TheraTrousers: Reactive wearable for playful therapeutic self-empowerment

Wearable for Therapeutic Exercising

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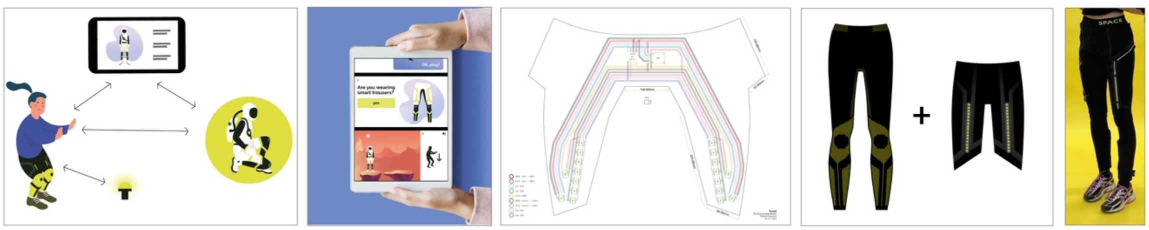

Figure 1: Gameplay, interface, circuit layout, garment construction, TheraTrousers

ABSTRACT

This paper introduces a smart garment for motivating children and teens to perform gait therapy exercises, while enabling them to do so at home, outdoors or otherwise outside a practitioner's facilities. Taking the shape of a pair of trousers that look and behave like sci-fi attire, the wearable connects with a similarly themed game that turns physiotherapy sessions into exciting explorations in a light-hearted science-fiction scenario. The garment includes embedded sensors and actuators, connected via embroidered conductive yarn tracks, and its overall construction was achieved using standardized industry techniques and machinery, aimed at large-scale automated production. While measuring the user's activity to detect the performance of specific movements, the wearable also reacts to these, as well as other gameplay events, as a form of feedback and positive reinforcement. The overall aim was both to increase enjoyment during and compliance to therapy routines, and to foster autonomy, self-empowerment and a positive outlook for user.

CCS CONCEPTS

• **embedded systems**; • **human computer-interaction**; • **integrated circuits**;

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KEYWORDS

Wearable, Therapeutic Gaming, Smart Trousers, patient self-empowerment

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1 INTRODUCTION

Accessible solutions for rehabilitation and treatment of diseases from a distance are topics of increasing importance, especially in light of the current worldwide pandemic. Among many approaches in the context of telemedicine systems and frameworks, portable electronic devices which perform measurement or contribute towards therapy, independently of time and place, are seen as a desirable [1]. To find out the weaknesses in patient's gait patterns or to see the proceedings of the therapy gait analysis and motion monitoring are common tools and are frequently employed at hospitals and therapy facilities – but can only be used on site. Regarding the rehabilitation process, different studies have shown that the patient's motivation and engagement are essential for the rehabilitation process, and decisive for successful long-term results. It is estimated that up to 65% of patients are non- or only partially committed to their rehabilitation program [2]. Carman et al. pointed out that the outcome and satisfaction of the patient improve if the patient is involved in their therapy [3]. Physiotherapeutic exercises,

