Bachelor's thesis

Can ambulatory biofeedback be helpful for students in daily life?

An explorative study into the evaluation of ambulatory biofeedback in a non-clinical target group

Lena Claussen

25.06.2019

UNIVERSITY OF TWENTE.

Faculty of Behavioral, Management and Social Sciences (BMS)
Psychology, Health & Technology (PGT)

Graduation Committee:
Dr. Matthijs Noordzij
Dr. Anneke Sools

Abstract

Background: In today's society, we are exposed to a high amount of stimulation, for example through stress and the constant influence of new technologies. One group that is particularly affected is represented by students. A high degree of stimulation or even over-stimulation can lead to our attention being diverted away from our body. This, in turn, can lead to consequences for health and well-being. The Sense-IT, a mHealth application, has been developed to help us become more aware of our body and our emotional world through ambulatory biofeedback.

Objective: The aim of this study was to explore students' attitudes and their individual reactions to the reception of ambulatory biofeedback in their daily lives.

Methods: A qualitative study has been conducted with 16 participants who were all students at the University of Twente, Enschede. The participants used the app for a period of time and were then conclusively invited to a semi-structured interview during which they also filled in two questionnaires (System Usability Scale and Scale for Wearable Technology Embodiment). The interviews have been transcribed with AmberScript and analysed with the software ATLAS.ti and inductively established codes.

Results: The way in which students assess ambulatory biofeedback was examined on the basis of four indicators: reaction to the reception of ambulatory biofeedback, their attitude towards it, potential and criticism. Taken together with the results from the two questionnaires, it resulted that students themselves assume an open and generally positive stance towards ambulatory biofeedback, but that further improvements can help to maximise the value for this target group.

Conclusion and Discussion: The findings from this study yield first novel insights into college student's evaluation of ambulatory biofeedback. Concluding, students can learn to cope with stressors and overstimulation more adaptively through the reception of biofeedback in their daily lives. Ambulatory biofeedback, therefore, can be used as a tool for future interventions in stress associated populations. Future work can determine and implement the required adaptations to match the needs of aforesaid populations.

Keywords: ambulatory biofeedback, mHealth application, college students, Sense-IT, daily life

Contents

Introduction

In our daily lives, we are continually exposed to numerous stimuli of both pleasant and unpleasant nature. Those stimuli can originate from our external environment, including noise, visual perception or tactile stimulation, and are commonly described as sensory stimuli (Robson, 2016). Stimuli can, however, also originate from within us, as a result of cognitive appraisal or emotional evaluation (Lewis, et al, 2015). Our bodies react to both kinds of stimuli, by generating bodily signals (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Further, it can be argued that we live in a world of continuous overstimulation due to the increasing diversity of stimuli that we experience through the extensive amount of channels of information and technologies in our daily lives (Robson, 2016; Thomée, Härenstam and Hagberg, 2011), combined with the resulting requirement to respond to this diversity of stimuli (Frankenhaeuser, Nordheden, Myrsten, & Post, 1971). When the rate of external stimuli is reaching its peak, our attention can be more easily drawn outside of our bodies and away from our emotions. This is particularly likely to occur in stressful situations (Price & Hooven, 2018). When we cannot attend to our bodily signals sufficiently, we might become increasingly insensitive to when and how our body reacts to a stimulus and also more insensitive to the kind of stimuli our bodies react more extensively to (Price & Thompson, 2007). When we are failing to sufficiently attend our body, it can become progressively challenging to adequately cope with the extensive exposure to stimuli. Ultimately, people may become overwhelmed with coping with this exposure but are simultaneously exposed to more stimuli, a process that might evolve in a vicious circle. In contrast, being aware of our internal state can highly contribute to our mental health, as it allows us to respond appropriately to our bodily signals (Gross & Muaoz, 1995).

Psychologists have acknowledged this issue and addressed it in a number of techniques, one of which is called biofeedback. The foremost goal of biofeedback is to increase a client's awareness of his or her own internal states and to further enable the regulation of these states (Yu, 2018). In order to provide the user with valuable physiological information, biofeedback devices are equipped with a sensor that measures bio-signals, such as the heart rate, skin conductance or brain waves (Yu, 2018). Biofeedback utilises the reactions of the human body to different types of stimulation. These reactions are expressed in bodily signals which include an increased heart rate, accelerated skin conductance or muscle tension. This so-called stress response is initiated by the autonomic nervous system (ANS) (Crocket, Gill, Cashwell, & Myers, 2017). The ANS is responsible for our immediate responses to ambiguous stimuli and it is widely acknowledged that it extensively contributes

to our emotional responses (Kriebig, 2010). Biofeedback is based on the theory of feedback loops which assumes the integration of information from the physiological, cognitive, and affective systems (Crockett et al. 2017). Thus the information provided by biofeedback can be instrumentalized to draw conclusions about the user's physiological state. Differently said, biofeedback can bring awareness to internal processes by providing information from an external device, allowing the user to adequately recognise their emotional arousal (Derks, Klaassen, Westerhof, Bohlmeijer, & Noordzij, February 2019). The interplay between internal psychological processes, such as cognitive appraisal and physical processes is widely acknowledged and is taken advantage of in biofeedback therapy, as it involves bringing feelings, thoughts and memories into consciousness through body sensations (Staunton, 2014). An increasing body of evidence supports the positive effects of biofeedback on well-being and performance in clinical settings (Crocket, Gill, Cashwell, & Myers, 2017) and its potential to be supportive in regulating the physical components of emotions (Peira, Pourtois, Fredrikson, 2013). It has also been found to be able to teach self-regulation and to offer a possible foundation for cost-effective, clinical interventions and also to connect technology and the human (Austad & Gendron, 2018). Overall, biofeedback can be advantageous to improve the quality of a person's everyday life (Houser, Rosen, Seagrave, Grabowski, Matthew, & Craig, 2013). Since biofeedback has been proven to be a helpful tool to increase well-being in clinical contexts, the questions arise whether it can find its applicability for non-clinical target groups for whom increasing well-being is beneficial. This study thus aims at exploring which attitudes non-clinical target groups will hold towards ambulatory biofeedback and the reception thereof.

As mentioned above, the current field of application for biofeedback is primarily in therapeutic and clinical environments. However, recently, there have been more attempts to further implement biofeedback in other environments. Possible target groups are those groups that are exposed to a higher risk of overstimulation, for example, due to stress. One of these groups is represented by college students. College students are forming a group that runs a high risk of being exposed to perceived threats and highly consuming stress. In fact, stress has been ranked as the most common health issue that affects a student's performance by the American College Health Association (Ratanasiripong, Sverduk, Prince, & Hayashino, 2012). One contributor to the perceived stress is the number of new stimuli that students find themselves confronted with. Firstly, students are facing social transitions as many students move away from their home to live in another city and instead of living with their family, they often proceed to live in shared flats, where they meet new people and might be confronted

with disagreements with their roommates. In line with this, finding and maintaining social networks is considered as a direct source of stress (Thomée, Härenstam and Hagberg, 2011). Secondly, students are prone to perceive parental pressure, new responsibilities as well as financial shortages (Chaló et al., 2017). Thirdly, being a college student often involves many personal issues on various aspects, including self-image, identity, sexual orientation as well as philosophical and social values (Fehring, 1983). Fourthly, college students frequently face deadlines, exams, as well as other study related stress (Ratanasiripong, Sverduk, Prince, & Hayashino, 2012). In summary, it is recognized that while students try to adapt to their new environments and challenges, high arousal and even overstimulation can occur frequently (Bamber, Kraenzle Schneider, 2015). In order to successfully cope with these demands of their environment, various strategies to practice exist, including cognitive appraisal and shift of focus (Birk and Bonanno, 2016). The study by Birk and Bonanno (2016) has additionally revealed that those who are highly responsive to their internal feedback are more likely to choose an appropriate coping strategy. Internal feedback refers to a person's awareness of their emotionally induced physical processes and states. However, when our attention is drawn outside of our body, our internal feedback loop might not operate effectively anymore. It can be conducive to engage in attempts of bringing back the attention to the body. One way of doing so might be offered by biofeedback.

Since the current college student population belongs to a generation that has been brought surrounded by technology (Tully, 2003), there is reason to assume that today's college students react openly to using a technical device that will provide them with information on their physiological state. Biofeedback might offer students a possibility to find a way to become more attentive to their body again, despite the continuous exposure to a diversity of external influences and to thereby promote their own wellness and even increase performance (Crocket, Gill, Cashwell, & Myers, 2017).

As it is currently mainly used in clinical settings, more commonly, a static approach to biofeedback is used. Static in this context refers to a single measurement of physical activity during a static position or a simple movement that is not related to the daily activities of the user (Huang, Wolf, & He, 2006). However, a more integrative approach might be offered by ambulatory biofeedback. Ambulatory biofeedback is integrated into a portable device, such as a smartwatch, and can, therefore, provide the user with feedback anywhere at any given time. The measurements of ambulatory biofeedback are taken in a continuous manner while the wearer can follow his or her regular daily activities. The feedback can thus be fully integrated into the daily life of the user (Derks, De Visser, Bohlmeijer, & Noordzij, 2017). Due to the

emerging flexibility, it might be assumed that ambulatory biofeedback is of higher value for non-clinical groups, including students, as the user of ambulatory biofeedback is not bound to one specific place, but can follow his daily activities without any limitations.

In an attempt to design an effective so-called mHealth application and thereby providing ambulatory biofeedback, a research team at the University of Twente has developed the Sense-IT, an app that operates on smartwatches. mHealth applications have the goal to "coach" their users to lead a better life (Derks, De Visser, Bohlmeijer, & Noordzij, 2017). The sense-IT is exemplary for these applications. The name of the Sense-IT refers to both, the technological nature *IT*, but also to its function to *sense* it (Derks, De Visser, Bohlmeijer, & Noordzij, 2017). The Sense-IT has been initially developed in collaboration with Borderline patients, a population that frequently lack emotional awareness. It uses a method called photoplethysmography (PPG) to obtain the wearer's heart rate (de Bruin, 2017).The Sense-IT thus relies on a biosensor technology that measures the wearer's heart rate by sensing the reflection of the bloodstream. While wearing a smartwatch that is equipped with the sense-IT application, the user is continually provided with information on the heart rate and as soon as a certain threshold is reached, the watch vibrates to inform the wearer about any considerable change in the heart rate and thereby offers the wearer a customizable reception of biofeedback. Ideally, mHealth applications that are incorporated in a wearable device can be used as an extension of cognition, the body and the self. This can be assessed by the scale for wearable technology embodiment (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019). One of its main advances is, that the measuring method is non-invasive and the Sense-IT can thus be brought into daily life, outside of clinical settings. Especially students might, therefore, benefit from the Sense-IT without having to adapt their lifestyle around any bulky technological equipment, as they only need their smartphone and a smartwatch.

