SuspenderMender - Designing for a Shared Management of Anxiety in Higher Education Context Through a Pair of Wearables Simulating Physical Touch

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ABSTRACT

Anxiety among university students has increased in recent years due to stressful factors of studies coupled with tightened individual performance requirements stemming both inside and outside the student. While prior anxiety treatment wearables have focused on aiding self-management through an automated tangible therapeutic response to the biometrics reading, this pictorial presents the design, development, and evaluation of the *SuspenderMender,* shared management enabling pair of wearables (i.e., a T-shirt and suspenders). Inspired by prior research suggestions on the power of physical contact and social support in anxiety management, the *SuspenderMender* allows transferring a touch through wearables. A Wizard of Oz pair evaluation with ten university students suggests that the concept idea is relevant and the simulated physical touch felt comforting, almost like a real hug. However, participants raised issues with the inequality of the interaction between the two wearables. Based on our findings, we suggest design considerations for future wearables for the shared management of anxiety.

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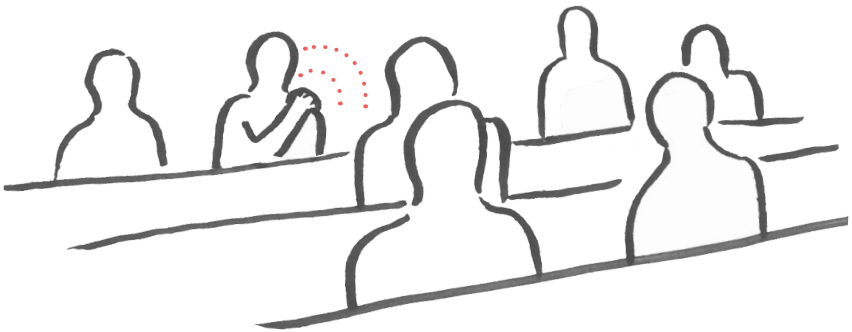


Authors Keywords

Wearables; Anxiety; Shared management; Subtle interaction.

CSS Concepts

• Human-centered computing~Interaction Design

INTRODUCTION

Anxiety is an unavoidable negative emotion and one of the most pervasive and ubiquitous emotions in any culture [46], resulting from any typical life worry about the economy, job, personal life, family matters, or social life [55]. Anxiety can impact a person's mental well-being, leading in the worst case to more severe anxiety disorders which are among the most common mental health and well-being issues [41], affecting approximately 264 million people worldwide [52]. One form of anxiety dis-

order, i.e., social anxiety, develops from negative experiences in social situations making such situations even more difficult due to anticipation of doing something wrong and fear of criticism from others [42, 43].

In this research, we focus on anxiety among university students in Denmark. Even though higher education level students are less affected by mental health issues [48], the number of students experiencing anxiety is rising. In 2016, the student counseling service in Copenhagen got 2,200 inquiries from students struggling with their studies of which the vast majority were because of stress, depression, and anxiety [4]. Alarmingly, the students experienced anxiety and depression symptoms at a level usually seen in outpatient psychiatry [4]. The reasons for increased anxiety can be traced to university studies with several individual performance requirements coming both outside and inside of the student, such as the pursuit of good grades [4], examinations, and group work [13]. Students also pressure themselves to live up to the ideal student of the study program, therefore performing and conducting studies like a career and trying to be social in certain ways [13].

To prevent students from being overburdened with anxiety and more importantly prevent anxiety from developing into a more severe disorder [49], early prevention through the management of anxiety is needed. Collective long-term solutions, such as changing the study culture to be safer [4] or implementing peer-to-peer group-based community programs [31], have been suggested as solutions. In addition, several kinds of anxiety self-tracking and -management technologies have been developed in prior research, of which most realized as mobile applications mainly focusing on the collection of data about anxiety [40]. For exposure therapy, in-home virtual reality solutions (e.g., [19]) and video game streaming [15] have been deemed successful in overcoming negative anxiety-causing emotions. For in situ presentation anxiety training, a virtual coach on a PowerPoint presentation has been proposed [27].

As anxiety feelings result from interactions in the world [55], prior research has explored wearables [9, 11, 8, 17, 39] for active in situ self-management of anxiety [41]. These wearables activate automatically based on biometrics readings and calm the wearer via different outputs, such as vibration [9, 11], pressure [8, 17], or pressure with heat [39]. Prior psychology research has, however, noted the importance of physical touch [26] and social support coming from a family member [20] or a close friend [43] in anxiety reduction. We therefore explore in this pictorial, *how a pair of wearables allowing for sharing a subtle embodied tangible support should be designed for in situ shared management* [25] *of study-related anxiety*? We believe this kind of intimate in situ support would allow for positive experiences and thus help in anxiety alleviation [47]. To understand this, *we study how participants experience the design concept and the pair of wearables?*

Next, prior wearables for anxiety self-management are presented. Then, we explain the difference between self- and shared management and rationalize and motivate our design concept. After that, we will focus on the main contributions of this work: 1) A constructive design process [29] of *SuspenderMender*, a pair of wearables for shared management of study-related anxiety, 2) 10 users' perceptions of the pair of wearables from Wizard of Oz evaluation, and finally, 3) design considerations for wearables for shared management of anxiety.

WEARABLES FOR ANXIETY SELF-MANAGEMENT AND TREATMENT

In the treatment of anxiety, deep pressure touch (DPT) therapy [30] conducted with a weighted blanket to simulate physical contact (e.g., hugging) has been shown to be a good way of calming individuals with short-term anxiety, e.g., dental anxiety [10]. The interest in therapy wearables, especially for DPT, is due to wearables' ubiquitous nature and accessibility [17]. Prior wearables have used different means of outputs for anxiety alleviation, such as pressure (e.g., [8, 17]), heat with pressure [39], and vibration [9, 11]. Vibration has been also combined with a linear movement for asynchronous touch-based emotional therapy [5].

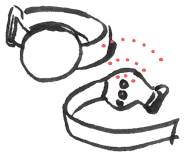
Movement-based wearables

Even though TapTap [5] was not designed specifically for anxiety management, it calms the wearer down through a touch-like sensation realized by a combination of vibration pattern and solenoid moment. The scarf allows the therapist or parent to record the nurturing touch pattern that can be played back later by the user in asynchronous emotional therapy. The straps allow for the scarf to be wrapped around the body in multiple ways making it possible for the user to customize the output location on the body.

