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KNOWLEDGE IN ACTION

Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Emotion meters for people with a severe disability

Siege Geerinck
Celine Spronck

Eerste deel van het scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie

PROMOTOR :
Prof. dr. Raf MEESEN

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Dhr. Ben SCHOUTEN

COPROMOTOR :
Prof. dr. Katleen BOGAERTS

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www.uhasselt.be
Universiteit Hasselt
Campus Hasselt:
Martelarenlaan 42 | 3500 Hasselt
Campus Diepenbeek:
Agoralaan Gebouw D | 3590 Diepenbeek

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Emotion meters for people with a severe disability.

The research question for the literature review was: 'Which devices exist to measure the emotion of people with a severe physical and/or cognitive disability?'

The most important take home messages of this literature study (n=12) are the following:

- Not many studies have used devices to measure the emotion of people with a severe physical and/or cognitive disability.
- The four devices found in this literature study that could possibly measure emotion of people with a severe physical and/or cognitive disability are: the Empatica E4 wristband, the Affectiva Q-sensor wristband, the Brain Computer Interface (EEG measurement) and the combination of EEG and eye-tracking
- Most devices measure skin conductance, skin temperature, blood volume pulse, acceleration or EEG signals.
- The devices measure changes in arousal but they do not measure differences between emotions (happiness or anger)

Authors: Siege Geerinck and Celine Spronck

Promotor: Prof. dr. Raf Meesen

Promotor: Prof. dr. Katleen Bogaerts

External promotor: Dhr. Ben Schouten

CONTEXT

The research domain of this literature study is neurological rehabilitation and mental health care.

There are people with a severe physical and/or cognitive disability who cannot express their emotions. They cannot tell their caregivers or health care practitioners how they feel and their communication through facial expressions is not always accurate because of their physical and/or cognitive disability. This can lead to unexpected outbursts and situations that are difficult for caregivers to deal with. To give the best care, it is useful to know if the patient is feeling happy, angry, stressful… during a treatment or activity. Knowing if your treatment is or isn't stressful could make the patient's life more comfortable and the caregivers' task easier to execute. That's why it would be interesting to measure the emotions of the patient with a device that can directly tell the caregiver if the treatment or activity is provoking and therefore should be changed.

This literature study and especially Master thesis part 2 will be guided by Dhr. Ben Schouten, coordinator scientific research for VZW Stijn. VZW Stijn offers accompaniment and support for people with a disability. They stand up for people with the biggest need for care and with complex problems (https://www.stijn.be/index.php?LOC=STI&PAG=org_missie_visie). For Master thesis part 2, we will also work together with Sint Oda in Overpelt, a care home for people with a moderate or severe disability.

This literature study was written in central format by two authors: Siege Geerinck and Celine Spronck, under the supervision and guidance of Prof. dr. Raf Meesen and Prof. dr. Katleen Bogaerts. The students did the literature study both separately and then combined it. Afterwards when both students agreed on the literature study, the promotor (Raf Meesen) approved it for further elaboration.

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PART TWO: PROTOCOL

PART ONE: LITERATURE STUDY

1. ABSTRACT

Background: Knowing what a person with a severe physical and/or cognitive disability feels is an important part of caregiving. Finding a way to translate their bodily signals may help the caregivers to provide better care.

Methods: Two electronic databases were searched for relevant articles: PubMed and Web Of Science. An article was included if it measured emotion with a device that could be used for persons with severe multiple disabilities with age ≥ 18 and scoring at least a 4/7 on the quality checklist. An article was excluded if it did not measure emotion, measured emotion in paintings, pictures or animals, if participants had to sing and dance to measure emotion or the intervention happened in an abnormal situation, for example in court. The following data was extracted: Which device was used, Kind of emotion, What does the device measure, Wearable or stationary, Negative points about the device, Positive points about the device and Information about the subjects.

Results: Twelve articles met all of the inclusion criteria and were used for the data-extraction. Four emotion meters were found: Empatica E4 wristband, Affectiva Q-sensor, Brain computer interface and EEG combined with eye movement.

Discussion: Only one article was found to use an emotion meter on people with a neurological condition, all the other articles used healthy subjects which makes the effects on people with a disability questionable. A low sample size was used in most of the articles.

Conclusion: The Empatica E4 wristband, Affectiva Q-sensor, Brain computer interface or EEG combined with eye movement was used to measure emotions. The Empatica E4 was used in most articles and measures the most physiological features.

Aim: The aim of this review is to investigate which devices are available to measure emotions of people with a severe disability that cannot express themselves.

Operationalization research question: The research question of this literature search is: “Which devices exist to measure the emotions of people with a severe physical and/or cognitive disability?”

Keywords: emotion meter, severe disability, emotion measurement

2. INTRODUCTION

"Emotion plays an important role in human-human interaction" (Das Chakladar & Chakraborty, 2018). These emotions are processes directed towards a specific event or object, which result in physiological changes in both behavior and bodily state during communication (Jang, Park, Park, Kim, & Sohn, 2015).

There is a basic set of emotions that are the same in every culture: happiness, fear, anger, disgust and sadness. To express these emotions, we use nonverbal communication which consists of facial expressions such as frowning and physiological reactions such as tearing, blushing (Anderson & Adolphs, 2014), pupil dilatation and increase of heart rate (Porges, Doussard-Roosevelt, & Maiti, 1994). We can also use verbal communication which consists of vocalizations such as screaming or sobbing and we verbally report our feelings to others (Anderson & Adolphs, 2014).

Emotions provide us with the ability to deal with sudden events or changes in our surroundings. In positive situations, optimistic feelings dominate and cognitive functions (e.g., problem-solving abilities) are improved. On the other hand, in negative situations, pessimistic feelings dominate and analytical thinking is increased. In particular, because emotion plays an important role in the contextual understanding of messages from others in speech or visual forms like facial expressions and body gestures, it has been recognized as one of the most important ways for people to communicate with each other (Jang et al., 2015). The effects of expressing emotions vary, depending on what is expressed, to whom, and how. Expression can contribute to self-knowledge and is necessary for the development of emotional intimacy (Johnson, 2000).

Some people with a severe physical and/or cognitive disability cannot express emotions themselves with external bodily responses. They are often unable to indicate when their emotional situation gets out of hand which can lead to an emotional outburst without any signals that the caregivers could pick up. If you cannot see emotional responses it would be valuable to know which internal responses are connected to emotion and if there is a possibility to measure these internal bodily responses.

Emotional reactions can cause changes in bodily responses including facial expressions, heart rate or skin conductance (Weis & Herbert, 2017). Skin conductance is a relatively direct (i.e.,

with a lag of only 2 seconds) reflection of the sympathetic nervous system and therefore has been related to arousal. The other mood dimension, valence, has been repeatedly related to skin temperature (ST). However, there is no clear agreement on the direction of this relation: Where several authors agree in reporting a lower skin temperature for negatively valenced experiences, others find the opposite, namely lower skin temperatures for positively valenced experiences (van der Zwaag, Janssen, & Westerink, 2013). Further, EDA parameters constitute a powerful tool to investigate both the subjectively enlightened and hidden parts of emotional processing (Sequeira, Hot, Silvert, & Delplanque, 2009).

Persons with a severe physical and/or cognitive disability may not be able to express their emotion with external bodily responses, but you can measure their internal bodily responses as mentioned above. When their bodily reactions are translated, caregivers can try to interpret and understand these emotions. It would be especially helpful for the caregivers to help them in their day to day activities.

Therefore, in this review, we research which devices exist to measure emotions and what kind of outcome parameters they measure that can be translated into emotions.

3. METHODS

3.1 RESEARCH QUESTION

For this literature study we have investigated which devices, that can measure emotion, could be suitable for persons who cannot express their emotions themselves. The following research question was formulated: 'Which devices exist to measure the emotions of people with a severe physical and/or cognitive disability?'

The following PICO (Patient, Intervention, Comparison and Outcome) can be the resume of our aim:

P: People with a severe physical and/or cognitive disability

I: An emotion-meter

C: /

O: An emotional outcome parameter

3.2 LITERATURE SEARCH

The databases PubMed and Web of Science (WoS) were used to find the appropriate studies for the research in this literature study. The search terms that are used, were chosen with the help of the PICO described above in '3.1 RESEARCH QUESTION'.

