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B.Sc. Thesis

Ambulatory Biofeedback Technology and Internal Body Awareness -

Integrating Biofeedback into Students' Daily Life

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Abstract

Background. In recent years, there has been an increasing interest in the use of Biofeedback technology in daily life. Research theorizes that biofeedback might be closely linked to internal body awareness and self-awareness which are central to subjective experience, awareness, and understanding of emotional processes. Investigating this relationship in depth is of importance to attain knowledge about self-regulation, emotional-regulation and stress regulation. Especially effective methods to decrease stress seem of great importance in light of an increasing number of people who are suffering from chronic stress in their everyday life. Consequently, biofeedback has been incorporated in a number of mHealth technology interventions. Yet, the qualitative nature of the experience of biofeedback remains unclear, although it provides the base for every kind of possible intervention.

Objective. The purpose of the present study was to explore how biofeedback relates to internal feedback. The way in which students respond to ambulatory biofeedback might offer deeper practical insights into how ambulatory operates, how it can be best utilized in daily life and which limitation may be experienced.

Method. The study is part of a qualitative research project in the form of a semi-structured interview. The final sample consisted of 16 students by means of conducting a mix of convenience sampling and purposive sampling. Participants used the mHealth bio-cueing application “Sense-IT” for four days and subsequent interviews were analyzed by means of a descriptive phenomenological psychological method.

Results. Five main codes were synthesized: attribution, body awareness, self-regulation, integration in daily life, and limitations which explored the objectives in depth. Results of the Wearable Technology Embodiment Scale indicated that students experienced the technology to have mainly extended their cognitive capabilities. The findings of the System Usability Scale showed that mean was 71.09, indicating an above average acceptable usability with Grade C+ and the adjective “Good”.

Conclusion and Discussion. This study provides explorative evidence on the relation between ambulatory biofeedback and internal body awareness, specifically, it is suggested that ambulatory biofeedback promotes self-awareness, self-reflection and self-regulation in daily life. To ultimately enhance body-mind integration and personal well-being, it has been integrated in daily life as an emotion screening-, stress prevention- and sports tool. Although some refinements of the technology should be considered, more importantly, additional quantitative information is needed. Future research is recommended to extend the testing

period to consequently examine in which way long-term exposure to biofeedback technology affects self-perception, how different self-reflection styles affect the perception of biofeedback and what level of guidance is needed.

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Introduction

In recent years, there has been an increasing interest in the use of Biofeedback technology in daily life. Biofeedback describes the utilization of feedback based upon activity in the body with real-time measurements of physiological variables such as heart rate, body temperature, or neuromuscular activity (Marotta Houser et al., 2013). Additionally, recent research theorizes that biofeedback might be closely linked to internal body awareness and self-awareness. Investigating this relationship in depth is of importance to attain knowledge about self-regulation, emotional-regulation and stress regulation (Howard, 2016). Especially effective methods to decrease stress seem to be of importance in light of an increasing number of people who are suffering from chronic stress in their everyday life (Ratanasiripong et al., 2012). Since it is hypothesized that ambulatory biofeedback might raise internal body awareness, and thus contributes to several regulation processes, it is of importance to explore how ambulatory biofeedback is perceived by lay people in daily life. This might offer deeper practical insights into how ambulatory biofeedback operates, how it can be best utilized in daily life and which limitation there are to it.

The existing body of research on biofeedback suggests that it might be closely linked to internal body awareness (IBA). IBA refers to the process of receiving, accessing and appraising internal bodily signals and stimuli originating from within the body (Garfinkel & Crichley, 2012). The perception of internal bodily states is central to subjective experience, awareness, and understanding of emotional processes and consequently provides the base for the perception of a self (Farb et al, 2015; Ferentzi, Drew, Tihanyi & Köteles, 2018). Additionally, IBA plays an important role in the way people perceive stress and cope with it (Saunders et al., 2007). However, in times of severe stress, people tend to ignore their emotions and bodily states (Howard, 2016). As a consequence, the dynamic homeostasis of the body is constantly being challenged and the risk of health problems such as anxiety, depression, heart disease, hypertension, diabetes and immune dysregulation increases (Howard, 2016). Thus, in light of an increasing number of people who are suffering from chronic stress in their everyday life it is of importance to be aware of one's body's stress level and to develop effective methods to prevent chronic stress (Ratanasiripong et al., 2012).

To enhance IBA, constant technologically mediated feedback on internal bodily states might be used as a tool to regulate the autonomous system and physiological functioning (Derks et al., February, 2019). Ambulatory biofeedback is based on the theory of feedback loops which integrate information from the physiological, cognitive, and affective systems

and interact in a self-regulating manner (Crockett et al. 2017). It can be visualized as a three-step process, including (a) becoming aware of physiological responses and subsequently linking them to unconscious cognitive, emotional, and behavioral states (b) learning to control the response, and (c) transferring control of the response to everyday life (Yu, 2019). Therefore, biofeedback can ultimately be thought of as an approach for gaining conscious control of the unconscious (Norris, 1986). Importantly, in contrast to therapeutic biofeedback which is being used in laboratory settings (e.g. thermal biofeedback, neurofeedback, electromyography), ambulatory biofeedback can easily be used in daily life. It allows for a non-invasive collection of behavioral and physiological data and can be used in a self-directed way, at any time and without being restricted to a specific location (Witte, Buyck & van Daele, 2019). Especially in recent biofeedback products, the usability and accessibility have been significantly improved and so biofeedback systems have become increasingly portable and affordable (Derks et al., 2017).

Consequently, biofeedback has been incorporated in mHealth technology interventions which aim at enhancing the user's well-being by means of analyzing, processing, integrating and transmitting health-based information (Derks et al., 2017). Several biofeedback interventions aim at developing self-regulation skills and constructing knowledge (Yu, 2018). As Yu (2018, p.34) proposes "Biofeedback can be envisioned as a small 'bio-mirror' that the user can grab from their pocket at any time to 'check' their stress level and manage the stress". Accordingly, immediate feedback would enable users to be aware of their current physiological activities and the heart rate could subsequently be regulated with breathing exercises, mindful attention and muscle contractions (Marotta Houser et al., 2013). In addition, biofeedback interventions appear valuable not only with regards to stress but also as an emotion regulation strategy (Peira, Pourtois & Fredrikson, 2013). Several interventions aim at providing a base to learn recognizing and regulating affective changes within daily life by fostering an awareness of the ongoing fluctuations of autonomic reactions of the body (Derks et al.2017). Hence, biofeedback interventions are presumed to serve as 'learning material' for acquiring self-regulation skills with regards to emotional and stress regulation (Yu, 2018). Examples for such interventions are products by Spire Health ("Spire Health: Clinical-Grade Health Monitoring and Insights", 2019) and Lief Therapeutics ("Lief Therapeutics", 2019) which mimic classic interventions that are considerably directive in their aims. Within these, biofeedback is used to monitor physiological activity, to control the body's natural stress response, to acquire self-regulating skills, to improve sleep and ultimately to 'coach' the user in achieving a better life (Yu, 2018).

However, one major issue that arises concerns the theoretical substantiation regarding the use and interpretation of biofeedback in classic interventions. Although a number of studies have been carried out on Biofeedback, there is still very little scientific understanding of how people actually respond to biofeedback and to which extend biofeedback relates to internal body awareness. There has been no detailed investigation of how people experience receiving biofeedback, how people deal with information about their body, and how people interpret biofeedback (Uddin et al. 2016). Thus, the qualitative nature of the extensive experience of biofeedback remains unclear, although it provides the base for every kind of possible intervention. Moreover, far too little attention has been paid to the limitations ambulatory biofeedback might face in daily life. According to a study by Nelson, Verhagen, Vollenbroek-Hutten and Noordzij (2019), the Wearable Technology Embodiment Scale can provide insights into the extent to which external objects are experienced as an integral part of one's own body which is presumed to predict the effect of mHealth interventions and wearable technology.

