certain hardware features to enable such interactions in the first place. First, it should stay where it is needed and always be accessible without encumbering the user. Typical remotes or smartphones occupy at least one hand for every interaction they offer and have to be carried around constantly. Since this is not beneficial a wearable device is needed that is attached to the body without obstructing everyday activities. Second, the device should offer touch-free interaction. This can be realised by adding movement sensors (e.g. accelerometer or gyroscope) and a microphone[5].

This thesis builds on the previous work of Karoline Busse [5] who developed a wrist-worn silicone bracelet intended for usage with lighting systems. The bracelet is missing on some important components, though, to gain more potential, namely a microphone and a display. Smartwatches basically offer the most important hardware

components needed for creating a comfortable and enjoyable casual interaction experience thus being a perfect device for the further studies of this thesis.

A music player is chosen as a representative everyday application. The music player is connected to a private Spotify account via the Spotify[1] Android Software Development Kit (SDK) [2] which serves the music library. Touch, speech and arm gesture input for player control realize different levels of engagement.

Chapter 2 first outlines the related work. Chapter 3 then gives an insight into the implementation of the music player's core features. Subsequently the user study design and the resultant data are addressed in chapter 4.

Finally, chapter 5 sums up the findings, draws a conclusion and provides ideas for future improvements to casual interactions with a smartwatch.

1 Music streaming service: www.spotify.com

2 https://developer.spotify.com/technologies/spotify-android-sdk/

2 RELATED WORK

Casual interaction has become a big research topic in human-computer interaction (HCI) nowadays. Since this thesis aims at using gesture and speech input it is helpful to study what other researchers have achieved in these fields.

Pohl and Murray-Smith [9] have characterised the term casual interaction in contrast to focused interaction and described the *focused-casual continuum*, which is a control-theoretic framework that characterizes input techniques in regard to how much flexibility, in terms of thinking and effort, they allow a user to invest into interactions. They showed in a user study that users adjust their level of engagement to the task's complexity.

On this basis, [5] constructed a wrist worn silicone bracelet. When worn, a user could casually interact with a light source. Simple actions like turning the light on and off up to picking individual colors with a capacitive touch stripe. Accelerometer based gestures could be used to activate previously defined and memorized light settings. Despite being highly accessible on the wrist, a user would still have to utilize the hand without the bracelet to activate it's features making interactions rather impractical in certain situations.

Another approach places a depth camera for capturing hand gestures on the user's foot pointing upwards [2]. This allows for discreet interactions thus neglecting concerns of social acceptability of performing gestures as they found out. In a lab study they compared physical and mental demand, user preferences and demonstrated a 94-99% recognition rate.

An alternative input technique is shown in [10]. They introduce around-device devices. Input is received by observing position and rotation as well as arrangement or absence of the around-device devices. To capture this information they propose placing a smartphone equipped with a depth camera nearby. In contrast to the aforementioned approaches, this technique is limited to stationary contexts automatically excluding any in-motion-situations.

Furthermore, casual interaction was applied to mobile music retrieval by [4]. They investigated the listening habits of 95 last.fm[1] users and divided them into three groups. The first group consists of the engaged listeners who invest high initial engagement by e.g. selecting a specific album and afterwards only make quick and decisive interventions. The second group consists of the casual users who invest little effort in interventions at any time. The third group is a mix-

1 Internet radio station: `www.last.fm`

ture of the first two groups where music listening behaviour highly depends on the context. Based on these groups they added a semantic zooming view of linear music space to a already given music retrieval interface. Zooming in on the view enables the user to make more specific music selections. A recommender system additionally infers other relevant music depending on the input specificity.

In the scope of interactions with smart home appliances [8] conducted a series of user study on gestural input for devices found in an average living room – namely blinds, lamps, tv, Electronic Program Guide (EPG), video recorder and answering machine. In the first study they tried to determine a gesture vocabulary. Therefor they observed eigtheen participants seated on a sofa in a fully functional living room with the above mentioned devices. The participants were asked to perform a gesture, they would deem appropriate, for every action or referent as [12] refer to. In a second study 22 new participants should then map the gestures from the vocabulary back to the referents. The last study was performed by 10 participants to study the memorability. In a training session every participant performed every gesture five times and then rated the suitability. Finally a slide show displayed every referent for 5 seconds in a random order. If the participant could not perform the gesture in this time, the correct gesture was shown again and the referent was added to the end of the slide show again. Overall their results showed, that simple and short physically or symbolic inspired gestures were rated most suitable and appeared to be most memorizable. These results were considered while designing the gestures for the music player.

In Addition, [6] conducted two related user studies. 28 participants were asked to propose gestures for referents similar to the above mentioned. A month later, the same participants had to choose the most suitable gesture for each gesture group (i.e. for each referent) which also included their own derived gesture. It turned out, that 65% of the top gestures from the first experiment were not the most chosen gestures in the second experiment. For some of the most agreed gestures in the second experiment, e.g. rubbing one's shoulders for turning off air conditioning, the frequency was only below 10% in the first experiment. Their results show that considering only the most frequent matching user derived gestures can not automatically be considered to be most suitable.

Casual interaction through speech input is yet to be explored. Some research, however, was inquired in the field of smart homes. For example, [3] prototyped a cooking assistant that was installed in their Ambient Living Testbed. Users could interact with the assistant either via touchscreen, mouse and keyboard or via speech input. The latter came in handy while being physically distracted as they were searching for ingredients or cutting vegetables. The findings from the user study based on the cooking assistant revealed that users prefer

the availability of mutliple modalities as the possibility to fall back to touch or mouse input provides an idea safety against failures of the voice recognition. Furthermore, they state a higher acceptance of command-based speech interactions instead of entering whole sentences, as short commands are easier to learn. For more complex commands, users tend to ask the system for help.

Using a smartwatch with touch, gesture and speech input over the bracelet from Karoline [5] has the advantage of purely handsfree interaction. Gestures are useful for simple commands when they are short and symbolic. The same demand for simplicity applies to speech input. Users prefer entering concisely commands over saying complete sentences. Finally, users expect casual interaction systems to get more autonomous with lower engagement. All of the results mentioned above are taken into account for the music player implementation.

3 IMPLEMENTATION

This chapter gives an overview of the implementation aspects of the smartwatch controlled mobile music player. It explains the application structure, the chosen interaction techniques and the mobile-wear communication system.

The essential music library is provided by a private Spotify[1] premium account. Spotify has a powerful and beneficial Application Programming Interface (API) which adds useful meta data such as audio features to each track. Audio features are high-level acoustic attributes like tempo or valence which are used in a system for coarse track selection. The prototype is divided into two separate applications, i.e. mobile (handheld) and wear (smartwatch) application. Users are able to access all features of the mobile application via the smartwatch application. In order to cover a lot of different levels of the focused-casual continuum [9], three interaction techniques, differing in the amount of control granted, are available for the user:

- Touch
- Speech
- Gesture

Each technique can be used for the simpler actions of the music player such as play and pause, skip to previous or next song and changing the volume. However, for the more complex interactions, e.g. choosing a playlist, only the touch and speech interaction methods suffice since gestures for every playlist would be too hard to remember. Gesture and speech input can be performed casually while not even looking at the smartwatch. Section 3.3 describes the functionality and the power of the different methods.

3.1 HARDWARE REQUIREMENTS

Both applications are implemented for the android platform. The handheld device has no further hardware or software requirements other than supporting the android wearable API for communicating with the smartwatch, thus a Samsung Galaxy S6 is chosen. The smartwatch application certainly requires the device to be equipped with a acceleration sensor and a microphone. A moto360 from Motorola is well suited for this. Both devices require Bluetooth functionality as well.