The following terms were used:

P: 'Handicap', 'Disabled', 'Disabled persons', 'acquired disability', 'Disability', 'acquired brain injury', 'Brain injury', 'Brain injuries, Traumatic', 'Mentally disabled persons', 'cognitive disorder', 'Minimally Conscious state', 'genetic disorder', 'Genetic Diseases, Inborn', 'Brain damage' and 'Stroke'.

I: 'slimme sok', 'buienradar', 'Mood Radar', 'Embrace watch', 'emotion meter', 'empatica', 'Q-sensor' and 'Affectiva'

C: /

O: 'galvanic skin response', 'arousal', 'valence', 'Cortisol level', 'heart rate', 'brain waves', 'Emotion', 'Body reaction', 'anger outburst', 'emotion recognition', 'EDA' and 'electrodermal activity'

These terms were combined with ‘OR’ and the P, I and O were combined with ‘AND’. The following different combinations were tried: P AND I, P AND O, I AND O, P AND I AND O. In the database PubMed, MESH terms, if available, or Title/Abstract were used for each term and for Web Of Science, TOPIC was used to link with the words in search of articles. The first combination P AND O with the addition of the terms AND ‘Measurement’ AND ‘Emotion’ only contained 2 usable articles. When I and O were combined, the most relevant articles were found which will be used in this literature study. An overview of the selected terms and each corresponding number of hits are provided in **Table 1.**

Table 1: Overview searchresults terms Pubmed and Web of Science

Terms Pubmed	Number of results PubMed: 23/02/2019	Number of results WoS: 23/02/2019
#1: ((((((((((((((((Handicap[Title/Abstract]) OR Disabled[Title/Abstract]) OR "Disabled persons"[Title/Abstract]) OR "Acquired disability"[Title/Abstract]) OR Disability[Title/Abstract]) OR "Acquired brain injury"[Title/Abstract]) OR "brain injury"[Title/Abstract]) OR "Cognitive disorder"[Title/Abstract]) OR "Minimally Consious State"[Title/Abstract]) OR "Disabled Persons"[Mesh]) OR "Mentally Disabled Persons"[Mesh]) OR "Brain Injuries, Traumatic"[Mesh]) OR "Cognition Disorders"[Mesh]) OR "Mental Disorders"[Mesh]) OR "Genetic Diseases, Inborn"[Mesh])) OR "Stroke"[Mesh]) OR "Brain damage"[Title/Abstract])	2 060 726	636 770
#2: ((((((((((((Slimme sok[Title/Abstract]) OR buienradar[Title/Abstract]) OR Embrace watch[Title/Abstract]) OR Emotionmeter[Title/Abstract])) OR "Mood radar"[Title/Abstract]) OR Empatica[Title/Abstract]) OR Q-sensor[Title/Abstract]) OR Affectiva[Title/Abstract]) OR "measurement of emotion"[Title/Abstract]))	51	50
#3: ((((((((((("Galvanic Skin Response"[Mesh]) OR "Arousal"[Mesh]) OR "Heart Rate"[Mesh]) OR "Brain Waves"[Mesh]) OR "Emotions"[Mesh])) OR Valence[Title/Abstract]) OR Cortisol level[Title/Abstract])) OR "Anger outburst"[Title/Abstract]) OR "Emotion recognition"[Title/Abstract])) OR EDA[Title/Abstract]) OR "Electrodermal acivity"[Title/Abstract]	515 701	376 460
#1 AND #2	2	2
#1 AND #3	109 802	12 901
#1 AND #3 AND measurement AND emotion	558	89
#2 AND #3	6	50
#1 AND #2A AND #3	0	2

3.3 SELECTION CRITERIA

The inclusion criteria are:

- People with severe disabilities OR healthy subjects
- Age ≥ 18
- Measurement of emotion with a device
- Outcome of emotion parameters
- Scoring at least a 4/7 on the quality checklist

The exclusion criteria are:

- The use of paintings, pictures, animals… to measure emotion
- Interventions consisting of singing or dancing
- An abnormal situation, for example in court
- A review
- Languages other than English or Dutch

3.4 QUALITY ASSESSMENT

The quality checklist was a self-made checklist that combined the Pedro Scale (first two questions) the Cochrane checklist (third and fourth question) and 3 self-made questions that were important for this literature search. See **Table 2.**

Table 2: Quality assessment

	Eligibility criteria were specified	Measurements of at least one key outcome from more than 85% of the subjects	Selective publication of results sufficiently excluded?	Academic bias is sufficiently excluded	Is it usable for the population?	Is it achievable to use in real life?	Clear explanation of measurement device?
(Chrisinger & King, 2018)	+	+	+	+	+	+	+
(Dao, Dang-Nguyen, Kasem, & Hung, 2018)	+	+	+	?	+	+	+
(Deravi et al., 2015)	+	+	+	+	+	+	+
(Garbarino et al., 2014)	-	-	-	-	+	+	+
(Gouverneur et al., 2017)	-	-	+	+	+	+	+
(Harley, Bouchet, Hussain, Azevedo, & Calvo, 2015)	+	+	+	?	-	-	+
(Hoogerheide, Renkl, Fiorella, Paas, & van Gog, 2019)	+	+	+	+	+	+	+
(Kappas, Kuester, Basedow, & Dente, 2013)	-	+	?	?	+	+	+
(Ollander, Godin, Campagne, Charbonnier, & Ieee, 2016)	+	+	+	+	+	+	+
(Stadler, Jepson, & Wood, 2018)	+	+	+	?	+	+	+
(van der Wal & Irrmischer, 2015)	+	+	+	+	+	+	+
(Zhao, Wang, Yu, & Guo, 2018)	+	+	+	?	+	+	+
(Zheng, Liu, Lu, Lu, & Cichocki, 2019)	+	-	+	+	+	+	+

3.5 DATA-EXTRACTION

Based on the devices used in the articles, they were divided into 4 groups. The Empatica E4 was used in 7 articles, the Affectiva Q-sensor in 3 articles, the Brain Computer Interface (BCI) in 2 articles and EEG + eye-movement in 1 article. The following data were extracted from the articles:

a) which device was used
b) Kind of emotion (stress, arousal, …)
c) what does the device measure (HR, EDA…)
d) Is it a wearable or stationary device
e) Negative points about the device
f) Positive points about the device
g) Information about the subjects.

An overview of all the data is provided in **table 3 in the appendix.**

4. RESULTS

4.1 STUDY SELECTION

With the combination of I and O a total of 56 articles were found, of which 6 on PubMed and 50 on Web of Science. With the removal of duplicates, 50 were left. After screening them on title and abstract 30 articles were excluded. Only studies that discussed the use of a device that could measure emotion in healthy subjects or severe disabled subjects were included.

After screening the 20 publications relevant for further reading, studies with questionnaires instead of devices (n=3), an opinion (n=1), non-valid outcome measures (n=1), insufficient quality (n=1), no real people (n=1) and singing (n=1) were excluded. For a small overview of all the articles and the reason of exclusion, **See figure 1** and for a broad overview **See table 4 in the appendix.**

In conclusion, 12 articles were left over to include in this review.

4.2 QUALITY ASSESSMENT

The quality assessment was performed on 13 articles with a self-made checklist that combined the Pedro Scale (first 2 questions) the Cochrane checklist (3e, 4e and 5th question) and questions that were important to include for the literature search. **See table 2**.

To be included, the articles must have at least 4 positive answers to the questions of the checklist. (Garbarino et al., 2014) did only score positive on 3 questions. This article did not have any participants or did some kind of research on the device. It only prescribed what the device could do. For that reason the article was excluded after evaluation with the checklist.

4.2.1 REPORTING

In most of the studies eligibility criteria were clearly specified (10/12) and results were reported of at least one key outcome from more than 85% of the subjects (10/12).

In every study, there was a clear explanation about the device, what it is, does and look like and how to use it. Because of this information, there was the ability to estimate if the device was usable for the population that was investigated (11/12) and if it was achievable to use in real life and in a research setting (11/12).