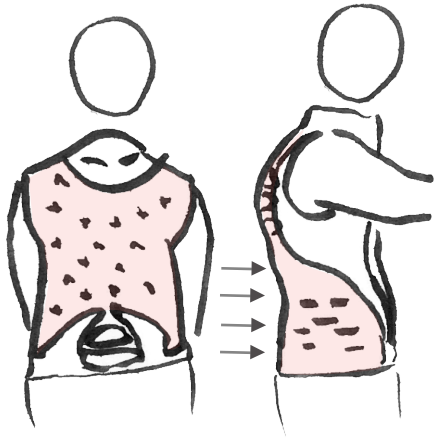
Vibration-based wearables

EEG-based massage headband uses two massage motors and an RGB LED that activates automatically when stress is detected [9]. Preliminary results with four subjects indicate that it can reduce anxiety.

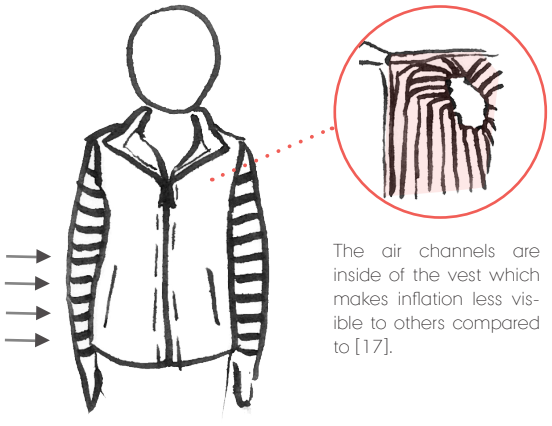
EmotionCheck [11] bracelet calms the wearer down by simulation a slow heartbeat rhythm through subtle vibration feedback. A study with 67 participants shows that the device was able to reduce anxiety without being distracting to the wearer.



Pressure-based wearables



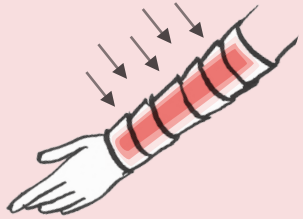
The CalmWear vest [17] wraps around the wearer's torso and inflates automatically based on biometric readings allowing immediate DPT therapy through compression. The vest inflates on the sides and back.



The air channels are inside of the vest which makes inflation less visible to others compared to [17].

Similarly, the AID vest [8] inflates automatically based on biometric readings allowing for immediate DPT therapy through compression. The preliminary results with four participants show that the vest may reduce anxiety.

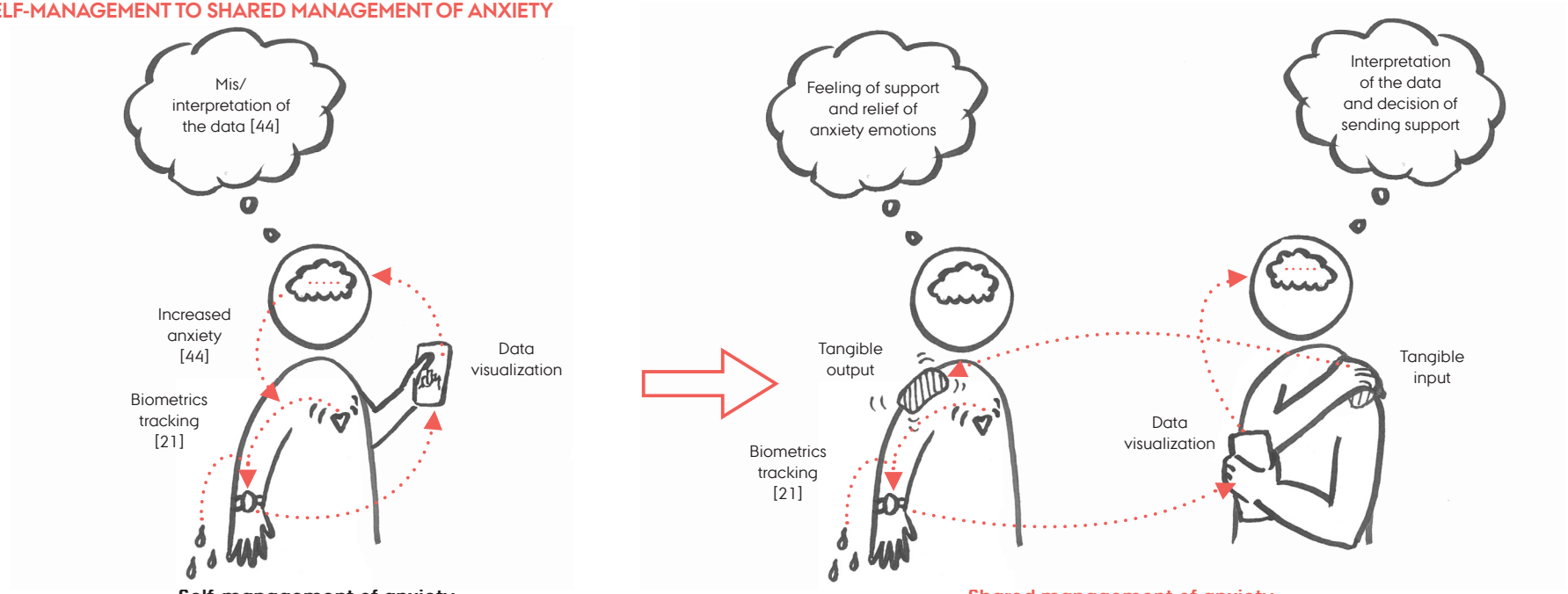
Heat-based wearables



The Affective Sleeve [39] uses a slight pressure with heat feedback presented at a rhythmic pace to reduce the anxiety of the wearer. The pilot study shows a positive influence on the subjects' breathing, calmness, and reduction of anxiety symptoms.

These different techniques cement the viability of using wearables to reduce and prevent anxiety, however, when used in situ, social acceptability [28] of the wearable should be carefully considered with the idea of non-stigmatizing the user [35]. Some of the aforementioned wearables could result in increased anxiety due to the look and placement of the wearable [9], the sound of the output [9, 11], or distinctive visual inflation accompanied by the rather loud sound of the air pumps [8, 17]. While heat [39] is a very subtle and socially acceptable output for the wearable, it can however be challenging for the wearer in warm weather [54]. Therefore, it is important to carefully explore the electronics and their placement on the body when designing wearables for anxiety management in a public setting.