1 Music streaming service: `www.spotify.com`

3.2 APPLICATION STRUCTURE

The application is divided into two dedicated android applications, one for the mobile device and one for the smartwatch. Since the smartwatch has less computing power and battery life than a mobile device, all of the music players functionality is implemented in the mobile application where the Spotify Android SDK for streaming functionality and the Spotify Web API for Android[2] for accessing the music information is used. Together they allow for every possible interaction with Spotify such as streaming music, creating playlists, searching for artists or tracks, etc. The wearable application provides an additional GUI which contains the same information about the music arrangements as the mobile application's GUI but with less overhead (e.g. images are not shown). It also is responsible for hosting the touch, speech and gesture input techniques. Figure 1 shows each application's different components which are separated by java packages. Both applications consist of four packages:

MOBILE APPLICATION The *view* package contains the MainActivity of the application. It is responsible for both maintaining the GUI elements (see section 3.3) and turning issued commands into music player actions which are then forwarded to the SpotifyManager class. The *speechcontrol* package contains the tool which interprets a speech command sent from the wearable application. See section 3.3.2 for a detailed description about speech commands. The *core* package contains both the CommunicationManager class that handles messaging between wearable and mobile application and the SpotifyManager class which ties the Spotify Android SDK and the Spotify Web API for Android together. On the application start it downloads information about the music items that belong to the logged in Spotify account and serves it to the GUI. Audio features are downloaded for each track in the user's library as well. They are stored in the AudioFeatureDatabase class in form of a Hashmap with the track's id as key and a list of the audio features as the value. The AudioFeatureDatabase class is also responsible for searching tracks from the library with a specified audio feature value (section 3.3.2 describes why this is useful and how it works). Audio features are also saved to the mobile phones disk by the SpotifyCache class to reduce the amount of data that has to be downloaded on the application start.

WEARABLE APPLICATION The wearable application's structure is similar to the mobile application. Classes responsible for maintaining the GUI elements are located in the *view* package. The *wiigee* package contains a pre-built event driven library for acceleration based gesture recognition (see section 3.3.3 for further details). The *core* pack-

2 https://github.com/kaaes/spotify-web-api-android

age contains the CommunicationManager that again is responsible for messaging between wearable and mobile application. Also the system for recording speech and transforming it into text is located in the *core* package. As soon as voice recognition is enabled (see section 3.3.2) the VoiceRecognitionListener class receives the recognized text from android's Speech Recognizer and waits until the final keyword is included. The text is then sent to the mobile application to be interpreted.

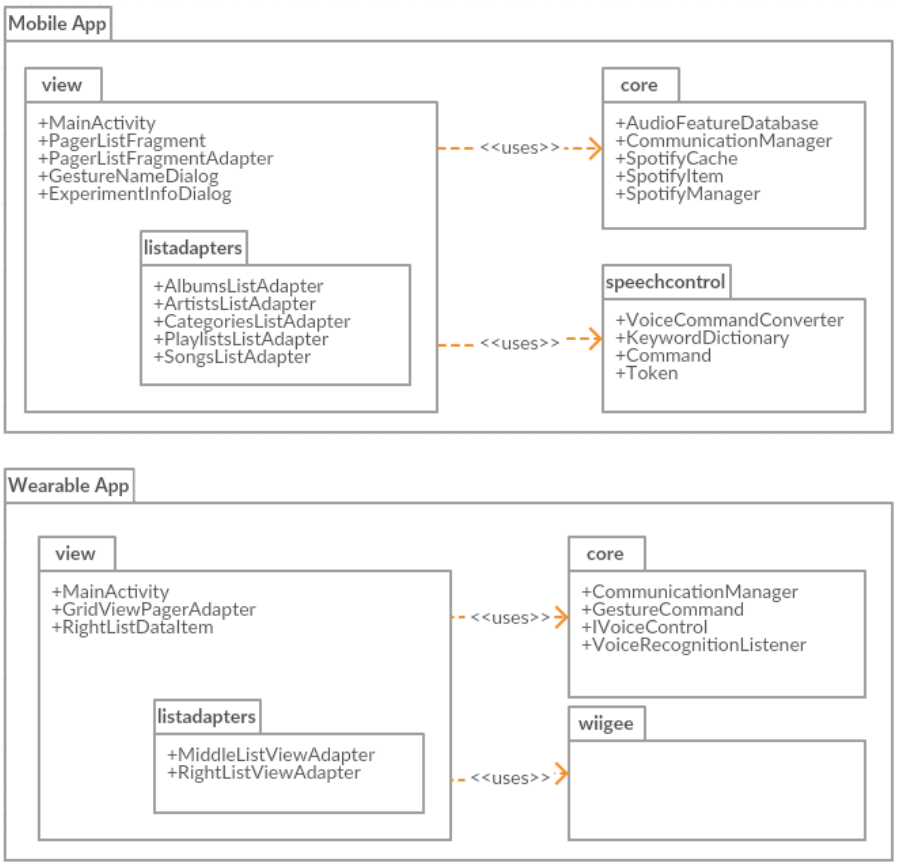


Figure 1: Package diagram of the mobile (top) and wearable (bottom) application.

3.3 USER INTERFACE

The GUI from the mobile application only differs from the wear GUI in terms of unimportant information such as images. In terms of control over the music player, both versions offer the same possibilities and show the synchronized player state (when connected) at any given time. The wear application, however, additionally introduces speech and gesture interactions which the mobile application is not capable of.

It is noteworthy that the Spotify SDK offers a lot more functionality than implemented, such as creating own playlists or searching the

entire Spotify music library for keywords. The implemented music player, however, just offers the basic playback functionalities in order to keep the application simple and to not overload the participants in the experiment with information since they have to remember how to control the music player. Moreover, more music player functions would not have an impact on the experiment results.

3.3.1 *Touch Input - GUI*

Both GUIs are designed to be simple and straightforward. The mobile version mainly consists of two areas. Figure 2 depicts a screenshot of this layout. A control panel is situated at the bottom of the screen. Above this is a left-right scrollable pager containing different kinds of lists. The scrollable list pager[3] contains five lists, one for each music arrangement which are playlists, songs, albums, artists and categories. The control panel located beneath the list pager contains four control

Categories are Spotify's extended version of genres

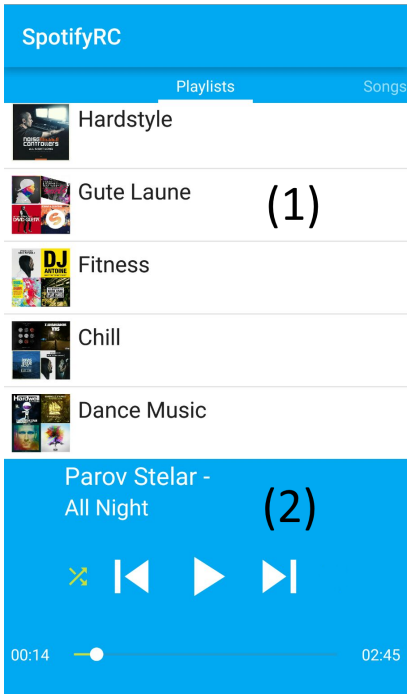


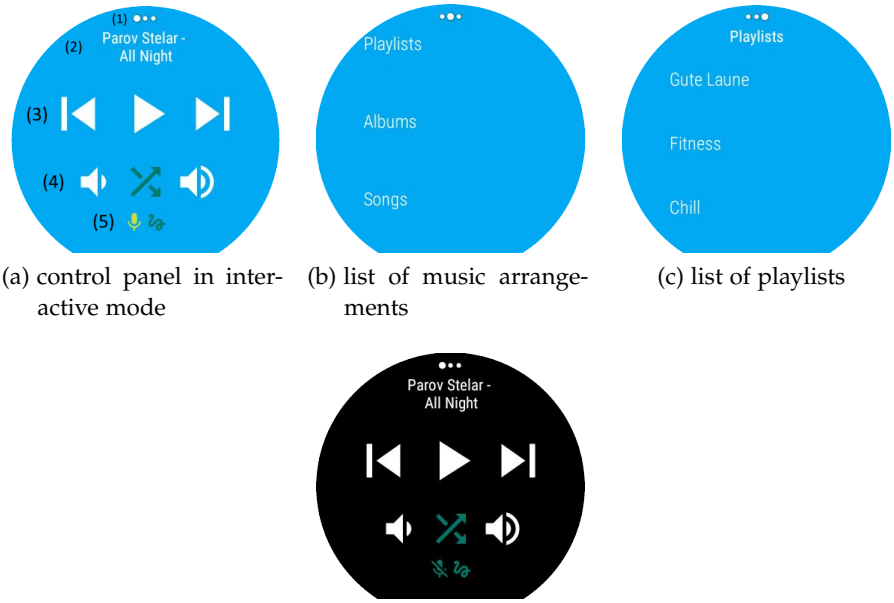
Figure 2: GUI of the mobile application. (1) shows the left-right scrollable list pager with indicators which list is shown at the top. (2) shows the player control panel in blue.