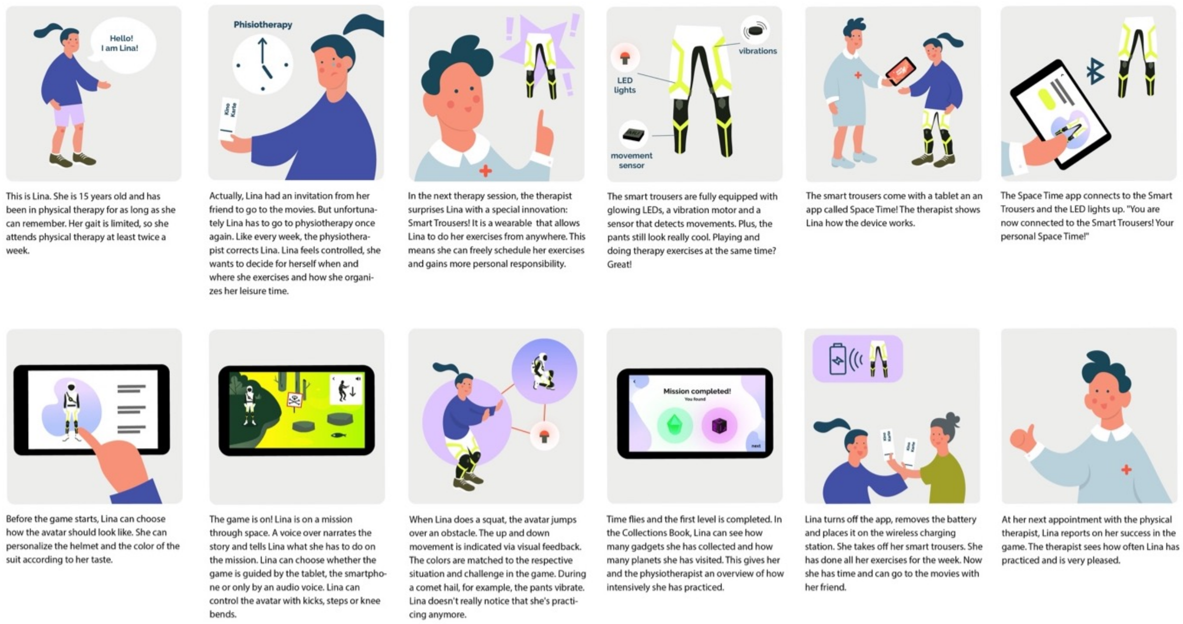

Figure 2: Illustrated use case

as one part of the therapy, can be performed individually or can be combined with other methods. As such, virtual games are already used to motivate patients, to do their physiotherapeutic exercises. However, these are employed exclusively at the facilities and are not meant to be used autonomously by patients. They can't be integrated into a patient's individual daily routine. During the preliminary research phase of the project, the desire for independence and self-empowerment was repeatedly noted. Especially among adolescents and young adults with mobility impairments, a sense of autonomy and self-control were identified as main factors for motivation in therapy.

2 RELATED WORK

The term "gamification" denotes the usage of gaming approaches in non-gaming contexts [4]. The use of games and structured play activities in rehabilitation contexts is very much a current topic of research - examples thereof being as numerous as the specific conditions to be treated and the technologies or formats employed, of which we highlight but a few for brevity. A review of recent developments in wearable technologies within the context of rehabilitation, offering insight into different approaches - including inertial measurement embedded into smart clothing [5]. The aesthetic aspects accompanying technical functions are also of great importance in the acceptance of a smart garment, with plenty of examples [6]. A qualitative analysis on the use of computer games as therapy tools for children with cerebral palsy is with positive outcomes [7]. Pokémon Go can motivate users towards beneficial physical activity and psychosocial development [8] [9]; and specific controllers such as the Wii Balance Board may even serve as tools for clinical assessment [10]. The Teslasuit for example can be paired with VR or used by itself to provide full body motion capture and haptic feedback for extended reality experiences, backed by biometrics for analytics. It can be used for athletics training, public safety but also for rehabilitation [11].

3 USE CASE

The scenario was defined through the methods mentioned in Section 4 and is shown in the Illustration in Figure 2. The resulting design is embodied in a pair of smart trousers, which function as a game controller and motivate adolescents and young people with mobility impairments to perform their physiotherapy exercises. Users are empowered to determine for themselves when and where to exercise, regardless of location and time. Embedded motion sensors measure the user's movements, which in turn trigger the movement of the avatar in a game, resulting in progression through the different levels. By overcoming in-game obstacles and being rewarded with new items and levels (see below), the user recognizes progress through play. Through previous research and discussions with experts, it became clear that when it comes to young patients performing basic gait therapy exercises, it is not so much a matter of performing them perfectly, but rather of performing the exercises at all. Therefore, monitoring how well each movement was performed was not a concern at this stage of the project. The use-case scenario, including wearable and game, were developed and tested exclusively for aspects of useracceptance, motivation and compliance to therapy, not for remote diagnosis.

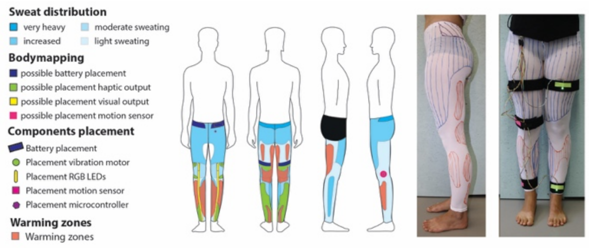

Figure 3: Placement of components, functional demonstrator

4 METHODS

In this section the methods that were used for the specific research phases and their results are described.