FROM SELF-MANAGEMENT TO SHARED MANAGEMENT OF ANXIETY



Self-management of anxiety

Shared management of anxiety

The use of self-tracked biometric data [34] in the self-management of health and wellbeing has become very popular due to the miniaturization of technology allowing for more jewelry-like wearables, such as the Oura Ring [37] and the Apple Watch [2]. This has made it easy to integrate self-tracking into the everyday life [14, 18, 24, 36] of a wearer. The aforementioned of-the-shelf wearables, as well as mobile applications, have been used in human-computer interaction (HCI) research for collecting biosensing, behavioral, and self-report data on anxiety [21]. Often this self-tracked data is suggested to be used in the self-reflection or self-management of anxiety (e.g., [12]). However, prior research in psychology is rather cautious of this approach as it might lead to misunderstandings of the data, thus increasing health anxiety [44] due to diagnostic uncertainty [45], depicted in the above figure, *Self-management of anxiety*. In addition, the devices designed for anxiety self-management should support the wearer in appreciation of the positive experiences and encourage achieving more of those [47].

Rationale and Motivation for Our Design Concept

Inspired by [41, 26, 20, 47] we decided to experiment with how to design a wearable that allows students to integrate the management of anxiety in everyday life [14, 18, 24, 36] by facing the anxiety causing issues and actively coping and recovering [41, 26, 20] through learning from positive experiences [47]. Herein, prior psychology research has noted the importance of social interaction and social support in the prevention and reduction of anxiety [20]. Especially, family-provided social support combined with an active coping style (i.e., facing actively the issues causing anxiety and depression) of the patient is a strong protective factor against anxiety [41]. Therefore, we want to enable shared management [25] of anxiety through social support [20] coming from a family member [41], a significant other, or a close friend [43]. When considering means to offer social support for an individual, physical touch has been suggested to be an effective way of reducing anxiety among social animals, including humans, due to the oxytocin hormone released in interaction [26]. We, therefore, aim to design a subtle pair of wearables that allow for the transmission of touch through an embodied interaction. The concept idea is depicted in the figure *Shared management of anxiety*, where the biometrics reading of the student is shared with a co-located or remotely located support person, who will interpret the data and send intimate support through embodied interaction with the wearable. The input is sent to a paired wearable, worn by the anxiety-facing student, which creates output (i.e., simulated touch sensation). The wearables aim to facilitate care in a DIY rather than clinical manner [22] to reduce anxiety emotions and train the student to cope better in anxiety-causing study-related situations through positive support.

DESIGN PROCESS

We conducted a constructive design research [29] process to realize a pair of wearable devices that could help to reduce student anxiety by simulating an intimate touch in a concealed and subtle way.

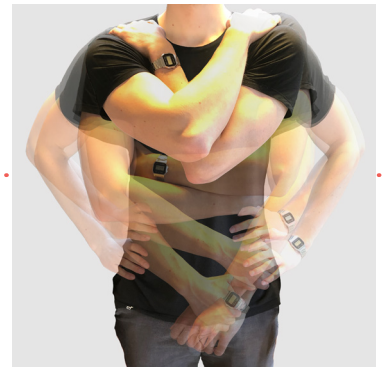
We started with setting up requirements for the wearables and interaction: 1) to make it into an intimate communication, the input and output should be symmetric (i.e., the input activation point on a human body should be located at the same point of actuation of the output). 2) In order not to draw attention to the wearers in a social setting, the wearables should not stand out from normal clothing. 3) The interaction should be unobtrusive and subtle to do without others noticing. 4) The interaction should not strain the wearers (i.e., not be too physically challenging). 5) The wearables should be reliable (i.e., input should not activate accidentally and output should activate only when intended), 6) The wearables should feel comfortable on the wearer's body also when activated.

The design was initiated with embodied ideation [53] of suitable locations for the subtle and unobtrusive one- and two-handed input. Therein, we considered prior anxiety garment pressure locations [8, 17], guidelines for wearable placement [16], the reachability of a human arm [54], and interaction appropriateness in public. We found that the touching of shoulder/s felt comforting and was natural, easy, and strain-free. It also seemed like a typical movement one could do in everyday situations.

Input Wearable Design

We decided to implement a soft button [23] for the input, as it is easy to hide into the garment and allows for very subtle interaction. We applied prototyping on the body [51] to test how the soft button materials and inputs felt on the body and to find the final placement, size, and configuration for the soft button. To make the device look like any normal clothing, we integrated the soft button in a T-shirt. The process resulted in an easy-to-activate and reliable soft button.

For one-handed interaction touching the shoulder felt supporting and almost like resting the hand and arm.



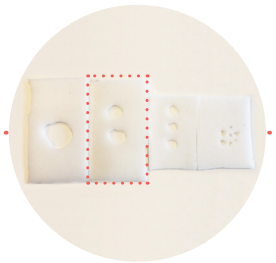
For two-handed interaction crossing arms and touching both shoulders felt comforting and easy to do.

Soft button design

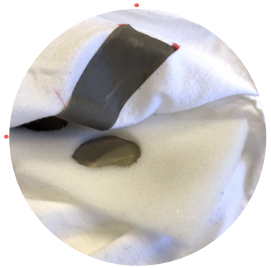
The best place to activate a soft button with a relaxed arm was found to be on the back side of the shoulder.

The final button was hand-sewn into a T-shirt with hidden stitches. An LED light was sewn to the sleeve and to the circuit to show a successful activation to the user.

A preliminary prototype proved the soft button to work reliably in a T-shirt, so we proceeded to the final prototype crafting.



After testing many options, the best performance for the button was achieved with two 40 mm holes in the foam spacer.



The initial button was made by gluing conductive woven ripstop on two fabric pieces separated with a 4 mm thick foam spacer with holes.

A hand-sewn soft circuit, powered with a 3V coin battery, inside of a T-shirt sleeve.

Final input wearable

Touching completes the circuit by connecting the conductive woven ripstop pieces through the holes in the foam spacer and an LED light illuminates.

The T-shirt hides the soft button well, only a minimal volume increase of the shoulder can be seen, which could also be a typical asymmetry of a body.

Design of the Output

Inspired by the embodied techniques used to reduce and relieve anxiety [8, 9, 11, 17, 39] we started exploring the output wearable with a range of embodied experiments to simulate physical contact through the sensation of touch. We began by prototyping on the body [51] and using props and electronics to embody temporal form [53]. The most prominent feeling of a hand on one's shoulder was a soft pressure, slight warmth, and a sense of the shape of a hand, which we tried to replicate with different output means (i.e., heat, inflation, vibration, and contraction). We self-evaluated output means relevance to the set design requirements based on the following criteria: 1) concealed look, 2) pressure provided, 3) warmness, 4) resemblance to a hand-like feeling, and 5) practicality. The positive outcome of the self-evaluation is marked with red and the negative with turquoise in the figure on the right.