While there might be some benefits for students in ambulatory biofeedback, no research has been found that surveyed how college students evaluate the reception of biofeedback in their daily life. A positive evaluation can be seen as an important prerequisite for the applicability of ambulatory biofeedback in student population, whereas a negative evaluation might raise the demand for further developments and improvements. This study aims at exploring this question in regard to ambulatory biofeedback provided by the Sense-IT app. In order to answer this question sufficiently, sub-questions in regard to the initial reaction to the reception, the attitude towards biofeedback, possible criticism about biofeedback and its usability, and lastly the perceived potential of biofeedback have been established.

How do college students evaluate ambulatory biofeedback in daily life?

1. How do college students react to receiving ambulatory biofeedback?
2. What is their attitude towards the reception of ambulatory biofeedback?
3. Which criticism do college students articulate towards ambulatory biofeedback, including the usability of the device?
4. What potential do college students see in ambulatory biofeedback?

Method

Study design

The present study is a qualitative exploratory research that is based on the interview study design. The chosen interview design was a semi-structured interview. The research was conducted at the University of Twente, Enschede by two Bachelor students in the third year. It has been approved by the ethical commission of the Behavioural Management Sciences Department of the university on March 28th, 2019 (See Appendix A). The aim of this study was to explore students' attitudes and their individual reactions to the reception of ambulatory biofeedback in their daily lives. While quantitative studies can often measure attitudes of well-established constructs, qualitative research allows a researcher to take a more individual approach. Qualitative research is regarded as more appropriate for newer constructs that are still subjective to redefinments (Forshaw, 2013). For this study, the researcher's aim was to explore possible new implications for a construct that might yet require adjustments. This study, for the first time, provides insights into the attitude and reactions from students towards ambulatory biofeedback. A qualitative design is, therefore, better suited to capture and ultimately reflect the complexity of these attitudes and reactions.

Procedure

The present study consisted of three phases, namely the instruction interview, the active testing days and lastly the evaluative interview. After the students signed up for the present study in the SONA-system, they were invited for an interview. During this first initial contact, the participants gave their informed consent (See Appendix B) and were asked to sign it. The informed consent contained information about the aim and the methods of the study, as well as information about the data processing of obtained data. Moreover, the participants were informed that their data will be treated confidentially. The participants were also informed that they are free to quit the study at any given point in time without a

declaration of reasons. The researchers additionally asked for some demographics, such as age, nationality, possible prior experience with biofeedback and their approximate daily activity. Afterwards, participants are given a smartwatch and, unless they have one, they were also given an Android smartphone. Both devices were equipped with the Sense-IT app and linked to one another. Afterwards, the first baseline measurement was executed, during which the watch takes 300 measurements. The baseline measurement established an average heart rate with the associated standard deviation. All participants were given the password for the settings, in order to freely adapt settings. When the technical devices were all set up, the participants could ask any remaining questions. After all questions have been successfully answered, the participants are instructed to follow their daily activities as normal as possible and are additionally given contact details of the researchers so that they are able to contact them if any problems may occur.

The participants now start the active testing phase during which they are instructed to wear the watch for four consecutive days for as many hours as possible. Participants did not have to wear the smartwatch watch during the night and were free to take them off during sporty activities. At the end of each testing day, participants sent the daily report via email to the researchers and were asked to write down some thoughts they had on receiving biofeedback during the day.

After the testing days, participants were re-invited for a second interview during which they were asked multiple questions about their experience from the preceding days. Before the interview started, they were given the Scale for Wearable Technology Embodiment (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019) to fill out, as well as the Usability Scale for the Sense-IT. Each interview was recorded with a mobile phone, which has been declared to the participants beforehand.

Participants and Recruitment

The study has been conducted at the University of Twente, students of this university, therefore, seemed a suitable choice to be participants of this study. The participants were recruited from the population of the students by the means of convenient sampling as well as purposive sampling. The research was enlisted via the subject pool system SONA, which provides the possibility for students to sign up for taking part in appealing studies and receive course credit. Moreover, participants have been directly approached by the researcher in a private setting, including friends and acquaintances. The two sampling methods and the

combination of such allowed the researcher to find eligible participants in the most efficient way.

In order to ensure the participant's ability to take part in the present study, certain criteria have been set. Next to the willingness to take part in this study, participants should be locally available for the researchers in case of any arising questions or technical problems. This study aimed at exploring the value of the normal population towards ambulatory biofeedback, so it was of the researcher's best interest to minimize the risk of bias as far as possible. Thus, two exclusion criteria have been established. Firstly, students with diagnosed mental illnesses were excluded from participation in the study. While the app has been designed in collaboration with this group, this study does not take place in a clinical setting and thus clinically diagnosed students have been excluded. Secondly, students with diagnosed coronary diseases were not allowed to take part in the study, because they might be highly biased in their attitudes towards their bodily sensations, as they have been already trained for higher awareness. Moreover, the Sense-IT might be misused as a diagnostic device in alike cases which it is not its purpose.

The final sample of this study as shown in Table 1, consisted of 16 participants between the age of 19 and 30 years (M=21.87, SD=2.64). The participants were of Dutch, Italian and German nationality. All participants study Psychology, except for two. Five participants had previous experience with receiving continuous information on their heart rate.

Table 1

Participant Characteristics (N=16)

	Category	Frequency	
		Absolute	Percentage
Gender	Male	9	56
	Female	7	44
Nationality	German	14	87.50
	Dutch	1	6.25
	Italian	1	6.25
Study	Psychology	14	87.5
	Communication	1	6.25
	Science	1	6.25
	IBM		
Level of Activity	Low: A lot of sitting	1	6.25
	Medium: Does sport but a lot of sitting	9	56.25
	High: Quite sportive but a lot of sitting	6	37.50

Materials

Hardware

Smartwatch and Android Phone. The participants were provided with a smartwatch by the researcher. There were two models available, either the ticwatch E (Mobvoi) or the Moto360 (Motorola / Lenovo), which were both equipped with the Sense-IT app (Version 2.12) and continuously connected to the phones through Bluetooth via the app WearOs. The smartwatches were provided by the University of Twente. As the Sense-IT app is only available for the operating system Android, all participants had to use an Android Phone whose operating system was at least the version 7.0. Participants were free to use their own phones if those met the requirements, otherwise they were given a respective smartphone by the researcher.

Software

Sense-IT. This research is based around the app Sense-IT, which has been developed collaboratively by different organisations, namely Scelta, University of Twente, VUmc, Arkin and Pluryn (Kern, 2019). It is a software that runs on Android phones and PPG equipped wearable smartwatches. The app has been programmed to measure the wearer's heart rate in a continuous manner. During the day, the app provides the wearer with information about the heart rate and notifies him or her by vibrating when a previously personalized threshold is surpassed. The download link for the app is spread via a sent Email. Sense-IT is set to the Dutch language.

On the first screen, as shown in Figure 1, the starting screen of the Sense-IT app on the phone is illustrated. At the top of the screen, the user can go to the settings by clicking on the gear icon, which can only be accessed by previously entering a password. The button next to it, is the power switch of the app. If the power switch is green, the smartwatch is actively measuring the heart rate and is thus linked to the phone. However, if the power switch is red, there is no active connection nor do measurements take place. In the middle of the screen, the user can see the last three measurements and also has the possibility to add a note (*Notitie toevoegen).* At the bottom of the starting screen, the user can also check whether the connection and synchronization are functional.

When clicking on the gear icon and successfully entering the password, the user will reach the settings of the app, as illustrated in Figure 1. The user is able to see the average heart rate (*gemiddelde hartslag*) as well as the standard deviation (*standaard afwijking).* In the settings, the base measurement can be configured and taken. When the smartwatch is

successfully connected to the Sense-IT app, the display of the smartwatch will show either of the following motives, as shown in Figure 2. Depending on the choice of display, either the circle in the middle will change in size or the number of circles adjusts. Both changes are representative of a variation in the heart rate. The final display shows a lettering that states the current level of the wearer.

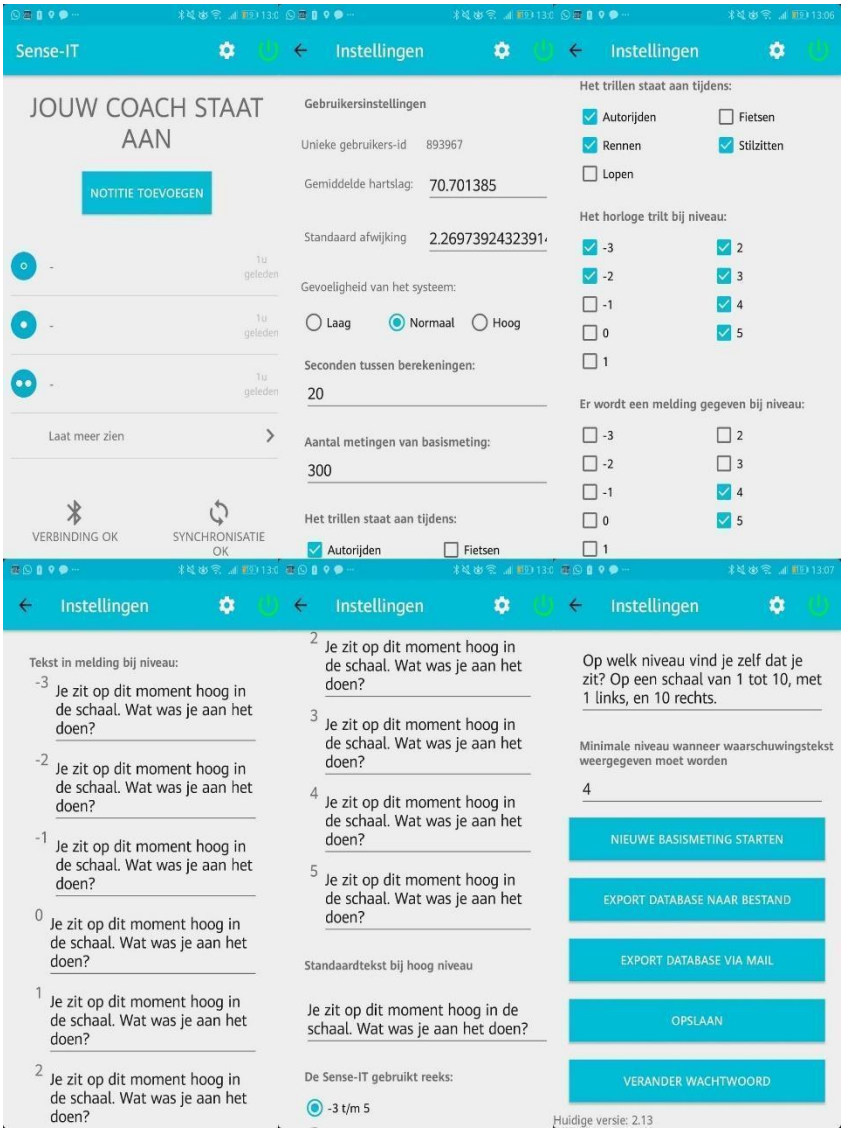

Figure 1. All screens of the Sense-IT app on the Android Phone.