buttons such as a shuffle button including on-off indicator, a skip to previous song button, a play-pause button and a skip to next song button. Unlike the wear application, the mobile version spares buttons for controlling the volume, because most devices own hardware buttons for this purpose. Information on the name of the current song and artist can be found above these buttons. The track's progress and

3 A horizontal scrollable container holding vertical scrollable lists.

total duration can be found at the very bottom of the screen.

However, the intention of the wear application is, that the user does not need to bother reaching his mobile phone. For this reason, the wear application's GUI offers the same amount of control over the music player via its touch input. Figure 3 demonstrates the layout of the wear application. It consists of a GridViewPager[4] with one row and three horizontal pages (columns).



(a) control panel in interactive mode

(b) list of music arrangements

(c) list of playlists

(d) control panel in ambient mode

Figure 3: The GUI of the wear application consists of a GridViewPager containing three horizontal pages. A dot indicator at the top of the screen shows the current page. 3d depicts the controls page in ambient mode, i.e. battery saving mode, while 3a is the same screen in interactive mode. Swiping right brings up the list of music arrangements 3b. Selecting e.g. playlists switches to the third page 3c showing a list with all playlists.

Figure 3a shows the main control page which is divided into five rows (1) - (5). A dot indicator showing the current page with a bigger dot is located at the top of the screen in row (1). Row (2) contains the current artist and track that is playing. Row (3) and (4) contain the control buttons, i.e. in (3) the buttons for play previous song, toggle play and pause, play next song and in (4) the buttons for decrease volume, toggle shuffle (grey = off, green = on) and increase volume are located. Row (5) contains two icons which indicate whether speech and gesture recognition are active (green) or inactive (grey).

4 A grid based omni-directional scrollable container holding views

Figure 3b shows the page in the middle which is reached by swiping over the screen from right to left. The page contains a vertical scrollable list of the five music arrangements, namely playlists, songs, albums, artists and categories. Selecting a list entry scrolls to the right (the third) page which always adapts its list showing the respective items in the selected arrangement.

The moto360 smartwatch is equipped with a battery saving mode called ambient mode. In this mode cpu processing is reduced and it is recommended[5] to reduce the User Interface (UI) layout to a black background and white text color. Updates to the UI should then happen on a several seconds up to a minute basis. Applications that run in both ambient and interactive mode are called *always-on apps*. The transition from interactive to ambient mode happens either automatically after a short period of user inactivity or can be forced by covering the screen. Leaving ambient mode happens either by touching the screen or by bringing up the wrist as in looking at the time. Figure 3d depicts the control page of the wear application running in ambient mode with a black background and white text and icon color.

3.3.2 *Speech Control*

The wear application offers the possibility to control the music player via speech commands. In order to enter a speech command, the application must be in interactive mode which activates the continuous speech recognition (indicated by the green microphone seen in 3a at the bottom of the screen). The user can then talk to the watch and issue a command. Speech data is recorded and converted to text by the android speech recognition service[6]. Since the speech recognition happens continuously input must be recognized easily as a possible valid command. Therefor every command has to end with a special final keyword, the word *"bitte"*. As soon as the wear application detects this keyword, the converted text is send to the mobile application where it gets parsed, transformed into a command and finally executed. Figure 4 illustrates this procedure with an activity diagram. The wear-mobile communication process is described in more detail in section 3.4.

"Bitte" is the german word for "please"

In order to cover the focused-casual continuum speech commands for this music player are divided into three groups based on their power and complexity. The first group contains the simplest commands that just consist of one keyword. Commands in the second group start with a keyword and are followd by additional words,

5 https://developer.android.com/training/wearables/apps/always-on.html
6 https://developer.android.com/reference/android/speech/SpeechRecognizer.html

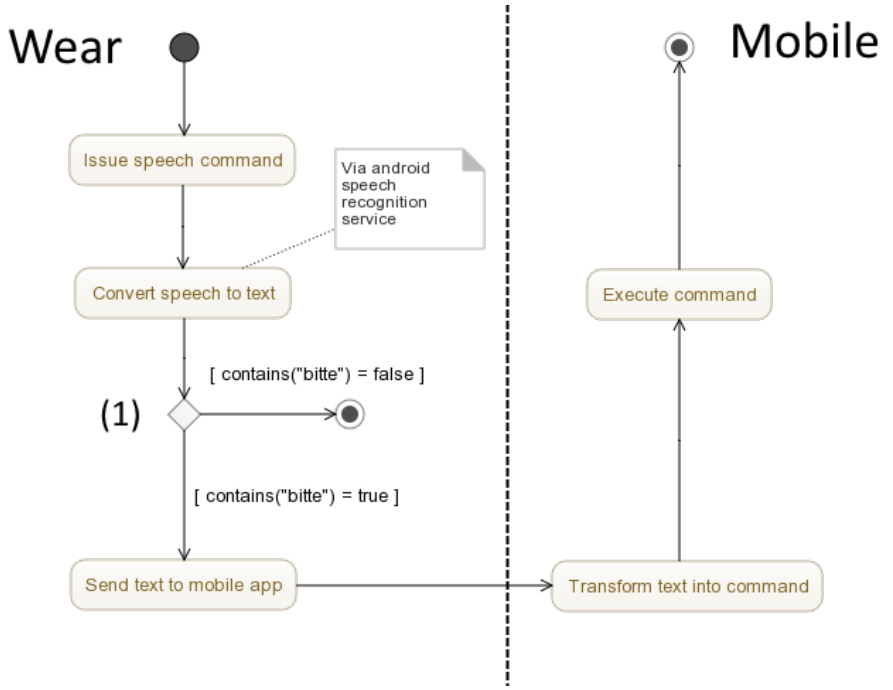


Figure 4: Activity diagram of the speech interaction procedure. Actions to the left of the dashed line happen in the wear application and actions to the right of the dashed line happen in the mobile application. At stage (1) a preliminary decision is made whether the converted text resembles a command or not.

until the final keyword occurs, that are handled as the input parameters. Commands in the third group are built by chaining different keywords together forming a simple sentence.

Table 1 contains the respective keywords for commands in the first two groups. The first six simple keywords each represent a command by itself and thus belong to group 1. The *play* command is the only command in group 2 meaning it requires a parameter to work as intended.

Commands in the third group, which are built by chaining the keywords shown in table 2 together, offer a special kind of control over the music player. They allow for queuing and playing tracks that differ in terms of an audio feature from the current playing track. This enables users to change the type of music in contexts not allowing for high engagement.

AUDIO FEATURE: Spotify runs a suite of audio analysis algorithms on every track in their catalog. These extract about a dozen high-level acoustic attributes from the audio. Some are well-known musical features, like tempo and loudness. Others are more specialized, like valence and energy.