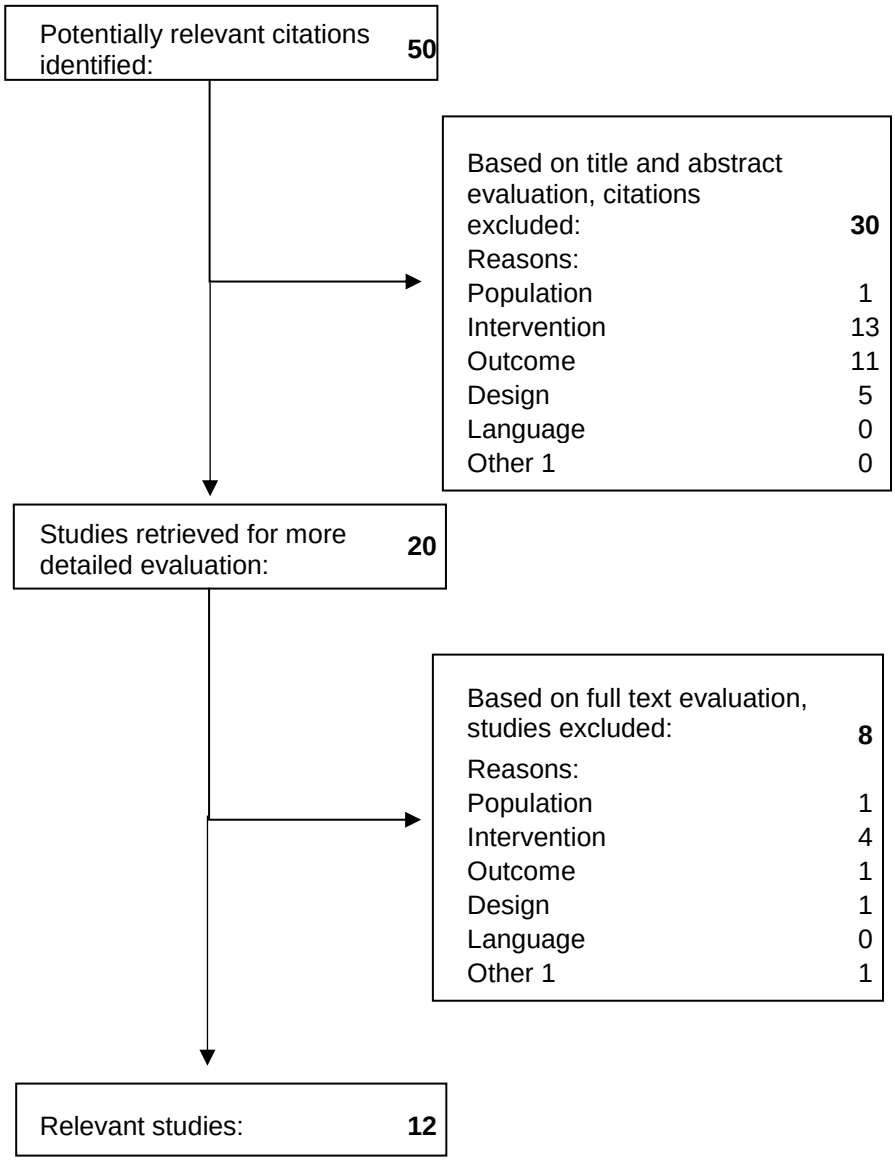

Figure 1: Flowchart of the search strategy

4.2.2 THE MAIN WEAKNESSES OF THE STUDIES

See table 5 in the appendix for an overview of the weaknesses and strengths of the included studies.

- Low sample size in most of the studies (8 studies ≤ 30 subjects)
- Only one study that discussed the use of the emotion measurement device with people with a severe disability (Deravi et al., 2015).
- Few studies that really validated the instrument
- In most studies, the academical bias couldn't be ruled out with certainty
- In most of the studies the recruitment and testing took place at one single location which possibly limits the generalizability of the results.

4.2.3 THE MAIN STRENGHTS OF THE STUDIES

- Combination of emotion measurement device and smartphone to collect and sent data or a combination of two devices was used in 7 articles.
- All of the articles had a clear explanation about the device, how to use it and its measurement outcomes
- Clear explanation about the processing of data
- Multiple studies in different settings about the same device (we can compare them to each other)

4.3 DATA EXTRACTION

An overview of the data extraction is provided in **Table 3.**

- **Empatica E4**

The Empatica E4 is a wearable wristband that measures multiple parameters. Dao, Dang-Nguyen, Kasem, and Hung (2018) say that the Empatica E4 uses four different sensors. A photoplethysmograph (PPG) sensor to measure blood volume pulse (BVP) from which the heart rate, heart rate variability (HRV) and other cardiovascular features may be derived such as blood volume pressure and heartbeat inter-beat interval. A 3-axis accelerometer (ACC) to measure gravitational force on three spatial dimensions allowing for a three-dimensional understanding of participant movement. An infrared thermopile (TEMP) that

reads peripheral skin temperature. And an Electrodermal Activity (EDA) sensor to measure sympathetic nervous system arousal and to derive features related to stress, engagement and excitement.

The Empatica E4 was used in 7 articles.

Chrisinger and King (2018) used the Empatica E4 to measure stress in neighborhood and social environments to identify elements of one's environment that contribute to chronic stress including the perception of comfort and discomfort associated with different settings. The Empatica E4 was connected to a DT (Discovering Tool) mobile application. The app could capture audio narratives, photos and participant-assigned valences for the elements that were captured by the participants. They used 14 adults (8 women and 6 men) who lived in the San Francisco Bay Area in their study. The inclusion criteria were: healthy, living in or around San Francisco and being able to complete an easy 20 to 25 minute walk. While using the Empatica E4, they found out that good contact with the skin is necessary to collect data and it is important to have baseline data so you can distinguish between 'signal' and 'noise'. The good things they found about the Empatica E4 is that it is a commercially available, easy to use means of continuously collecting time stamped biometric data.

Dao et al. (2018) investigated the daily moods of students using the Empatica E4 and smartphones to send the event tags, location and physiological data to a cloud computing platform. The wristband sends physiological and location signals to the smartphones. The smartphones preprocess the data and capture tagging data if the subjects provide it. They used 15 students and 1 lecturer. They did not discuss any positive or negative points about the device.

Gouverneur et al. (2017) used the Empatica E4 to collect the data and assess the stress level of the user. Their findings were that the device is comfortable, continuous and gives real-time data acquisition, but motion artefacts can occur when it is not worn tightly or when the subject does rapid or fast movements. There is a greater risk of errors when the wristband shifts or hits against an object.

Hoogerheide, Renkl, Fiorella, Paas, and van Gog (2019) used the Empatica E4 to assess the effects on arousal when students had to teach on video. Sixty-one psychology students (of which 17 male) participated with a mean age of 20y/o. They had to have low or no prior

knowledge of parallel circuit troubleshooting. During the teaching on video task, their EDA was used to evaluate their increase in arousal. The researcher reported two things that made working with the Empatica E4 difficult. First of all, there must always be a baseline calculation to determine what a neutral state is. Secondly, Empatica wristbands are new technology: remain cautious when interpreting the arousal findings.

Ollander, Godin, Campagne, Charbonnier, and Ieee (2016) compared a wearable (Empatica E4) and a stationary sensor for stress detection. The stationary signals were an electrocardiogram (ECG) and finger skin conductivity. 7 subjects (1 male and 6 females) were recruited for this study with a mean age of 22y/o. The Empatica E4 device had a significant loss of Interbeat intervals (IBI) with the BVP signal, especially when performing a task. The positive things about the device were that the mean HR and the standard deviation of HR have been estimated to be acceptable and provided promising results for stress discrimination. Also the skin conductivity was more discriminating than the finger electrodes of the stationary device.

Stadler, Jepson, and Wood (2018) measured the arousal in leisure experiences using the Empatica E4. They included 5 groups of 3-4 women who took part in the research facilitated by 'Age UK' and 4 groups of 4 women who participated in the research at sessions hosted by an art provider. The inclusion criteria were being a 70+ years old women and being a resident in the rural areas. The Empatica E4 is designed to be unobtrusive and comfortable for the wearer. EDA is the only autonomic psychophysiological variable that is not contaminated by the parasympathetic activity of the body such as the functioning of major organs and it can detect implicit emotional responses that may occur without conscious awareness or are beyond cognitive intent (i.e. threat, anticipation, salience or novelty). Bodily responses cannot be easily faked but for a good measurement, the subjects have to be in good health. Coughs, sneezes and deep respiratory movements can generate SCRs which lead to false readings. Subjects with cardiovascular abnormalities can produce rhythmic artefacts (spiking) in the EDA.

