Combining smart sensor systems with gamification to increase the efficiency of therapies

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***Abstract*— The potentials and opportunities created by digitized healthcare can be further customized through smart data processing and analysis using accurate patient information. This development and the associated new treatment concepts basing on digital smart sensors can lead to an increase in motivation by applying gamification approaches. This effect can also be used in the field of medical treatment, e.g. with the help of a digital spirometer combined with an app. In one of our exemplary applications, we show how to control an airplane within an app by breathing respectively inhaling and exhaling. Using this biofeedback within a game allows us to increase the motivation and fun for children that need to perform necessary exercises [1].**

I. Introduction And Motivation

Gamification, digitization, mobile health care, personalized medicine and bio-feedback are upcoming trends in medicine or in medical technologies. Their aim is to improve the quality and effectiveness of therapies in terms of reaction on individual, personalized needs of patients, prevention of side effects, increase of efficiency and reduction of costs. Mobile devices and applications form a useful basis for those trends [1].

Over the last few years, mobile devices such as smartphones and tablets became a standard in everyday life. Children grow up with the use of such devices and for older children it is a "must-have" equipment. For this reason, it is a promising approach to use mobile devices not only for entertainment. Additionally, body-worn sensors with integrated mini-computers, the so-called wearables, have a growing number of usage. The hype surrounding mobile data collectors, such as smart watches, will continue over the next years.

Smart sensor systems enable innovative solutions for improving our health. Typical applications are both numerous and heterogeneous: They range from mobile diagnostic devices for rapid on-site analysis of infectious diseases over intelligent oral medication dosing systems to assistance systems during medical rehabilitation, or improvement of medical instruments [2].

The combination of mobile devices, gamification, and smart sensor systems builds up new possibilities and perhaps more motivation for therapies.

II. Application Examples

In order to implement a gamification approach with a smart sensor system, it needs to be clarified which disease or handicap should be treated and if it makes sense to create an application for it. Often the success of a training therapy highly depends on the execution quality and quantity of training exercises though a continuous daily exercise is beneficial.

A. *Example SpiroSpiel*[3]

Cystic fibrosis is a metabolic disease that causes the formation of mucus through a genetic defect in organs such as the lungs disturbing the activity of this organ. The lungs with the airways are most and worst affected [3]. Various breathing techniques and respiratory training equipment help patients to reduce the discomfort of their disease. Figure 1 shows the volume distribution within the lung with different respiration cycles. Patients should train all three marked areas [3].

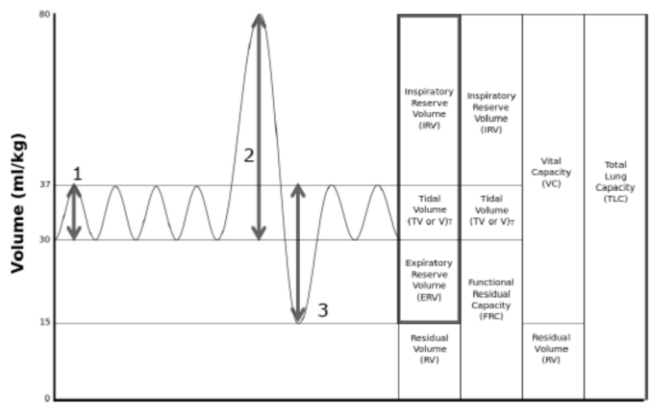

Figure 1. Volume capacity of the lung [4]

In one of our exemplary applications, we use a respiratory flow sensor developed by Hahn-Schickard for therapeutic use [5]. This digital spirometer is equipped with a Bluetooth interface. In the following, we describe our app *SpiroSpiel* showing the gamification of the therapeutic use for children suffering from cystic fibrosis. The data collected by the sensors are not only made available to the patient, but can also be used to be inspected and analysed by the attending physician or therapist in order to determine whether the therapy needs to be adapted [4].

Figure 2 shows the use case diagram for the *SpiroSpiel* application [4]. Different persons have access to the game: patient (child), parents, doctor and therapist. These four users access the *SpiroSpiel* in different ways. The left-hand side represents the home area, e.g. the area of self-directed

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[3] *SpiroSpiel* is an Hahn-Schickard named game.

exercises at home between two sessions with the therapist. The specialist staff with doctor and therapist that can make adjustments to the system respectively training parameters in addition to the control view. The system itself is divided into six (main) use cases: games, user data, training control, configure breathing curve, training data sets, and long-term control. These use cases describe the purpose for which the *SpiroSpiel* system has been developed [4].