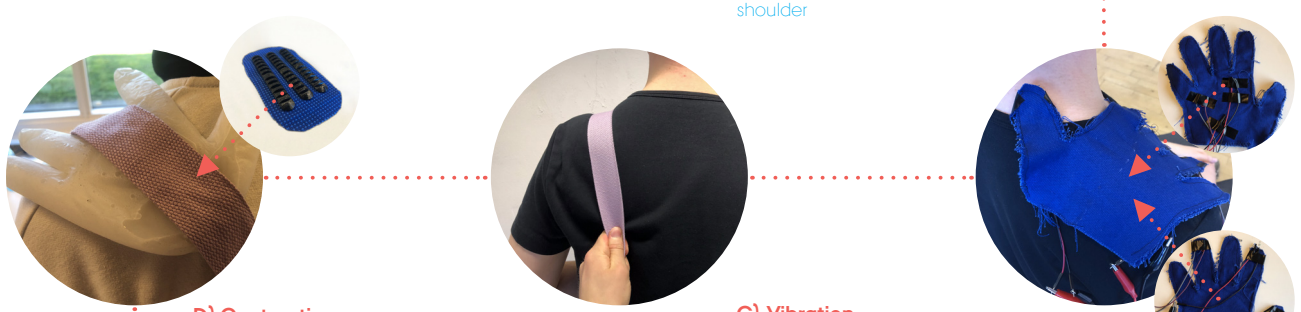
We started experimenting with the outputs with a latex glove filled with warm water (A), inspired by [39] which felt warm but failed to resemble a hand and was impractical. Next, inspired by [8, 17, 39] we experimented with different levels of air pressure through inflation (B), first with a set of long balloons and then with a latex glove placed under a T-shirt. Again, the feeling was not at all handlike. Then inspired by [5, 7, 9, 11] we explored different vibration strengths and patterns (C) by placing a glove-shaped prop with small coin vibration motors taped on the palm and fingertips. Due to the lack of pressure, it was hard to imagine it would be a hand on a shoulder. Finally, we explored contraction by pulling a strap placed over a shoulder on one side, while holding the other side firmly (D), which resulted in quite significant pressure over the shoulder. To enhance the feeling of a hand touching the shoulder, we placed objects (i.e., a silicone hand and a shoulder pad with 3D-printed finger-like objects) under the strap. The pad created a more handlike feeling, but quite an uncomfortable one as it carved into the flesh. We found leather as a better material for shoulder pads because of its softness, yet rigidness after wet forming [38]. As a common material in everyday accessories, leather fits with the use case.

A) Warm water

1) Thick and obtrusive
2) Nice pressure
3) Human-like warmth
4) Artificial, wobbly, & loose feel
5) Needs a water container & heating element

B) Air pressure

1) Thick and obtrusive
2) No pressure without extra force
3) Room temperature
4) Uneven, flimsy, & loose feel
5) Difficult to create pressure around the shoulder

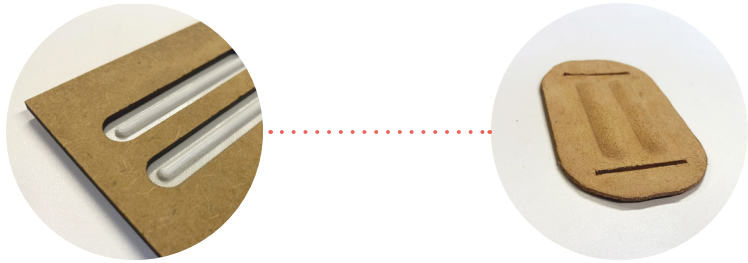


D) Contraction

1) Thin and unobtrusive with a small prop
2) Significant pressure with little effort
3) A slightly warm sensation through pressure
4) With a prop, a hand-like feeling achieved
5) Electronics able to contract are available

C) Vibration

1) Thin and unobtrusive
2) No pressure
3) A slightly warm sensation
4) Not like a hand
5) Difficult to create a hand-like feeling



The final 3D finger-like forms for the leather shoulder pads were wet formed in a mold (i.e., laser cut MDF upper mold & 3D printed lower mold). The dried shoulder pads were cut into shape with holes for the suspender straps.

The final leather shoulder pads attached to the output wearable straps.

Crafting the Electronics for the Output Wearable

After finding a satisfying output, we started experimenting with the actuation of the output. Based on our prior experiences with electronics, we chose to explore different servo motors (i.e., a tiny linear servo and a continuous servo) for actuating the movement of the suspender straps (A). A continuous servo motor had enough strength and a larger range of motion; thus, it was chosen.

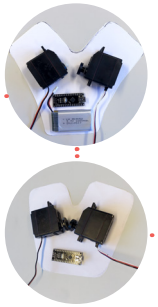
While experimenting earlier with suitable shoulder pad designs, we settled on suspenders as the final form of the output wearable as it could be worn discreetly in everyday situations either on or under a shirt. We started by exploring the placement and angle of the servo motors with paper models and found the trapezium shape best for both the operation of the motors and enclosing the electronics (B). As the space needed for electronics was rather large, it made sense to locate the electronics on the back of the wearer instead of in the shoulder straps. Based on the paper model, we made a cardboard prototype for testing the strength and feel of contraction on us (C). The servo motors had sufficient strength to create a feeling of pressure on the shoulders and the casing place felt comfortable. Next, we 3D printed a plate with tight pockets for the servo motors and Arduino Nano (D). The plate had also holes for the attachment of the strap and back plate of the casing.

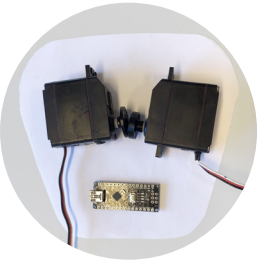
As the shoulder pads were made of leather, we wanted to retain the same material aesthetics in the casing for the electronics. We wet molded [38] the leather by hand on a one-sided wooden mold (E). After the leather was dry, it was cut to the right size with a rim for the closing mechanism. By using the front casing as a template, we cut the back plate into the same size. For the closing mechanism, inspired by [38] suggestion for easier maintenance access to the electronics, we attached snap buttons for the casing (F). Snap buttons worked well with suspender straps, allowing them to move freely inside the casing through the small gap between the casing and the cover. Finally, we attached the casing to the suspenders and added electronics inside.

A) Testing the servo motors

A tiny linear servo motor:
+ Easy to conceal,
– Weak in strength and a little range of motion.

A continuous servo motor:
– Difficult to conceal,
+ Strong strength and a large range of motion.





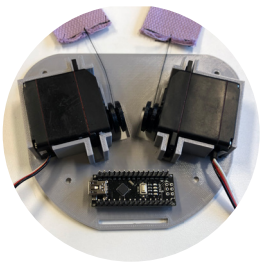
B) Electronics container shape

To follow the suspender straps' natural angle, we explored the Y- and V-shapes first. However, to ensure enough space for electronics and wiring, we settled with a simpler shape.