Zhao, Wang, Yu, and Guo (2018) measured human emotions, especially happiness, sadness, fear and anger with the Empatica E4 and the use of an emotion stimuli corpus which was a compilation of different types of film clips. They included 15 subjects (9 males and 6 females) between 22 and 28 years old. The inclusion criterium was being a graduate student

and the exclusion criteria were having a cardiovascular, neurological, epileptic or hypertension disease. The Empatica E4 showed a 75,56% overall accuracy of emotion recognition in humans. However, signal noise influences the stability of features and the emotion recognition accuracy. This signal noise can be caused by subject's movement or subject and instrumental differences. This happens especially at the beginning and the ending of each recording.

- **Affectiva Q-sensor**

The Q-sensor by Affectiva is a wearable wristband that measures EDA, acceleration (ACC) and skin temperature (Deravi et al., 2015). It passes a small amount of current between two electrodes placed on the skin to measure the variations of electrical conductance of the skin. This is a method to measure EDA (Harley, Bouchet, Hussain, Azevedo, & Calvo, 2015). You can view the data through the Q-software or live streaming of the data through the Q-live-software.

Deravi et al. (2015) examined whether patients with brain injury and a sample of reference population were able to use a low-cost EEG based BCI system (Emotiv EPOC headset) to interact with a computer and to communicate with spelling words. To measure the emotional arousal of participants, the Affectiva Q-sensor was used. The sensor consists of electrodes for measuring electrodermal conductance, temperature and an accelerometer. They included 5 patients with different neurological conditions and 5 controls. The exclusion criteria were having prior experience in using BCI headsets, having epilepsy, use of neurostimulators or patients with pacemakers.

Harley et al. (2015) presents the evaluation of the synchronization of three emotional measurement methods (automatic facial expression recognition by the face reader 5.0, self-report by an emotions-value questionnaire, electrodermal activity by the Q-sensor) and their agreement regarding learners' emotion. The Affectiva Q-sensor was used to measure EDA. They included 67 students at the North American University with a mean age of 21. The inclusion criteria were being 18+ years old, being a full-time undergraduate student and being able to tie long hair and bangs back because of the facial recognition software. The exclusion criterium was having a bad vision (wearing glasses). The agreement between the

Q-sensor and EV is weak (41.3%) but the agreement between the Face Reader and the Q-sensor is better (60,1%).

Kappas, Kuester, Basedow, and Dente (2013) investigated the validation of the Q-sensor by affectiva in different social laboratory situations and compared it in a re-test study with finger-electrodes. They used 30 subjects and their findings were that the device was not as precise as stationary systems but it has an advantage of not needing any cables, boxes or skin preparation.

- **Brain Computer Interface (BCI)**

BCI systems make a direct link between a brain and a computer by taking measurable neurophysiological signals and turning them into computer commands that can be used by computers, switches or protheses. These signals can be measured by detecting a magnetic (MEG) or an electric (EEG) field, fMRI and other ways. The link can be made by the Emotiv EPOC EEG headset with 16 (hydrated) sensors that should be placed on the participant's scalp. (Deravi et al., 2015)

Deravi et al. (2015) (described in 0.2) also used the BCI to measure EEG signals. EEG signals can be contaminated by various noise sources such as powerline interferences and the presence of unwanted physiological signals etc. This is particularly an issue if there's contamination (e.g. hair, sweat) at the skin-electrodes-scalp interface. The BCI is user friendly by using styles such as baseball caps, headbands, headsets etc. that let the patiënts have freedom of posture. It is also relatively inexpensive and non-invasive. The patiënts also reported that they found the BCI useful.

van der Wal and Irrmischer (2015) used the Myndplay Brainband XL from the BCI to measure emotion. 53 students were included, the inclusion criteria were being healthy, Dutch or English speaking and between 18-67 years old. The exclusion criteria were having a history of neurological complications or substance abuse and having previous experience with meditation, yoga or laughter yoga. The headset is commercially available and non-invasive. They use a dry active sensor technology. This means that the sensors do not need a conductive gel and because of that are more comfortable and easy to use.

- **EEG + eye-movement**

It is a combination of six symmetrical temporal EEG electrodes that can be embedded in a headset or spectacle frames with eye-tracking glasses.(W. L. Zheng, W. Liu, Y. Lu, B. L. Lu, & A. Cichocki, 2019a) (fig. 1)

W. L. Zheng, W. Liu, Y. F. Lu, B. L. Lu, and A. Cichocki (2019b) used a multimodal framework for recognizing human emotions where they combined EEG and eye movements. They included 15 right-handed college students (8 females and 7 males) between 20 and 24 years old. Power spectral density (PSD) and differential entropy (DE) were used as data from the EEG. Pupil diameter, dispersion, fixation duration, blink duration and saccade were used as data from the eye-tracking glasses. The emotions that they measured were valence (sad-happy), arousal (calm-excited) and neutral. Especially neutral emotion has a respectively high accuracy in both the EEG (78%) and eye movements (80%) when you use them separately. The wearability and feasibility is good and it has an accuracy of 85,11% when combined.

Table 3: Overview of the data-extraction

Author	Wich device was used	What kind of emotion	what does the device measure	Wearable or stationary	Negative points about the device	positive points about the device	Subjects
(Chrisinger & King, 2018)	Empatica E4	stress	Time-stamped data, 3-axis accelerometry, skin temperature, blood volume pressure, HR, heartbeat inter-beat interval and EDA.	Wearable	Good contact with the skin surface is necessary to collect data. What are 'signals' and what is 'noise'. It is important to have baseline data.	It provides a commercially available, easy-to use means of continuously collecting time stamped biometric data.	14 adults (8 women, 6 men) Inclusion: healthy, living in or around San Francisco and be able to complete an easy 20 to 25 minute walk.
(Dao, Dang-Nguyen, Kasem, & Hung, 2018)	Empatica E4	Nervous, stressed and excited, relaxed	photoplethysmography (PPG), EDA, 3-axis accelerometer, infrared thermopile	Wearable	/	/	15 students, 1 lecturer. have to wear the empathica E4 for continuous 3 weeks' time

Author	Wich device was used	What kind of emotion	what does the device measure	Wearable or stationary	Negative points about the device	positive points about the device	Subjects
(Deravi et al., 2015)	1. Brain Computer Interface (BCI) 2. Q-sensor by Affectiva	2. Arousal	1. EEG 2. EDA, temperature and acceleration	wearable	1. EEG signal can be contaminated by various noise sources such as power line interferences and the presence of unwanted physiological signals etc. This is particularly an issue if there is contamination (e.g. hair, sweat) at the skin-electrodes-scalp interface.	1. user-friendly styles (baseball caps, headbands, headsets...) --> Freedom of postures, Patients find the BCI useful.	5 controls and 5 patients with neurological conditions. exclusion (not have prior experience in using BCI headsets) exclusion (epilepsy, use of neuro-stimulators or pacemakers)
(Gouverneur et al., 2017)	Empatica E4	stress	photoplethysmography (PPG), EDA, 3-axis accelerometer, infrared thermopile	Wearable	Motion artefacts can occur when it is not worn tightly, when the subject does rapid or fast movements, when the wristband shifts or hits against an object.	comfortable, continuous, real-time data acquisition., accuracy of 71%	Data of 1 person

Author	Wich device was used	What kind of emotion	what does the device measure	Wearable or stationary	Negative points about the device	positive points about the device	Subjects
(Harley, Bouchet, Hussain, Azevedo, & Calvo, 2015)	1. affectiva's Q-sensor 2.0 2. Emotions-value questionnaire (EV) 3. Facereader 5.0	1. Arousal 2. Happy, enjoyment, hope, pride, anger, frustration, anxiety, fear, shame, boredom, surprise, contempt, disgust, confusion, curiosity, sadness, eureka, neutral hopelessness 3. Happy, sadness, anger, fear, surprise, disgust, neutral	1. EDA (by passing current between 2 electrodes placed on the skin) 2.19 different emotional states on a 5-point Likert scale (Valence/Arousal) 3. Facial expression recognition	1. Wearable 2. Stationary 3. Stationary	41,3% agreement between Q-SENSOR and EV. the relationship between arousal remains weak.	60,1% agreement between the FACEREADER and the Q-SENSOR when comparing arousal levels.	67 students (55 females and 12 males) at the north American University. Their mean age was 21y/o. Inclusion criteria: Be 18+ years old, full time undergraduate students and because of the facial recognition software, participants had to be able to tie long hair and bangs back. Exclusion criteria: Bad vision (wearing glasses)