SPEECH COMMAND KEYWORDS	ACTIONS IN MUSIC PLAYER
pause	pause music playback
weiter	resume music playback
nächstes	skips to next song
zurück	skips to previous song
lauter	increases the volume
leiser	decreases the volume
play <music element>	load and play an element from the music library

Table 1: Speech commands from the first two groups. The play command is the only command accepting parameters. All other commands in this table belong to group 1. To issue a command, simply activate speech recognition by entering the watches interactive mode and say the keyword followed by the final keyword "bitte".

The four most intuitive audio features are supported by the music player to be used with speech commands, which are[7]:

TEMPO: The estimated tempo of a track measured in Beats per Minute (BPM). It derives directly from the average beat duration.

ENERGY: A measure from 0.0 to 1.0 and represents a perceptual measure of intensity and activity. Typically, energetic tracks feel fast, loud, and noisy. For example, death metal has high energy, while a Bach prelude scores low on the scale.

LOUDNESS: The overall loudness of a track in decibles (dB). Loudness values are averaged across the entire track. Loudness is the quality of a sound that is the primary psychological correlate of physical strength (amplitude). Values range between -60 and 0 db.

VALENCE: A measure from 0.0 to 1.0 describing the musical positiveness conveyed by a track. Tracks with high valence sound more positive, while tracks with low valence sound more negative.

Changing tracks based on the current track's audio features enables the user to specify what kind of music she wants to listen to without deciding on the exact tracks to be played in a situation where high engagement is not possible. The pseudo code in listing 1 is responsible for searching the corresponding tracks in the music library. The new value for the specified audio feature is calculated in line 2 respectively 4 by first evaluating the direction keyword which determines

7 A complete list of audio features and their meaning can be found at: `https://developer.spotify.com/web-api/get-several-audio-features/`

SCALING	DIRECTION	AUDIO FEATURE
etwas	mehr	Tempo
viel	weniger	Energie
		Lautstärke
		Stimmung

Table 2: Building blocks (keywords) for commands from the third group. Choose a keyword from each column, chain them to a sentence and attach the final keyword "bitte" at the end. The scaling keyword can be omitted.

whether to increase or decrease the current value. The scale keyword then determines the scaling factor which indicates by how much the current value is changed. Therefor the scaling factor is multiplied by the distance between the current value and either the global minimum or maximum value for the given audio feature depending on the direction keyword. Afterwards, tracks in range of the new calculated value, determined by a tolerance radius, are searched (line 7 and forth). The tolerance radius is increased by a fix amount as long as no tracks are found. Figure 5 explains this mechanism with example values.

Listing 1: Pseudo code for calculating the new audio feature value and looking up respective tracks with a tolerance radius from the music library

```
1  if(direction == negative) {
2          newValue = cur + (cur - min) * -scale;
3  } else {
4          newValue = cur + (max - cur) * scale;
5  }
6
7  while(noTracksFound) {
8          lookupTracksWithValueAndTolerance(newValue, tolerance);
9          increase(tolerance);
10 }
```

After sending a possible speech command to the mobile application, the text needs to be converted to an applicable command. For this, a conversion algorithm first searches the text for command keywords from the first two speech command groups (see table 1) and creates a token of a respective type for it when found. Tokens that belong to the simple commands in the first group are directly mapped to their corresponding music player command and then executed.

In case the text contains a *play* keyword which is followed by at least one word, an additional token is created for it, being the parameter of the command. The algorithm then tries to find the desired music library item by comparing the item name with the parameter text.

Item names of songs and albums are a combination of their name and the artist

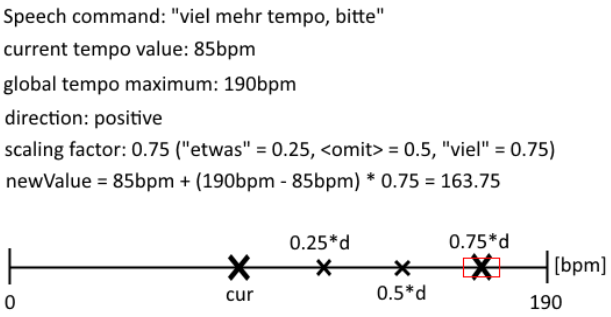


Figure 5: Example calculation for changing tracks based on the audio's tempo. The big X's show the current and the new value, while the smaller ones depict values with a smaller scaling factor. The red rectangle around the new value illustrates the tolerance radius in which new tracks are searched.

Because item names often contain additional artifacts, such as *Radio Edit* or *Original Mix*, and the speech to text conversion is not always accurate, comparison is not based on equality but rather on similarity. The pseudo code in listing 2 finds the item name with the highest similarity to the parameter text based on the *Levensthein distance*[8]. An item name which equals the parameter text can be considered as most similar. However, in case the item name is longer than the command's parameter, the foreach loop starting in line 7 computes the minimum distance for every substring of the item name with the same length of the parameter. In the end, the item with the minimum distance which is equal to the highest similarity to the parameter is returned and played.

Listing 2: Calculating parameter and music item name similarity

```
1  var mostSimilarItem = null;
2  foreach(item in library) {
3    if(parameter == item.name) {
4      return item; //distance is already 0, so we found the item
5    }
6    var minDistance = Integer.MAX;
7    foreach(substring s of item.name with s.length == parameter.
         length) { //if the parameter is longer than the item name,
         only one iteration happens
8      distance = Levensthein(parameter, s);
9      if(distance < minDistance) {
10       minDistance = distance; //less distance = higher similarity
11       mostSimilarItem = item;
12     }
13   }
14 }
15 return mostSimilarItem;
```

8 String metric for measuring the number of required edits in one string in order to match the other.

If no keywords for group 1 or 2 are found, the conversion algorithm checks for keywords belonging to the third group and creates a token for each one. The text is a valid command if at least a token for the direction and the audio feature is present. A scaling keyword can be omitted and the order of the tokens is not considered. The tokens are then used to directly set the parameters of the formula for calculating the new value for the specified audio feature (see listing 1).

The following commands are examples from every group executed on the music library from a private spotify account:

1. "NÄCHSTES, BITTE": skips to the next song in the queue
2. "PLAY HARDWELL, BITTE": enqueues and plays all tracks by Hardwell from the library
3. "VIEL MEHR TEMPO, BITTE": plays tracks from the library with significantly increased tempo compared to the current

3.3.3 *Gesture Control*

The third interaction technique supported by the implemented music player involves acceleration based gesture recognition. With this the user is able to issue commands to the player without looking at or touching the screen with the other hand. Gesture commands on the contrary are not as powerful as touch input or speech commands. They only offer control for pause and resume, skip to next song, back to previous song as well as increase and decrease volume. The other commands that speech input offers would result in gestures too complex to perform and remember for a user[8].

For this, a pre-built event-driven gesture recognition library called *Wiigee*[9] is used. Wiigee accepts three dimensional acceleration vectors as input for pattern training and recognition. The vectors are sent through a four-level recognition pipeline which is shown in Figure 6. [11] describe the four stages of this classical recognition pipeline in detail. They observed an average rate of correctly recognized gestures of 90%.

In order to recognize gestures, they first have to be trained to wiigee. For later use, the data for every gesture can be saved to a file afterwards. [11] claims that a training session with five to ten repetitions is sufficient for Wiigee to learn a new gesture. The gestures for controlling the music player are kept short, simple and symbolic as [8] suggests. However, to avoid unintentional commands and to save battery life, an activation gesture has to be performed beforehand. Also, Wiigee does not support continuous gesture recognition.

9 Official Wiigee site: `www.wiigee.org`

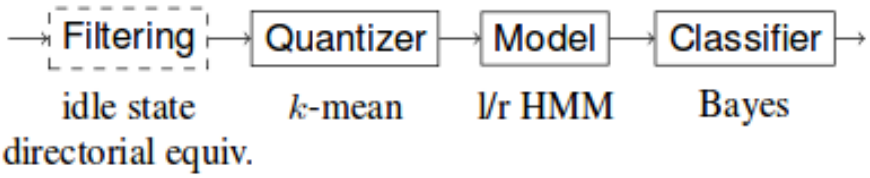


Figure 6: Original from [11]. Four-level recognition pipeline that first filters vector data und clusters it using a k-means algorithm. Subsequently a hidden markov model is fed with the clustered data and classified by a Bayesian classifier.