E) Crafting the leather casing

The wet leather was hand-formed slowly on the mold and left to dry until the next day.

A one-sided mold was made of plywood for wet molding the upper case for electronics.

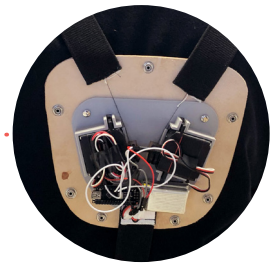


D) 3D printed plate

Arduino Nano and servo motors in their pockets in 3D-printed back plate.

C) Testing the feel

The cardboard prototype proved the contradiction strength to be suitable.



F) Final wearable from inside

The excess leather was cut away so that there was enough rim left for the attachment of the snap buttons.

The straps were attached to the motors with a strong sewing yarn and powered with 2 Li-po 1000 mAh batteries.

On output activation, the servo motor/s spins the yarn/s attached to the suspender straps tighter, pulling the shoulder straps against the shoulders. The tension is released when the servo motors disengage.

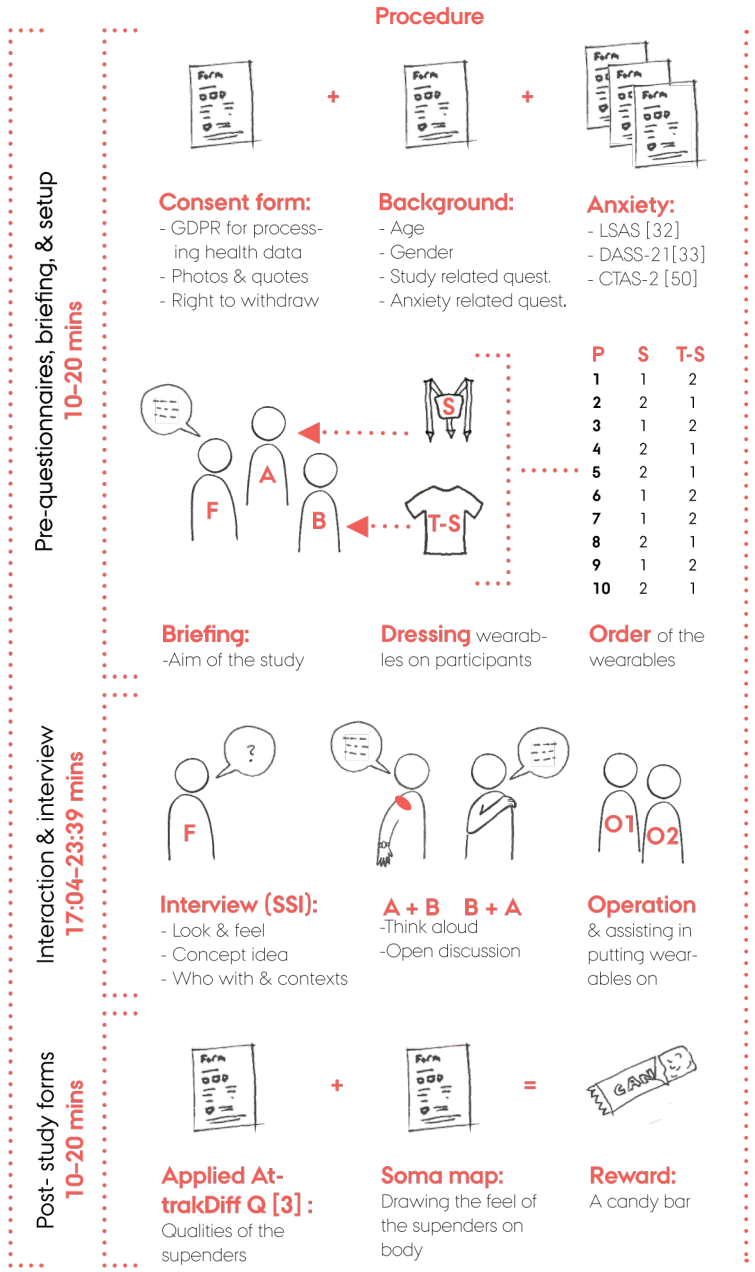
USER STUDY

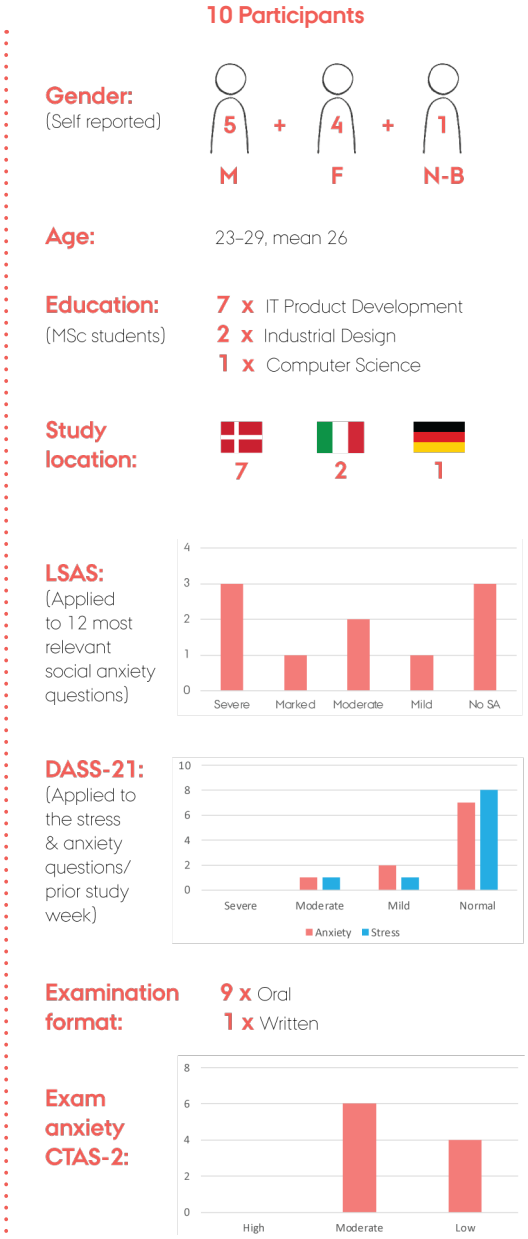
We ran a Wizard of Oz user study with 10 student participants in 5 pairs to investigate their perceptions of the design concept, the appearance of the wearables, and the feel of the input and output. The study had a within-subject design, with each participant experiencing both the suspenders and the T-shirt in a randomized order. The study was conducted in a lab-like setting in an empty classroom, during the second last course week. The procedure is depicted in the figure on the right[1]. The study duration ranged between 45 to 60 minutes. The participants received a candy bar as a reward.