This study

Considering the lack of understanding, it appears to be of interest to conduct a study which tries to dismiss all presuppositions and thus to explore subjective use in daily life. In order to do so, this study will take advantage of ambulatory bio-cueing technology which represents an alternative to classic interventions (Derks, 2017). Bio-cuing information only indicates personalized high values, alerts the user when changes occur and thus, users are encouraged to read and interpret biofeedback themselves by engaging in self-reflection (Yu, 2018). In addition, the qualitative nature of this study provides valuable insights into the nuanced perception and lived experience of receiving ambulatory biofeedback by means of investigating subjective beliefs and attitudes (Giorgi, 2012). By means of adopting a semi-structured interview approach, this study seeks to investigate practical insights into how ambulatory biofeedback operates, how it can be best utilized in daily life and which limitations are perceived by students. More specifically, this study aims at investigating how biofeedback relates to internal body awareness by exploring students' response in daily life. The following questions will be answered throughout the study:

a. How does ambulatory biofeedback relate to internal body awareness?
b. How do students integrate ambulatory biofeedback into their daily life?
c. What are the perceived limitations of ambulatory biofeedback in the student's application in daily life?

Methods

Study design

his study was part of a qualitative research project in the form of a semi-structured interview and has been carried out in close cooperation with another bachelor thesis student. The aim of the study was to explore how students respond to ambulatory biofeedback in daily life. In line with this, qualitative research has significant value to assess the nuanced perception, perspective and lived experience. By means of investigating subjective beliefs, attitudes, and concepts, it was possible to get a thorough understanding of the theoretical base on which biofeedback functions, how students conceptualize their body and to evaluate the profound meaning. The University of Twente BMS ethical commission has approved the research on March 28th, 2019.

Data collection

Participants and Recruitment

The final sample consisted of 16 students, 9 males, and 7 females, who study at the University of Twente and Saxion Hogeschool of Applied Science. Their age ranged from 19 to 30 years, with a mean age of 22 years (SD= 2.64). A complete overview of the participant's characteristics is presented in Table I. During a time period of one month (19.04-21.05.2019), students were able to take part in the study. In order to reach participants, a mix of convenience sampling and purposive sampling was conducted. Mostly friends and acquaintances of University were approached face-to-face, next to students who signed up for the study online. By means of the SONA system, BMS students are able to obtain Sona credit points in exchange with participating in other students' studies. The study has been approved of the Sona ethical committee on April, 2nd and for this study, students were granted 2.5 Sona points. None of the approached subjects refused to participate or dropped out during the study. Initially, it was intended to collect 10 to 16 participants, equally distributed across male and female. To participate, students needed to be 18 years or older, voluntary subjects, needed to have sufficient English language skills and had to be locally available in case of technical difficulties of arising questions. As the study aimed at a normal population in contrast to a clinical setting, certain exclusion criteria were determined as well. Students who have been diagnosed with mental illnesses or coronary diseases were excluded from the study as they might misuse the technology as a diagnostic device or have extreme biases towards their bodily sensations and bodily awareness. The researchers themselves were both female third-

year bachelor psychology students with a German nationality. Their age was 20 and 22 with high interest in the research topic and qualitative research. Considering this background information, the contingency of a somewhat homogenous environment for recruitment cannot be ruled out.

Table I: *Characteristics of Participants (N=16)*

	Category	Frequency	N%
Gender	Male	9	56
	Female	7	44
Nationality	German	14	87.5
	Dutch	1	6.25
	Italian	1	6.25
Study	Psychology	14	87.5
	Communication Science	1	6.25
	International Business Management	1	6.25
Level of Activity	Low	1	6.25
	Medium	9	56.25
	High	6	37.5

Procedure

The data collection was split into three distinct phases: the instruction meeting, the active testing days and the subsequent evaluative interview. Participants were able to register online or in consultation with the researchers. In the instruction meeting, information regarding the general aim of the study and content, the settings of the watch and smartphone and detailed information on how the watch and the app works were provided (see Appendix D). The informed consent had to be signed and questions regarding the users' characteristics have been addressed. In order to meet the ethical requirements, the form of consent enclosed a declaration of confidentiality, information about the right to withdraw from the study and the aim and content of the study (Appendix A). As the app is only eligible for android software, participants could either use their own device or were provided a suitable phone. As soon as the smartphone has been connected with the smartwatch through the Sense-IT, a baseline measurement of the heart rate of 300 measurements at a 20-second interval was conducted. To adjust the settings to each participant individually, the average heart rate and standard deviation determine when the smartwatch informs the participant of changes in the heart rate. In addition, participants were provided with the password for the settings of the app to be able

to freely adjust them. Afterward, remaining questions were answered and students were free to leave to incorporate the technology in their daily routine.

During the active testing days, students wore the technology for 4 successive days and were asked to wear the technology as often as possible during those days and to attribute the signals to a reason why they received a notification. They did not need to wear them at night, during sports or in the shower. Every night, both devices had to be charged and a daily report has been sent via mail to the researchers' accounts. The evaluative interview took place subsequent to the four testing days in a private room of the university's library in consultation with the researchers. At the start, they were asked to fill out both the usability scale for the Sense-It and the Wearable Technology Embodiment Scale (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, February 2019) (see Appendix B+C). Subsequently, the interview was conducted in English and recorded by both a notebook and a smartphone. A short introduction was given which was followed by my part and my research partner's part. In the end, remaining questions were answered and students were thanked for the participation. On average, the interviews took 35 minutes (SD=9.18) (see Appendix D). Subsequent to the data collection, the data was anonymized by removing names, times and places. Furthermore, the data has only been accessible to the researchers and their supervisor and thus has not been given out to third parties.

Materials

To allow for an exploration of how students respond to ambulatory biofeedback in daily life, four distinct types of materials were used in the data collection phase. These were the hardware, the software, the questionnaires regarding the usability and wearable technology embodiment and the subsequent interview. In the following, these will be elaborated on in detail.

Hardware. As the software is only available for AndroidOS, participants were provided with a suitable smartphone or used their own Android phone if it matched the requirements. The University of Twente provided a Samsung Galaxy S6, S7 and Motorola phones. The smartphones were continuously connected via Bluetooth and the app WearOS with a smartwatch. Two models were available, the TicwatchE (mobvoi) and the Moto360. Importantly, participants were advised to not turn on the energy saver mode due to connectivity issues.

Software. For the purpose of the study, the mHealth bio-cueing application "Sense-IT" has been selected which has been developed by researchers from the University of

Twente in collaboration with three different organizations Scelta, VUmc, Arkin and Pluryn. It operates on a smartwatch which has an in-built biosensor that measures the user's heart rate (HR) by means of a photoplethysmography or 'PPG' sensor. The HR is triggered by the sympathetic nervous system and is therefore a cardiovascular parameter for physiological arousal. It also enables the user to receive a notification when considerable (this can be fully personalized) and changes in the HR occur (e.g. an increase of more than 5 or 10 beats per minute) in the absence of physical exertion. Initially, it has been designed with Borderline-Personality-Disorder Patients with low emotional awareness and their therapists to effectively help to learn to better recognize and monitor emotional arousal (Derks De Visser, Bohlmeijer, & Noordzij, 2017).