Figure 7 shows a list of all supported gestures and their meaning including the activation gesture.

Once Wiigee recognized a gesture it notifies the registered listeners sending the recognized gesture id and a confidence score between 0 and 1. In order to filter out false positives, the confidence score has to exceed 0.97 before the gesture is accepted by mapping its id to a music player command.

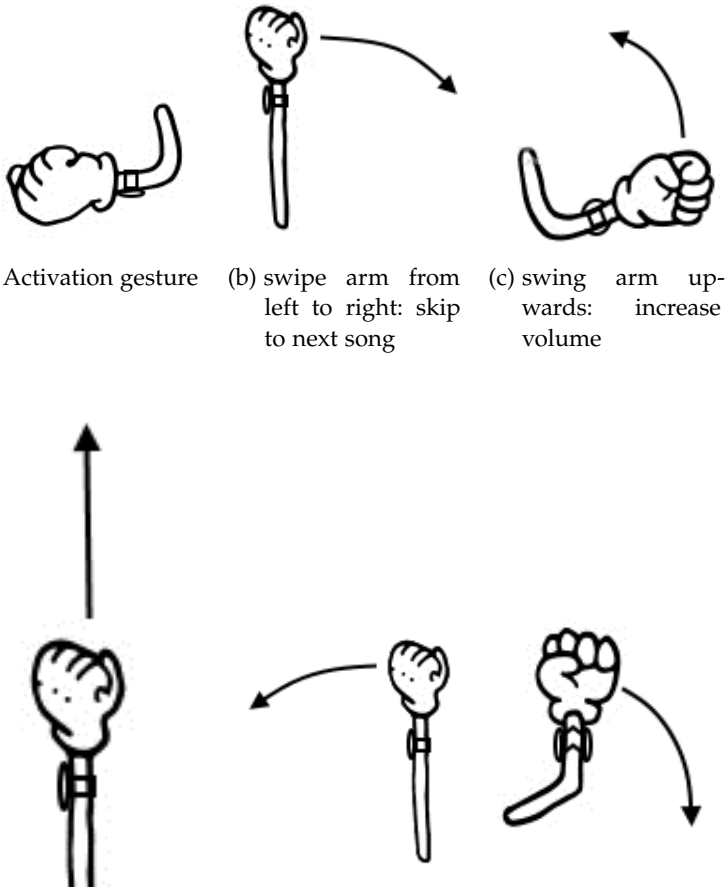
The activation gesture is performed by rotating the watch with its face down reaching a pitch of at least -70°or lower. For this, the rotation of the watch is constantly measured with android's software-based *Game Rotation Vector Sensor*[10]. When the gesture recognition gets activated, the user receives a sequence of three vibrations as feedback from the watch after which a gesture can be performed. Wiigee's recognition algorithm is sensitive to the device rotation, hence the device orientation during recognition should be approximately the same as it was during the training in order to be recognized correctly.

Since it can not be assumed that users wear their watch in the same position and certainly have different wrist anatomies, a suited pitch value for the activation gesture has to be determined. An informal experiment involving 26 participants has been conducted, where each participant had the task to turn their wrist five times as much as possible without getting uncomfortable. The minimum values from each participant series are plotted in figure 8.

Wiigee is an event-based library where the training and recognition process is started by virtual button presses and completed by virtual button releases. In case of the Wiimote[11], for which wiigee was originally designed, users were able to press real buttons. Gesture recognition on the smartwatch, however, can not be activated by real buttons, therefor training and recognition are activated by a virtual button press which is send to wiigee after the vibration countdown from the activation gesture. The virtual button release for finishing the training or recognition process is send automatically to wiigee

10 Documentation can be found here: `https://developer.android.com/guide/topics/sensors/sensors_position.html`

11 Wiimote is a remote controller for the Nintendo Wii



(a) Activation gesture

(b) swipe arm from left to right: skip to next song

(c) swing arm upwards: increase volume

(d) punch forward: play and pause

(e) swipe arm from right to left: back to previous song

(f) swing arm downwards: decrease volume

Figure 7: 7a depicts the activation gesture where the arm is bent and the watch face is turned down until the pitch threshold is reached. When the vibration countdown is over, one of the other five gestures can be performed to issue a command to the music player.

after 750ms, which is enough time to perform each gesture. Deactivating the recognition process as soon as the device stops moving could not be used in this case, since this event can not be reliably detected.

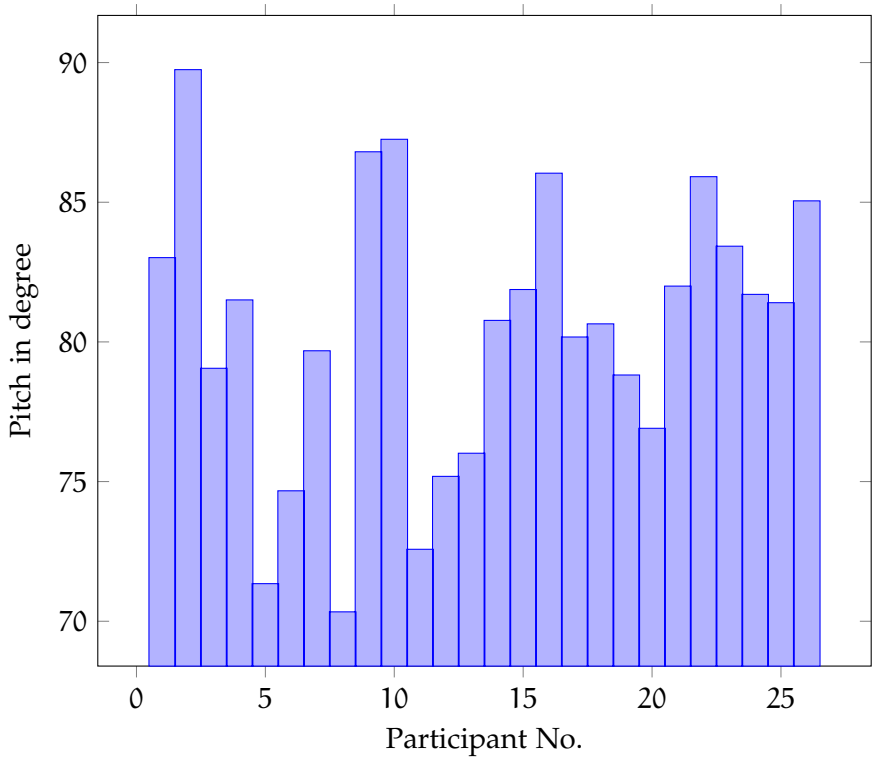


Figure 8: Minimum absolute pitch values for each participant. The minimum absolute pitch value that every participant reached is 70.3

3.4 MOBILE-WEAR COMMUNICATION

Controlling the music player with the smartwatch requires some communication to happen between the watch and the mobile device. Android provides a solution for this which is called the Wearable Data Layer API[12] that is part of Google Play Services. It offers a communication channel for smartphone and wearable applications. In particular, the *MessageApi* class which is responsibule for sending text messages back and forth suffices for the music player. A message can have different types determined by a string that has to be attached to the message. Table 3 lists all types that can be attached to a message in both the wearable and mobile application as well as their purpose and when they are sent. Figure 9 illustrates in which direction the messages are sent.

A communication manager class in both applications is responsible for sending and receiving these messsages. When a message is received, the communication manager forwards the message to the concerned application parts which then execute a corresponding action.