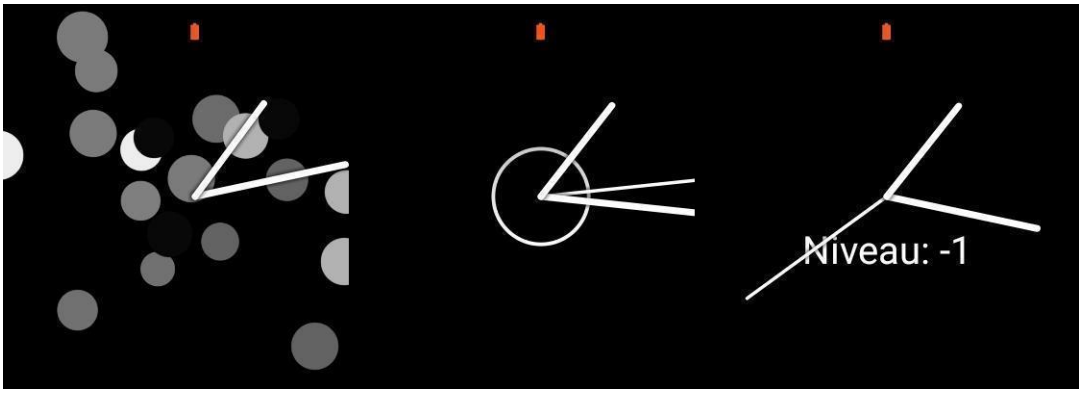

Figure 2. The different display settings on the smartwatch.

Questionnaires. Each participant was asked to fill out two questionnaires. Both questionnaires were handed to the participants in English before the second interview and the debriefing. The first one was a recently developed scale for wearable technology embodiment (See Appendix C). This scale regards wearable technology embodiment as a threefold concept consisting of body extension, self-extension and cognitive extension and asks three questions on each respective dimension which are answered on a 5-point-Likert Scale (1= *strongly disagree* to 5= *strongly agree*) (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019). The results on the respective subscales can deliver insights into how the participants have been using the device. Using the Scale for Wearable technology embodiment also provides researchers, as well as developers, with implications on how to improve trust, acceptability and customizability (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019). The responses by the participants on this scale can be used to draw possible implications on their preferences about receiving ambulatory biofeedback from the Sense-IT app, as they provide insights to trust and attitudes towards the wearable technology.

Another questionnaire that can contribute to understanding the participant's responses is the System Usability Scale (SUS*)* developed by John Brooke in 1996 (Jordan, Thomas, McClelland & Weerdmeester, 1996) (See Appendix D). This questionnaire assesses to what degree a participant finds the present technology usable and appropriate to a purpose by asking ten questions. The participant has to answer these questions on a 5-point-Likert Scale (1= *strongly disagree* to 5= *strongly agree)* and is instructed to not give the answers too much thought but choose their immediate notion on that question (Jordan, Thomas, McClelland & Weerdmeester, 1996). This scale has been used in a variety of research projects and stands out due to its flexibility and the ability to adapt to various technological contexts. (Jordan, Thomas, McClelland & Weerdmeester, 1996).

Interview scheme. In the first interview, the participants were introduced to the study and were asked questions about their characteristics and demographics, including questions about age, ethnicity and possible prior experience. In this interview, the questions were asked in a closed manner in order to provide the researcher with unvarnished answers about the participants' characteristics.

After the completed testing phase, a second appointment for an interview has been scheduled. The second interview was a semi-structured interview. Semi-structured interviews provide enough flexibility to adapt to the respective participant's answers and allows further clarifying follow-up questions, but at the same time will guarantee similarity, so that given answers can be compared (Forshaw, 2013). Semi-structured interviews allow for spontaneous, questions and deepening probes to gain more knowledge on an often complex issue (Wilson, 2014). The interviews have been conducted in English. Most questions were asked in an open way to allow the interviewee honest expression of opinion without being led by the researcher.

The used interview scheme can be found in Appendix E. It consisted of mainly three parts. The first part contained an introduction and a short disclaimer. The researcher asked about the settings, as well as potential technical problems that might have arisen during the testing days. In the second part, the research specifically asked about the experiences from the testing days. This part consisted of three main questions which had pursueing sub-questions. Depending on the given answers, the researcher was free to either add more probes to acquire more knowledge or skip a question when the topic of the question has been sufficiently covered by previous answers of the participants.

Data Analysis

Before the interviews were analysed, the documented characteristics of the participants were gathered. Moreover, the completed questionnaires have been scored and aligned with the respective participant. For the scale for wearable technology embodiment, the answers were added according to the value of each given answer and then divided by the number of questions (9) (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019). The final scores ranged from 1 to 5. In order to acquire a more differentiated picture, the subscores of the respective factors have been calculated. The instruction for scoring the SUS has been taken out of the manual "*SUS- a quick and dirty usability scale*", which has been published in the book "*Usability evaluation in industry*" (Jordan, Thomas, McClelland & Weerdmeester, 1996). This scale requires a specific measurement. For items 1, 3, 5, 7 and 9 the value of the

given answer is subtracted by one. For items 2, 4, 6, 8 and 10, the value of the given answers is subtracted from five. The final values of the answer now range from 0 to 4. After the individual items are scored, the scores are summed. The summed score is then multiplied by 2.5. The test yields at one final number to represent the perceived usability, which ranges from 0 to 100 (Jordan, Thomas, McClelland & Weerdmeester, 1996), scores below 50 indicate non-acceptance of the usability, while scores above 50 indicate acceptance. The exact subdivision of the scores on the SUS can be seen in Figure 5 (Bangor, Kortum, Miller, 2008).

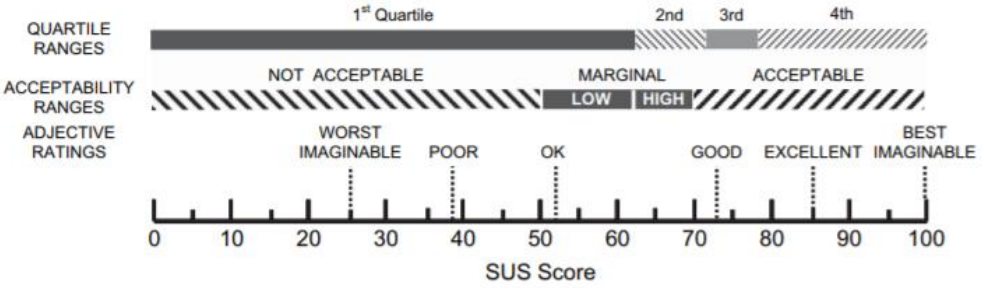

Figure 5. Subdivision of scores on SUS and accompanying system acceptability.

The interviews have been recorded with a mobile phone and eventually have been transcribed into written form by the researcher with the help of AmberScript, a transcription software by AmberScript B.V.. Transcriptions were then analyzed with ATLAS.ti 8, a software for qualitative research by ATLAS.ti Scientific Software Development GmbH. During the process of transcribing, all personal data has been anonymised in order to ensure confidentiality.

The codes for answering the research questions were based on an inductive approach according to the Grounded Theory methodology by Glaser and Strauss (1967) whose aim is to enable the researcher to discover theories in an inductive manner. The Grounded Theory and its application are one of the most frequently used approaches in qualitative research (Wiesche, Jurisch,Yetton, & Krcmar, 2017). Within the grounded theory methodology, constant comparison analysis (*CCA*) is frequently applied. It is a method of comparing and contrasting given answers in order to establish categories, determining their boundaries and settling content of those categories (Fram, 2013). CCA is often applied when the primary goal is not inevitably to establish a new theory but to organise newly collected data. It can help especially novice researcher to systematically organize data (Fram, 2013). Additionally to CCA, the method of memoing has also been used. This method contains the write-up of ideas about categories that occur during the analysis (Wiesche, Jurisch, Yetton, & Krcmar, 2017). After an initial coding scheme has been developed, further interviews have been coded.

During this process, it was established whether the codes required further adjustment. After a total of ten interviews have been coded, a final coding scheme has been developed by the means of this iterative process and has been applied to all interviews in order to ensure concordance. In the interest of establishing reliability, all codes have been developed in collaboration between the two researchers involved in this project, which ensures intercoder-reliability. The final coding scheme can be found in table 2.

Table 2

Final Coding scheme per sub question

	Code	Definition
Sub-question 1	Ignore	This code was used, when the interviewee stated that (s)he did not pay attention to the cueing of the wearable technology
	Acknowledge	This code describes the behaviour of the interviewee that showed that (s)he acknowledges the feedback and made sense of it
	Adapt	This code describes an active change in the behaviour of the interviewee after the feedback
Sub-question 2	Positive	Interviewees displayed a positive evaluation of the reception of ambulatory biofeedback
	Neutral	Interviewees display impartiality towards the reception of ambulatory biofeedback
	Negative	Interviewees perceived the reception of ambulatory biofeedback as burdensome
Sub-question 3	Technical Shortcomings	The usability of the technical device has been criticized.

	Risks	Possible risks of ambulatory biofeedback as seen by the interviewees.
	Lack of Credibility	The interviewees claim a lack of trust in confidentiality or accuracy.
Sub-question 4	Target group	A specific target group was mentioned for which ambulatory biofeedback can be of use
	Context	A specific context was mentioned in which ambulatory biofeedback can be instrumentalized
	Improvements	Specific suggestions towards improvement about ambulatory biofeedback, also in regard to the technical usability

Results

In order to answer the overarching research question in an extensive manner, the four sub-questions have been established and will be answered consecutively. In average, the interviews took 34.90 minutes (*SD*=9.17). The longest interview lasted 65.10 minutes, while the shortest one was finished after 24.48 minutes.

Scale for Wearable Technology Embodiment. The average score was 2.88 (*SD*= 0.14). The minimum score was 2.10, while the maximum score was 4.20. However, looking at the subscales, one can acquire more meaningful scores (See Fig. 6). These scores show that participants mostly utilised the watch for a cognitive extension which encompasses an increase of knowledge about the user's activity, help to learn more about the wearer's activity and a gain in understanding of the wearer's activity by the smartwatch. The lowest average score was for Self-Extension, a factor which is related to the connection between the user’s personal identity and the wearable device.

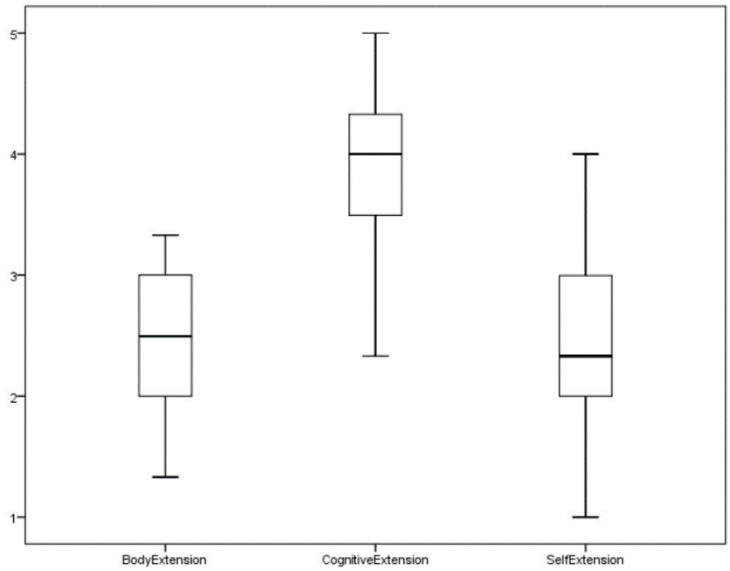

Figure 6. Boxplot for the three factors of the Scale for Wearable Technology Embodiment.