By means of a web link, the app is being installed on the phone and via the linkage of a google mail account, it is possible to install the app on the smartwatch as well. The operating language is Dutch and the settings are explained in the following and displayed in Figure I. The app continuously records the heart rate and levels of arousal and informs the user about changes and certain amounts of increase or decrease by means of vibrational cues. In addition, a notification on the watch's surface pops up where the user is being forwarded to the phone display to reflect on the reasons for arousal by typing in a note. The start screen displays four major functions: whether the app is connected with the watch, a button to add a note regarding a vibration (Notitie toevoegen), a button to open the settings and a button to turn off the connection. To access the settings, users have to type in a password which was provided in advance. To adjust the settings to each user individually, a base measurement has to be conducted before using the technology (nieuwe basis meeting starten). Based on it, the app calculates an average heart rate (gemiddelde hartslag) and the standard deviation (standaard afwijking) which indicates when a higher level is reached. Depending on the chosen sensitivity (low/ normal/ high), the watch informs the user with varying frequency. By means of the 'export database via email' button, the user is able to send the data to the researcher's e-mail account. In addition, the user is able to choose a watch display design of his/her preference from three options. In the first, the heart rate is represented by a changing number of dots, in the second one, a growing circle represents a rising heart rate and in the last one, the level of arousal from -3 to 5 is represented by characters (exp. Niveau: -1) (see Figure II).

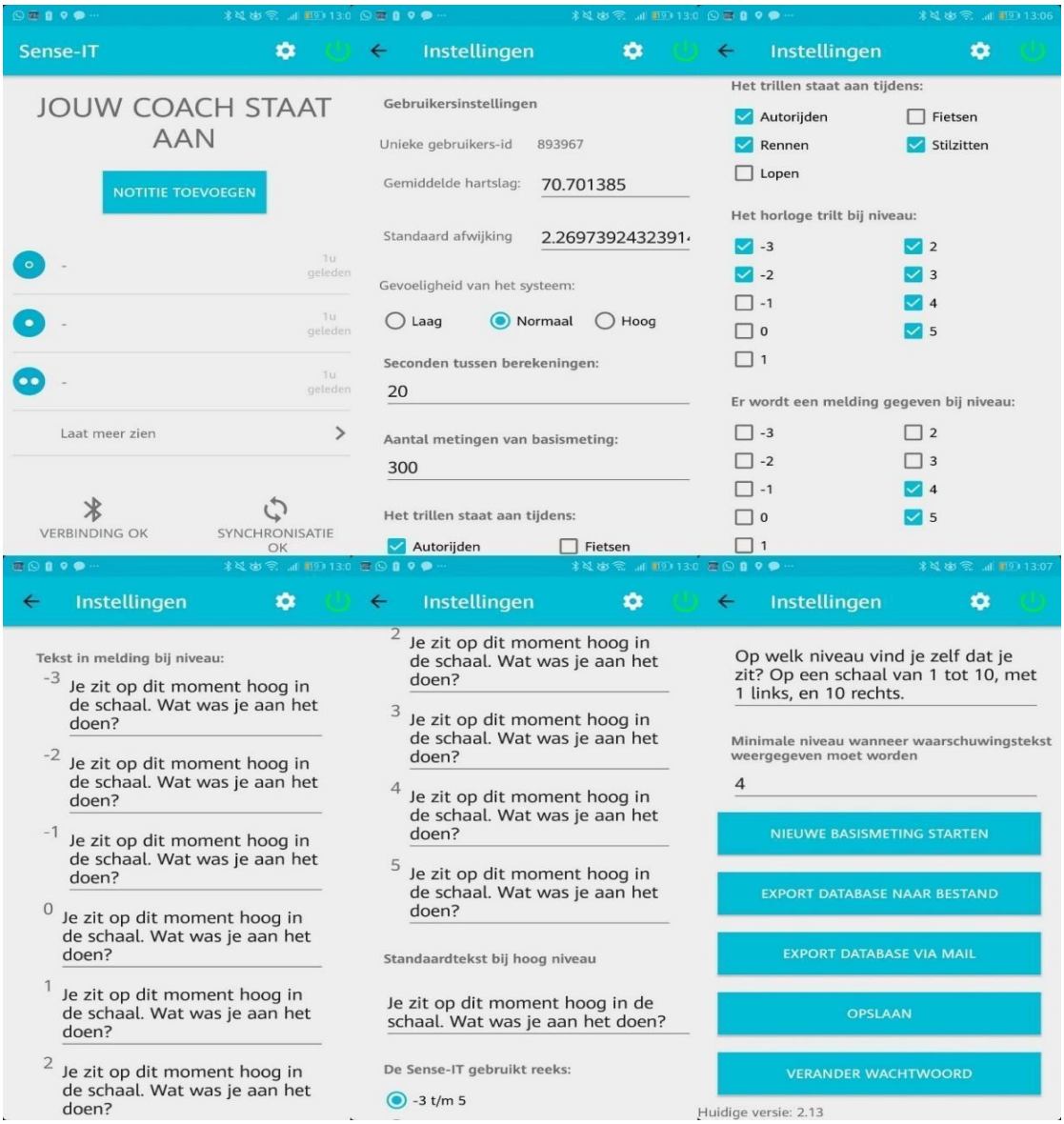

Figure I: Screen Sense-IT (start screen and setting menu).

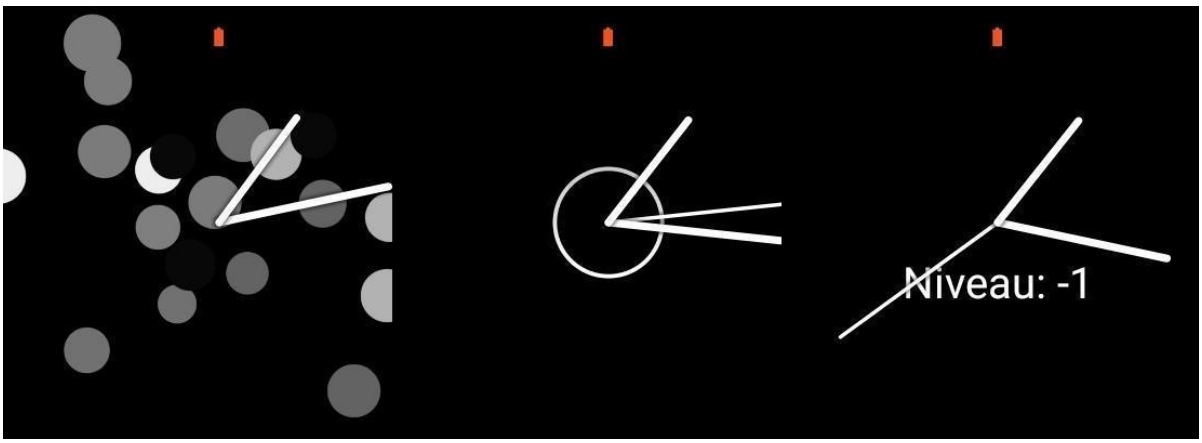

Figure II: Sense-IT watch display designs.

Scales. After interacting with the biofeedback technology, students were asked to fill out the English questionnaires at the start of the evaluative interview and to rank the items according to their level of agreement on a 5-point-Likert Scale. The *Wearable Technology Embodiment Scale* has recently been developed to measure the extension of an individual's body, cognition, self, and technology adoption and thus, to what extent external objects are experienced as an integral part of one's own body (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019). The instrument has 9 measurement items which are evenly distributed between the 3 dimensions: *body extension, cognitive extension,* and *self-extension.* The dimension *body extension* refers to a physical addition or replacement of the body, whereas *cognitive extension* refers to the experienced extension of one's cognitive capabilities and *self-extension* refers to an object being perceived as part of a person's identity or sense of self. The extent to which people embody the technology is presumed to predict the effect of mHealth interventions and is of importance to this study to develop an understanding of students' attitudes and experience of receiving biofeedback. To analyze the *Wearable Technology Embodiment Scale, t*he items are added according to the value of each given answer and then divided by the number of questions (9). The final scores range from 0 to 5 (Nelson, Verhagen, Vollenbroek-Hutten & Noordzij, 2019).

