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Enhancing engagement with motor rehabilitation therapy through gamified rehabilitation interactions.

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Abstract

Health applications that seek to increase motivation for motor rehabilitation fail to provide patients with sufficient variety to sustain long-term interest in exercising. In order to help improve the development of such applications a framework was developed for the design of digital rehabilitation practice. As 'proof of concept' of the framework, a design case is presented in which motor effective interactions facilitated by Leap motion technology were combined with a game to stimulate motivation for daily practice. The results of initial evaluative research show that this changed the nature of rehabilitation exercises from a repetitive physical effort to a playful challenge. The initial evaluation showed an increased motivation to engage with daily practice. The framework thus provides a basis for the design of digital systems that enhance rehabilitation practice performance.

Keywords: Serious games; Possible Selves; Gamification; Motor Rehabilitation; Leap Motion; Interaction Design

Introduction

Volar plate injuries are finger injuries that result either from sports activities or a fall onto the outstretched hand. Immediate mobilization of the injured finger has been shown to be more effective than static splinting in order to regain a full range of motion (Arora *et al,* 2004). This treatment approach requires patients to be highly motivated during rehabilitation therapy, especially in the first three weeks. Although frequent practice is necessary to fully recover, many patients are not motivated to exercise regularly. This is because patients experience rehabilitation exercises as boring and meaningless due to their repetitive nature (Rego *et al,* 2010). Therefore, solutions are needed that motivate patients to exercise frequently and so enhance engagement with therapy. To dissolve the repetitive nature of rehabilitation exercises and increase engagement with therapy, practitioners introduce serious games. Although participation in games for motor recovery has been shown to significantly increase the patient´s motivation to practice, current games for motor rehabilitation are less engaging as normal video games, because they are not designed to entertain (Flores *et al,* 2008). Instead, they intend to fulfil a medical purpose by facilitating patients in developing new skills or endorsing goal-oriented behaviour. Thus, we face a contradiction between the primary motivator of games and the intended medical purpose. This results in having to sustain long-term interest for a therapeutic game on top of the treatment itself. The premise of this research, then, is to provide guidelines to develop serious games for motor rehabilitation that address entertainment and motor recovery equally, as well as effectively sustaining long-term interest for the application and the rehabilitation practice itself.

This paper presents a framework for designing meaningful interactions within digital rehabilitation systems in order to motivate patients to practice regularly by presenting treatment-effective tasks in a playful way. We present the development of the framework and a pilot study to assess the usefulness of the framework in fostering engagement. A set of rehabilitation exercises is redesigned and incorporated into an early prototype version of a system that supports the required interactions. The effectiveness of the system in terms of engagement with therapy is analysed. We hope to illustrate a purposeful approach to rehabilitation game design and evaluation, before moving on to full development.

Theory & research context

In preliminary research, we analysed the current treatment process and found that patients are biased towards passive receivers of the interactions they receive during treatment. This is detrimental to the aims of rehabilitation therapy, because it requires the patient to be highly proactive. By actively involving patients into treatment procedures and fostering their health awareness they will engage with rehabilitation practices on a long-term (McCallum, 2012).

Framework for rehabilitation game design

To design a game that contends that, we linked the persuasive game design model by Visch, Vegt, Anderiesen and van der Kooij (2013), to engaging interaction and game components (fig.1) that fulfil the basic motivational needs according to Self-determination theory (SDT) (Ryan & Deci 2000).