We used convenience sampling by recruiting 10 MSc-level students from the Designing Wearables 5 ECTS course under the IT Product Development program at Aarhus University in Denmark. We chose the participants due to their knowledge of wearables and our knowledge of their workload in 2 to 3 parallel courses during the study (worth 20-30 ECTS, mean 28). The participants' demographic information and results of the anxiety questionnaires (i.e., LSAS [32], DASS-21 [33], and CTAS-2 [50]) filled out before the study, are reported in the figure on the right[1]. The anxiety questionnaire results showed that 7 experienced different levels of social anxiety (LSAS) and all had either moderate (6) or mild (4) exam anxiety (CTAS-2), yet only 3 had felt anxious during the last week (DASS-21).

Data Collection and Analysis

The evaluations were recorded with an audio recorder and data was transcribed verbatim by a third author resulting in a total of 9494 words. The transcripts were analyzed by theoretic thematic coding [6]; starting with a reading of the transcripts while making notes, and open coding the data. Then, the final themes were searched and refined. The Soma map drawings were combined into one image showing the marked locations and call-outs were used to exemplify participant's markings. The mean values of the applied Attrakdiff [3] forms were calculated. The data was collected, stored, and analyzed in a pseudonymized format (P1-10) and we followed the Danish ethical guidelines and European GDPR rules.





[1] It is possible to read the textual explanation by hovering the cursor on the image.

F: facilitator/ interviewer A & B: participants O1 & O2: operators

M: male F: female N-B: non-binary

RESULTS

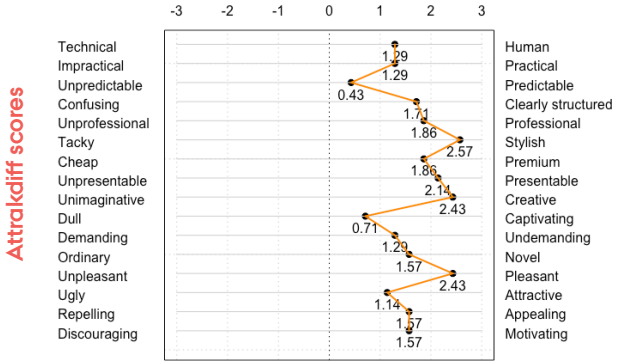
Participants thought the concept design was interesting (P1), novel (P3, P8), better than the digital solution (P7, P8), and a very good idea (P1, P7, P9). As P9 stated: "*It is a very good idea because it is something we are scared to talk about or do something about, it is often really hard to... know they have anxiety... if you know a person really well you know the signs of them maybe stressing out and breaking down... so this a good tool to have.*" P8 and P9 appreciated tangible support over digital applications, as explained by P8: "*Tangible is way more intimate, I can feel something.*" The AttrakDiff mean scores (on the right) show the concept was perceived in general as positive, especially in words *Stylish*, *Creative*, and *Pleasant*.

A Suitable Support Person

As it is hard to tell if a close classmate is feeling anxious (P1, P2, P5, P9), most participants preferred wearing the wearables with someone they know very well, such as a close friend (P1, P2, P4, P9), relative or family member (P2, P3, P7), or partner (P1, P4, P5), whom they can trust, feel comfortable with, and who can read their facial and body language correctly (P1, P2, P5, P6, P9). As P5 stated: "*It is quite an intimate connection, you are trusting someone with this device that is linked to one you are wearing. I do like it, but I do think it is a big responsibility if you give it to someone and I would not just randomly give it to anyone.*"

Interaction in the Public

Half of the participants (P1, P2, P3, P9, P10) thought the two types of interactions would be perceived very differently in the public context. The one-handed interaction was perceived to be fine (P3), discreet (P2), and typical action in a public context (P3). Two-handed interaction was then described as something they could never do in a social context (P2) or feel comfortable doing (P3), intrusive (P1), distorted/tense (P3), and it also seemed very visible (P3, P9) and obvious to others in the social context (P9, P10), but also good as it shows comfort (P10). These impressions stemmed from the fact that the interaction reminded them of a hug sign in sign language (P1, P2, P9, P10). Two participants were more relaxed with using that gesture in public, as stated by P9: "*Input is visible and they would know that you are sending a hug for someone. But it is not something with bad intentions, so people would probably just think that is cute.*" Similarly, P7 stated: "*It makes me feel like I am a very nice guy who wants to support the other.*" To avoid people noticing the two-handed interaction, P4 wanted to replace it with a fast tap on one shoulder and then on another launching the same output, which P3 agreed to and added that the input pressure could be used for adjusting the output tension.