Author	Wich device was used	What kind of emotion	what does the device measure	Wearable or stationary	Negative points about the device	positive points about the device	Subjects
(Hoogerheide, Renkl, Fiorella, Paas, & van Gog, 2019)	Empatica E4	Arousal	EDA	Wearable	There always has to be a baseline calculation (what is a neutral state in a person with a severe disability that cannot expres if they are calm or aroused?) Empatica is new technology: remain cautious when interpreting the arousal findings.	/	61 psychology students (17 male, 44 female) from a dutch university. Their mean age was 20y/o. Low or no prior knowledge of parallel circuit troubleshooting.
(Kappas, Kuester, Basedow, & Dente, 2013)	1. Affectiva's Q-sensor 2. Finger-electrodes	User states	EDA	Wearable	Not as precise as stationary systems.	No need for cables, boxes or skin preparation	30 subjects
(Ollander, Godin, Campagne, Charbonnier, & Ieee, 2016)	1. Empatica E4 2. AD Instruments Powerlab (ECG)	Stress	1. BVP, interbeat intervals (IBI), wrist skin conductivity 2. ECG, finger skin conductivity	1.Wearable 2.Stationary	1.significant loss of IBI with the BVP signal (especially when performing a task) 2. SC signal of the finger electrodes are less discriminating	1.mean HR and Standard deviation of HR have been acceptably estimated (promising results for stress discrimination). More discriminating skin conductivity than the finger electrodes	7 subjects (1 male, 6 females), mean age 22 +- 2.

Author	Wich device was used	What kind of emotion	what does the device measure	Wearable or stationary	Negative points about the device	positive points about the device	Subjects
(Stadler, Jepson, & Wood, 2018)	Empatica E4	Arousal	EDA, BVP, HR, temperature, accelerometer	Wearable	Subjects have to be in good health: potential for signal distortion and pollution: coughs, sneezes and deep respiratory movements can generate SCRs which lead to false readings. Persons with cardiovascular abnormalities can produce rhythmic artefacts (spiking) in the EDA.	EDA is the only autonomic psychophysiological variable that is not contaminated by the parasympathetic activity of the body such as the functioning of major organs. EDA can detect implicit emotional responses that may occur without conscious awareness or are beyond cognitive intent. Bodily responses can not be easily faked.	5 groups of 3-4 women age > 70 took part in the research facilitated by Age UK. 4 groups of 4 women over 70 participated in the research at sessions hosted by the art provider. Inclusion: 70+ years old women and residents in the rural areas
(van der Wal & Irrmischer, 2015)	Brain Computer Interface (BCI) (Myndplay Brainband XL)	Emotion regulation Positive-Neutral-Negative Arousal	Brain activity (Alpha band and Gamma activity)	Stationary	/	It is commercially available, noninvasive. They use a dry active sensor technology, this means that the sensors do not need a conductive gel and because of that are more comfortable and easy to use.	53 students, 29 Meditation- and 24 Laughter training. Inclusion: Healthy, Dutch/English, 18-67 y/o Exclusion: history of neurological complications or substance abuse and previous experience with meditation, yoga or laughter yoga.

Author	Wich device was used	What kind of emotion	what does the device measure	Wearable or stationary	Negative points about the device	positive points about the device	Subjects
(Zhao, Wang, Yu, & Guo, 2018)	Empatica E4	Human emotions (especially happiness, sadness, fear and anger)	Blood volume pause, EDA, skin temperature	Wearable	Signal noise influences the stability of features and the emotion recognition accuracy	75,56% overall accuracy shows that the E4 can recognize human emotion.	15 subjects (9males and 6 females) age range 22-28. Inclusion: graduate students. Exclusion: cardiovascular, neurological, epileptic or hypertension disease.
(Zheng, Liu, Lu, Lu, & Cichocki, 2019)	EmotionMeter (Combination of EEG and Eye movements)	Happy, sad, neutral and fear Valence (sad-happy) Arousal (calm-excited)	1. EEG-data (Power spectral density (PSD) and Differential entropy (DE)) 2. Pupil diameter, Dispersion, Fixation duration, Blink duration and Saccade	Both (wearing a headband)	/	Especially neutral emotion has an respectively high accuracy in both the EEG (78%) and eye movements (80%). wearability and feasibility accuracy of 85,11% when combined	15 right-handed college students (8 females and 7males) between 20-24 years old

5. DISCUSSION

5.1 REFLECTION STUDY SELECTION

For the P in the PICO, many terms were used. In Dutch the concerned patients are called persons with an 'Ernstige Meervoudige Beperking (EMB)'. In English there is no direct translation of this term and that's why so many other terms were used in the literature search. For the I in the PICO, terms known to be emotion meters were included. To prevent a bias, the term 'emotion meter' was included as a neutral term. This knowledge about several emotion meters was brought to us by VZW Stijn, a non-profit organization that asked UHasselt to conduct research about emotion meters.

It wasn't possible to use all of the PICO terms in the literature search. There is little to no research done about the use of an emotion meter on the concerned patients. When all of the PICO terms were combined, there was only one hit on PubMed and Web Of Science. First, the I of the PICO was dismissed and there were 122 703 studies found so the terms 'measurement AND emotion' were included to make it more specific. When the found articles were investigated, there were only a few articles that could be used. That's the reason why the decision was made to only use the terms of the ICO. These terms had the most relevant articles and it included also the few good articles found when using PCO and the terms 'measurement AND emotion'.

The articles were included based on the fact that the device could be used on the concerned patients and measured emotion. Our target audience is cognitively unable to express their emotion or to tell how they feel. For that reason, articles that used a device that only measured facial expressions or with only the use of questionnaires or self-report to measure emotions were excluded. One article (Novak, 2019) was also excluded based on the fact that it happened in court, an abnormal situation that couldn't be generalized for the concerned patients. Studies that contained paintings, pictures or animals were also excluded because the main target is real life human emotions.

The quality checklist contained the questions that were important for this literature study. The last three questions aren't standardized questions for quality assessment, but they are questions about the content quality of the articles. It was important that the study contained

a device that's usable for the population, that it was achievable to use in real life and that it contained a clear explanation of the measurement device.

5.2 REFLECTION ABOUT THE FINDINGS IN FUNCTION OF THE RESEARCH QUESTION

In the literature search, four devices were used to measure emotion: The Empatica E4 (N=7), the Affectiva Q-sensor (N=3), the Brain Computer Interface (BCI) (N=2) and the combination of EEG and eye-movements (N=1).

Only one article (Deravi et al., 2015) discussed the use of a BCI system and an Affectiva Q-sensor on patients that have a neurological condition. All the other articles used healthy subjects. Because of this, there is no certainty about the effects , usability and generalizability of the use of the Empatica E4, Affectiva Q-sensor, BCI systems and EEG and eye-tracking movements on people with severe disabilities.

The Empatica E4 wristband is comfortable, easy to use and available (Chrisinger & King, 2018). The mean HR and the standard deviation of HR provided promising results for stress discrimination and the skin conductivity was more discriminating than finger electrodes (Ollander et al., 2016). It is necessary to distinguish between 'signal' and noise'. Sometimes movement can provoke noise (Chrisinger & King, 2018) but also shifting or hitting against an object (Gouverneur et al., 2017). The Empatica E4 showed an 75,56% overall accuracy of emotion recognition (Zhao et al., 2018).

The studies that used the Affectiva Q-sensor didn't report a lot of negative or positive points about the device. Only (Kappas et al., 2013) reported that the device was not as precise as stationary systems but the advantage is that it doesn't need any cables, boxes or skin preparation.

Most articles (N= 7) used the Empatica E4 because it's the most feasible, available and easy to use device that can measure many different parameters. The affective Q-sensor is a simpler version of the Empatica E4. It can measure EDA, ACC and temperature while the Empatica E4 also measures PPG and BVP.

The BCI is user friendly (Deravi et al., 2015) and commercially available and non-invasive (van der Wal & Irrmischer, 2015). Contamination (e.g. hair, sweat) at the skin-electrodes-scalp interface can cause noise in the EEG signals (Deravi et al., 2015) which makes it difficult to read the signals correctly.