12 https://developer.android.com/training/wearables/data-layer/index.html

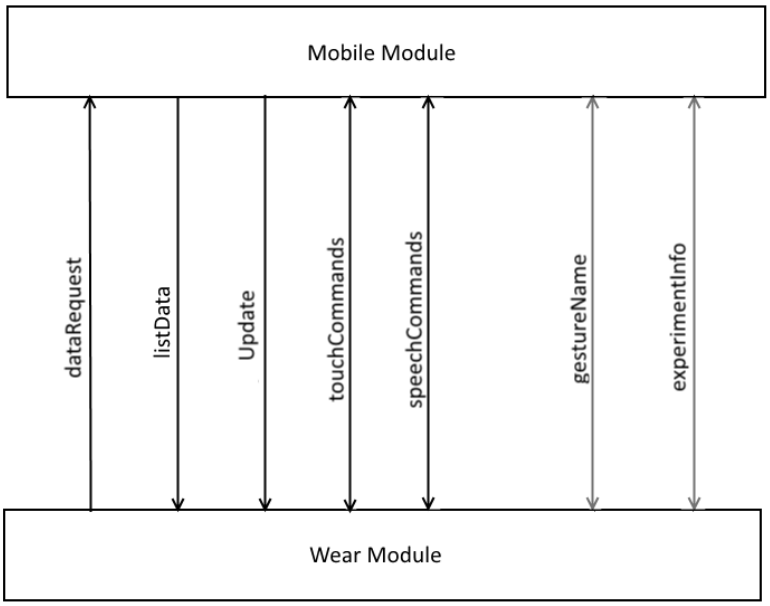


Figure 9: A Message can be of five different types: a data request type, list data type containing information about the music library, an update type containing the current music player state, a touch command type and a speech command type which both are sent from the wearable application and answered by the mobile application afterwards. The two greyed out message types on the right are included for the sake of completeness and are only used for the user study.

MESSAGE TYPE	WHEN SENT	PURPOSE
data request	wear app start.	Indicates the mobile app that music library data is needed.
list data	mobile app start or when a data request was received.	Contains a list of display names for all music items in the library.
update	on music player's state change, i.e. when the track is changed, a play or pause command ocurred or shuffle was toggled.	Contains all information to keep mobile and wear UI synchronized.
touch command	on touch or gesture input on the wear app.	Contains a string representation of the issued command. A gesture id is mapped to the same string as its respective touch command is (see 3.3.3).
spech command	after user completed a speech command	Recorded text is sent to the mobile app to convert it into a command

Table 3: List of the different message types, when they are sent and what their content or purpose is.

4

USER STUDY

The purpose of the music player described in chapter 3 is to examine user behaviour regarding the focused-casual continuum. The idea behind this concept is that users can vary their level of engagement for a certain action while not being bound to interact strictly focused or casual with the device. The three interaction techniques introduced in section 3.3 and the variable amount of control they offer to the user create different levels in the focused-casual continuum. It is interesting to see whether users recognize and use the different levels of engagement.

4.1 PROCEDURE

However, the viability and beneficing of the system also needs to be confirmed by users in form of a study. Ten participants (2 female, age 21-29 $\bar{x}$=26, σ=2.47) with different backgrounds were invited. All participants own a smartphone, but only one person owns a smartwatch. Eight participants already had some experience with gesture controlled devices such as the Nintendo Wii or Microsoft's Kinect. Nobody used speech controlled devices beforehand. Before the actual experiment started, the music library and the input techniques were introduced. In a fifteen minute training session the participants were able to acquaint themselves with the music player and practice especially the gesture input. Every participant was then observed while using the music player in six different scenarios that were both private and in public. In each scenario the participants wore the smartwatch on their left wrist and were sometimes more, sometimes less either physically or mentally distracted. The order of the scenarios for each participant was determined using a 6x6 latin square in order to prevent learning effects.

Scenarios and their settings[1]:

OFFICE WORK The participants are seated at a desk in an office. Their task is to copy a text from a sheet of paper to a file on a laptop thus being mentally and physically distracting. This scenario is in a private surrounding.

1 Bicycle and headphones were provided but one could bring her own to feel more comfortable.

READING ON COUCH The participants are seated on a couch in a private living room. Their task is to read a chapter from a book and summarise the content afterwards.

RIDING A BICYCLE The participants are riding a bike on a public parking area. Their task is to follow a pre-defined route (depicted in figure 11). The distraction is both mental and physical.

JOGGIN The participants are jogging the same route on the parking area (depicted in figure 11), thus being in public and physically distracted.

WALKING MENTALLY DISTRACTED The participants are walking a pre-defined public route (depicted in figure 10) playing a memory game on a mobile phone. This is mentally distracting. Touch is still possible.

WALKING PHYSICALLY DISTRACTED The participants are walking the aforementioned pre-defined public route (depicted in figure 10) carrying a bag in their right hand. This is physically distracting.

Figure 10: Z-shaped route for both of the walking scenarios. During the day this route is much-used by students and other people.

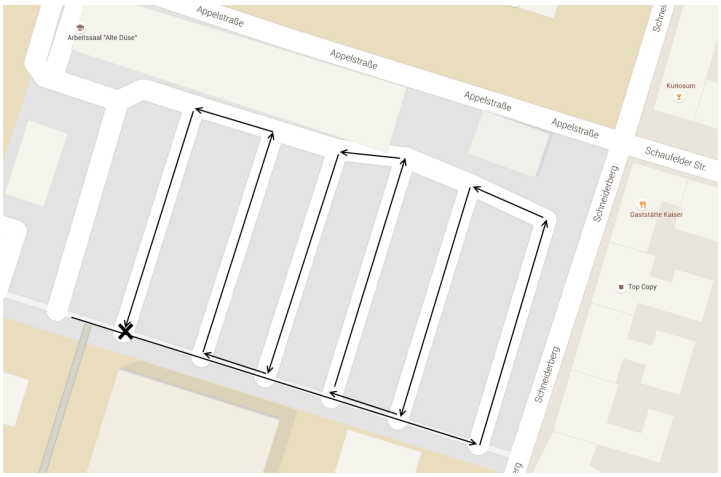


Figure 11: Zigzag route completely on a parking area for the bicycle and jogging scenario. Participants had to mind arriving and leaving cars and other cyclists.

To force the participants to interact with the music player, they were tasked with eight coarsely formulated player interactions in each scenario. For every forced interaction the participant could always freely choose between at least two interaction techniques to use, however, scenario constraints made using some techniques more difficult, e.g. using touch on bicycle. The use of each interaction technique was recorded during the experiment session ignoring interactions with recognition errors. Table 4 lists the interaction tasks and the possible interaction techniques that generally could have been used.

FORCED INTERACTION	POSSIBLE TECHNIQUES
1. start a playlist	touch, speech
2. adjust the volume	touch, speech, gesture
3. toggle shuffle	touch, speech
4. skip one or more songs	touch, speech, gesture
5. change song relative to a chosen audio feature	touch, speech
6. skip one or more songs	touch, speech, gesture
7. play song from different genre	touch, speech
8. pause current song	touch, speech, gesture

Table 4: Interaction tasks for each scenario instructed in this specific order. The skip to next song task was instructed twice in each scenario.

4.2 EVALUATION

In addition to the experiment every participant answered a questionnaire about the experiences they made. First, they were asked to classify their music listening behaviour on a scale from 1 to 5 where 1 means they choose every song they listen to by themselves and 5 means they turn the music on in the morning and turn it off again in the evening. Figure 12 shows the distribution of listener types that participated in the experiment. Most people rated themselves to be a mixture of both extreme listening types. This implies that the participants generally interact a lot with a music player.

The answers to the general questions about the experiment (seen in figure 13) show an overall agreement on the suitability of the scenarios. 9 out of 10 participants found these or similar scenarios in their everyday life and all participants are regularly listening to music in these situations. Also 9 participants perceived controlling the music player with a smartwatch in contrast to a mobile phone in the scenario contexts as helpful. In General 8 out of 10 participants support the idea of smartwatch aided systems. These answers confirm that a smartwatch in general can be a well suited device for supporting casual interaction.