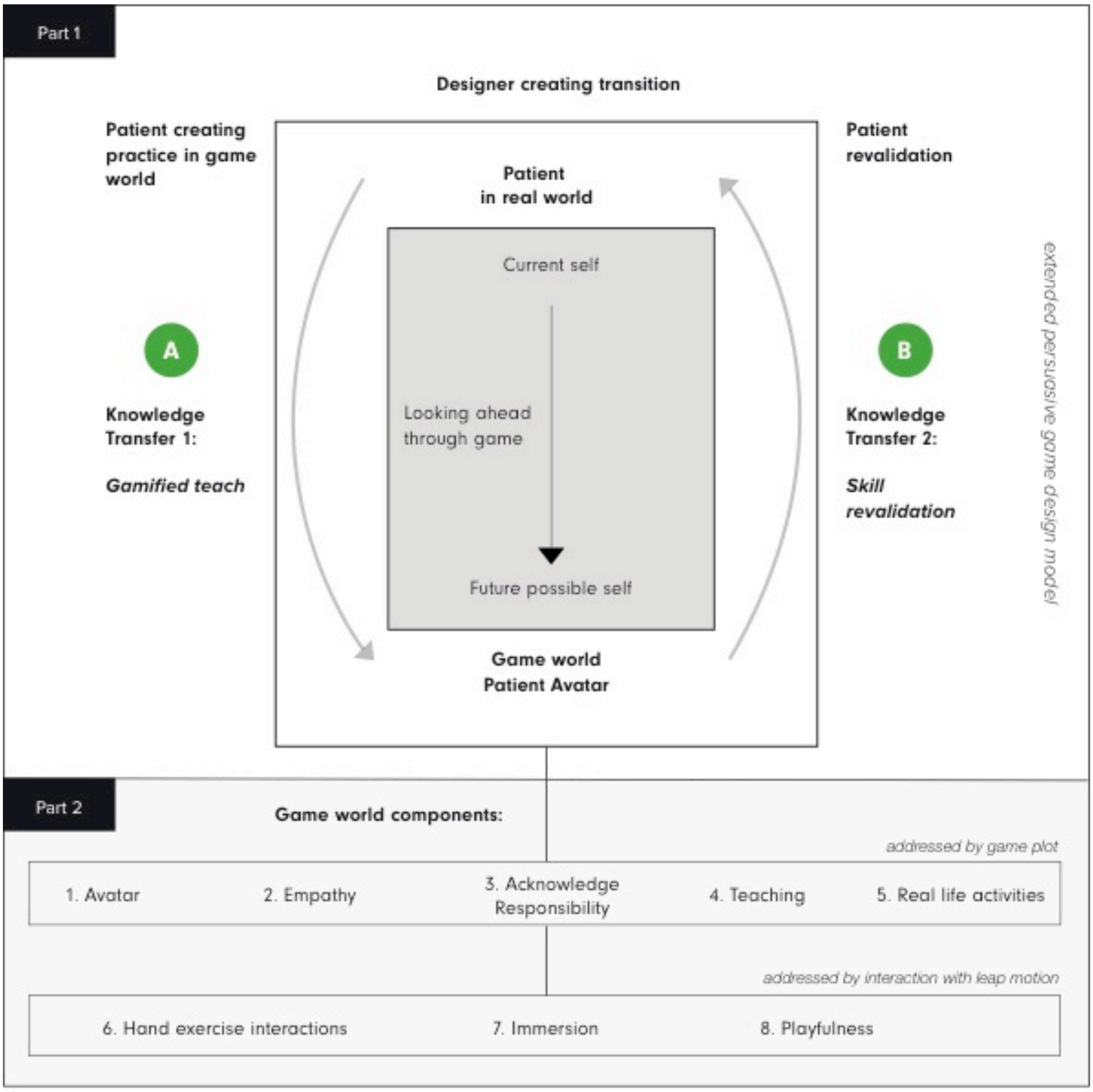

Figure 1. Framework for rehabilitation game design.

A motivating game-based practice should trigger patients to perform rehabilitation exercises autonomously by presenting them meaningful practice interactions. According to Visch *et al,* (2013) new skills can be acquired in a game and made applicable in the real world through a knowledge transfer from game world to real world (fig.1 part 1, B). However, in rehabilitation

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therapy patients do not seek to acquire new skills but regain old ones. Therefore, we introduced to the model a new concept as an engaging game element for this situation.

Future possible-self

According to the theory of future possible selves (Markus & Nurius 1986), "in addition to self-representations in the present, we form mental representations of ourselves in future times, the so-called 'future possible selves'. They encompass both hoped-for and feared-for future representations and provide an evaluative and interpretative context (...) which may have an influence on subsequent behaviour and also on the way a person copes with life events" (Kenter *et al,* 2014). For this, a digital patient avatar is introduced as a motivational game element (fig. 3, part 1). The game avatar represents a patient´s future possible-self, showing the patient the progress of their practice in relation to their future skills. An interaction relationship is established with this future self: the patient teaches the avatar the skills the patient had and needs to regain. In this way the patient will perform a gamified knowledge transfer of the skills they want to regain on their future-self avatar.

Engagement through motivational game elements

The motivational needs 'autonomy', 'social relatedness' and 'competence' from SDT served as the foundation for the development of the motivational interaction and game components. Because our framework serves to support patients in regaining their existing skills and not acquiring new ones, the skill transfer effect as described by Visch *et al,* (2013) will occur twice. The first transfer will occur when shifting existing knowledge about how to perform an activity from the real world to the game world (fig. 1, part 1, A). Creating a future-self as an avatar will satisfy the patient´s need for social relatedness and autonomy. Teaching an avatar, these specific skills that are based on real life activities, will evoke the patient´s competence, since the skills are part of their existing skill repertoire and patients can call on them. Thus, patients will teach their avatar the skills they have lost, and are enabled to look ahead towards their healthy future-self. The second knowledge transfer (fig. 1, part 1, B) will occur from game world to the real world, enabling patients to revalidate the skills they have practiced in the game. Next to a second knowledge transfer, our extension to Visch´s model conceptualizes not just the designer but also the user, the patient, as creator of the gamified rehabilitation interactions when playing the game (fig. 1, part 1, top left). Our system allows patients to create own practice sequences, based on the patient´s explorative course of play within the game. Instead of just exercising, patients will interact with the game by using a predefined set of interactions that will be extended throughout the process in relation to the patient´s recovery. During each practice session with the system, the patient assembles the predefined interactions into a personal practice sequence. This sequence differs in every gamified practise session, according to the skills, patients want to teach their avatar. In this way interaction and exercise variety is generated. This variety should contribute to sustaining patient interest for regular practice.