The study from (Zheng et al., 2019b) about the combination of EEG and Eye-tracking was very promising. It has a good wearability and feasibility and it had an accuracy of 85,11% when combined. There was only one study that used that device and had also a small sample size of 15 subjects. More studies on this are needed to make it generalizable.

No study linked the data observed with a specific kind of emotion. They could tell if there was arousal but there is no mentioning of the valence and for this study, finding results about valence would be of extra value because both happiness and anger cause the same changes in arousal.

5.3 REFLECTION ABOUT THE STRENGHTS AND THE LIMITATIONS OF THE LITERATURE STUDY

The literature study has multiple strengths.

First of all, a lot of search terms were used in the literature search to make sure all relevant articles would be found. A long time was spent on finding the best possible research technique. Both researchers did the screening of the articles separately to make sure no faults were made or important details were missed.

All the articles had a clear explanation about the device. Some of these also had a clear explanation how to use the device and how to process its data. This way, the researcher could make a decision about which devices could be used on the targeted audience.

The articles all used different settings that made it possible to know if the operation of a device was the same in different circumstances.

The literature study also has several limitations.

Multiple studies (N=8) had a small sample size (<= 30). For that reason, the results found in those studies cannot be generalized and should be looked at with caution.

No studies discussing the following emotion meters were found: ‘Slimme sok’ (smart sock) and ‘buienradar’ (Mood radar). Because of this, the possibility exists that we missed more than only these two emotion meters because they aren’t used in a study yet.

Since only 2 databases were used, the possibility exist that some relevant articles were missed.

Only one study discussed the use of the emotion measurement device with people with a severe disability (Deravi et al., 2015). The other studies discussed the devices used on healthy people. Therefore, the effects of the use of the device cannot be predicted on people with a severe disability.

In most of the studies the recruitment and testing took place at one single location which possibly limits the generalizability of the results to groups in other regions or countries.

Most articles did no long term follow up. Because of this, there is no certainty that results will remain unchanged if the same measurement is executed at a later point in time. Neither did they perform measurements over a longer time span. Different moments of the week may have their impact on the participants emotions and give different results.

Furthermore, few studies really validated the measurement instrument used during their experiment. Therefore, the quality of the studies is questionable.

As a final point, in most studies, the academical bias couldn't be ruled out with certainty.

5.4 RECOMMENDATION ABOUT FUTURE RESEARCH

For further research, studies with a larger sample size are recommended in order to generalize for a certain population. Not many studies in general are conducted on people with a severe disability. Therefore, research specifically conducted on people with a severe disability is necessary to understand more about them. The same applies to research consisting of the use of emotion meters. It is still limited and this specific population could benefit from it the most. As a final point, research about valence or the meaning of arousal, does high arousal automatically mean anger or could it also be happiness, measured with an emotion meter, is still limited.

6. CONCLUSION

The Empatica E4 wristband, the Affectiva Q-sensor, the Brain Computer Interface and the EEG combined with eye movement was used in the articles to measure emotion. The Empatica E4 wristband was used the most in the articles, it is available and easy to use and it has the most outcome parameters (3-axis accelerometry, skin temperature, blood volume pressure, HR, heartbeat inter-beat interval and EDA). All of these emotion meters could be used on people with a severe physical and/or cognitive disability but further research is necessary.

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APPENDIX

Table 4: An overview of the excluded studies

Reason exclsusion	Number of studies	Author
No emotion measurement outcome	12	(Bakhtiari, Liao, Elmer, Gopalsami, & Raptis, 2011; Condori-Fernandez, Lopez, & Ieee, 2017; Corino et al., 2017; Hutchison et al., 1996; Lo, Sehic, & Meijer, 2017; Pietila et al., 2018; Pijeira-Diaz, Drachsler, Jarvela, & Kirschner, 2019; Pijeira-Diaz, Drachsler, Kirschner, & Jarvela, 2018; Sano, Picard, & Ieee, 2011; Scherer, 2005; Siirtola, Koskimaki, Monttinen, & Roning, 2018; Van Voorhees et al., 2018)
Design	6	(Bariola, Gullone, & Hughes, 2011; Bjornsten & Sorensen, 2017; Halberstadt & Parker, 2007; Horner & Wallace, 2013; Lagast, Gellynck, Schouteten, De Herdt, & De Steur, 2017; Li, Scott, & Walters, 2015)
Use of questionaires in intervention	14	(Cho & Kim, 2017; Collinsworth et al., 2014; Han & Shaffer, 2013; Ipser et al., 2013; Kerns, Mennin, Farach, & Nocera, 2014; Kessler et al., 2005; Li, Walters, Packer, & Scott, 2018; Moon, Qu, & Ieee, 2017; Ram et al., 2005; Tonti & Salvatore, 2015; Veilleux, Salomaa, Shaver, Zielinski, & Pollert, 2015; Verduyn, Tuerlinckx, & Van Gorp, 2013; Wang, Chien, & Moutinho, 2015; Warrenburg, 2002)
Unusual situation during intervention	3	(Novak, 2019; Smith & Crabbe, 2000; Wardana, Ramadijanti, & Basuki, 2018)
Quality to low	1	(Garbarino et al., 2014)
Population	2	(Kleckner et al., 2018; Magdin & Prikler, 2018)

Table 5: An overview of the strenghts and weaknessess

	Strenghts	Weaknessess
(Chrisinger & King, 2018)	-Combination of emotion measurement device and smartphone to collect and sent data. -10min pre-walk with wrisband to collect baseline measurements	-Small sample size (n= 14) -recruitment as a convenience sample -Only 1 day of measurements (no follow-up or new measurement to check if first one is correct)
(Dao, Dang-Nguyen, Kasem, & Hung, 2018)	-Combination of emotion measurement device and smartphone to collect and sent data. -Clear explanation about (the working of) the device -Longer period of measurement (Had to wear wristband 3 weeks for continuous time.)	- Small sample size (n= 16) -No baseline measurement (included in 3 weeks) -Recruitment in 1 class
(Deravi et al., 2015)	-Combination of BCI systems (EEG) an Affectiva Q-sensor -Clear explanation about (the working of) the device and how to use it.	- Small sample size (n=10) -Recruitment at the neuro rehabilitation unit at Kent and Canterburry hospital -One session with a duration between 65 min and 98 min
(Gouverneur et al., 2017)	-Clear explanation of the device and its measurement outcomes - Comparison between resting and stressing phase of the test.	- Small sample size (n=1) - No clear description of subjects - No discussion section -No information about how long they collected the data
(Harley, Bouchet, Hussain, Azevedo, & Calvo, 2015)	- Combination of Affectiva Q sensor and Facial expressions - Moderate sample size (n=67) -Clear explanation of the device	-Recruitment at 1 university - Only one session of 90 min (no longer follow ups)
(Hoogerheide, Renkl, Fiorella, Paas, & van Gog, 2019)	-Explanation of the device -Baseline measurements for the device -Moderate sample size (n=61)	-Recruitment at 1 university and course credits were given for participation. -Experiment only lasted 50 minutes (representable EDA measurements?)
(Kappas, Kuester, Basedow, & Dente, 2013)	-Comparison of two devices	-Small sample size (N=30) -Little explanation about the device -39% were judged as unusable

	Strenghts	Weaknesses
(Ollander, Godin, Campagne, Charbonnier, & Ieee, 2016)	-Comparison of two devices -Explanation of the devices -Comparison of all the outcome measurements of both devices -distinguish stress from activity	- Small sample size (N=7)
(Stadler, Jepson, & Wood, 2018)	-Broad explanation of the device and its measurement outcomes -Baseline measurements for the device -Moderate sample size (n=36)	-Focus primarely on the social experiment
(van der Wal & Irrmischer, 2015)	-Measurement of EEG with a single electrode -Measurements also before and after the training -Moderate sample size (n=53)	-Training effect
(Zhao, Wang, Yu, & Guo, 2018)	-Broad explanation about the decive and its measurement outcomes -Explanation were you have to pay attention to when using the device -Using a questionnaire as the ground-truth	-Small sample size (N=15) -No discussion section
(Zheng, Liu, Lu, Lu, & Cichocki, 2019)	-Combination of two devices -Broad explanation about the devices -Broad analysis -Moderate sample size (n=44)	-No discussion section

PART 2: RESEARCH PROTOCOL

1. INTRODUCTION

Emotion plays an important role in human-human interaction (Das Chakladar & Chakraborty, 2018). These emotions are processes directed towards a specific event or object, which result in physiological changes in both behavior and bodily state during communication (Jang et al., 2015). One of these physiological changes could be changes in Electro Dermal Activity (EDA), skin temperature, heart rate, etc..