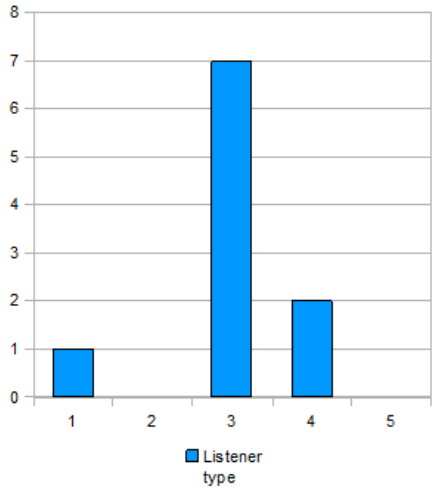


Figure 12: Distribution of music listener types.
1 = I choose every song;
5 = I don't care about which song is playing.

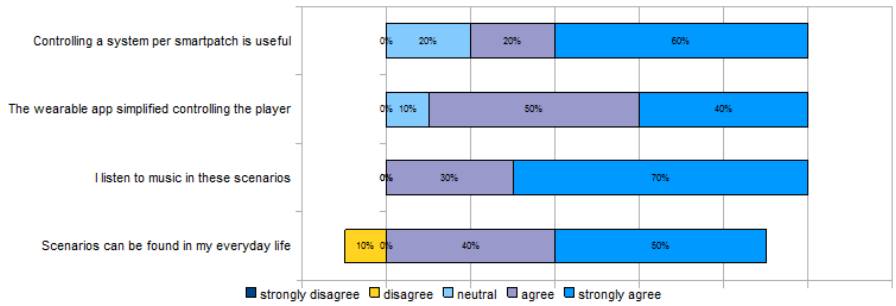
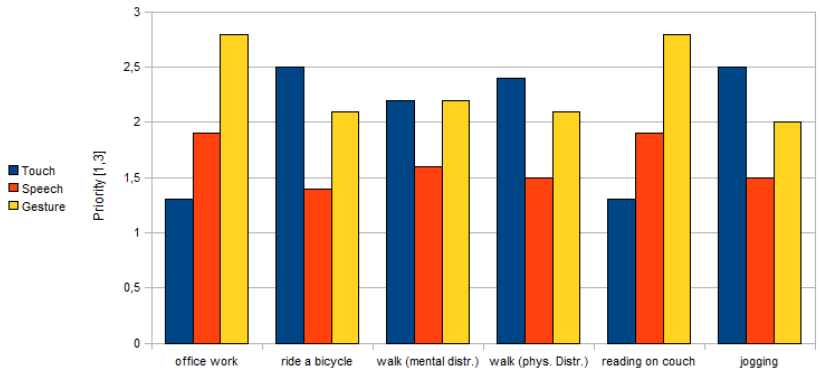
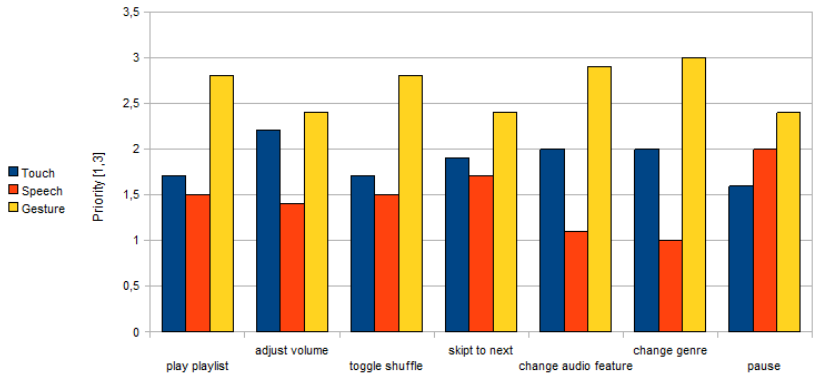


Figure 13: General questions about the scenarios and smartwatch controlled systems. Answers were made on a five point Likert scale from strongly disagree to strongly agree.

A big factor for suitability are the offered input techniques and their implementation, though. Hence, the participants were asked to prioritize the three input techniques separately for every scenario and every interaction task they were given. Values range from 1 (highest priority) to 3 (lowest priority). Since some techniques were not possible to use in certain scenarios or for certain tasks, they were automatically prioritized as the lowest. Figure 14 plots the respective results. It is striking that gesture input was least prioritized for each task and also for most scenarios, except where touch was not very suitable (e.g. the bicycle scenario). Overall the speech input technique was prioritzed the most which is approved by the overall input technique choice during the experiment seen in figure 16b. Figure 15 additionally plots the amount of input choices that were used most in every scenario and for every task. In the bicycle scenario for example eight participants used the speech input for most of the tasks. However, gestures could only be used for half of the tasks in contrast to touch and speech input. Nonetheless, gestures were, next to speech input, the most chosen technique in the *walking while mentally distracted* scenario. In general gestures were avoided where the participant was physically distracted. Touch input on the other hand was higher prioritized when the time to complete the interaction did not matter as in the *office work* and *reading on couch* scenario. The low usage of speech input for the pause task seen in figure 15b stands out, though, and was caused by the participants finishing their scenario task before pausing the music. Thus, they were able to choose the input technique without physical or mental constrains. The averaged rating of the overall control over the music player with each input technique shown in figure 16a can be one reason for these usage numbers. A high rating would mean that the participant felt to have sufficient control while using the interaction technique. Gesture input, however, received a low rating of 3.7 out of 10 mainly caused by falsely recognized gestures which led to unwanted music player actions.



(a) Averaged priority rating for the input techniques in every scenario

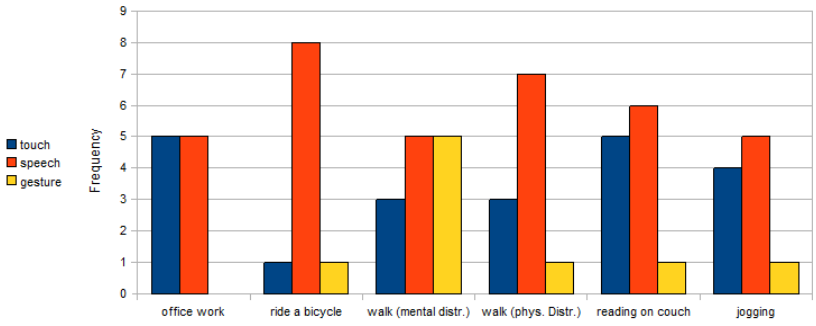


(b) Averaged priority rating for the input techniques for every task

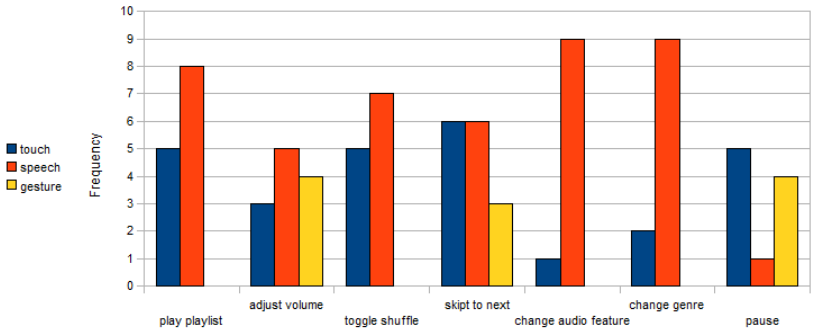
Figure 14: The participants prioritized the three input techniques from 1 (highest priority) to 3 (lowest priority). The values are averaged over all participants.