In addition, the *System Usability Scale* has been selected as a second measurement which is a popular and well-researched instrument to measure the usability of a system. It is a relatively short questionnaire (10 items) which was initially created by John Brooke in 1986 and which has the advantage of being suitable for a wide range of interfaces and thus allows for comparison with other products (Kortum & Peres, 2014). To calculate the usability scores, participants rank 10 questions based on the level of agreement. For each of the odd-numbered questions, 1 is subtracted from the score whereas, for each of the even-numbered questions, their value is subtracted from 5. The values are added up to a total score and multiplied by 2.5. Thus, the perceived usability ranges from 0 to 100, scores below 50 indicate non-acceptance towards the usability score, while scores above 50 indicate acceptance (Bangor, Kortum &Miller, 2008).

Interview. The study design was a semi-structured interview with open-ended and closed questions to seek views on the focused topic of the experience of biofeedback. Open-ended questions were asked to avoid suggestiveness and to capture a complete range of experience. Follow up questions aimed at specifying the experience and to help participants to reflect on their experience in detail. In the evaluative interview, two questions were asked regarding the occurrence of technical difficulties and the sensitivity settings of the Sense-IT

after a short introduction. Subsequent to my own part, my research partner continued with several questions which aimed at receiving insights on students' attitudes and their individual reactions to the reception of ambulatory biofeedback in their daily lives. The interview scheme consisted of six open-ended main questions, each of them had two to four sub-questions (see Appendix D).

The first question referred to the heart rate, as it connects subjects' bodies with the technical device. Through the provision of information on the heart rate, participants receive information about their body, they reflect on their behavior, emotions, and thoughts. Furthermore, to start gentle, students were asked to explore their mind on a general topic which asked for personal and subjective experience. The second question referred to the concept of body awareness. The sub-questions were based on the *Body Vigilance Scale* (BVS) which was developed by Schmidt, Lerew and Trakowski (1997) to assess attentional focus to internal body sensations and the *Body Awareness Questionnaire* (BAQ) which was developed by Shields, Mallory and Simons (1989). These aimed at following up on body attention in daily life, attention to internal body sensations, perceived sensitivity to body sensations and time effort of scanning for sensations. The fourth questions focused on the experience of emotions, the reflection upon emotions and the link to bodily sensations and especially the heart rate. The fifth question referred to the experience of stress in students' daily life. Sub-questions aimed at reflecting on which occasions and how many times students experienced stress and how biofeedback has been experienced when using biofeedback. It further aimed at establishing how students reacted to the cues in stressful situations and how biofeedback influenced their behavior, thoughts, and emotions. Lastly, picking up on the other concepts, the last question referred to the experience of biofeedback as such and in combination with the different concepts. Sub-questions aimed at specifying concrete situations, the possible impact of the use of biofeedback on students, insights on the body and specific thoughts and emotions which were connected to the use of biofeedback.

The length of the Interview differed significantly with regards to the participants' characteristics. The longest interview took 65.1 minutes whereas the shortest interview only took 24.48 minutes with a mean of 34.9 minutes (SD= 9.18). Some participants were quite talkative whereas others were rather short-spoken but all of them were kind, open-minded and interested in the topic.

Table 2: *List of open-ended questions*

Q1:	How did you experience your heart rate?
Q2:	How did you experience your body?
Q3:	How did you experience emotions?
Q5:	How did you experience stress?
Q6:	How did you experience receiving biofeedback?

Data Analysis

Steps of Analysis

The data analysis aimed at answering the question: how does ambulatory biofeedback relate to internal body awareness in students' daily life.? Therefore, five steps have been made in the course of analysis. Firstly, the *Wearable Technology Embodiment Scale* and *System Usability Scale* have been scored. Secondly, prior to processing, the tape recordings were transcribed via *AmberScript* by AmberScript B.V. which is an artificial intelligence-based speech-to-text software. Transcripts were revised and checked for mistakes afterward and also reviewed for accuracy by the second researcher who witnessed the sessions. Thirdly, the transcripts were uploaded to *ATLAS.ti* which is a software for qualitative data analysis which has been developed by ATLAS.ti Scientific Software Development GmbH. Subsequently, a coding scheme was developed based on recurring themes, was applied to the data and phenomena were described. Lastly, the nuanced meanings were analyzed and were searched for essences.

Development of the coding scheme

To develop a coding scheme, an inductive approach was applied. More specifically, a Descriptive Phenomenological Psychological Method was used which seeks to understand how people experience a particular situation or phenomenon and attempts to identify themes or to make generalizations how a particular phenomenon is actually perceived (Giorgi, 2012). In a phenomenological inquiry, specific statements are analyzed and categorized into clusters of meaning that represent the phenomenon of interest in a process of decontextualization and recontextualization (Creswell & Miller, 1997). Thus, the interviews were closely read for several times and themes and important passages were noted. Special attention was given to descriptions of what was experienced as well as how it was experienced. By means of

'bracketing', a priori knowledge and assumptions have been recognized and set aside to focus on the analysis of the experience (Giorgi, 2012). Units of analysis were sentences and meaningful passages. During decontextualization data was separated from the original context of individual cases and codes were assigned to units of meaning in the texts. In recontextualization the codes we examined for patterns and reintegrated to central themes. The codes were refined throughout the initial coding by means of adding, collapsing, expanding and revising coding categories. In addition, missing codes were defined and added, and unnecessary codes were deleted. Via an iterative process of reviewing data, themes, generating codes and code categories, a final set of codes were developed.

Consequently, this final coding scheme was applied to all interviews. Saturation was initially expected after applying the coding scheme to five interviews and achieved after eight. The final coding scheme consisted of five main codes, each of them consisted of three to five sub-codes, yielding to a total of 16 codes which are presented in table 3. Irrelevant passages have been coded with 'irrelevant' to ensure all data was covered. In order to establish higher reliability, both coding schemes have been established in close consultation with a research partner by means of talking through them to examine how ideas evolved as we engaged more deeply with the data. In addition, my research partner randomly selected 10 interviews and coded them via a tool for intercoder comparison by *ATLAS.ti* to reduce coder biases. The agreement between the raters can be used as an indicator of the quality of the categories of the codes and the raters' ability to apply them.