Some people, often those with a severe physical and/or cognitive disability, are not able to physically show their emotion or tell someone how they feel. Sometimes they have an emotional outburst or they get aggressive towards others, caused by a certain situation. This often happens without a warning that could be picked up by the caregivers. People without these disabilities can indicate when a situation becomes emotionally difficult for them but these people can't. For them, it would be practical to have some sort of device that could translate their emotions to understandable signals for their caregivers or family members.

One device that could be useful would be the Empatica E4. The Empatica E4 wristband is comfortable, easy to use and available (Chrisinger & King, 2018). It uses four different sensors: A photoplethysmograph (PPG) sensor to measure blood volume pulse (BVP), a 3-axis accelerometer (ACC) to understand a three-dimensional movement of the participant, an infrared thermopile (TEMP) to measure skin temperature and an Electrodermal Activity (EDA) sensor (Dao et al., 2018).

There are a lot of studies that used the Empatica E4 already such as Chrisinger, B. W., & King, A. C. (2018), Dao, M. S., Dang-Nguyen, D. T., Kasem, A., & Hung, T. T. (2018), Gouverneur, P., Jaworek-Korjakowska, J., Koping, L., Shirahama, K., Kleczek, P., & Grzegorzek, M. (2017), Hoogerheide, V., Renkl, A., Fiorella, L., Paas, F., & van Gog, T. (2019), Ollander, S., Godin, C., Campagne, A., Charbonnier, S., & Ieee. (2016), Stadler, R., Jepson, A. S., & Wood, E. H. (2018) and Zhao, B. B., Wang, Z., Yu, Z. W., & Guo, B. (2018) but nearly no studies used it on people with a severe physical and/or cognitive disability. Moreover, nearly no study investigated which signal refers to which emotional outcome.

2. AIM OF THE STUDY

The aim of this investigation is to link certain outcome parameters from an emotion meter with a certain behavior in people with a severe physical and/or cognitive disability. If there is a link between a certain outcome parameter and a certain behavior, can an emotional outburst be prevented? By using the Empatica E4 wristband, physiological signals such as the Electro Dermal Activity (EDA) of the participants can be monitored. This will be monitored over a longer time span because most previous studies investigated one-day measurements.

2.1 RESEARCH QUESTIONS

- "Can changes in the outcome parameters of the Empatica E4 be linked to a certain emotion in people with a severe physical and/or cognitive disability."
- "Can an emotional outburst of people with a severe physical and/or cognitive disability be prevented by the outcome parameters of the Empatica E4?"

2.2 HYPOTHESES

1. A change in the Electro Dermal Activity (EDA) can be linked to a certain behavior in people with a severe physical and/or cognitive disability.
2. An emotional outburst can be prevented by the outcome parameters of the Empatica E4.

3. METHOD

3.1 RESEARCH DESIGN

An observational case study of three residents of Sint Oda in Overpelt to compare the behavior of the persons with a severe physical and/or cognitive disability and the outcome parameters of the Empatica E4 wristband.

3.2 PARTICIPANTS

- Three residents of Sint Oda in Overpelt with a severe physical and/or cognitive disability.

3.2.1 INCLUSION CRITERIA

- Residents of Sint Oda Overpelt
- severe physical and/or cognitive disability
- Unable to express their emotions
- Having >1 emotional outburst par week
- Age ≥ 18

3.2.2 EXCLUSION CRITERIA

- Taking sedatives or medication that mutes the physical responses

3.2.3 RECRUITMENT

The participant are recruited from Sint Oda in Overpelt. A nursing home for people with a moderate or severe physical and/or cognitive disability.

3.3 MEDICAL ETHICS

All of the representatives of the participants will have to sign the 'informed written consent'. All of the representatives of the other inhabitants that life in the same group as our participants and the caregivers have to sign the 'informed written consent' to give permission to be filmed. The independent Ethics committee of the University of Hasselt will approve the study in August, 2019.

3.4 INTERVENTION

This will be an observational case study were the participants will be observed through camera footage and at the same time, data will be collected from the Empatica E4.

The Empatica E4 will be worn every day for two weeks by the participants. Every morning when the participants get dressed, the caregiver will put on the Empatica E4 and show it to the camera. When the light of the Empatica E4 turns green instead of red, the researchers know when the Empatica E4 started recording so they would be able to connect the time of the collected data with the corresponding footage. When they get ready for bed, the Empatica E4 will be taken off by the caregiver to prevent and check for any potential pressure wounds.

All of the camera footage will be watched by the same researchers individually and also a second time.

The clinical assessments that will be taken before the testing:

- Information about the participants:

  Questionnaire filled in by the caregivers or by the representatives:

  - Age
  - Gender
  - Kind of disorder (Genetic, acquired…)
  - Medical history
  - Things that are known that the participants like and dislike
  - How they express their emotion
  - Number of emotional outburst in two weeks

The clinical assessments during the testing:

An observation checklist will be made to connect the data of the camera footage with the data from the Empatica E4. Special attention will go to changes measured with the Empatica E4 and the corresponding behavior seen with the camera footage, is the change visible with an outburst or is there no change visible.

- Camera footage:
  - Activities
  - Behavior
  - Emotional outbursts

- Data from the Empatica E4:
    - Blood Volume Pulse (BVP):
        - Heart Rate (HR)
        - Heart Rate Variability (HRV)
    - Electrodermal activity (EDA)
    - 3-axis accelerometer (ACC)
    - Skin temperature

3.5 OUTCOME PARAMETERS

3.5.1 PRIMARY OUTCOME PARAMETERS

Primary outcome parameters are

- electrodermal activity (EDA) changes linked to an emotion
- participants movements linked to an emotion
- skin temperature changes linked to an emotion

3.5.2 SECONDARY OUTCOME PARAMETERS

The secondary outcome parameters are

- the BVP changes linked to an emotion
- any changes recorded with the camera footage

3.6 DATA-ANALYSIS

This will be an observational study, in which footage of the participants will be made that can be linked to data of the Empatica E4 wristband.

Two researchers will observe the footage separately. One month later, the researchers will observe the same footage and confirm with their first observation to see if their findings are still the same. This will be done to ensure a higher intra-rater reliability. Then the researchers will discuss their findings between each other to assess the inter-rater reliability.

4. TIME PLANNING

The data-collection will be done during the period of October 2019 and November 2019. The data-extraction and the analysis will then be finished in December 2019. Ultimately the manuscript will be finished at the end of January.

5. REFERENCES

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APPENDIX

LITERATUURSTUDIE	Gestelde deadline	Behaald op	Reflectie
De belangrijkste concepten en conceptuele kaders van het onderzoekdomein uitdiepen en verwerken	10/12/2019	10/12/2019	Opzoekwerk gedaan en duidelijke uitleg gekregen van de medewerker van VZW Stijn.
De belangrijkste informatie opzoeken als inleiding op de onderzoeksvraag van de literatuurstudie	10/12/2019	10/12/2019	Opzoekwerk op het internet en in de databases PubMed en Web of Science.
De opzoekbare onderzoeksvraag identificeren en helder formuleren in functie van de literatuurstudie	10/12/2019	10/12/2019	Met de uitleg die we gekregen hadden en het onderwerp hebben we een vraag opgesteld die bij het domein paste.
De zoekstrategie op systematische wijze uitvoeren in relevante databanken	20/02/2019	23/02/2019	We zijn verschillende keren opnieuw moeten beginnen, dit heeft langer geduurd dan verwacht.
De kwaliteitsbeoordeling van de artikels diepgaand uitvoeren	20/04/2019	16/04/2019	Eens we de artikels gevonden hadden ging de kwaliteitsbeoordeling heel vlot.
De data-extractie grondig uitvoeren	02/05/2019	02/05/2019	Geen problemen ondervonden.
De bevindingen integreren tot een synthese	27/05/2019	27/05/2019	Heeft lang geduurd maar is toch op tijd afgeraakt volgens onze planning. Hier meer tijd voor ingepland omdat er nog examen van een 3e bach vak moest afgelegd worden.