System Usability Scale. The average score on the SUS was 71.09 (*SD*=4.22), which indicates acceptance of the usability. A score of 71 approximately corresponds to a grade of C+. The lowest score was 45 and the highest score was 95. All participants except for one found the system at least acceptable. Figure 7 shows the given mean scores in comparison to the divisions of the SUS.

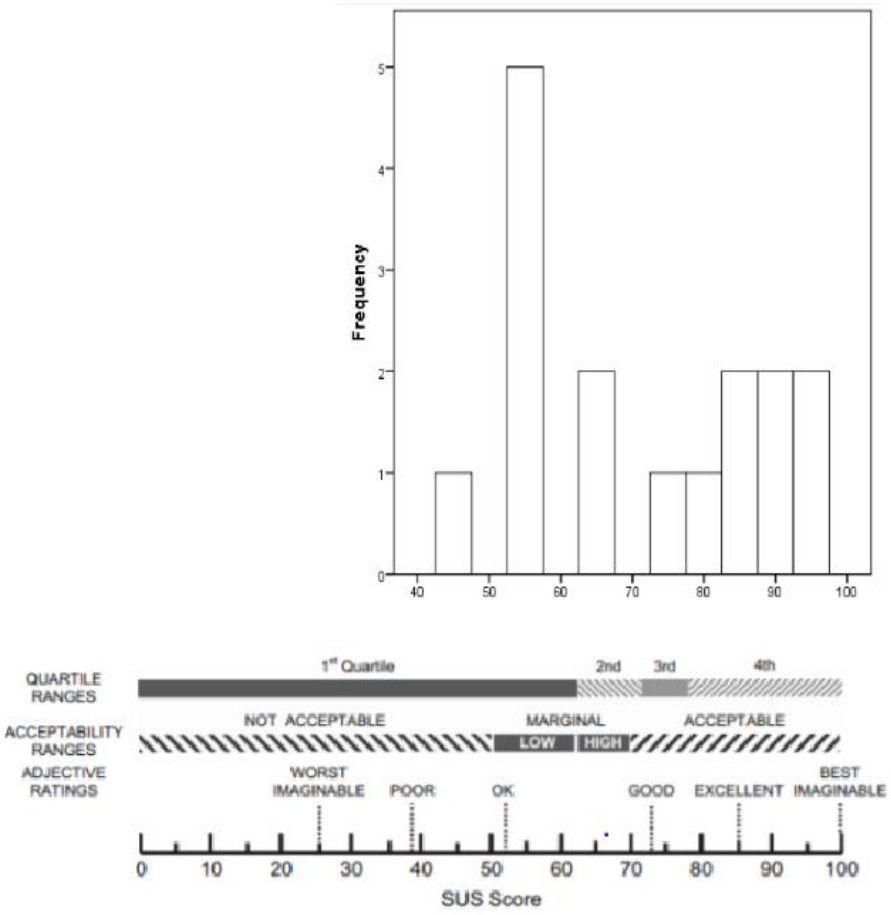

Figure 7. Mean scores in comparison to SUS score divisions.

As a general remark, all participants showed initial interest in the concept of ambulatory biofeedback prior to the study. All displayed a willingness to cope with the reception of biofeedback. This became particularly apparent in the initial phase when the participants had to get used to wearing the watch and the vibration. After overcoming this initial phase, which was marked by some insecurity, the participants pointed out that they had slowly become accustomed to biofeedback and were able to form their own opinion about ambulatory biofeedback.

Reactions

For four days, the participants wore a smartwatch that continually informed them about their heart rate. In those days, the vibration elicited various reactions in the participants. These reactions have been divided into three categories, namely acknowledge, adapt and ignore. There has been a total of 101 statements that were categorised as reactions. Reactions already yield first insight into the usefulness of ambulatory biofeedback for students. The

responses can be dependent on the student's personal preferences and might also be influenced by the circumstances a student finds himself in. Some participants have for instance found themselves in situations where they would have liked to react to the feedback but could not do so as the situation did not allow for it.

Ignore. The code of ignoring was used when the participant voluntarily decided to not pay attention to the vibration. This was indicated by four participants on eleven occasions (10.89%) Those four participants also displayed a rather negative attitude towards biofeedback and additionally stated a lack in the trustworthiness. Since ignoring usually did not occur within the first days, but only towards the end of the trial days, it can be assumed that this response results from a negative attitude towards ambulatory biofeedback or the device. Participant 15 for instance, stated that there was no value in the vibration for him as he did not perceive it as correct.

> *"When I got the vibration, I did not really paid attention to it anymore. It was not that supportive, there was not really a lot of extra value, it just kept vibrating all the time. [...]Well, I didn't really pay a lot of attention to it. Mostly I ignored it, because I said "yeah, this is not true!"."*

Acknowledge. A reaction fell into the category of acknowledging when the participant indicated that he attended the watch when it vibrated and afterwards at least tried to make sense of the change in the heart rate that has been indicated by the vibration. All participants have acknowledged the information provided by the watch at least at the beginning of the trial. Acknowledgement was the main reaction to the vibration, being coded 61 times (60.40%). However, there have been nuances in the processes of acknowledgement. While some only scanned their internal world, others also took external environment into consideration. Participant 8 stated that she always tried to connect the vibration to her mindset, too. Earlier she has shared her assumption that emotions and physical activity are very closely linked.

> *"And then other times when it was vibrating, and I just like had to think about what happened. And like I kind of like get into my head and see what's going on now. So I just think about the last minute or so that happened. And like I tried to analyse how I felt about what happened."*

Some participants have moreover stated, that it was not always easy or effortless to find a valid reason for their change in heart rate. Participant 9 stated that this was sometimes also quite difficult to handle as it frequently challenged the participants to find a reason for the vibration. Another participant stated, that making sense of the vibration has not always been easy because of the ambiguity of the heartbeat. Due to this ambiguity, he was not always sure whether he actually found the valid reason for the acceleration of the heartbeat. Nevertheless,

the participants tried to overcome this hurdle and attempted to make sense of the biofeedback which they have received via the watch.

> *"But sometimes I really couldn't find an explanation for it. And that got me a bit in the other direction like a bit frustrated because it vibrated, and I didn't find any clue why I would have a high heart rate now."*

Adapt. Lastly, a reaction has been categorised as adapt, when the participant stated that he or she voluntarily changed his behaviour in order to bring the heart rate back to a normal level. This code has been used 29 times (28.71%). In order to achieve this goal, the participants have engaged in various strategies, including breathing techniques, telling themselves to calm down and also leaving the specific situation. Adaptation in response to the ambulatory biofeedback has been indicated by ten participants. Adaptation mainly occurs when the participant was certain of the origin of stress and has therefore been able to actively reduce the source of stress or counteract it. Participants who adapted their behaviour as a response to the biofeedback have also scored higher on the scale for wearable technology embodiment, which can be regarded as an indicator of trust in the technology. Exemplarily, Participant 4 stated

> *"I used to breathe special, maybe closing the eyes and also used to leave the situation, so like to go somewhere where you're not in a stressful environment."*

Attitudes

The second research question was concerned with attitudes that the participants have developed towards the reception of biofeedback. With regards to attitude, it became obvious that some participants have based their attitude on the combination of the Sense-IT and the concept of ambulatory biofeedback and did sometimes not express their attitude towards the concept itself. The codes that have been developed are a positive attitude, neutral attitude and lastly negative attitude. In these codes, there is yet a high variability of evaluation. Overall, it can be stated that only two participants displayed a solely negative attitude towards the reception of ambulatory biofeedback. However, there have been three participants who did express a solely positive attitude. For some participants, their attitude towards ambulatory biofeedback evolved during the trial days. This evolvement occurred from a negative to a positive attitude, as well as from a positive attitude towards a negative one. There have been 115 statements that fell into a code that is associated with attitude.

Positive. An attitude has been considered positive, when the participant stated that they consider biofeedback as helpful, fun, interesting, useful, reassuring or valuable, but also when participants stated that it raises awareness. Due to various overlaps and the breadth of these

attributes, an all-encompassing code for positive evaluation has been established. This code was used 78 times (66.10%). Participant 10 stated that he perceived biofeedback as a reassuring method to quantify his emotions, but that receiving the biofeedback can also be reassuring, as it can indicate that everything is fine and functions as it is supposed to. Moreover, this participant stated that biofeedback has helped him to place himself on a map of his emotions, which he perceived as very helpful. This mapping has also been helping the participant to instrumentalize the feedback and to act according to it, by for instance going somewhere else. Mapping seems to be an indicator for increased awareness of the internal states, as the user is able to classify and consciously distinguish his current internal state. Participants who evaluated ambulatory biofeedback as positive were generally more likely to adapt their behaviour in response to the feedback.

> *"So I absolutely see the use in this technology because you kind of can acknowledge your current state of mind and as I said just map yourself where you are and just be like: Ok Let me go somewhere else. Let me get into a more positive or less energizing area and I think the location is really key. So it helps. Definitely helps you locate on the map."*

The main positive attribution was that participants found it helpful in raising awareness of their internal states and activities. This is also reflected in the scores on the subscales for wearable technology embodiment. Overall, participants have scored highest on the subscale of cognitive extension, which entails increasing awareness about activities. Participant 13 mentioned that it helps to refocus on your body in between the daily duties and that this focus also helps to possibly adapt the behaviour. Using the ambulatory biofeedback as a support for refocusing can be highly beneficial for students in the face of overstimulation.

> *: "Oh yeah definitely awareness. I think it's for many people the case that during their everyday lives, they are just doing what they have to do, and they go to work and they go shopping and stuff and I think in between they never really focus on their body. So I think that's I think the main strength is that it helps you to be aware and then to act on it."*

Neutral. An attitude was coded as neutral when the participant display impartiality towards ambulatory biofeedback. This has not occurred frequently; it was only coded five times (4.24%). Impartiality was indicated only by participants who have not experienced any stress throughout the trial days. Participant 5 stated

> *"it didn't really change anything in my state. Uh didn't really give me something or some emotions. It was just like a kind of reminder that my heart rate is now a bit off. But generally didn't really feel anything towards the watch".*

In line with this, Participant 1 claimed that biofeedback has not been significant enough to make a major difference in his daily life. Moreover, Participant 11 considered ambulatory biofeedback as a nice luxury gadget to own but that there was not sufficient value in order to

continue wearing the watch. All participants who have displayed a neutral stance, have indicated beforehand that they do not experience stress often and consider themselves to be of a calmer nature. Neutrality can possibly also stem from a general disengagement with bodily signals. If this is the case, there is a possibility for individuals with similar characteristics to use ambulatory biofeedback to become more engaged with their bodies.

