Textile Game Controller: Smart knee pads for Therapeutic Exercising

Esther Zahn*
esther.zahn@dfki.de
Interactive Textiles, DFKI
Berlin, Germany

Hannah F. Fischer*
hannah.fischer@dfki.de
Interactive Textiles, DFKI
Berlin, Germany

Clara E. Gleiss*
clara_elisabeth.geiss@dfki.de
Interactive Textiles, DFKI
Berlin, Germany

Eleftherios Avramidis
eleftherios.avramidis@dfki.de
Interactive Textiles, DFKI
Berlin, Germany

Gesche Joost
gesche.joost@dfki.de
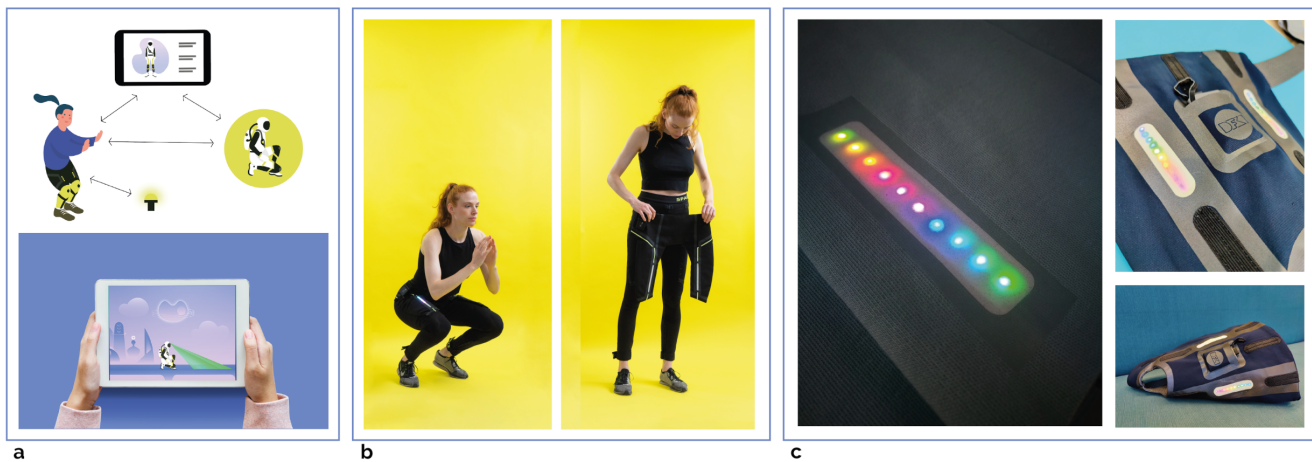Interactive Textiles, DFKI
Berlin, Germany

Figure 1: a: Game play as a way to increase motivation to be physically active, b: TheraTrousers [12], 3: Smart knee pad.

ABSTRACT

In the field of physiotherapy and rehabilitation, location-independent training has gained importance. We present the further development of a wearable for this purpose including gamification to improve successful training. A wearable was developed to increase the motivation of patients to perform their prescribed physical therapy exercises at home. Extending a pair of smart trousers [12], smart knee pads connected to a gaming app were developed. A comparative qualitative study was conducted in order to explore how users react to playing a game as an extension of their physiotherapy session. The results of the user test show that the majority of respondents consider technology-enabled training to be helpful for their therapy success. Aspects of a "playful approach" and "competition" were named as the main motivating factors for the use of wearables in a therapy context. However, "competition" was only rated positively by male participants.

CCS CONCEPTS

• **Human-centered computing** → *Systems and tools for interaction design.*

KEYWORDS

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

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*All three authors contributed equally to this research.

1 INTRODUCTION

Physical therapists face the problem that the prescribed training is not fully performed by the patients at home: Studies show that 24.8 % of patients do not adhere to their prescribed medical treatment [2, 11]. In the long run, non-compliance with prescribed medical treatment reduces the chances of successful therapy. A study has shown that integrating gamification into therapy routines increases motivation in patients to engage in physical activity [8]. To increase motivation to perform prescribed home exercise and thus improve therapy outcomes, this paper presents a wearable for the knee that brings gamification aspects into a DiGA[1] application and thus into a therapeutic context. The smart knee pad is a wearable that functions like a game console, allowing users to control an avatar in a game through movement [12]. The smart knee pad is an improvement of the TheraTrousers concept: In order to make the wearable accessible to a wider range of users regardless of size and weight, the smart trousers were converted into smart knee pads and the integration of the electronics was adapted to improve fail safe operation in a user study.