Table 3: Coding scheme: Code with definition and quote from the interview

Code	Definition	Example
A) Attribution through self-reflection		
Physical activity	Bodily movements produced by skeletal muscles	*"Yeah. So, when your muscles move, your body is more active, hence a higher heart rate."*
Emotions	Affective state of consciousness in which joy, sorrow, fear, hate etc. is experienced	*"One reason is that I'm scared, another reason is I'm very nervous"*
Stress	Mental, emotional or physical strain or tension	"So, my heart is still on a higher level because of the stress before"
Environment/ Drugs	Stimulus with reference to the environment/ Substances taken into the body	*"But I think in situations where you have an external stimulus. I got a very loud music."*
B) Body awareness		
Self- awareness	Biofeedback as a tool to enhance conscious self-awareness	*"In general, it is really helpful to know something about what's going on in your body because it raises awareness for your whole body and all the feelings you have."*
Body-mind-integration	Biofeedback as a tool to unite mind and body	*„It is important to listen to my body because I would argue I am my body also and if my body doesn't feel good, I don't feel good. It doesn't affect me directly but it is me in a way. If it feels pain, I feel pain."*
	Biofeedback as a tool to enhance overall well-being/ health	*"I guess most people are not paying attention to their heart rate or breath or something in their daily life. So, this would also benefit their health* "
Self-consciousness	Biofeedback yielding to a negatively connotated heightened sense of self-awareness	*"It's more like "oh you should do something about it". You should maybe eat healthier or do sports."*
C) Integration in daily life		
Stress prevention	Biofeedback as a tool to notice signs of stress at an early stage	"*I think the physical heart beat is somehow related with mental stress level. I think that's also so good to know in which situations you feel stressed or not.* "
Emotion screening	Biofeedback as a tool to reflect on emotions	*"But the thing vibrated, and I realized that I was just really emotionally involved in this situation. And sometimes I did get a little bit angry and things like that just triggered the watch."*
Sports	Biofeedback as a tool to monitor the body and enhance activity	*"I think with the parameters you get from the biofeedback or heart rate; you can observe your body in an objective way. And in that sense then you can look how your body is adapted to certain stimuli and then you can adapt your training or something."*
D) Self-regulation		
Relaxation (Taking a deep breath; Standing still; Taking a break; Walking; Watching the watch	Engaging into activities which aim at decreasing the heart rate by a method of relaxation	"*When I feel stressed, I mean I guess in any situation I have the possibility when I feel stressed to watch my breath to try to breathe slowly or to take a more relaxed posture.* "
Taking initiative (Reflecting; Talking to another person)	Engaging into an active method of finding the reason for a cue	*"I try to write down like a plan how I can structure my day better so I get less stressed. Or I try to talk to someone about it.* "
E) Limitations/ Negative experience		
Inaccuracy	The belief that biofeedback is not accurate and does not reflect reality to a sufficient quality level	"*Because a watch can be wrong. Sometimes the watch told me I was sitting or once the watch told me I was sitting in a car when I was sitting."*
Redundancy	The perception of biofeedback not being useful/ helpful/ has no perceived added value to daily life	*"So, it was kind of "OK yeah, I'm upset" but at that point, I already knew that I was upset. So yeah, it didn't really tell me anything new."*
Dependency	The fear to become dependent on biofeedback	*"The watch can be super-efficient and maybe it's better than anybody could have read him or herself. However, for me personally that is not how I want it to be, I don't want to depend on a watch in order to be OK if I can be OK if I take care of myself by myself.* "
Irrelevant	Passages which are not relevant to the research question	

Results

In order to explore how ambulatory biofeedback relates to internal body awareness in students' daily life, the interviews have been analyzed and a coding scheme has been developed. A total of 9.3 hours (558.94 minutes) of recorded interview material from 16 individuals has been analyzed, yielding to five main concepts: *attribution, body awareness, self-regulation, integration in daily life,* and *limitations*. Thus, a coding scheme has been developed during the data analysis which will be elaborated on in the following (see also Table 3). To start with some general remarks, most of the participants evaluated participating as a positive experience even though only a few would want to have the watch as a gadget in their own life. It became apparent that most of the students mentioned several phases of getting used to receiving biofeedback and to the app. It was mentioned that most students had the need to become accustomed to receiving biofeedback and did experience emotions of insecurity and tension but also of curiosity at the start. However, after a day or two, they started to reflect on the vibrational cues, tried to attribute the cues to a reason, became more aware of their own body and also mentioned feelings of validation and assurance of their own perception. Thus, they started engaging in self-regulative behavior, integrated the device in their daily lives but also shared their beliefs about the limitations and negative experiences.

A) Attribution through self-reflection

The first theme that occurred throughout all interviews was an *attribution through self-reflection*. By means of reflecting on own behavior, emotions and thoughts, participants attributed their arousal to certain causes. These possible causes differed from situation to situation but also differences between subjects were observed. Thus, it became apparent that participants actively reached out for a cause which is able to explain their level of arousal. They were curious to understand their own body, self and state they find themselves in. If a cause could still not be found, students were left with feelings of confusion, irritation and frustration. Being consciously aware of not being able to understand one's complex condition seemed to cause feelings of dissatisfaction and resentment. Depending on the individual, students tended to attribute their arousal to one category of cause in a constant manner. Some students tended to attribute their arousal to their mental activities (emotions/stress), whereas others tended to prefer a biological reason such as physical activity, environment, food or drugs. The cause that was mentioned the most was *physical activity* (N=33.3%). Further mentioned causes were *Emotions* (N=27.1%), *Stress* (N=20.7%), *Environment/Drugs* (N=18.9%).

Interestingly, the concepts of *Stress* and *Emotion* were mentioned both in the context of positive/ negative stress as well as in positive/ negative emotions. Thus, students pointed out that the level of heart rate merely indicated the level of arousal and even a causal relationship could not be drawn between but only a correlation, as illustrated by participant 14.

> And by now I don't think that there is a direct relation anymore but rather an indirect because I think that having emotions kind of raises the heart rate sometimes and the other way around and I think that they're related but I don't think that there is just a unilinear causal relationship nor is there a direct relationship in which I would say that perceived arousal is just equal to the heart rate. (Participant 14)

B) Body awareness

The second theme that has been identified, was a heightened sense of *body awareness*. Identified sub-codes were *self-awareness, body-mind integration, well-being, and self-consciousness.* It became apparent that students displayed different levels of sensitivity to bodily sensations and differed in the evaluation of importance they ascribe to internal body sensations. In addition, students also attended to different stimuli originating from within the body. These ranged from sensations of pain, hunger, heart rate, etc. However, eleven out of sixteen students remarked that ambulatory biofeedback affected their *self-awareness* (59.5%). Students described a shift in attention regarding the conscious perception of their body and self. Normally, many students would only pay attention to their body and heart rate when they engaged in physical activity or if something felt off as they get sick. However, students mentioned that they started paying more attention to their own body during the week of interacting with biofeedback technology and reduced the amount of attention turned outwards.

> I think a real advantage of it is that if you're a person like me, if you are really having a lot of stressful situations or if you're really emotional it's really helpful because you're just starting to be a little bit more aware of yourself. (participant4)

As stated by participant 4, users often forgot to pay attention to one's own body, find themselves in stressful situations without being consciously aware of it. However, as participant 10 remarked, by means of receiving a signal and by looking on the watch, users became consciously aware of their own body and paid attention to one's actual state and needs.

That's the funny part. You look on the watch and you immediately feel your heart. (participant10)

In addition, biofeedback was mentioned to unite mind and body as through constant adaptation, both needs can be met. Thus, biofeedback was perceived to operate as a *Body-mind-integration* tool (16.5%). Besides bringing body and mind in one line, students also expressed that they became aware that it is of great importance to do so as their own identity is twofold. They are their body and mind at the same time.

> Every time I become aware of emotions, I'm trying to comprehend how they occurred and what their causes or meanings are for myself. I am aroused because my expectations about how I understand myself are not met, or are other people not behaving as I would like them to behave. That usually makes me kind of frustrated and then I'm thinking about frustration. And why it frustrates me and thereby I think I get more understanding about myself. And usually if I'm frustrated, I can sense it in my body through feeling tense and also not really being able to properly think because I'm educated in my mind as well. So, there's some coherency between my body and mind. (participant12)

Participant 12 stated that by means of the induced reflection, he started thinking about the connection between body and mind and attained insights into his own personality and information about himself. Biofeedback would also help reassuring students own perceptions by means of an objective' evaluation thus bring in line one's perception of the body and the actual state.