Negative. Responses were considered negative when the participant stated issues with the watch to the extent of not feeling capable to use the assets of the watch anymore or perceived the biofeedback as burdensome. In total, this code has been used 35 times (29.66%). However, there were only two participants who assumed a full negative stance. Participant 8 stated that from her experience, she perceived biofeedback as something confusing rather than helpful. In her case, this was due to significant deviations between the biofeedback and the perceived state of her body, which has left her feeling out of touch with her body. This perception is not in line with the connection she usually claims to have with her body, she, therefore, blamed the ambulatory biofeedback for this unpleasant feeling and thus developed a negative attitude. For Participant 9 the negative evaluation mainly stems from the dependence on technology. She stated that for her, her mobile phone is a stress-inducing factor for her and now she had to carry her phone with her.

> *P:"I know that with the biofeedback you always need some kind of a phone or at least Bluetooth connection to receive messages and stuff and I would see this as a weakness because this is why I get stressed a lot of times because of my phone and because of the Internet and because of no messages, I get a lot of stress. So I think I would see this as a weakness to always need your phone with you.*
> *I: Oh, because you kind of have to carry the source of stress on you?*
> *P: Yeah, exactly. So I don't like it."*

Other participants experienced it as annoying in some situations but did not feel negatively affected by it. Some participants complained that the watch vibrated too many times and therefore, even perceived the ambulatory biofeedback as distracting in some moments. In the trials, the participants were free to adapt setting so the frequency of the vibration would be reduced, but not all participants made use of this. For some participants, the attitude towards ambulatory biofeedback has also evolved throughout the trial days. First, they thought the ambulatory biofeedback was very nice, but towards the end of the trials, they perceived it as annoying.

Criticism

The third research was concerned with the criticism that the participants voiced towards the biofeedback or the device. Three codes were developed for this, namely technical shortcomings, risks and lack of credibility. These categories were corresponding with the nature of criticism that was voiced. Overall criticism was articulated in 71 statements by all participants. In contrast to the negative attitude, criticism pinpoints specific shortcomings, while the attitude is a more overall feeling. Therefore, different codes have been developed.

Technical Shortcomings. This code was used, when a participant criticised the technology behind the biofeedback rather than the concept of itself. A total of 26 statements (36,61%) referred to technical shortcomings. However, in regard to the entry question whether there have been any technical problems, only three participants talked about major technical problems. Many of the articulated criticism was concerned with the battery of the watch. Participants frequently complained about the short battery life and that they had to charge the smartwatch multiple times in order to use it throughout the day. This has been perceived as burdensome as the participants had to constantly keep the battery in mind. Furthermore, Participant 1 criticised the app itself, stating that there is room for improvement in the usability. This participant yet scored 75 on the SUS, which indicates a good usability.

> *"But can I be honest, the app itself, I think there is room for improvement. Like the legibility of the screen was not good. But also for the functioning, because it was not so appealing and so I might have missed some interesting information."*

Risks. This code was used when a participant saw existing or potential risk in receiving biofeedback via a smartwatch. Seven of the 16 participants have pointed out risks that they see. This code has been used 19 times (26.76%). Participant 1 and Participant 10 were mainly concerned with the risk of data usage by third parties. The Sense-IT does collect very personal data, i.e. the user's heart rate. Moreover, users have the possibility to enter notes, that can potentially contain very personal information. Additionally, the application is installed on a watch which in turn is connected to a smartphone. Therefore, there are numerous personal data that could possibly, accessed by third parties, if not sufficiently secured,. Participant 1 said:

> *"What I think is problematic with biofeedback is that it might provide a lot of information on yourself, because those watches connect your location activities and all that stuff, like there is a lot of information you may want don't want other people to know of you. So well, if there are some issues with data safety then you could have some kind of problem."*

This statement mainly addresses the richness of gathered data, which is not necessarily associated with the primary goal of the application that could potentially be given to third

parties. This perceived risk can substantially influence the use of a technical device, as users might be more hesitant to fully integrate it in their lives. Another origin of risks lays in the interpretation of biofeedback. Three participants have voiced the risk of potentially becoming too dependent on external feedback and to lose autonomy. While acknowledging its initial helpful character, they saw the risk of losing their ability to read their own bodily signals in the long term.

In line with this, Participant 14 said:

> *"Because I don't think that the inferences that I made for example are always truthful for the most part, but that there are even more complex things going on in our body. And I think that if we kind of like overestimate the value of biofeedback then it gets kind of critical because we assume that the watch can know us better than we can ourselves."*

These statements show that students do value their own autonomy and do not want to become fully dependent on a mobile device. Thus, there seems to be a fine line between a helpful tool and an addictive device. Moreover, the current version of the Sense-IT uses only the heart rate as its first source of input. While the heart rate gives important insights into internal states, it cannot always represent the entire complexity of all processes that lead to changes in the heart rate. Students seem to, therefore, find it crucial to acknowledge the limitations of biofeedback and to not regard biofeedback as a replacement for own assessment.

Lack of credibility. This code describes any statement that indicated a lack of trust or credibility in either the technology or the concept of biofeedback based on heart rate. In total, this code has been used 26 times (36.62%). Six participants demonstrated a lack of credibility. Participant 15, for instance, said that he interpreted unexpected measurements simply as mismeasurement and that this happened frequently to him. He proceeded by saying:

> *"I felt it was a little bit more a joke because it really wasn't trustworthy. So I couldn't do anything with the information.".*

In line with this, Participant 8 pointed out that whenever she could not attribute her high arousal to any specific stimulus, she started to doubt the watch. She also claimed that she completed the base measurement twice because she felt that something was wrong. However, she softened her tone by saying that this doubt was probably irrational. Four out of the six participants who addressed the lack of credibility in their interview have scored below average on the scale for wearable technology embodiment, in particular on cognitive extension. It might result, that ambulatory biofeedback is perceived as more credible when wearable technologies are understood as a method for cognitive extension.

Potential

The last research questions assessed the potential that college students see in ambulatory biofeedback. Three codes have been developed in order to answer this research question, namely target group, improvement and context. These codes were applied whenever a participant indicated that the usability of ambulatory biofeedback could be increased by using it either for a different target group, in a different context or by overcoming some drawbacks. In total, there have been 63 statements by all participants in regard to the potential of ambulatory biofeedback.

Target Group. This code was used when a participant specified one group of individuals that might benefit from ambulatory biofeedback, there have been 19 statements (30.16%) about potential target groups. These target groups could be identified very precisely, as for instance Participant 13 did. She pointed to patients with Borderline Personality Disorder, a disorder characterised by a lack of emotional awareness and difficulties regulating their emotions. She also stated that the biofeedback might hold valuable information not only for the patient himself but also for the caretaker. Another well-defined target group that has been pointed out several times were students. The participants who were all students themselves identified students as a group that can benefit from biofeedback, particularly in the state of stress. Moreover, participants voiced that students can benefit from the self-awareness raising property of the watch, as they considered self-awareness to be an important skill. Some participants stated that ambulatory biofeedback can help students to break out of unhealthy regular routines and can thereby contribute to their personal health. Lastly, Participant 8 considered students as a highly stressed population and that biofeedback could help to cope with this stress, by raising awareness.

> *"So if we would have gained that awareness of our stress like earlier I think it's way easier to deal with that. So if you get biofeedback you can deal with stress as it occurs and otherwise it just builds up and piles up."*

Other target groups were more broadly defined, such as people with coronary diseases or elderly people.

Context. This code was used when participants indicated a context or an environment in which ambulatory biofeedback can be instrumentalized. The code has been used 16 times (25.40%)While there is arguably some overlap with the target group, this code does not take characteristics of the wearer into consideration but solely the context they find themselves in. The context that has been articulated the most was sports. Some participants have also been voluntarily wearing the watch during sports during the testing days. They all experienced this as very interesting and actively played with their heart rate during training.

In line with this was the statement of Participant 11 who pointed out:

> *"When I go sporting and I could pay attention to my heart rate and see if I am really training and I'm working out to see if my heart rate was lowered, the more amount of times that I train or something like that."*

Another context that was mentioned frequently was a stressful environment, particularly at work. All students stated that, if they have perceived a stressful situation, the ambulatory biofeedback has helped them to become more aware of this stress and to actively counteract their high arousal. As stress and the neglect of attention to the body often go hand in hand, ambulatory biofeedback can be particularly valuable to bring back the attention to the body in stressful situations. In this context, ambulatory biofeedback has, for instance, helped Participant 2 to take a little break and try to calm down during a busy working day.

> *"For example, while doing my work and I'm working at a restaurant and it is always pretty busy, so I tried to calm down for a few seconds [after receiving the cue]."*

Improvement. This code was used when an interviewee suggested a specific development or attribute that could increase the value of ambulatory biofeedback or the use of the technical device. Twelve participants have voiced those suggestions, in a total of 28 statements (44.44%). Some participants stated that they would appreciate a smaller device. This improvement can be particularly relevant for users who are not used to wearing watching or similar accessory, as they find a watch distracting or eye-catching. In line with this, Participant 6 said:

> *"But I think the thing should be smaller, maybe like a little bracelet or something, then I would like to keep it forever".*

Participant 15 wished for a design, where the watch states the exact heartbeat rather than a level of the heartbeat. He felt that he would not get sufficient information from seeing only bubbles as he then still had to learn what these bubbles indicate. Therefore, he wished for a more straightforward indication of the heart rate. Other participants also voiced their wish for a more unequivocal design. Another improvement that has been wished for frequently was that the watch does not vibrate every time when heart rate is high, but to combine the measurement. The participants have all said that in a phase of high arousal, it was not necessary to be informed about their heart rate frequently, but that it would have been sufficient to receive another feedback when the heart rate has been normalised again. In this context, Participant 14, for instance, pointed out:

> *"I think they should like integrate a function that it does not beep all the time. But then when you have reached a peak that it kind of shuts off for two minutes".*

The improvement that has been articulated the most, however, was that the watch should not only make aware but then provide some instructions on how to bring the heart back to a normal level. Participant 8 said that she would have liked a device that gives advice rather than just awareness. While the personal preferences about the exact instructions differentiated slightly, the emphasis was always that the instructions should be small and easily integrable into daily life, so that everybody has the possibility to follow the instruction without drawing too much attention to it. In line with this, Participant 2 said:

> *"Maybe get some tips from the watch, like now, take a deep breath. Or now close your eyes for 10 second. Something that can any everybody do, at any time in the life. So small things maybe or just sit down something like this or some little instructions."*

Incorporating small possible techniques to regulate the heart rate can offer the user of ambulatory biofeedback direct ways of acquiring more beneficial coping mechanisms. These instructions have to fulfil two criteria. Firstly, they can be carried out without being too disruptive to the daily activity and secondly, they should not require extensive previous knowledge about those techniques, as this might alienate an inexperienced user.