4.1 Observational Studies

To get an insight about therapy-sessions there was done qualitative expert interviews and observational studies (e.g., Shadowing). During a one-week observation at a neurological physiotherapy facility for children, an approximation of the needs of therapists and children was defined. A first scenario was illustrated. This was expanded with another observational study of one day at a university clinic for rehabilitation and then adapted in the further course. By means of the mentioned methods, the target group could be concretized – adolescents and young adults, with an affinity to technology with full cognitive ability that can assign symbols and colors to meanings at a screen. Through discussions with parents, the need for playful motivation of the children to use therapeutic aids at all was expressed.

4.2 Participatory Workshops

Using the findings from observations and interviews, two workshops were hosted. First, one participative workshop with doctors and therapists from a university clinic for rehabilitation checked the outlined use case for its consistency. Challenges and desires were filtered out in order to adapt or supplement the use case. In the second workshop, affected children and parents participated as experts. In both workshops the needs of the children and parents were determined by means of user-centered methods – with different design methods –such as Card Sorting - Quick and Dirty Prototyping and Storytelling. Adolescents of the target user group expressed their desire to have more autonomy, self-empowerment and more individual recreational time. Their parents expressed the high challenges in time management also because of the lots of visits at doctors and therapists. The final scenario was then created, as shown in Figure 2

4.3 Bodystorming

Bodystorming is a method to create empathy for the user while simulating the experience during the use of an object or system [12]. It is a first-hand experience and creates an understanding of how interaction must be designed. For that a modular hardware was to determine and evaluate the placement. A pair of white leggings were color-coded with the maximum heat and sweat zones on the body [13], as shown in Figure 3, to avoid short circuits due to sweat or heat points on the human body. For the bodystorming, evaluation sheets with relevant criteria were developed. The criteria varied depending on the function of the electronic components - for example, tactility/visibility, handling/physical accessibility and restriction of normal body movements in everyday life based on the work of Gemperle et al.[14]. The evaluation forms were used to record observations and to evaluate the results. The results are shown in Figure 3

Figure 4: Final Demonstrator

4.4 User Test

In addition, one user test could take place in a later intermediate stage by evaluating the design, scenario, app and battery handling. Due to the pandemic situation, final user tests could only be carried out to a very limited extent and only with a single individual.

5 GARMENT DESIGN

To create an inclusive/accessible and functional design demonstrator, the following aspects were relevant to the design process:

5.1 Inclusive Design and Usability

The conception of the trousers follows inclusive design parameters in design and pattern construction, to address the needs of users in terms of handling and wearability. Therefore, the demonstrator (shown in Figure 4) is designed in a two-part construction: a functional knitted legging and a removable electronic layer. Both parts can be connected by a system of self-finding magnets to ensure independent. In addition to use enlarged tabs for gripping and fasteners have been eliminated so that no additional hand grips are required for tightening and when putting on the trousers. The placement of components and handling of the trousers were verified in one Bodystorming session and two user tests as described in Section 4.

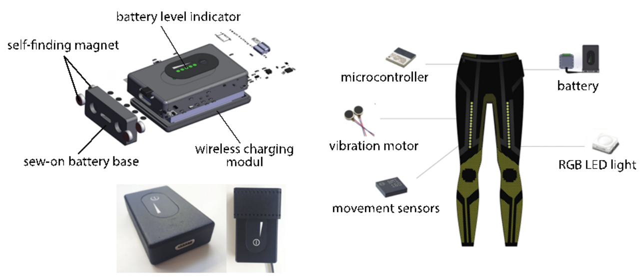

Figure 5: Integrated microelectronics, 3D-modell of battery, final battery design

5.2 Textile Construction

The technical-textile development of the demonstrator was designed according to requirements relevant to the field of rehabilitation and sports, aiming at maximum user acceptance and wearing comfort. In cooperation with the Textile Prototyping Lab KHB Weißensee, the design elements and textile-technical functional zones were implemented using industrial knitting technology. The knitting pattern was designed according to the different heat and sweat zones of the lower extremities. In addition to the use of a particularly skin-friendly and hypoallergenic yarn, open knit structures with high breathability and thermal conductivity were selected for the areas of the legs that are particularly exposed to heat and perspiration. In the knee area, a 3-dimensional rib structure provides more freedom of movement, which is needed during exercising.