As part of the project, a qualitative user study was conducted with the smart knee pads, comparing the application with two wearable technologies from movX[2] and an industry partner from the medical sector. The aim of the study was to evaluate further development with potential users and to assess the acceptability of tech-enabled training formats.

2 RELATED WORK

The concept of gamification for therapeutic purposes has been motivated in several previous works[5][6][4][7]. When it comes to wearables there are several examples: The wearable SONIS [1] presents a sock that, together with an app, checks gait quality during a workout in real time, whereas users receive visual and auditory cues as feedback. [14] present a knee pad connected to an app, developed to detect instability of the knee joint and actively support the rehabilitation process. [9] present a pair of smart pants for playing soccer, being able to monitor the movements of the knee with IMU sensors. [10] present a knee pad using IMU sensors for knee joint health assessment.

3 DESIGN

The current work is extending the prior design of TheraTrousers [12], a smart garment for motivating children and teens to perform gait therapy exercises and enables them to do so independently of the physiotherapists' time and premises. Taking the shape of a pair of trousers (Fig. 1.b), the wearable is equipped with sensors and actuators that are connected via embroidered conductive yarn tracks and can be connected to a science-fiction themed game via Bluetooth (Fig. 1.a). In order to distinguish the trousers from classic therapeutic and medical aids, the wearable was designed in the form of a contemporary garment and adapted in color and design to the aesthetics of the sci-fi game. Common gait therapy exercises performed by the player trigger the movement of an avatar in the game

and motivate children with gait disorders to be physically active by giving them positive feedback. The overall aim of the wearable is not to diagnose remotely, but to increase enjoyment and adherence to therapy routines and to foster autonomy, self-empowerment, and a positive outlook for users.

3.1 Design and Construction

During the design process of the TheraTrousers, observations, user workshops and qualitative interviews with children with gait disorders, parents and physiotherapists revealed a need for more autonomy, self-determination and a more individualized approach to leisure time. Based on these findings, the TheraTrousers were designed as a two-piece construction consisting of a functional knitted legging and a removable electronic layer. With the smart knee pads the design and cut construction was transformed into a pair of knee pads to make the wearable accessible to a wider range of users applicable for user testing in terms of hygiene and sizing. To improve user needs in terms of handling and wearability, the wearable is made from flexible textile that contributes to a good adaptation to different body shapes, regardless of weight and body sizes. The smart knee pads can be continuously adjusted to the legs of the wearer with the help of elastic bands and velcro fasteners, whereby three fastening straps ensure optimum wearing comfort (Fig. 3).