Discussion and Conclusion

The aim of this study was to explore students' attitudes and their individual reactions to the reception of ambulatory biofeedback in their daily lives, as students represent a possible future target group for ambulatory biofeedback. Particularly in stressful times, that students encounter frequently, biofeedback can help them to become more aware of their bodily signals again (Yu, 2018; Ratanasiripong, Sverduk, Prince, & Hayashino, 2012). This awareness, in turn, can help students to respond more adaptively when facing stressful stimuli. Overall, this novel study yields first important insights in how students perceive ambulatory biofeedback, which can serve as a basis for future developments. In the following, the respective will be discussed.

The first sub-questions explored the various reactions that the participants expressed when receiving the biofeedback. An overall trend of willingness to work with the provided information about their heart rate has been detected. By acknowledging and adapting feedback, students indicated their openness to this comparatively new technology, which is line with what Tully found in a study about implementing technologies in young target groups (2003). By acknowledging the biofeedback, students can become more responsive to their internal feedback in the long run, as they are continually made aware of their internal states. As proposed by Birk and Bonanno (2016), a high responsiveness to internal feedback can

eventually lead to improved coping strategies when facing stressful situations. While ambulatory biofeedback cannot directly reduce the environmental stressors, it can help students to cope with those stressors more efficiently by becoming better at regulating the physical aspects of emotions (Peira, Pourtois, Fredrikson, 2013). Therefore, when students are willing to integrate ambulatory biofeedback in their daily lives, by using the Sense-IT app, they are likely to benefit from the positive consequences, including increased performance and better well-being (Crocket, Gill, Cashwell, & Myers, 2017). For this particular study, one participant also approached the researcher and stated that after the trial days, he continued to engage in the strategies that he used during the testing days to regulate his heart rate. This certainly indicated the willingness of this particular student to work with the information provided by ambulatory biofeedback. Overall, the open reaction towards biofeedback can be regarded as an important prerequisite for future interventions.

The second sub-question evaluated the attitude, participants hold towards ambulatory biofeedback. It was found that most students perceive ambulatory biofeedback as positive, as indicated by approximately two-thirds of all attitude-related statements. Almost all participants thought of ambulatory biofeedback as something interesting and helpful in becoming more attentive to their body. This finding can be supported by a study by Ratanasiripong (2016), that showed students' overall acceptance of biofeedback training in a college counselling centre. In another study, the value of biofeedback has also been indicated by the continued use of biofeedback and the perceived benefits for the participants (Beckham, Greene, & Meltzer-Brody, 2012). Students in this study have commonly stated to appreciate the increased awareness of their internal state, which, as already indicated in the introduction, can increase our mental well-being (Gross & Muaoz, 1995), particularly when exposed to over-stimulation. However, there have been some concerns in regard to ambiguity and abundance of information. Ambulatory biofeedback has been perceived as irritating by some participants, as it left some participants insecure about their capability to detect their bodily signs correctly. In the human body, an increased heartbeat can be traced back to various origins. An increase can have a purely physical origin, but it can also be of a psychic origin (Kriebig, 2010). The valence of the stimulus cannot always be identified either, because both positive and negative excitement cause an increased heart rate. These attributes can lead to insecurity and eventually contribute to a negative attitude.

The third sub-question explored criticism that was voiced about ambulatory biofeedback via the Sense-IT. In order to answer this research question, the participants were asked to assess the usability of the Sense-IT, by using the SUS. While the system usability has

been overall perceived as acceptable, there is still room for improvement. The criticism in regard to the usability has to be cautiously assessed, since neglecting the needs of users can have a negative impact on the compliance to mHealth applications (Derks, de Visser, Bohlmeijer, Noordzij, 2017). In line with this, the score for Self-Extension, which reflects the connection to the user's identity, has been the lowest score on the Scale for Wearable Technology Embodiment. A diminished connection to the user's identity can stem from too little customizable features. Thus, this score can be increased by integrating more customizable features to improve the connection between the device and the user's identity (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019). In regard to the scores for the Scale for Wearable Technology Embodiment, it is thought-provoking that despite wearing the watch on their body and receiving information on their very own body, participants did not score high on self or body extension. As this scale is still comparably new, exact interpretation and application, remain to be determined. It is possible that the three individual factors gradually build on each other and cognitive extension is the precondition for the other two extensions. Possibly, the wearer must first attribute a value to the wearable technology before a thorough embodiment is achievable. In this case, a high level of cognitive extension is indispensable for a complete embodiment and must, therefore, be guaranteed, which could not be ensured in four days.

Another important criticism has been the perceived risk of losing autonomy and becoming too dependent on the information provided by the watch. Ambulatory biofeedback can be integrated in the daily life of students, which by no means signifies that it should remain unnoticed. In contrast, continuous monitoring can be guiding the user in his daily activity, which can potentially be regarded as a limitation to autonomy and independence. This criticism is possibly related to the characteristics and personal preferences of the user. Nevertheless, this criticism is important to consider in further developments, as the maintenance of the wearer's autonomy and independence belongs to the ethical challenges of continuous health monitoring (Gilmartin et al., 2018). As indicated in the introduction, many students are still forming their identity, values and self-image, a process that could be significantly influenced by a perceived lack of independence and autonomy. Therefore, a critical assessment of the exact level of required guidance is indispensable.

The fourth sub question examined what potential college students see in ambulatory biofeedback. One important finding suggests that the interviewed students do consider the student population as a potential target group for ambulatory biofeedback interventions. Students acknowledge that they are frequently stressed. Moreover, they indicate that they

often lack awareness of their internal states, especially when they are stressed or overstimulated. In stressful situations, the Sense IT and the associated ambulatory biofeedback can find an important application, as it increases the students' awareness of their internal states. This finding is particularly crucial as it serves as a basis for future interventions with students.

One more main result from the fourth questions yields at improvements that were stated by the college students. While there have been some suggestions to improve the design of the app, the most mentioned proposition was to include instructions on how to regulate the heart rate. Such instructions have been perceived as positive in a previous study, where it was found that biofeedback-assisted relaxation techniques, such as special breathing, have been perceived as helpful (Reiner, 2008). Moreover, short meditation can help to stabilize the ANS, as well as raising mood and diminishing symptoms of anxiety (Yu, 2018). A more balanced ANS can ultimately lead to more controlled emotional responses since these components are closely linked (Kriebig, 2010). These assets can be highly beneficial for college students who experience high levels of stress. Thus, it appears advantageous to integrate aforesaid instructions in order to increase the value of ambulatory biofeedback and the Sense-IT app for college students. However, provided instructions should not jeopardise the autonomy and self-determination of the user by exaggerated intervention in everyday life. Once more, the level of guidance should be assessed before implementing instructions.

Overall, it can be assumed that the positive effects of biofeedback, including improved well-being, that have been identified by Crocket, Gill, Cashwell and Myers (2017) for clients in the mental health environment, are also applicable for college students and other stress associated groups. This finding is also in line with the findings of Chaló et al. (2017) who found that static biofeedback sessions can significantly reduce stress in college students. College students in this study have assumed a positively open stance towards ambulatory biofeedback. However, the presentation of ambulatory biofeedback requires further revision to be fully valuable and usable for a non-clinical target group.

Implications for further research and further development

From the present study, it can be argued that some improvements in the design of the Sense-IT can further increase the value for college students. A very interesting point to consider is that many young people are stressed because of their mobile phone and the perceived need of always being accessible (Thomée, Härenstam and Hagberg, 2011), so it appears contradictory to become more reliant on the mobile phone for ambulatory

biofeedback. Therefore, it might seem advantageous to develop a standalone app on a smartwatch, that does not require any connection to the phone. By designing a standalone application, the problem of losing the connection between the phone and watch would also be conquered.

There are further aspects of the design of the app that can be improved. The current design has been developed with a clinical target group, however, non-clinical users might have different preferences and needs. As mentioned above, not sufficiently taking the needs of users into consideration can diminish the coherence to mHealth applications (Derks, de Visser, Bohlmeijer, Noordzij, 2017). During the interviews, multiple participants have criticised the current design and wished for some improvements. Therefore, it is advisable to take the specific needs and preferences of students into account and to allow more customizable features that are in line with those needs, when developing future interventions based on the Sense-IT for this specific target group. It is likely that an improved design will ultimately lead to higher scores on the respective factors of the scale for wearable technology embodiment, which in turn might be a prerequisite for sufficient coherence. A natural progression of this work is to analyse the specific needs of non-clinical target groups. One major advancement in the design and functionality of the app could include instructions for techniques to regulate the heart rate (Reiner, 2009), as the lack thereof represents a frequently voiced criticism. This is in line with the finding that instructions on breathwork can support the development of more adaptive responses to psychological and physiological stimuli that occur in stressful situations (Crocket, Gill, Cashwell, & Myers , 2017).

Finally, it can be stated that ambulatory biofeedback has the potential to elicit positive effects in non-clinical environments, too. The Sense-IT, as an exemplary tool for providing ambulatory biofeedback, can be used in future interventions that aim at increasing students' well-being. The development of technologically based interventions is already advanced. Ambulatory biofeedback can possibly join the ranks of these interventions, as it can establish the link between technology and human skilfully, without any invasive methods. It, therefore, seems reasonable to improve the presentation of ambulatory biofeedback further, for example by enhancing the usability of the Sense-IT App. In this process, however, the needs and freedoms of the respective target groups must by no means be neglected. Future research can design and test specific interventional programs that are well-adapted to the requirements of a comparable stress-associated, non-clinical target group.

Strengths and limitations

While there are numerous studies on static biofeedback in clinical and medical settings (Huang, Wolf, & He, 2006; Travers et al., 2017), this research offers novel insights into the reception of ambulatory biofeedback in a non-clinical environment. The findings of this study offer a foundation for future developments and possible interventions outside the clinical context. By interviewing 16 participants, the researchers were able to gather rich data that provides unique, in-depth knowledge about ambulatory biofeedback in non-clinical environments. Another strength is presented by the semi-structured interview study design. This has additionally facilitated the process of gathering rich and detailed information about the participant's perspectives and experiences on ambulatory biofeedback (Bambusch, 2010). In the context of an interview study, another strength is presented by the positive private relationships between the researchers and the participants. These relationships guaranteed a strong foundation of trust. Trust can be regarded as a crucial prerequisite for open disclosure of thoughts and emotions in interviews (Wilson, 2014). During the interview, participants have been asked in which situations they perceived the biofeedback as particularly relevant. As a response, participants often talked about very personal situations. Because of this open disclosure, the interviews have been more fruitful and have delivered more sophisticated insights, that would be lacking without a foundation of trust.