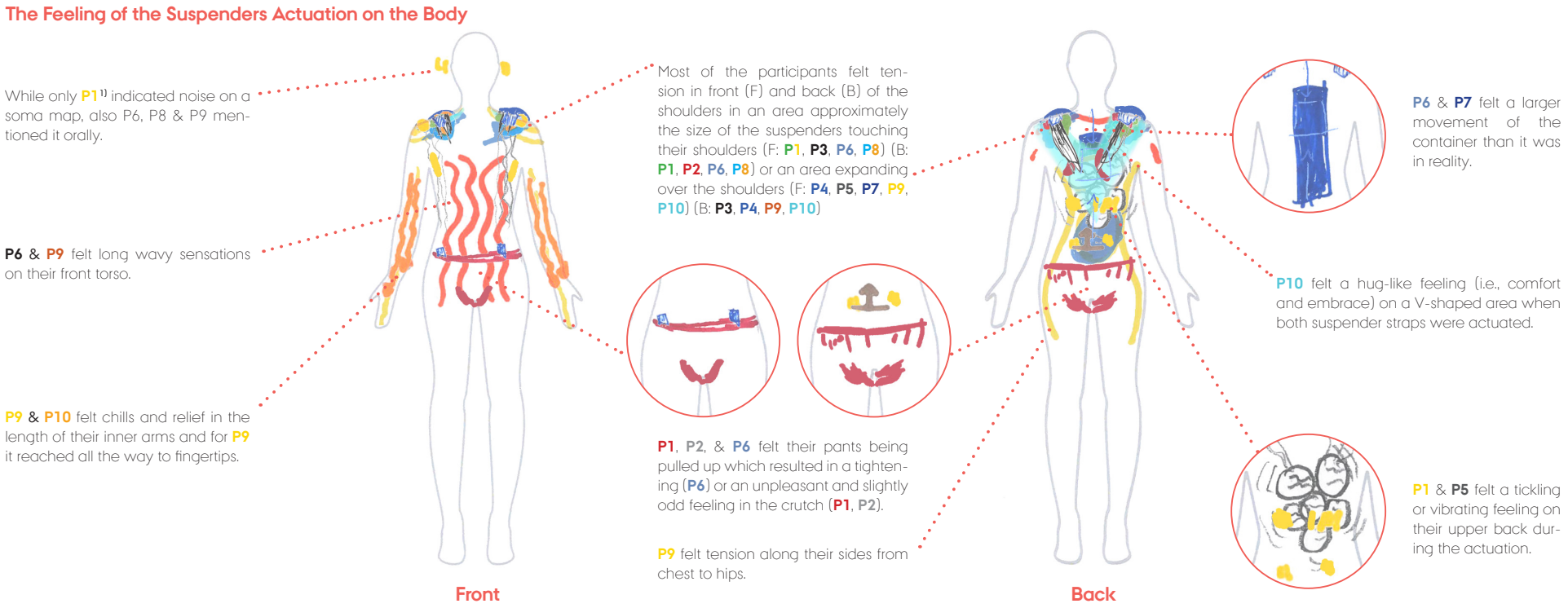


Unequal Interaction

Most participants (P2, P3, P4, P6, P7, P9) reflected on the unbalanced interactions as the person wearing suspenders has a passive role not being able to ask for help or deny support whereas the T-shirt wearer has all the power (P7, P9), as stated by P7: "*People who wear this shirt are stronger…than those who are wearing this* [suspenders] *just passively receiving the message of being tightened up and released.*" The unbalance was perceived by P1, P3, and P5 as an interesting twist. However, P9 commented: "*There needs to be some kind of acceptance of the hug, not be it like, oh shit! I am getting hugged, haha.*" This is also reflected with neutral approaching Attrakdiff scores (above) for words *Predictable* and *Captivating*. P1, P2, and P4 were also concerned about how the supporter would know when to support. P1 and P2 thought that facial expressions are reliable indications only for a close person being anxious in a collocated situation. For the automatic biometrics reading, P1 was a bit skeptical due to its perceived inaccuracy, however, P4 found it fine and stated: "*Ideally the person with the shirt would be able to know... at least slightly before the person with the suspenders would start to feel anxious, so they could do it preamble.*" P1 agreed that the biometrics reading can show an indication already before the person even notices it, but added that: "*You should* [still] *pay attention to that person and then make a judgment.*" P2, P3, P4, and P10 wished to be able to communicate to the supporter that they need support, as P3 suggested: "*Maybe there could be something like pulling the strap…*[or] *just some fidgeting or something.*" However, P6 thought that the interaction was not needed: "*It is not equal, …when you have anxiety, you feel that you are a little bit lower than the other person, you need support from a person who feels better at this moment, so it does not matter a lot if you don't have a similar equal connection.*"

Suitable Use Contexts for the Wearables

P1, P2, P3, P4, and P6 found the wearables suitable and supportive in the presentation context, as P6 stated: "*In situations where you are very nervous, e.g., if you are holding a presentation and nobody can touch you because you are standing in front of the class, you can have a little bit of support from one or two people in the audience.*" However, P1, P2, P8, P9, and P10 were a bit more skeptical about it, as P10 stated: "*If you are presenting something, or standing in front of the class, it might throw you off.*" P3, P9, and P10 suggested using it in other study-related contexts, e.g., group work. P2 and P3 envisioned the wearables to be a good tool for helping in managing panic anxiety (P2) social anxiety (P2, P3), or neurodivergence (P3), as P3 stated: "*If I am out with someone who is not that comfortable in social settings, e.g., in a party, even if I leave them, I am still nearby, I can still help them.*" The wearables were also suggested for supporting one in high-stress and high-intensity situations (P1), doctors or hospital visits (P4), or walking home alone after dark (P7). Or use it for remote support of a friend (P9, P10) and intimacy (e.g., hugs, and touch) with loved ones (P1, P5, P8).



Most of the participants (P1-4, 6 -7, 10) were laughing when the suspenders activated for the first time because the output felt funny (P4), interesting (P1), cool (P1), Wow! (P2), or nice (P6). However, for some participants, laughter related also to unpleasant feelings in their body, as P1[2], P2, & P6 depicted in their soma maps.

Not surprisingly all the participants described orally or by drawing that they felt compression and tension on their shoulders during the actuation. Nine participants (P1, P3-P10) depicted the feeling on the front side of the shoulders in their soma maps. This was also described orally by a few participants (P5, 7-8), such as P5 stated: "*When it contracts and it pulls these, you can feel it in your whole body, but not in your legs. Then it gives like a puh!* [blows air out]… *feeling when it releases, detracts*." Eight participants (P1-P4, P6, P8-P10) felt compression and tension on the backside of their shoulders. The feeling was described as being like getting a big pat (P2) or a tap (P6) on their back. For a few, it was more like someone grabbing (P3) or pulling (P10) their muscles. For some participants (P1, 3-5, 7), the tension was felt also down towards the lower back along the suspenders, which for P1 and P3-4 felt like it was trying to straighten their back, as P3 stated: "*Before you told me what was it about, I could get an idea that the other person could tell me to stand more straightly…that could be a sort of negative thing.*"

There was a difference between the feeling of the one and both shoulder actuation. P9 and P10 found the one-shoulder subtraction weird and described it as more like pulling their sides, such as depicted in P9's soma map. However, when both suspender straps were actuated, it was explained to feel like an actual hug (P1-2, 9-10), as depicted in P10's soma map. P9 explained during interaction why it felt like a hug: "*I think it is because it tightens around your body… when you are hugging… something is tightening around your body, being it arms or being it that* [suspenders]." Both P9 and P10 also felt the suspender's hug comforting.

On the backside of the body, the participants depicted the electronics container as either stationary (P4, 8, 9) or moving up and down on their back (P6, P7). Two participants (P1, P5) depicted a tickling or vibrating feeling on their upper back. P1 stated: "*...there is a bit of fabric rubbing up at my back which is slightly ticklish.*" P5 found it more pleasant and funny: "*It is also quite fun to be massaged…, it feels like it is crawling around, like a turtle wiggling, haha.*"

[2] If the participant ID is marked with color/s in the text, then the above image contains that drawing. Color coding of participants' ID (i.e., P1-P10) follows the color of the marker they used to draw their feelings on their soma map. If the participant used two colors, then P is marked with the first color and ID number with the second color.

Perceptions of the Wearables Design

Participants who commented about the T-shirt (**P1**[3], P3, P6, P7, **P8**) perceived it as anonymous and typical. Also, the wear comfort and hidden electronics were acknowledged by **P1**, P3, and **P6**. P7 suggested, however, that the input wearable could be just a shoulder pad that can be attached to any shirt and could actually be more visible in its design, as support to others does not need to be hidden.