Further, the participants were asked to rate the amount of physical or time-wise effort (figure 17a) and the amount of required attention (figure 17b) for each input technique regarding each scenario. Values range from 0 (almost no effort/attention) to 10 (high effort/attention such that current task has to be interrupted). It again stands out that speech input was rated as the best in each scenario. Gestures were often times rated better than touch input, though, but since speech input was apparently much more convenient, gestures were still not used more often.

In order to better understand the input technique choices, the participants were asked to reflect about their usage decisions. *Why did you prefer technique X the most and why did you avoid using technique Y?* Seven participants used the speech input the most and agreed on their arguments for that. It was a novel technique, but at the same time they perceived the technique as powerful, fast, intuitive and not very distracting, so that they could always focus on the current task. Nevertheless, one participant used speech input the least and states a high error rate in noisy situations for the speech recognition as a



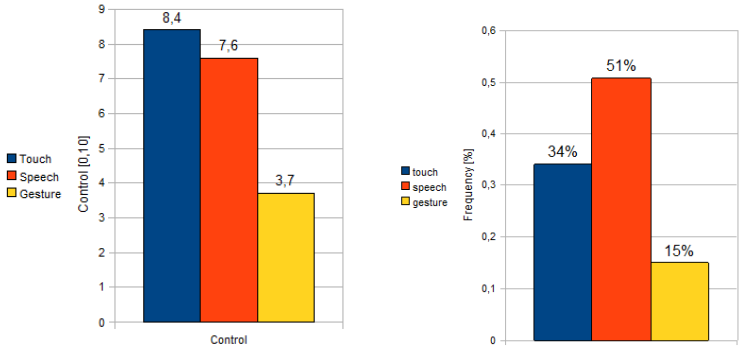
(a) Amount of most made choices for each scenario.



(b) Amount of most made choices for each task.

Figure 15: Plot of how often an input technique was the most used during a scenario or a task respectivley. Speech input clearly dominates in the bicycle scenario and the complex music player tasks.

reason. This participant, together with two others, instead prefered using touch the most and explained it with familiarity and a high success rate. It was also described as fast and accessible for simple commands since the smartwatch was attached to the wrist. On the other hand, touch was also described as highly distracting and slow when used for complex commands like changing the genre or selecting a playlist. Gestures were described as error-prone, time consuming and inconvenient. Concentrating on the beginning of the gesture recording window was claimed to be difficult and distracting. Only one participant had concerns about performing gestures in public describing them as “looking silly”. None of the other participants was concerned about using speech or gesture input in public.

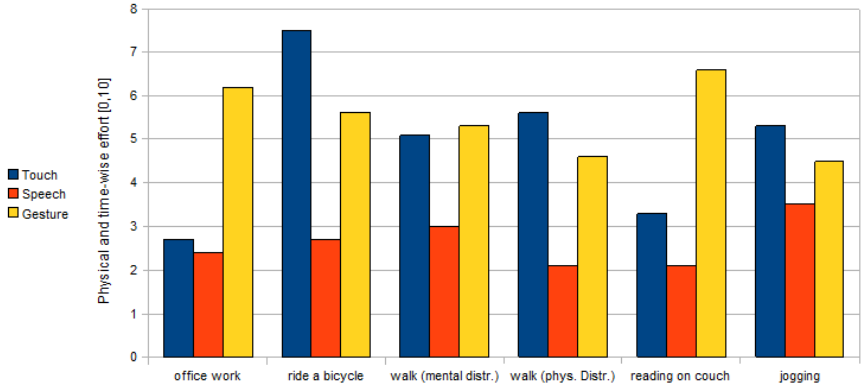


(a) Averaged perceived amount of control over the music player with an input technique while using it. Values range from 0 (no control) to 10 (full control).

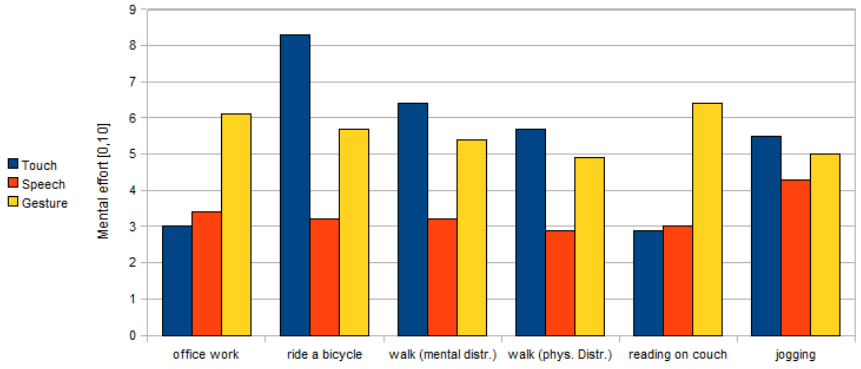
(b) Overall usage numbers of each input technique for all participants.

Figure 16

Summing up, the results show that a smartwatch is indeed a suited device for supporting casual interaction whether it is used in smart homes or other environments. The three input techniques introduced with the smartwatch already cover a wide area of the focused-casual continuum offering at least one alternative technique, but it depends on the user's context which technique is applicable. Touch input was the prefered technique for all engagement levels when the user's hand or fingers were not occupied. It was, however, only used for complex tasks when the required input time did not matter. Gesture input was only designed for the simple music player tasks, hence it was expected to not being used often. But gestures were not used very much at all which is related to false recognitions causing a lack of control over the music player. Also speech input was possible to use in every scenario and for each task, thus the participants got quickly used to this technique not considering using gestures instead. It is noteable, though, that the error rate of speech input increases with louder background noises and presumably the technique would then become less appealing to use. Apart from that, the speech input technique turned out to be the most convenient and flexible interaction technique for casual interaction with a smartwatch.



(a) Required amount of physical effort in each scenario.



(b) Required amount of attention in each scenario.

Figure 17: Participant rating of required ressources namely physical or time-wise effort and attention for each input technique. Values range from 0 (almost none needed) to 10 (current task has to be interrupted).

5

CONCLUSION AND FUTURE WORK

This thesis explores casual interaction with a smartwatch. Therefor, a mobile music player is implemented on smartphone as a representative application. Three different input techniques namely touch, speech commands and armgestures covering a wide range of the focused-casual continuum enable the user to control the music player with the smartwatch regardless of the current context. In a user study with ten participants the input techniques and how they were implemented are verified with respect to their convenience. The participants are observed interacting with the music player in six common everyday scenarios and asked to rate different aspects of the interaction techniques afterwards.

Armgestures turn out to be avoided and they receive a poor rating as well which can be reasoned with high error rates due to insufficient training and the decision of adding an activation gesture followed by a vibration countdown. Concentrating on when to perform the gesture draws more attention from the current task than intended.

Touch input on the smartwatch is favored in contexts with mental distraction for simple tasks like play and pause. For complex tasks touch input is used when a distraction from the current task has no significant consequences. Most importantly users choose touch as a reliable fallback in case of other techniques malfunctioning.

Speech commands are surprisingly popular and high rated for their intuitive operability and their lack of demanding attention. They cover a wide area of the focused-casual continuum with their control possibilities and are usable in many different situations. Speech recognition is, however, vulnerable to loud background noise which sets a limitation to this interaction technique and shows a demand for alternatives to use.

Overall a smartwatch is a suitable device for offering casual interaction regardless of the supported interaction techniques due to being highly accessible and enabling quick interactions. Needless to say, the casual interaction system chosen for the music player has room for further improvements and research. Gesture input can for example be enhanced by including wrist or even finger gestures which would introduce more complex interaction possiblities. It is also imagineable to add additional sensor hardware to the smartwatch such as a proximity sensor or a camera for enabling around-device interactions that would require even less attention from the user.

LIST OF FIGURES

LIST OF TABLES

LISTINGS

ACRONYMS

API Application Programming Interface

BPM Beats per Minute

EPG Electronic Program Guide

GUI Graphical User Interface

HCI human-computer interaction

SDK Software Development Kit

UI User Interface

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