Moreover, as a value on a deeper level, students expressed that they perceived biofeedback to ultimately enhance overall *Well-being* (10.7%). By means of bringing attention to the present moment, students were able to appreciate the moment, enjoy feelings of gratitude and increase states of recreation free from stress and tension. By means of bringing attention to the body and current moment, it would be possible to decrease stress symptoms and enhance one's health. Participant 7 stated that through becoming aware of the moment, he would appreciate the emotion he is living and took a moment for himself.

> So that is I think what I do in any case when I recognize I feel stress especially if it is positive stress, I think of it as positive stress. I would probably just smile into myself or just smile but I wouldn't try to repress it. If I have a positive tension, I wouldn't try to breathe more slowly or to change my posture I would rather try to focus on me. In order to enjoy. (participant7)

Lastly, students also mentioned a negatively connotated heightened sense of self-awareness due to the raised attention towards their own body. The code *self-consciousness* (23.3%) entailed a negative evaluation of their own body as a result of too much attention towards their own body or unresolved questions. Participant 8 mentioned that she perceived to feel out of touch with her own body as she was not able to figure out the reasons for heightened heart rates.

> Well I was thinking about my body a lot more obviously, right. And like about how I feel. But that's just kind of got me more out of touch with my body because I just couldn't find

> an answer to why my body is doing that right now and that was not the most pleasant feeling I've ever experienced. (Participant8)

Feelings of uneasiness and frustration could also be induced when confronted with a clash between expectations and reality. To illustrate, students mentioned that when they realized that their heart rate was higher than expected, they started questioning themselves, their own perceptions and their past. In a sense, they started re-evaluating themselves, were unsure of themselves and started questioning their own behavior and appearance. In two cases, students even reported the fear of not being healthy and the consideration of visiting a doctor although we indicated that the Sense-IT is not a medical device at the start. Due to the great extent of freedom in the interpretation of cues, students reported that one may also interpret something in negative terms and draw negative conclusions which may not actually represent reality. As students made the connections themselves, they might fall prey to negative assessments depending on the evaluation of themselves. Thus there remained the danger of becoming overly conscious of oneself, reinforcing a poor self-image and apprehension.

C) Integration in daily life

Fourthly, as ambulatory biofeedback has the advantage of being easily incorporated into daily life, students disclosed how they made use of biofeedback in their daily life and in what way they regarded biofeedback as helpful and advantageous. Predominantly, three main uses have been synthesized: biofeedback as an *emotion screening* tool, as a *stress prevention* tool and as a *sports* tool. To start with, students reported that they used biofeedback as an *emotion screening* tool (29.2%) to reflect upon emotions and become aware of them at an early stage. Many students expressed the belief that emotions and bodily sensations such as the heart rate are closely connected and on the base of information on the heart rate, inferences and conclusions about emotions could be drawn.

> When I was getting angry. (…) When I was talking with G*** and we were in a fight, just talking and nothing more. That was not a severe discussion. But the thing vibrated, and I realized that I was just really emotionally involved in this situation. And sometimes I did get a little bit angry and things like that just triggered the watch. And when it vibrated, I knew that I had to calm down. (Participant6)

As Participant 6 stated, biofeedback made him aware of his emotional state in the present moment which made it possible to react upon it right in the moment. Although the technology did not give clear instructions on how to react on cues, he perceived the watch to display information about his emotional states. Thus, he was able to screen for changes in emotional states and increasingly reflected upon them. In addition, biofeedback was used as a tool for *Stress prevention* (56.3%). It was expressed that one of the biggest advantages of biofeedback

is the ability to recognize and become aware of signs of stress at an early stage. Students indicated that they often tended to oversee signs of stress and only realized their extreme tension at a very late point of time or when it was already too late. However, stress was not only perceived as something negative but many students also mentioned positive sites of stress. As participant 5 stated, stress seemed to be part of students' life and did also have an important function.

> but at the same time, stress makes me get shit done. So, I realized in the time I studied here, that I procrastinate a lot (…). I automatically just put it at the end because personally think I need a certain stress level to do something". (Participant5)

Surprisingly, some students also found it helpful to track their heart rate whilst doing S*ports* (14.6%). Although the Sense-IT ceased to vibrate with continued activity on default settings, students used biofeedback as a tool to monitor the body, enhance activity and achieve better results. It was mentioned that extra information on the body's functioning might be helpful to adjust their workout schedule in the gym. Even though the technology has not specifically been designed for this purpose, it seemed that students appreciated the function.

> That's because I think with the parameters you get from the biofeedback or heart rate. I think you also can widen that to some others and that's how you can observe your body in an objective way. And in that sense then you can look at how your body is adapted to certain stimuli and then you can adapt your training or something. (Participant1)

D) Self-regulation/ self-care

The third theme that has been identified is the activity of engaging in *Self-regulation* and self-care. Self-regulation aimed at actively influencing the heart rate and was differentiated in *Relaxation* (77.1%) and *Taking initiative* (22.9%). Subsequent to becoming aware of one's level of stress, noticing emotions and accepting them, many students engaged in subtle strategies to consciously regain control of their body and to decrease their level of arousal. As participant 7 stated, it would not be possible to change the bodily sensation but only the reaction and to adapt the following behavior.

> However, with time I learned I cannot change the bodily sensation, whatever but what I can do is change my reaction, my response to it, and I learned to do that and interestingly, I also cannot change the emotion but I can change my bodily response that I have control over. For instance, my breath, when I try to calm down to settle my thoughts. All these things then affect my emotions and also my body. (Participant7)

On the one hand, mentioned methods of *Relaxation* were looking at the watch, engaging in no other act than standing still, breathing deeply, walking at a slow regular pace for a small amount of time, taking a break and interrupting one's activity at hand. These methods aimed

at decreasing the level of arousal in the present moment and were perceived to only be effective in the short run. Thus, especially the breath was seen as a central link between body and mind which can be used as a tool to relax but also other techniques have been applied. *Taking initiative,* on the other hand, implied thinking about the reasons of a cue, talking to another person about the reasons of a cue and actively engaging in an activity to reduce the reason of a cue such as making a schedule. Students reported that as they became aware of their emotions, thoughts and stress level, they had the urge to change and to improve their physical state of being to consequently improve their mental health in the long run.

E) Limitations/ Negative Experience

Next to the positive aspects of experiencing biofeedback, students also mentioned several negative aspects and limitations of biofeedback: *inaccuracy* (43%)*, redundancy* (40.7%) and *dependency* (16.9%). To start with, the most common expressed perception was that the displayed biofeedback may not reflect reality to a sufficient level of quality (*Inaccuracy*). 9 students mentioned that due to a gap between their own perception and biofeedback, or inconsistencies, they did not trust the technology. One student even mentioned that after conducting 'little tests' with a heart rate measurement application which is installed on watch, he did not trust the biofeedback any longer.

> But I think it's really not so good working. I made some more experiences with it. When I was walking around for half an hour, it's switching between 80, 180, 70, 120, 50 and then I thought "OK kids I don't know about this". (Participant15)

Secondly, students also disclosed that they often perceived the biofeedback to not be of any use or help and thus did not add any value to their daily life. To illustrate, 11 students mentioned that they would not need information that they were already aware of. This was coded as *Redundancy.*

> So, I became a little bit careless with regard to the watch because I had understood the information that it gave me and it was nothing new about it." (Participant7)

In addition, students also reported the fear of becoming dependent on the technology and thus to lose their own capabilities of screening their body (*Dependency*). However, only 5 students expressed this fear with regards to the technology.