The appearance of the suspenders was described as not that bad (P3, P8, P9), minimal design (P8), hipster (P2), fashionable and good-looking (P5), very beautiful (P7), and only one found them nonaesthetic (P2). P6 acknowledged the leather details. P6 complemented the look of the suspenders on **P5**, who agreed (see figure with P5's comment). For P3, **P9**, and P10 the suspenders looked a bit too formal for a more relaxed university setting.

The electronics container raised most comments both positive and negative. Two participants perceived it as a small turtle shell (P5, **P7**), and four as a small backpack (P2, P5, P8, P9). Three participants (P1, P5, P9) discussed the appearance of the container giving an impression of an electronic product (**P9**), electro-fashion piece (P5), or some kind of techno-augmentation (P2) and how that would be okay to wear also in a public context. P5 envisioned that electro-fashion would become more popular eventually and then be like any clothing.

For some participants (P1, P2, **P7**, **P9**) the suspenders design would reveal that person has issues with coping. Also, P1 and P2 discussed how the wearable might reveal to others that the user has anxiety and agreed that it is not good if the person is standing out, however, P2 notified that if the aim is to create pride by wearing such things, then it would be okay. To resolve the issue, most participants (P1, P2, P4, P8, P9, P10) agreed that it would be easy to hide suspenders under a loose shirt, as presented in the above figures that were also shown during the interview. **P2**, **P4**, P9, and P10 found it appealing to wear the suspenders in that way in public. P8 was a bit skeptical about it due to the noise of the motors.

[3]Direct quotes (i.e., the positive in a red bubble and the negative in turquoise) are presented in the above image when the participant ID is marked with bolded **red** or **turquoise** text in the body text.

DISCUSSION

When considering shared management of student anxiety through a pair of wearables, our design process and Wizard of Oz study findings suggest that careful consideration needs to be put in the design of interactions and appearance of such artifacts used in the public context.

The role of the wearers in the interaction of shared management wearables. While participants liked the overall idea of shared management of anxiety of a close one, they also commented on the unequal interaction. Even though the situation of one being anxious and needing help from someone who is feeling better at that moment is not very equal either (P6, P9) *the interaction with the wearables should not enforce this inequality to an anxiety-facing student or the other people around the wearers*. Instead of relying on biometrics reading [8, 17] or interpreting the facial expressions of the anxious student, the participants wished that *the wearer should be able to communicate in a subtle manner to the supporter their need or no need for support*, such as through small and unnoticeable fidgeting of part of the wearable (P3). These changes would allow for more equal interaction between the wearers, and the student with anxiety to take a more active role in coping [41] and training to manage their anxiety better. In addition, it could also help them to prevent more harm by stigmatizing them [35] or causing more social anxiety [42, 43] as they could prevent others from seeing or hearing the actuation by accident.

The appearance of the output wearable. Participants found the output wearable electronics container a bit large and not so easy to wear with all kinds of clothing as suspenders are usually worn with pants. Participants had also a fear of wearable stigmatizing the wearer [36] and suggested for more invisible and silent design. While prior anxiety self-management wearables are worn on the clothing [8, 17] or around the head [9] or wrist [11], we suggest instead that *the design of the wearable for the anxiety-facing student needs to be easy to hide from public sight and hearing*. We believe that less stigmatizing output wearable could be realized as an undergarment with a silent actuation, making it easier to hide under different kinds of clothing, (e.g., dresses, sports outfits), maintain the wearable (e.g., clean), and keep firmly in place during actuation as it is attached directly to the skin.

The appearance and interaction of the input wearable. The support person has a much more powerful and active role in the design concept in helping and caring for their close friend, so the participants suggested *the input wearable can have a more visual presence to showcase that the wearer is a good person caring for someone*. While participants preferred both suspender straps detracting at the same time as it felt comforting, intimate and reminded of a hug, they perceived the visually distinctive input (i.e., crossed arms with hands on both shoulders) as possibly revealing that the person is supporting someone in the classroom possibly revealing the student with anxiety. In order not to reveal and cause more harm to the anxiety-facing student, a less symmetrical input is needed. We suggest that *the input should be possible to be made in a subtle and customizable manner in a public setting*. Input wearable could thus be an accessory, such as a scarf or jewelry, which would be easier to wear on an everyday basis and would allow moving it to different places on the body when interacting with it, such as in [5]. The wearable could thus utilize 3D-knitted structures [1] to allow different kinds of inputs, such as adjusting the length and strength of the input as well as enclosing the electronics seamlessly to the garment [7].

Limitations and Future Work

As this work was our first attempt to understand what kind of wearables could be used in shared management of student anxiety, we acknowledge some limitations. First, even though our study involved students who faced anxiety in study-related contexts, the sample was relatively small and homogeneous (i.e., 10 students majoring in either IT (8) or design (2)). The participants might thus have more positive attitudes toward the technology; however, the findings show also negative and critical perceptions towards the prototype. Second, even though the study was run in a classroom where some people were passing or staying at the time of the study, we could not study the wearables during anxiety-causing activities (e.g., presentations, exams, or social activities). Third, as the study duration was rather short, we do not know how the long-term user experience would develop. In future work, we, therefore, plan to continue towards a more refined concept and mature prototypes to be able to run longitudinal in-the-wild studies in authentic settings with more varied sample. Future work needs to cover also the ethical aspects of such technology.

CONCLUSION

Prior research has been interested in designing and developing wearables alleviating anxiety [8, 9, 17, 38]. While these wearables have focused purely on self-management, we created a pair of wearables, i.e., a T-shirt and suspenders, that allow shared management [25] of anxiety of university students. As suggested by psychological research, *SuspenderMender* combines important anxiety prevention and reduction means by allowing an active coping style of the person with anxiety [41] by asking the person to confront the anxiety-causing issues. Instead of asking students to do it alone, social support [20] is provided by a family member [41], close friend [43], or significant other through an intimate physical touch [26] simulation. Differentiating from prior pressure-based [8, 17, 39] or vibration-based [9, 11] anxiety management wearables the *SuspenderMender* introduces contraction as a means for creating a feeling of physical touch on the shoulder of the anxiety-facing student. A Wizard of Oz pair evaluation with ten university students who face anxiety in their studies, suggests that the concept idea is good, novel, and relevant. They also found the simulated physical touch as comforting, almost like a real hug. However, participants wanted more equal interactions between the wearables and a more unobtrusive design of the input style and output wearable. Based on our findings, we discuss the most important aspects other designers and researchers should consider when designing wearables for the shared management of anxiety.

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