5.3 Integration of Electronics

The placement of electronic components, determined through Bodystorming (Section 4.3), formed the starting point for the design of the circuit. The circuit was conceived as a multilayer textile structure, to protect the components and PCBs from mechanical stress and avoids direct skin contact and the associated risk of injury. The electronic components, which are also used in large-scale industrial production, are interfaced with using a conductive yarn laid out through an industrial embroidery process. The suit is powered by an individually designed battery, that can be easily attached via a magnet system for user-friendly handling, the battery provides wireless charging and an USB-charging option. It supports the wearable several hours with electricity. To ensure the washability of the trousers, the electronic layer was designed as a separate and removable element.

5.4 Interaction and Feedback

As feedback for the user's movement, the game's user-interface and gameplay events, visual and haptic output capabilities were integrated into the design of the wearable – respectively as strips of independently controlled RGB LEDs and via coin-shaped vibration motors, one in each leg. To improve the LED lighting diffusion, a component was developed from translucent and flexible 3D-printing filament, which, due to its flexible properties both fits into the design of the trousers and withstands the repeated movements of the player.

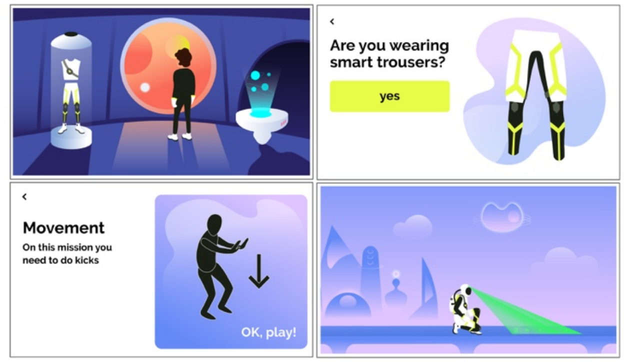

Figure 6: User interface

6 EMBODIED GAME DESIGN

A draft of the game activity was developed based on the results of the bodystorming tests and further consulting with physiotherapists. The game mechanics – that is, the core activities that the player performs – were based on specific exercises and duration of therapy sessions. The resulting game design draft, accompanying app flow and storyboards, encompassed a complete game session with a duration of approximately 5 to 10 minutes. The player controls an in-game avatar by alternately performing three different exercises commonly used in gait therapy: squats, kicks, and steps. Thematically and in the longer term, the game was meant to play out as a sequence of exploration missions (each a therapy session) in a light-hearted science-fiction setting. Each mission takes place at a specific location, such as an alien planet. The player's movements allow the character – a space explorer – to overcome obstacles, such as jumping over pits or sneaking past monsters. Upon completion of a session, the player is awarded upgrades for the character's space suit, unlocking further locations to be explored. This serves as positive reinforcement and motivation to carry on with further sessions.

The visual user interface (UI) was designed with large control surfaces, with a preference for simple shapes and high contrast, which is shown in Figure 6. Additionally, pre-recorded voice-over guidance is provided for each menu. In this way, the app is meant to be more accessible for users who may have some form of visual and/or motor impairment. To amplify the fantasy and provide positive reinforcement, the haptics and lighting in the wearable react to events in the game. For instance, when the character uses booster jets to jump, the lights strips on the wearable animate with a pattern mimicking fire. The sequence of gameplay situations and process. A functional prototype of the game was developed and evaluated in a brief user test.

7 CONCLUSION

In this paper we present a motivational therapeutic tool for young people with gait problems, which increases the user's sense of self-empowerment and autonomy. The goal was to develop an interactive wearable with an inclusive design, being easy to handle for individuals with motor impairment. The textile circuit is produced through an industrial processing technique, accommodating embedded electronic components targeted for mass production. This results in a smart garment that is practical and desirable textile characteristics are preserved. The wearable works as a game-controller, thus allowing the user the chance to experience their exercises as a game or playful fantasy. The form factor facilitates the practice of exercises in an independent way, at almost any time or any place. Both the general use case but also the wearable itself were developed from the very beginning through participative design methods with all relevant user groups.

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