ONDERZOEKSPROTOCOL	Gestelde deadline	Behaald op	Reflectie
De onderzoeksvraag in functie van het onderzoeksprotocol identificeren	20/05/2019	20/05/2019	Deadline werd behaald
Het onderzoeksdesign bepalen en/of kritisch reflecteren over bestaande onderzoeksdesign	25/05/2019	25/05/2019	Deadline werd behaald
De methodesectie (participanten, interventie, uitkomstmaten, data-analyse) uitwerken	01/06/2019	12/06/2019	Data-analyse werd nog aangepast na afspraak met de promotor.

ACADEMISCHE SCHRIJVEN	Gestelde deadline	Behaald op	Reflectie
Het abstract tot the point schrijven	31/05/2019	27/05/2019	Na de synthese hebben we meteen het abstract kunnen afwerken. De deadline werd vervroegd behaald.
De inleiding van de literatuurstudie logisch opbouwen	20/05/2019	18/05/2019	Hier hadden we al een ruime deadline gesteld omdat we op voorhand wisten dat dit moeilijk zou worden.
De methodesectie van de literatuurstudie transparant weergegeven	25/04/2019	10/05/2019	Door drukte met schoolwerk is deze datum opgeschoven.
De resultatensectie afstemmen op de onderzoeksvragen	20/05/2019	19/05/2019	We hebben een tandje bijgestoken en deze deadline vervroegt behaald.
In de discussiesectie de bekomen resultaten in een wetenschappelijke tekst integreren en synthetiseren	25/05/2019	25/05/2019	Deadline werd behaald.
Het onderzoeksprotocol deskundig technisch uitschrijven	12/06/2019	11/06/2019	Na overleg met promotor werden alle details 1 dag sneller dan verwacht afgewerkt.
Referenties correct en volledig weergeven	04/06/2019	04/06/2019	Afwerking op het einde ging vlot.

ZELFSTUREND EN WETENSCHAPPELIJK DENKEN EN HANDELEN	**Aanvangsfase**	**Tussentijdse fase**	**Eindfase**
Een realistische planning opmaken, deadlines stellen en opvolgen	Voldoende	Goed	Goed
Initiatief en verantwoordelijkheid opnemen ten aanzien van de realisatie van de wetenschappelijke stage	Voldoende	Voldoende	Goed
Kritisch wetenschappelijk denken	Goed	Goed	Goed
De contacten met de promotor voorbereiden en efficiënt benutten	Goed	Zeer Goed	Zeer Goed
De richtlijnen van de wetenschappelijke stage autonoom opvolgen en toepassen	Voldoende	Goed	Goed
De communicatie met de medestudent helder en transparant voeren	Goed	Goed	Zeer Goed
De communicatie met de promotor/copromotor helder en transparant voeren	Goed	Goed	Goed
Andere verdiensten: /	/	/	/

LITERATUURSTUDIE	Gestelde deadline	Behaald op	Reflectie
De belangrijkste concepten en conceptuele kaders van het onderzoekdomein uitdiepen en verwerken	10/12/2019	10/12/2019	Opzoekwerk gedaan en duidelijke uitleg gekregen van de medewerker van VZW Stijn.
De belangrijkste informatie opzoeken als inleiding op de onderzoeksvraag van de literatuurstudie	10/12/2019	10/12/2019	Opzoekwerk op het internet en in de databases PubMed en Web of Science.
De opzoekbare onderzoeksvraag identificeren en helder formuleren in functie van de literatuurstudie	10/12/2019	10/12/2019	Met de uitleg die we gekregen hadden en het onderwerp hebben we een vraag opgesteld die bij het domein paste.
De zoekstrategie op systematische wijze uitvoeren in relevante databanken	20/02/2019	23/02/2019	We zijn verschillende keren opnieuw moeten beginnen, dit heeft langer geduurd dan verwacht.
De kwaliteitsbeoordeling van de artikels diepgaand uitvoeren	20/04/2019	16/04/2019	Eens we de artikels gevonden hadden ging de kwaliteitsbeoordeling heel vlot.
De data-extractie grondig uitvoeren	02/05/2019	02/05/2019	Geen problemen ondervonden.
De bevindingen integreren tot een synthese	27/05/2019	27/05/2019	Heeft lang geduurd maar is toch op tijd afgeraakt volgens onze planning.

ONDERZOEKSPROTOCOL	Gestelde deadline	Behaald op	Reflectie
De onderzoeksvraag in functie van het onderzoeksprotocol identificeren	20/05/2019	20/05/2019	Deadline werd behaald
Het onderzoeksdesign bepalen en/of kritisch reflecteren over bestaande onderzoeksdesign	25/05/2019	25/05/2019	Deadline werd behaald
De methodesectie (participanten, interventie, uitkomstmaten, data-analyse) uitwerken	01/06/2019	12/06/2019	Data-analyse werd nog aangepast na afspraak met de promotor.

ACADEMISCHE SCHRIJVEN	Gestelde deadline	Behaald op	Reflectie
Het abstract tot the point schrijven	31/05/2019	27/05/2019	Na de synthese hebben we meteen het abstract kunnen afwerken. De deadline werd vervroegd behaald.
De inleiding van de literatuurstudie logisch opbouwen	20/05/2019	18/05/2019	Hier hadden we al een ruime deadline gesteld omdat we op voorhand wisten dat dit moeilijk zou worden.
De methodesectie van de literatuurstudie transparant weergegeven	25/04/2019	10/05/2019	Door drukte met schoolwerk is deze datum opgeschoven.
De resultatensectie afstemmen op de onderzoeksvragen	20/05/2019	19/05/2019	We hebben een tandje bijgestoken en deze deadline vervroegt behaald.
In de discussiesectie de bekomen resultaten in een wetenschappelijke tekst integreren en synthetiseren	25/05/2019	25/05/2019	Deadline werd behaald.
Het onderzoeksprotocol deskundig technisch uitschrijven	12/06/2019	11/06/2019	Na overleg met promotor werden alle details 1 dag sneller dan verwacht afgewerkt.
Referenties correct en volledig weergeven	04/06/2019	04/06/2019	Afwerking op het einde ging vlot.

ZELFSTUREND EN WETENSCHAPPELIJK DENKEN EN HANDELEN	**Aanvangsfase**	**Tussentijdse fase**	**Eindfase**
Een realistische planning opmaken, deadlines stellen en opvolgen	Voldoende	Goed	Goed
Initiatief en verantwoordelijkheid opnemen ten aanzien van de realisatie van de wetenschappelijke stage	Voldoende	Voldoende	Goed
Kritisch wetenschappelijk denken	Goed	Goed	Goed
De contacten met de promotor voorbereiden en efficiënt benutten	Goed	Zeer Goed	Zeer Goed
De richtlijnen van de wetenschappelijke stage autonoom opvolgen en toepassen	Voldoende	Goed	Goed
De communicatie met de medestudent helder en transparant voeren	Goed	Goed	Zeer Goed
De communicatie met de promotor/copromotor helder en transparant voeren	Goed	Goed	Goed
Andere verdiensten: /	/	/	/

www.uhasselt.be
Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Campus Diepenbeek | Agoralaan gebouw D | BE-3590 Diepenbeek
T + 32(0)11 26 81 11 | E-mail: info@uhasselt.be

UHASSELT

VOORTGANGSFORMULIER WETENSCHAPPELIJKE STAGE DEEL 1

DATUM	INHOUD OVERLEG	HANDTEKENINGEN
10/12	Bespreking zoekstrategie	Promotor: Copromotor/begeleider: Student(e): Student(e):
20/03	Bespreking vortgang	Promotor: Copromotor/begeleider: Student(e): Student(e):
22/05	skype gesprek + bespreking vragen	Promotor: Copromotor/begeleider: Student(e): Student(e):
29/05	skype gesprek + protocol + bespreking	Promotor: Copromotor/begeleider: Student(e): Student(e):
27/05	oefenmoment verdediging	Promotor: Copromotor/begeleider: Student(e): Student(e):
		Promotor: Copromotor/begeleider: Student(e): Student(e):
		Promotor: Copromotor/begeleider: Student(e): Student(e):
		Promotor: Copromotor/begeleider: Student(e): Student(e):
		Promotor: Copromotor/begeleider: Student(e): Student(e):
11/06	**Niet-bindend advies:** De promotor verleent hierbij het advies om de masterproef WEL/NIET te verdedigen.	Promotor: Copromotor/begeleider: Student(e): Student(e):