However, personal relationships can also lead to a bias in the gathered data. Participants might have fallen prey to the social desirability bias. This bias can, for instance, occur if the interviewee assumes expectations from the interviewer (Krumpal, 2011). In this case, the interviewees might have perceived the need to express a positive attitude towards the concept and were more hesitant to express their reluctance. Another limitation is presented by the high homogeneity of the sample, consisting of almost only German Psychology students, from the same university. Students from this field of studies are likely to have already acquired more extensive knowledge about internal states or the link between stress and well-being. However, students from other universities or more technical focussed studies might have a very different attitude towards the reception of ambulatory biofeedback. While they might lack prior knowledge, they are possibly highly interested in the technology itself, and therefore according to Roger's Diffusion of Innovation Theory (2003), more willing to work with it. Thus, generalizations of the findings have to be carried out cautiously.

Conclusion

Taken together, this study provides novel insights into the attitudes of students and their reactions to the reception of ambulatory biofeedback in their daily lives. While students appear to be open towards working with ambulatory biofeedback, some adaptations in regard to the usability, self- and body extension. These adaptations can further increase the value of ambulatory biofeedback for a stressed associated group as represented by students. The acquired insights can further be used as a basis for the future development of the app itself, as well as interventions that use ambulatory biofeedback.

References

Austad, C. S., & Gendron, M. S. (2018). Biofeedback: Using the power of the mind–body connection, technology, and business in psychotherapies of the future. *Professional Psychology: Research and Practice,49*(4), 264-273. doi:10.1037/pro0000197

Bamber, M. D., & Schneider, J. K. (2015). Mindfulness-based meditation to decrease stress and anxiety in college students: A narrative synthesis of the research. *Educational Research Review,18*, 1-32. doi:10.1016/j.edurev.2015.12.004

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An Empirical Evaluation of the System Usability Scale. International Journal of Human-Computer Interaction, 24(6), 574–594. https://doi.org/10.1080/10447310802205776

Beckham, A., Greene, T., & Meltzer-Brody, S. (2012). A pilot study of heart rate variability biofeedback therapy in the treatment of perinatal depression on a specialized perinatal psychiatry inpatient unit. *Archives Of Women's Mental Health, 16*(1), 59-65. doi: 10.1007/s00737-012-0318-7

Birk, J. L., & Bonanno, G. A. (2016). When to throw the switch: The adaptiveness of modifying emotion regulation strategies based on affective and physiological feedback. Emotion, 16(5), 657–670. https://doi.org/10.1037/emo0000157

Chaló, P., Pereira, A., Batista, P., & Sancho, L. (2017). Brief Biofeedback Intervention on Anxious Freshman University Students. *Applied Psychophysiology And Biofeedback*, *42*(3), 163-168. doi: 10.1007/s10484-017-9361-5

Crockett, J. E., Gill, D. L., Cashwell, T. H., & Myers, J. E. (2017). Integrating Non-Technological and Technological Peripheral Biofeedback in Counseling. *Journal of Mental Health Counseling*, *39*(2), 163–179. https://doi.org/10.17744/mehc.39.2.06

de Bruin, L. (2017). *Sense-IT Designing a therapists specific section of the app by the therapists mental model of emotion and an user centered design model* (Master). University of Twente.

Derks, P. M. J., De Visser, T., Bohlmeijer, E. T., & Noordzij, M. L. (2017). mHealth in Mental Health: How to efficiently and scientifically create an ambulatory biofeedback e-coaching app for patients with Borderline Personality Disorder. *International Journal of Human Factors and Ergonomics*, *5*(1), 61–92.

Derks, Y., Klaassen, R., Westerhof, G., Bohlmeijer, E., & Noordzij, M. (in press). Development of an Ambulatory Biofeedback App to Enhance Emotional Awareness in Patients with Borderline Personality Disorder: A Multi-cycle Usability Testing Study (Preprint). doi: 10.2196/preprints.13479

Forshaw, M. (2013). *Your undergraduate psychology project* (2nd ed.). Hoboken, N.J.: John Wiley and Sons, Inc.

Fram, S. M. (2013). The Constant Comparative Analysis Method Outside of Grounded Theory. The Qualitative Report, 18(1), 1-25. Retrieved from https://nsuworks.nova.edu/tqr/vol18/iss1/1

Frankenhaeuser, M., Nordheden, B., Myrsten, A., & Post, B. (1971). Psychophysiological reactions to understimulation and overstimulation. *Acta Psychologica*, *35*(4), 298-308. doi: 10.1016/0001-6918(71)90038-2

Gilmartin, C., Arbe-Barnes, E., Diamond, M., Fretwell, S., McGivern, E., Vlazaki, M., & Zhu, L. (2018). Varsity medical ethics debate 2018: constant health monitoring - the advance of technology into healthcare. *Philosophy, Ethics, And Humanities In Medicine*, *13*(1). doi: 10.1186/s13010-018-0065-0

Glaser, B. G., and Strauss, A. L. 1967. The Discovery of Grounded Theory: Strategies for Qualitative Research, Chicago: Aldine.

Gross, J. J., & Muaoz, R. F. (1995). Emotion Regulation and Mental Health. Clinical Psychology: Science and Practice, 2, 151–164. https://doi.org/10.1111/j.1468-2850.1995.tb00036.x

Houser, M. M., Rosen, L., Seagrave, M. P., Grabowski, D., Matthew, J. D., & Craig, W. A. P. (2013). Exercise heart rate monitors for anxiety treatment in a rural primary care setting: a pilot study. *Family Medicine*, *45*(9), 615–21. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/24136691

Huang, H., Wolf, S., & He, J. (2006). *Journal Of Neuroengineering And Rehabilitation*, *3*(1), 11. doi: 10.1186/1743-0003-3-11

Jordan, P., Thomas, B., McClelland, I., & Weerdmeester, B. (1996). *Usability Evaluation in Industry* (pp. 189-194). Taylor & Francis.

Kern, S. (2019). *How to reduce the arousal in daily life by means of the Sense-IT ambulatory feedback app?* (Master). University of Twente, Enschede.

Kreibig, S. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology*, *84*(3), 394-421. doi: 10.1016/j.biopsycho.2010.03.010

Krumpal, I. (2011). Determinants of social desirability bias in sensitive surveys: a literature review. *Quality & Quantity*, *47*(4), 2025-2047. doi: 10.1007/s11135-011-9640-9

Lewis, P., Chandra, A., Faniyi, F., Glette, K., Chen, T., & Bahsoon, R. et al. (2015). Architectural Aspects of Self-Aware and Self-Expressive Computing Systems: From Psychology to Engineering. *Computer*, *48*(8), 62-70. doi: 10.1109/mc.2015.235

Mauss, I. B., Levenson, R. W., Mccarter, L., Wilhelm, F. H., & Gross, J. J. (2005). The Tie That Binds? Coherence Among Emotion Experience, Behavior, and Physiology. *Emotion*,*5*(2), 175-190. doi:10.1037/1528-3542.5.2.175

Nelson, E., Verhagen, T., Vollenbroek-Hutten, M., & Noordzij, M. (2019). Is wearable technology becoming part of us? Developing and validating a measurement scale for wearable technology embodiment. *JMIR Mhealth And Uhealth*. doi: 10.2196/12771

Peira, N., Pourtois, G., & Fredrikson, M. (2013). Learned Cardiac Control with Heart Rate Biofeedback Transfers to Emotional Reactions. *PLoS ONE, 8*(7), e70004. https://doi.org/10.1371/journal.pone.0070004

Price, C., & Hooven, C. (2018). Interoceptive Awareness Skills for Emotion Regulation: Theory and Approach of Mindful Awareness in Body-Oriented Therapy (MABT). *Frontiers In Psychology*, *9*. doi: 10.3389/fpsyg.2018.00798

Price, C., & Thompson, E. (2007). Measuring Dimensions of Body Connection: Body Awareness and Bodily Dissociation. *The Journal Of Alternative And Complementary Medicine*, *13*(9), 945-953. doi: 10.1089/acm.2007.0537

Ratanasiripong, P., Sverduk, K., Prince, J., & Hayashino, D. (2012). Biofeedback and Counseling for Stress and Anxiety Among College Students. *Journal of College Student Development,53*(5), 742-749. doi:10.1353/csd.2012.0070

Reiner, R. (2008). Integrating a portable biofeedback device into clinical practice for patients with anxiety disorders: Results of a pilot study. Applied Psychophysiology and Biofeedback, 33, 55-61.

Robson, G. (2016). The threat of comprehensive overstimulation in modern societies. *Ethics And Information Technology*, *19*(1), 69-80. doi: 10.1007/s10676-016-9414-0

Rogers, E. (2003). *Diffusion of Innovations*. Fifth edition. Free Press: New York.

Staunton, T. (2014). *Body psychotherapy*. London: Routledge.

Thomée, S., Härenstam, A. and Hagberg, M. (2011). Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults - a prospective cohort study. *BMC Public Health*, 11(1).

Travers, B., Mason, A., Mrotek, L., Ellertson, A., Dean, D., & Engel, C. et al. (2017). Biofeedback-Based, Videogame Balance Training in Autism. *Journal Of Autism And Developmental Disorders*, *48*(1), 163-175. doi: 10.1007/s10803-017-3310-2

Tully, C. (2003). Growing Up in Technological Worlds: How Modern Technologies Shape the Everyday Lives of Young People. *Bulletin Of Science, Technology & Society*, *23*(6), 444-456. doi: 10.1177/0270467603260812

Wiesche, M., Jurisch, M., Yetton, P., & Krcmar, H. (2017). Grounded Theory Methodology in Information Systems Research. *MIS Quarterly*, *41*(3), 685-701. doi: 10.25300/misq/2017/41.3.02

Wilson, C. (2014). Semi-Structured Interviews. *Interview Techniques For UX Practitioners*, 23-41. doi: 10.1016/b978-0-12-410393-1.00002-8

Yu, B. (2018). Designing biofeedback for managing stress Eindhoven: Technische Universiteit Eindhoven

Appendices

Appendix A

Approved Ethical Consideration

APPROVED BMS EC RESEARCH PROJECT REQUEST

Dear researcher,

This is a notification from the BMS Ethics Committee concerning the web application form for the ethical review of research projects.

Requestnr. :	190410
Title :	How Do College Students Interpret Ambulatory Biofeedback in Daily Life?
Date of application :	2019-03-27
Researcher :	Claussen, L.
Supervisor :	Noordzij, M.L.
Commission :	Klooster, P.M. ten
Usage of SONA :	Y

Your research has been approved by the Ethics Committee.

The ethical committee has assessed the ethical aspects of your research project. On the basis of the information you provided, the committee does not have any ethical concerns regarding this research project.

It is your responsibility to ensure that the research is carried out in line with the information provided in the application you submitted for ethical review. If you make changes to the proposal that affect the approach to research on humans, you must resubmit the changed project or grant agreement to the ethical committee with these changes highlighted.

Moreover, novel ethical issues may emerge while carrying out your research. It is important that you re-consider and discuss the ethical aspects and implications of your research regularly, and that you proceed as a responsible scientist.

Finally, your research is subject to regulations such as the EU General Data Protection Regulation (GDPR), the Code of Conduct for the use of personal data in Scientific Research by VSNU (the Association of Universities in the Netherlands), further codes of conduct that are applicable in your field, and the obligation to report a security incident (data breach or otherwise) at the UT.