3.2 Integration of Electronics

Extending the prior electronic integration (Fig. 2.a), a smart knee pad includes the following components: An IMU sensor for positioning, RGB LEDs for visual feedback, vibration modules for haptic feedback, a microcontroller [3] and a power bank for energy supply (Fig. 2.b). As an update to the previous version, the electronic connections were made of conductive textiles to ensure fail-safe operation. This method of processing represents an innovation to the processing of electronic connections in the TheraTrousers: The embroidered electronic connections used in the TheraTrousers have not shown long-lasting function due to corrosion and mechanical impacts, e.g. LEDs initiated deviating colour values. To protect the components and circuit boards from mechanical stress and avoid direct skin contact, the circuit in the smart knee pads was designed as a multi-layer textile structure: The electronic components are sandwiched between two textile layers that protect and conceal the electronics and can be completely removed from the smart knee pads to ensure the wearable is washable. As feedback for the user, RGB LEDs [4] were integrated into the middle textile layer, whose light signals are visible through a semi-transparent layer on the surface. Textile conductive strips [5] from the MYOW toolkit[6] [13] were used as the connection system for the electronic components. The smart knee pads are connected to the game app via Bluetooth LE.
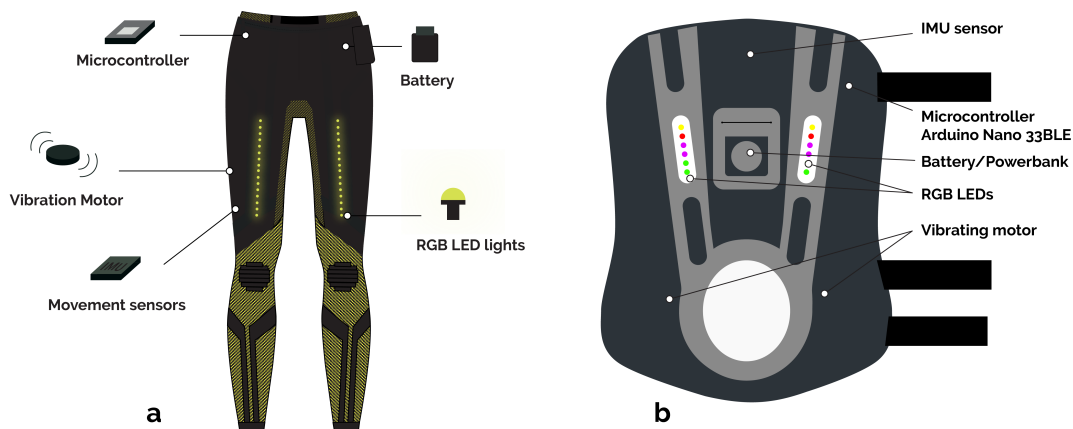

Figure 2: Placement of components a: Thera trousers [12] and b: further development smart knee pad

3.3 Interaction and Feedback

The wearable features embed motion sensors that detect the user's movements and are used to control the avatar in the associated game (Fig. 1.a, Fig. 1.b). Movements performed by the player, based on specific exercises and duration of therapy sessions, such as squats, kicks and lunges, allow the in-game character - a space explorer - to overcome obstacles and, for example, jump over pits or sneak past monsters. Upon completion of a session, the player receives upgrades to the character's spacesuit that unlock additional locations to explore. As visual and haptic output options, the knee pads feature RGB LEDs and vibration motors that respond to the user's movements, the game interface and the gameplay.

4 USER TEST

Within a user test, the smart knee pads were tested and evaluated on 15 participants of variable gender (m/f) and age (25 to 54 years). 13.3% of the study participants suffered from diagnosed gonarthrosis and 46.7% reported suffering from knee pain during physical activity. The aim of the study was to investigate the acceptance of gamification within a DiGA application and to find out motivational criteria for the use of technology-enabled training. In the user test, in addition to requesting general information about the person, health and affinity for technology, exemplary training sessions were carried out with the wearable. By means of questionnaires, the usability of the app and wearable, the design and interface of the gameapp, the characteristics of the avatar and the added value about the use of a wearable in the training session were evaluated. As part of the user test, the smart knee pads were compared with two wearable technologies from other manufacturers (industry partner from the medical sector and movX); only the results relevant to the knee pads are listed below.

80% of respondents said they already use digital health/fitness services (e.g. fitness trackers, smart watches, health boards). However, for all of them, the concept of a technology-assisted training session was new. The results of the questionnaires show that the majority of respondents considered a technology-assisted training session helpful to their therapy success and 93,3% of participants

would consider using this kind of device on a regular basis in and outside of therapy. A "playful approach" (25.6%) and "competition" (23.3%) were cited as the main motivating factors for using wearables in a therapy context. However, "competition" was only rated positively among participants defined as male. It can be deduced that in an inclusive application aimed at all genders "gamification" could be a better motivational lever than "competition". This aspect should be investigated and verified in a further study. The game character proved to be too pronounced for the adult target group in the medical context. This was particularly evident in the rating of the avatar of the game. According to the questionnaire, a realistic avatar was preferred to the futuristic comic avatar used in the associated game. Further results of the user test show that a wearable needs to be be either self-explanatory or freely positionable in order to be clearly understood by users. The haptic and visual feedback on the wearable was rated positively by study participants. Tough study participants would have preferred more detailed explanations of the exercises by the app. The illustration was not sufficient for all study participants. Study participants would have liked an evaluation or a feedback on the quality of the exercise performed. For legal reasons, the application could only be tested by adult subjects. In a further study, the application should be extended to the target group of children and/or the game should be adapted to the target group of adults.