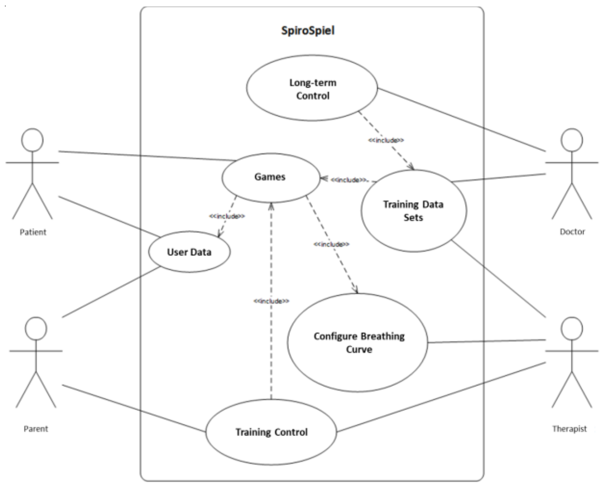

Figure 2. Use case diagram of the *SpiroSpiel* [4]

Looking at the home user side containing the patient and its parents, the use case diagram shows that only the use-cases *games*, *user data* and *training control* are relevant for independently performing the exercises at home. The training control gives a chronological list of performed exercises [4]. Parents can check whether the child has performed the exercises regularly and with which intensity. The user data contains information about the patient itself.

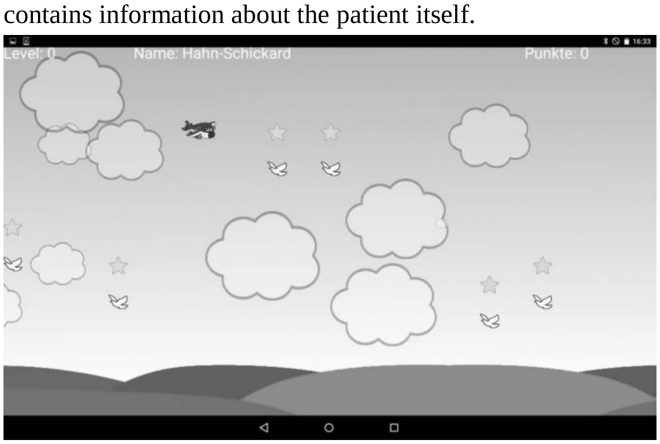

Figure 3. Screen of *SpiroSpiel* [4]

B. Example DermaPad[4]

The *DermaPad* is a multi-function sensor-actuator system for recording and processing bio signals [6]. It can also deliver a TENS[5] pulse to the skin surface. The wireless connection to one or more *DermaPads* creates a so-called Wireless Body Area Network (WBAN). In such networks, mobile terminals (e.g., smartphones or tablets) can conveniently interact with near-body sensor systems [6].

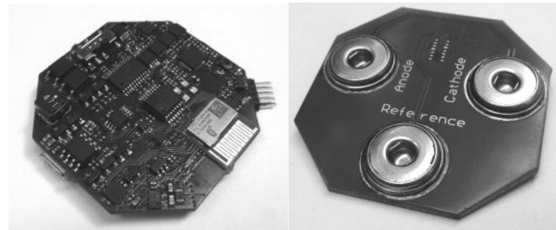

Figure 4. *DermaPads* [6]

Figur 4 shows the *DermaPad* with all its sensors and actors:

- Derivation of bio potentials, e.g. ECG, EEG, EMG
- Skin conductance measurement
- Pulse oximetry (heart rate, oxygen saturation)
- Accelerometer
- Touch sensor
- TENS

In our exemplary application, we demonstrate the navigation of visually impaired person using TENS pulses. We place several *DermaPads* at appropriate places on the visually impaired person's body that all connect to a mobile device [6]. The software activates the TENS function of the different pads, causing the blind person to experience a stimulus. The location of the stimulus allows an interpretation for the navigation direction or movement (stopping, forward etc,). For example, a TENS pulse perceived on the right half of the body corresponds to a corresponding right turn of the navigated person. Since our application focuses on the feedback channel and not an autonomous navigation, the navigation of the visually impaired person and operation of the software is done by an additional user. As an extension, of course, a supplement with navigation software or additional sensors for obstacle detection is possible.