-

This is an automated e-mail from My University of Twente.

University of Twente, Drienerlolaan 5, 7522NB Enschede, The Netherlands

Appendix B

Informed Consent

Informed Consent

"How Do college Students Interpret Ambulatory Biofeedback in Daily Life?

Researcher: Lena Claussen and Leonie Spitzer

To be completed by the participant

I declare in a manner obvious to me, to be informed about the aim, method, and procedure of the study. I know that the data and results of the study will be anonymized and treated confidentially. I am aware that all names, times and places will be removed. Citations may be used in the report, but the data is treated anonymously to the degree that my answers cannot be traced back to me. I know this study takes place in a learning environment and therefore I am aware that the data will be seen by other students and teachers of the University of Twente. My questions have been answered satisfactorily.

I am aware that the study will be recorded. I understand that the audio file thereof will be used only for analysis and scientific presentations.

Taking Part in the Study

Please tick the appropriate boxes

	Yes	**No**
I have read and understood the study information or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
	Yes	**No**
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○

Name participant:

.....

Date: .....

Signature participant:.....

To be completed by the executive researcher

I have given a spoken and written explanation of the study. I will answer remaining questions about the investigation. The participant will not suffer any consequences in case of any early termination of participation in this study.

Name researcher:

.....

Date: .....

Signature researcher: .....

Appendix C

Scale for Wearable Technology Embodiment

		Strongly disagree	Disagree	Neither Agree/Nor Disagree	Agree	Strongly Agr
Body extension	When using a SmartWatch it feels like it is part of my body.	●	●	●	●	●
	When using a SmartWatch it feels like it is an extension of my body.	●	●	●	●	●
	When using a SmartWatch it almost feels like it is incorporated into the body.	●	●	●	●	●
Cognitive extension	Using SmartWatch heightens my knowledge about my activity.	●	●	●	●	●
	Using SmartWatch helps me learn about my activity.	●	●	●	●	●
	Using SmartWatch helps me gain understanding of my activity.	●	●	●	●	●
Self extension	When using a SmartWatch it feels like it is an extension of myself	●	●	●	●	●
	When using a SmartWatch it feels like it is related to my sense of self.	●	●	●	●	●
	When using a SmartWatch it feels like it is a psychological extension of myself	●	●	●	●	●

Appendix D

System Usability Scale

System Usability Scale

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Appendix E

Semi-Structured Interview about Sense-IT

Introduction Interview

1. **Introduction**

Hello, thank you for taking part in our study. This study is part of two bachelor's theses of me and my research partner Leonie/Lena.

This study is all about the Sense-IT, an app that has been developed here at the UT. The Sense-IT is an app that runs on a Smartwatch and is connected with an Android Smartphone via Bluetooth. You will be wearing the watch for four days in a row and afterwards, we will have a second interview with you.

At any time, you are free to withdraw from our study without giving reasons.

Do you have any questions so far?

Before we proceed with the explanations of some features of the sense-It, we would like to ask if you are willing to sign our informed consent.

2. **User characteristics**
    a. What is your age?
    b. What do you study?
    c. What is your level of daily activity (mainly sitting, mainly active)
    d. What are your experiences with smartwatches or fitness tracker until now?
        i. For what did you use the smartwatch or fitness tracker?
        ii. How long did you use the smartwatch or fitness tracker?
        iii. How did you experience the use of the smartwatch or fitness tracker?
    e. In what ways are you (familiar with) monitoring your heart rate?/bodily sensations?

Post application interview

· Thank you for your time. We hope that you have had some nice days while wearing our technology.

1. **Disclaimer**
    a. Before we talk about your experience, can you quickly state whether there have been any technical difficulties? (especially those that might have hindered you)
    b. To which sensitivity did you set your Sense-IT?

2.1 Experience (LEONIE)

a. Body conception
    1. What is your heart rate?
    2. What does it tell you?
    3. When do you pay attention to your heart rate?
b. Body awareness
    1. When do you pay attention to your body in daily life?
    2. Do you pay attention to internal body sensations?
    3. Are you sensitive to body sensations?
    4. How much time do you spend each day scanning for body sensations?
c. Emotional Awareness
    1. How often do you normally reflect on your emotions?
    2. How do your emotions link to bodily states?
d. Influence of Biofeedback
    1. In which situations did you pay attention to your body?
    2. Did you notice any differences?
    3. How did frequent body attention influence your daily life?
    4. What did the biofeedback tell you about your body?
    5. Has there been a situation where your body was not in line with your thoughts and emotions?
e. Stress
    1. How often do you normally experience stress?
    2. Did you experience any particularly stressful situations during the time being?
    3. How did you react to the cues?
    4. Has there been a situation where the biofeedback was helpful?

2.2 **Experience (LENA)**

a. What was your experience with the Sense-IT app?

i. Can you point out one to three specific situations during which biofeedback/sense-IT was particularly relevant for you? Please describe your emotions, thoughts and the situation itself.

ii. What was your response to the cueing?
    1. How did you feel about receiving feedback? What did you do?
    2. Explain thoughts/emotions? And what you did when you received feedback?
    3. For the most part, did the cues occur according to your sensations or against them?
    4. Can you talk about 1-3 situations where the cues differed from your expectations? Please describe your emotions, thoughts and the situation itself.

iii. Can you talk about the strengths/weaknesses of Biofeedback in daily life?

Appendix F

Final Coding tables, including frequency

*Coding scheme **Research Question (1)** Code with definition and quote from the interview (N in percent)*

Code	Definition	Frequency		Example
		N total	N(%)	
ignore	This code was used, when the interviewee stated that (s)he did not pay attention to the cueing of the wearable technology	11	10.89	*Well I didn't really pay a lot of attention to it. Mostly I ignored it, because I said "yeah, this is not true"* *I felt annoyed by it and so I didn't do anything.*

acknowledge	This code describes the behaviour of the interviewee that showed that (s)he acknowledges the feedback and made sense of it	61	60.40	*And then other times when it was vibrating and I just like had to think about what happened. And like I kind of like get into my head and see what's what's going on now so just think about the last minute or so that happened. And like I tried to analyze how I felt about what happened and where that handling certain emotions whether it's about like the person or the environment.* *I tried to like link it to the things that I did*
adapt	This code describes an active change in the behaviour of the interviewee after the feedback	29	28.71	*Yeah I looked at the watch and I immediately tried to breathe more calm* *I used breathing techniques especially or maybe closing the eyes and I think I also tried to leave the situation, So gllike go somewhere*

where you're not in like a stressful environment.

*Coding scheme **Research Question (2)** Code with definition and quote from the interview (N in percent)*

Code	Definition	Frequency		Example
		N total	N(%)	
Positive attitude	Interviewees displayed a positive evaluation of the reception of ambulatory biofeedback	78	66.10	*just the vibration can be helpful because it's like someone telling you to calm down* *I think in general it made me more aware of what I do on a day, so that was nice*
Neutral attitude	Interviewees display indifference towards the reception of ambulatory biofeedback	5	4.24	*But apart from that, there was no real impact. I would say it was just a gadget, maybe nice to have but not necessary* *Yeah I didn't really feel anything towards the*

				watch or what it stands for
Negative Attitude	Interviewees perceived the reception of ambulatory biofeedback as burdensome	35	29.66	*Most of the time the feedback was annoying because it went off a lot.* *I know that with the biofeedback you always need some kind of a phone or at least Bluetooth connection to receive the feedback and stuff and I would see this as a weakness because this is why I get stressed a lot of times because of my phone and because of the Internet and because of messages, I get a lot of stress*

Coding scheme ***Research Question (3)*** *Code with definition and quote from the interview (N in percent)*

Code	Definition	Frequency		Example
		N total	N(%)	

Technical Shortcomings	The usability of the technical device has been criticized.	26	26.23	*So I would have to charge it the whole day and then I'd put it on again and charge it again and put it on again and then I would have to do that like three times. So I think that's like a disadvantage of it.*
Risks	Potential risks of ambulatory biofeedback as seen by the interviewees.	19	31.15	*t kind of it could be powerful to help you but it could also be powerful to work against you because you would start to depend on it in a way that you take that information for absolute*

Lack of Credibility	The interviewees claim a lack of trust in the confidentiality or accuracy.	26	42.62	*Those watches connect your location activities and all that stuff, like there is a lot of information you may want don't want other people to know of you. So well, if there are some issues with data safety then you could have some kind of problem.* *All in all, it's just, when I want to use this technology, I would say it must be 100% accurate or like 99%. Otherwise, it's not trustful. That's my problem.*

*Coding scheme **Research Question (4)** Code with definition and quote from the interview (N in percent)*

Code	Definition	Frequency		Example
		N total	N(%)	
Target group	*A specific target group was mentioned for which ambulatory biofeedback can be of use*	19	30.16	*But I think if you're a young person if you used to this technique and if you want to be more aware of yourself then it can be really helpful.* *I guess students they have to deal with a lot of stress and sometimes at least for me and I think for a lot of other peoples the same. Sometimes we don't realize how stressed we are until there's that one point where like the stress stops and you suddenly realize that you are crushed basically. So, if we would have gained that awareness of our stress like earlier I think it's way easier to deal with that.*

Context	A specific context was mentioned in which ambulatory biofeedback can be instrumentalized	16	25.40	*Also like I think at sports; it can be super interesting to check this*
Improvement	Specific suggestions towards improvement about ambulatory biofeedback, also in regard to the technical usability	28	44.44	*I mean there could be this whole software that also gives you like like a rundown of your day and like shows you when you're stressed when you're not and then gives recommendations like "you should go to sleep earlier at night". That gives advice rather than just awareness. Okay. I mean that would be quite interesting I think.* *I think it is useful. But I think the thing should be smaller. Like maybe like a little bracelet or something, then I would like to keep it forever.*

Appendix G

Statement about AmberScript.

In order to shorten the process of transcribing all 16 interviews, the transcription software *AmberScrip*t has been used. It is an artificial intelligence-based speech-to-text software. We requested 10 hours of transcription time at the BMS Lab of the University of Twente. You upload the audio file .mp3 or .mp4 and within one hour, the software is able to transcribe the audio file into an online document, that can still be edited and corrected.

Strengths of AmberScript

Amberscript is capable of easing the transcription process to a high degree, as it can detect many different accents (Italian, German, Dutch). The handling is very easy and the editing process within the software is designed in a user-friendly way. This software is well capable of ignoring white noise and background noise in the interview.

Weaknesses of AmberScript:

In this study, two female researcher have interviewed some female participants. The software often was not fully able to distinguish between the female voices, and therefore, some editing was still required afterwards. Another weakness was that it was not very sensitive to punctuation, it often connected sentences that have been said separately. The software also needs quite loud voices and a high sound quality.

Conclusion

Despite some shortcomings, I do consider AmberScript as a recommendable software for qualitative research. It surely helped us a lot and it has shortened and eased the process of transcribing. It is just important to ensure that the audio file is of high quality and it might be advisable to instruct the interviewee to speak loud and clear.