> I think at first it helps and at some point, you get dependent on it. At some point all you know is the level four. You don't know any more. Is what I'm about to do actually okay? If it is an unusual activity, if you don't have the indication of the watch. And once you did it with the watch, you know the level and then you can assess 'ah okay that's Okay'. So, I can do that again. Level seven Wow. Okay that's not good so I won't do it. But if you don't have to watch you have to think of yourself and I think thinking of yourself in that regard is very

> important because in some way the watch was interesting but it was of no use cause I believed to know my body and my body is very, very efficient in telling me when something is too much for something. (Participant7)

Results of Scales

Wearable Technology Embodiment Scale

The findings for the *Wearable Technology Embodiment Scale* showed that the median was 2.8 (SD= 0.57), ranging from 2.1 to 4.2. When looking at the Boxplots (see *Figure* III), it became apparent that the three dimensions differed in their distributions. The boxplot for *cognitive extension* was located much higher than the others, indicating that students experienced the technology to have extended one's cognitive capabilities. Both the *body extension*- and *self-extension* dimension were scored comparatively low, indicating a neutral attitude to slight disagreement towards the technology being an extended part of the body and self.

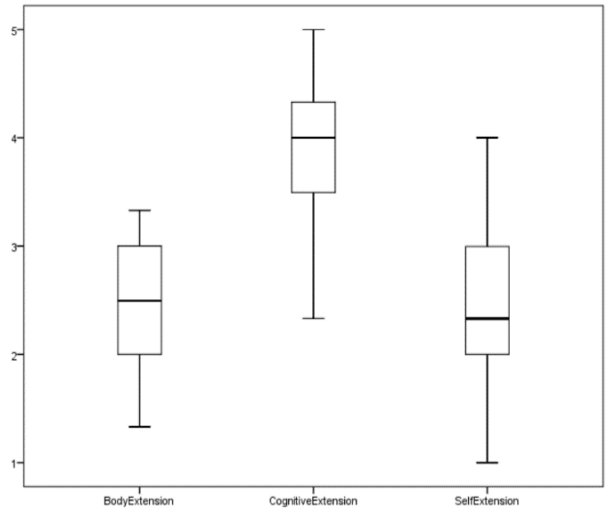

Figure 3: Wearable Technology Embodiment Scale Boxplot, distributed according to body extension, cognitive extension and self-extension.

System Usability Scale

The findings of the System Usability Scale showed that mean was 71.09 (SD=16.88), ranging from 45 to 95. According to Bangor, Kortum and Miller (2008), a score of 71.09 can be converted into a score in the 60st percentile which indicates an above average acceptable usability with Grade C+ and the adjective "Good". It could be argued that only participants who scored a SUS score higher than 53would further be focused on and detractors (below 53) would be disregarded in the analysis. However, it did seem of importance to also take into account voiced critics of the technology. An overview of the distribution of mean scores in relation to SUS scores is presented in *Figure 4*.

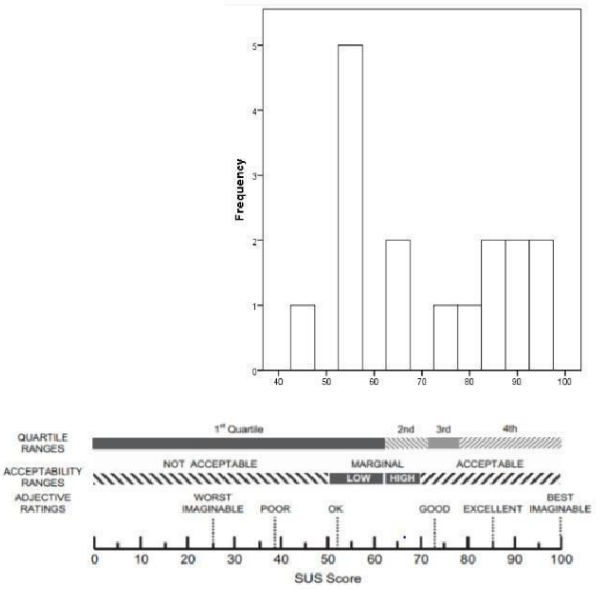

Figure 4: Mean scores in relation to subdivision of scores on SUS and accompanying system acceptability.

Discussion

The aim of the study was to explore how students respond to ambulatory biofeedback in daily life and to add to the theoretical debate. The findings have shown that biofeedback most importantly promotes internal body awareness and ultimately self- awareness, self-reflection, and self-regulation. Participants used bio-cueing technology as an emotion screening- stress prevention- and sports tool which ultimately enhances body-mind integration and well-being. Below further elaboration will be provided on these findings in the light of the relation between ambulatory biofeedback and internal body awareness, the integration of ambulatory biofeedback in daily life, the limitations in a student population and future research.

Firstly, to provide an answer to the first question and thus to analyze how ambulatory biofeedback relates to internal body awareness, the first two codes appeared to be of great importance which will be elaborated on in the following. In daily life, most students revealed to rarely pay any attention to their body. By means of receiving biofeedback, they had to reflect on their internal body, themselves and their level of arousal. They attributed vibrational cues to internal or external causes but agreed that especially in stressful situations, it would be of advantage to listen to the signs of one's body and regulate it at an early stage. Consequently, they often engaged in self-regulative behavior such as breathing techniques, etc. Therefore, it has become apparent that conscious awareness to their body was enhanced

by ambulatory biofeedback which thus served as a tool to enhance internal body awareness and ultimately self- awareness. These results reflect those of Norris et al. (1986) which also indicated that biofeedback can be thought of as a method to gain conscious control of the unconscious. Accordingly, awareness in terms of "*knowing* that we know" (p. 5) is essential to true self-regulation. In addition, the findings have also shown, that a heightened sense of body awareness was positively perceived to enhance body-mind integration and overall well-being. This can be supported by the findings of Mehling et al. (2016) and Crocket et al. (2017) which pointed out the growing body of evidence of qualitative studies which demonstrate that body awareness-enhancing methods provide psychological and pain-related benefits and thus improvements in health and performance.

In contrast, students also mentioned that extensive attention to the body could also be perceived as a burden and lead to emotions of confusion, frustration, and dissatisfaction. This finding is in agreement with those of Fairclough (2009) who observed a split of self-perception in the sustained use of physiological computing technology. Accordingly, as the user is exposed to a parallel representation of emotions and motivations, the unitary experience of the self is fractured. Thus, it has been proposed to examine in depth in which way a long-term exposure to technology affects self-perception. However, these results could also be attributed to the differentiation between self-reflection and self-rumination which has been introduced by Morin (2002). Accordingly, both types of attention focus on the self although, one is motivated by an epistemic interest in the self, whereas the other is rather motivated by fear and self-doubts. Self-reflective people tend to be curious about themselves and are interested to learn about their attitudes, values, emotions and thought processes, whereas self-ruminative people tend to question their behavior and appearance, re-evaluate themselves and keep wondering about their self-worth. Therefore, participants who perceived the extensive attention to the body as rather negative might tend to apply self-ruminative strategies to think about themselves. It may thus be of interest to further investigate this hypothesis in future studies. Nonetheless, self-confrontation has also been shown to be valuable as it increases knowledge about one's behavior and "the more an individual knows about his [or her] behavior, the more he [or she] is in a position to do something about it" (Sanborn, Pyke & Sanborn, 1975, p. 185).