5 DEMONSTRATION

Visitors can try out a training session as part of an on-site demonstration. With the help of the wearable, which can be attached to the knee, participants can run through the first level of the game, which takes about 5 to 10 minutes. The associated game is set in a light-hearted science-fiction setting and aims to guide the avatar through different levels, which appear in the game as different planets. Using movements, the player controls an avatar in the associated game that takes turns performing three different exercises common in gait therapy: In the first setting, the participant must do squats to get the avatar moving. In the next setting, the participant must perform kicks to ward off opposing attackers. In
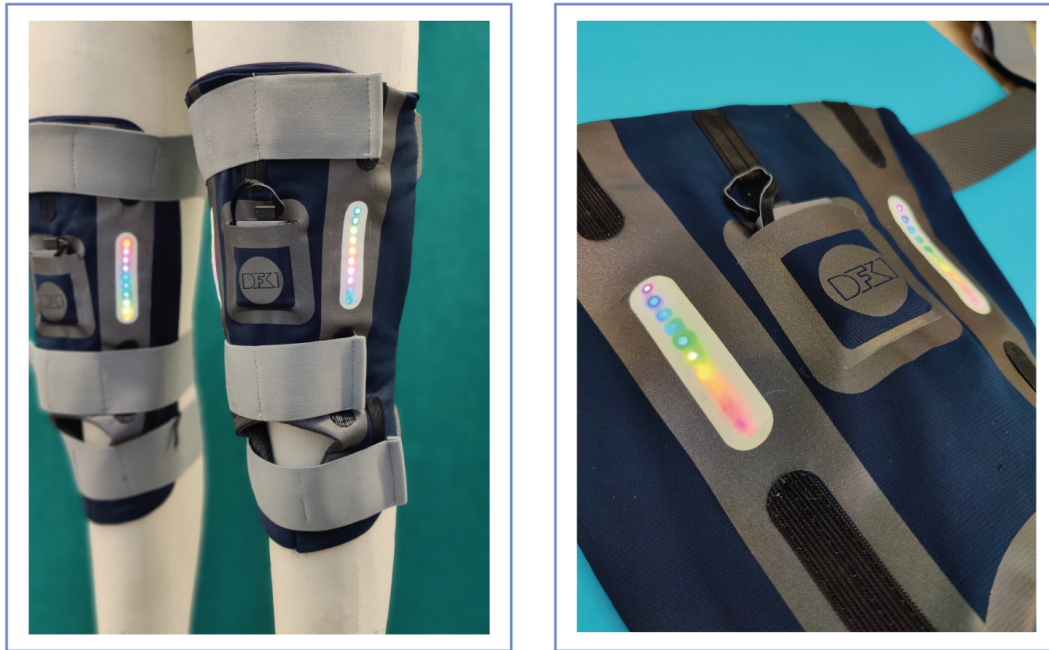
Figure 3: Smart knee pads.

the third and final setting, the participant can move the avatar by performing lunges. As a reward for successfully completing each task, the player receives upgrades for the character's spacesuit and unlocks new levels.

6 CONCLUSION

With the further development of the TheraTrousers concept presented here, a wearable with gamification reference was developed that is suitable for supporting physiotherapeutic training sessions and that can be used regardless of the users' size and weight. In a user test, it was possible to evaluate that the majority of the respondents considered technology-supported training to be useful for their training success. In this context, the majority of the participants considered a game-based approach to training as motivating in particular, with differences found in the gender of the respondents.

7 OUTLOOK

Further research directions include improving the accuracy of motion detection. Given that only one IMU per knee pad has been implemented, the measure of the exact angulation of a knee bend cannot be recorded. Therefore, knee misalignments cannot be detected. However, this would be important for performing exercises as part of the digital health application. An expansion of the system would therefore be a prerequisite. Further development of the app should include a reduction of the delay in the data transfer from wearable to app. The game should be adapted to additional target groups, by adapting the story line and avatars. Users and therapists

would also benefit from a qualitative assessment of the users exercises, e.g. whether or to what degree the exercises were performed correctly.

ACKNOWLEDGMENTS

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