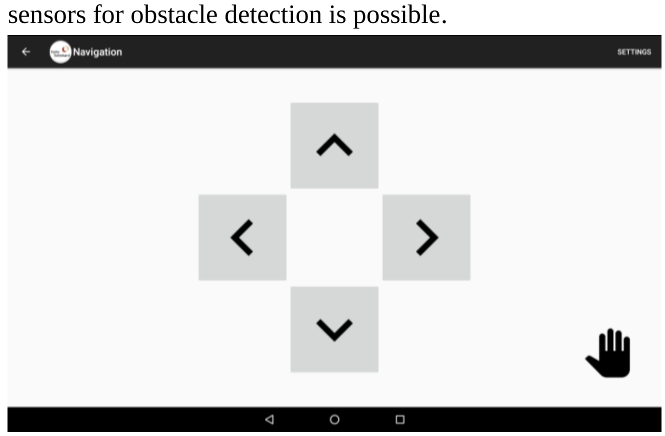

Figure 5. Surface Navigation App **[6]**

For navigation, a simple scheme similar to the arrow keys on a keyboard is used. When an arrow key is pressed, the app activates the TENS function of the associated derma pad or a combination of derma pads. The visually impaired person receives the desired TENS feedback and can react accordingly. If a pulse is perceived only subliminally, the TENS parameters can be adjusted via the option menu "Settings". Since the navigation requires multiple derma pads

[4] *DermaPad* is a Hahn-Schickard given name and consists on the one hand of the Latin word "Derma" for skin and on the other hand the English word "pad".

[5] TENS - transcutaneous electrical nerve stimulation

combined in different feedback groups, the navigation buttons are activated only if two or four derma pads are connected. In the following, the key assignment of the TENS activation patterns are explained as an example in the shoulder area.

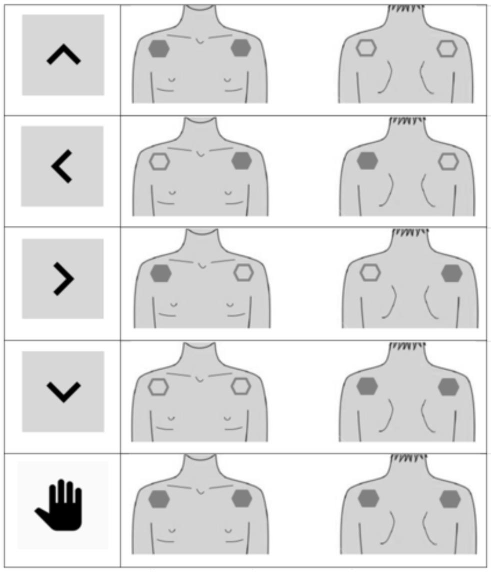

Figure 6. Navigation part [6]

In the case of the implementation with four derma pads, two derma pads are located on the front of the body and two pads on the back of the body.

III. Results And Discussion

Our exemplary applications show the benefits that can be reached by combining medical sensors with smart phones. Especially the capabilities of smart phones in term of connectability, user interfaces, and data processing power in combination with their high spread allow multiple applications. The *SpiroSpiel* application highlights that a pure sensor system measuring the breathing airflow can be extended to a complete digital therapy system. This system on the one hand opens completely new application domains and on the other hands creates additional value due to the intelligence that is hidden within the gaming app.

Discussions with parents of children with cystic fibrosis show that, children and adolescents often see the necessary exercises as very boring due to less variation and low motivation. Exercises in combination with inhalers are often associated with static and calm posture. It is also a special challenge for parents and therapists to motivate the children, as they are kept away from playing with friends or toys during this time. Furthermore, it is hard to adapt the exercises reflecting the current health status since it has not been quantitatively measured. Additionally the automatically digital monitoring of health data and therapy results offers new individual studies and evaluation of therapies and provides the basis for personalized and individually optimized therapies.

The *DermaPad* example shows that medical sensor actor systems can be applied in applications that have not been foreseen when developing the system itself by adding new functionality in terms of an additional app. With our app for visually impaired person, we demonstrated only one possible application. Many different applications can be envisioned that require a feedback channel that is not as noticeable as visual or audible feedback.

IV. Conclusion And Outlook

In our paper, we showed two exemplary applications in which we extended medical sensor systems with an additional app running on a smart phone. Using the breathing data to control a game, allows us to increase the motivation for children to perform necessary exercises based on a gamification approach. The second example demonstrates the use of body-worn sensor-actor system as feedback channel allowing the interaction between app and human being based on a TENS stimulus instead of the often used visual or audio feedback.

In our future work, we plan to follow-up and extend our approach on using gamification techniques combined with medical or body near sensor systems on smart phones to increase the motivation and efficiency of therapeutic exercises. Furthermore, the collected data can be used to optimize therapies in general or to optimize them according to the individual needs or therapy results of a patient.

V. References

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