Secondly, to provide an answer to the second question, the findings have shown, that based on the features of biofeedback technology, students integrated ambulatory biofeedback as an emotion screening, stress prevention, and sports tool in their daily life. Students indicated that they got more aware of their experiences and paid more conscious awareness to

their emotions. By regulating their level of arousal, students made use of the ambulatory biofeedback to decrease stress levels, to become aware of emotions and the body's functioning. The mentioned strategies of relaxation and taking initiative can be supported by Marotta Houser et al.'s study (2013) which proposed using breathing exercises, mindful attention, and muscle contractions to regulate the autonomous system and physiological functioning. In line with this, self-regulation and self-care have been pointed out to be of crucial importance to deal with the stressors of studying (Chaló et al., 2017). As Yu (2018) remarked, students could use biofeedback as a 'learning material' which enabled them to acquire self-regulative skills. In line with this, Norris already proposed in 1986 that biofeedback-acquired skills should be as much a part of physical education to begin to practice self-regulative control of internal states at an early age. Moreover, these findings have shown that it is indeed effective to conduct biofeedback interventions which aim at controlling the body's stress response, acquiring self-regulating skills and regulating physiological activity as proposed by Yu (2018). However, students also reported that they valued the autonomy of bio-cueing technology and consequently it remains unclear how much guidance people need in the application of biofeedback. For future research, it might be of interest to explore differences between bio-cueing technology and classical biofeedback technology interventions. Additionally, the majority of participants were students who were perceived to be well-reflected and interested in human studies. Therefore, it would be of great interest to conduct a study with participants of a different study which might display different levels of self-reflection and world-views. Ambulatory biofeedback might be interpreted in different terms and might serve different functions.

Thirdly, when looking at mentioned negative aspects of ambulatory biofeedback, it becomes apparent that ambulatory feedback also has its limitations regarding the use for students and its positive relationship with internal body awareness. Due to negative experiences of inaccuracy, redundancy, and dependency, students evaluated the ambulatory biofeedback with a Grade C+ on the *System Usability Scale* and according to the findings of the *Wearable Technology Embodiment Scale,* the ambulatory biofeedback was also not perceived as an extended part of the body and self. It has become apparent that ambulatory biofeedback mainly served as a cognitive extension and thus supported the notion of enhancing self-awareness. Hence, the bio-cueing technology was perceived to heighten students' knowledge about their activity, helped them learn about their activity and helped them gain an understanding of their activity (Nelson et al., 2019). However, Nelson et al. (2019) indicated that all three dimensions of the *Wearable Technology Embodiment Scale* are

crucially important to the user's evaluation of the technology. Therefore, the Sense-IT might not have been the best choice to experiment on biofeedback as alternative biofeedback with higher scores on the self-extension and body-extension scale are theorized to be perceived as more effective. Nonetheless, these findings might merely indicate that four days of active testing days did not suffice to internalize the technology and remained alien for students. In future research, an extended testing period might thus be advisable. Still, to further improve the Sense-IT technology and to seamlessly fit it into the user's daily life, it might be of interest to adapt features which add to the extension of body and self. The developers of the Sense-IT could therefore benefit from this knowledge by adjusting the technology in such a way that they would better fit the user's body shape (body extension) and connect to the user's personal identity (self-extension). In addition, minimizing problems of accuracy by means of testing the validity and quality of the physiological data of the Sense-IT technology would be of interest. For instance, a study by van Lier et al. (2019) proposed a validity assessment protocol which makes it possible to make clear inferences by means of explicit decision criteria considering the three levels: signal level, parameter level, and event level. Moreover, it would be of interest to further to look into problems of redundancy in depth as well. As students mentioned they did not require any information they already had, in future research, it has to be explored at which occasions, at what exact time to inform user, how the technology can be further personalized, and also which information users would appreciate been given.

Strengths and Limitations

Due to the nature of qualitative research, it was possible to get insights into an in-depth knowledge of participants' personal attitudes, feelings, thoughts and behavior and to provide detailed information of the relation between biofeedback and body awareness. One strength of the study was a comparatively large sample size of 16 participants which provided a richness of data. As the sample also consisted to a large part of psychology students, differences between individuals became apparent who had similar interests. In addition, as participants were mostly friends and acquaintances, the private relationships and anonymization allowed for full information disclosure without subjects being afraid to share certain private information. Lastly, the analysis was based on a strong inter-rater agreement and a clear saturation has been noted in the analysis of the interviews after eight interviews.

Some limitations of the current study require discussion. To begin with, participants mentioned that four days of active testing days were perceived to be too short to fully

integrate the technology into daily life. A period of habituation was needed at the start, to learn how the technology works also needed time and due to short battery life, students had to charge the technology multiple times per day. Moreover, many students did not make use of the possibility to fully personalize the technology with regard to the frequency of cues which may have contributed to feelings of frustration and annoyance. For future research, it may be of importance to disclaim the possibilities at the start and to lay more focus on these strengths and options of the technology. In addition, to ensure better reliability and validity of the study, in addition to an inter-rater agreement, it may be advisable to check for an interrater-reliability to assess nominal agreement between two raters. Lastly, as the study has been conducted with quite a homogenous sample at one university in the Netherlands, there might remain a lack of generalizability. According to the Diffusion of Innovation theory by Rogers (1971), innovations are not adopted by all individuals in a social system at the same time. Adoption depends on the degree to which an individual is relatively early in adopting a new idea compared to other members of a social system. Thus, as we mainly interviewed psychology students and not students of a technical study, these students characteristically thought about the advantages and disadvantages in depth and reflected extensively. And so, they may be classified as early majority adopters as they took time to make their decision, observed the experience in detail and would only adopt an innovation once they are convinced it has real benefits. Consequently, they do play an important part in the diffusion process but represent a distinct group which cannot be generalized to the whole public (Rogers, 2003).

Conclusion

This study provides explorative evidence on the relation between ambulatory biofeedback and internal body awareness. It is suggested that ambulatory biofeedback promotes self-awareness, self-reflection, and self-regulation in daily life. To ultimately enhance body-mind integration and personal well-being, it has been integrated into daily life as an emotion screening-, stress prevention- and sports tool. Although some refinements of the technology should be considered, more importantly, additional quantitative information is needed with regard to the mechanisms by which biofeedback works. Future research is recommended to focus on a different target group and extend the testing period to consequently examine in which way long-term exposure to biofeedback technology affects self-perception, how different self-reflection styles affect the perception of biofeedback and what level of guidance is needed with regard to the provided information and time of notification.

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Appendix

Appendix A

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.	○	○
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 B

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 C

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 D

Semi-Structured Interview

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 4 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. This interview is split in 3 parts, one is just a short disclaimer. The other one are questions about your experience in regard to some specific situations. Lastly, Leonie will ask you some questions about your bodily awareness in combination with the sense it. If you have any questions or don't understand something you can always pause and ask. If you feel insecure about expressing something in English, you can say it in German if you like.

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?

2.2 Experience (LEONIE)

a. Heart rate - How do you experience your heart rate?
    1. What is your heart rate to you?
    2. What does it tell you?
    3. When do you pay attention your heart rate?

b. Body awareness – How do you experience your internal body?
    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 - How do you experience emotions?
    1. How often do you normally reflect on your emotions?
    2. How do your emotions link to bodily states?

d. Stress - How do you experience 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?

e. Biofeedback - How did you experience receiving biofeedback?
    1. In which situations did you pay attention to your body?
    2. How did the frequent body attention impact you?
    3. What did the biofeedback tell you about your body?
    4. Has there been a situation where your body was not in line with your thoughts and emotions?

2.1 **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 expectation? Please describe your emotions, thoughts and the situation itself.
    iii. Can you talk about strengths/weaknesses of Biofeedback in daily life?