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To sum up, the framework consists of the game world components 'avatar', 'teaching', 'acknowledged responsibility', 'empathy' and 'real life activities' that are directly linked to the game plot and the patient future-self avatar. 'Acknowledged responsibility' (Visch, Rozendaal, Rosmalen 2013) represents the responsibility for taking care of one's own game-practice progress, further reinforced by empathy with the avatar.

The other game components 'hand exercise interaction', 'immersion' and 'playfulness' are being addressed by the gamified hand rehabilitation interactions facilitated through Leap motion. The key components that are presumed to lead to engagement are the future possible-self avatar, real life activities, hand exercise interactions and playfulness.

Creating playfulness and motor effective interactions with Leap motion

In order to create playfulness, we harness Leap motion technology as it addresses the motor demands that are needed for successful rehabilitation. It translates complex hand and finger motion into an input with sub-millimetre accuracy (Weichert *et al,* 2013) and evokes playfulness since it is a very experiential way of influencing objects on a screen (Thorne *et al,* in review).

Figure 2. Playing a game with Leap motion

Enface case study

Real life activities as exercising interactions

In order to investigate activities for motor rehabilitation that could be gamified, mental simulations with 12 subjects were performed. Individuals were asked to put on a splint on the index finger of their dominant hand and asked to imagine coming back home from the hospital after the examination. Subjects were then presented a leaflet depicting a patient persona to help them get immersed into the situation (fig.3). The leaflet was designed in relation to the theory of

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possible selves and seeks to elicit patients' fears about their abilities after the injury and their aspirations towards the rehabilitation therapy.

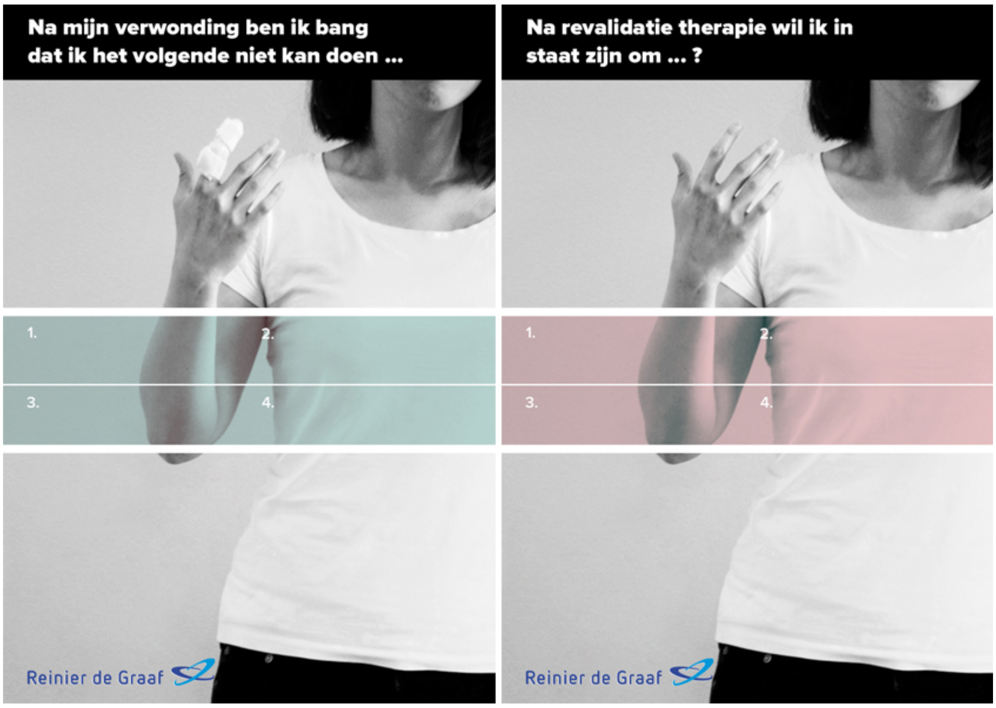

Figure 3. Possible selves intervention leaflet.

Playful rehabilitation game exercises

To create the new playful hand rehabilitation exercises we analysed the existing ones and adapted them to typical game character in order to dissolve their boring nature (fig. 4). The basic exercise to bend and extend the fingers carefully was harnessed to moving a character forward (A) and jump in a game (B). Once these are mastered, patients continue with making a fist and fully extend all fingers upwards to 90°. These were utilized to perform an action (C) and slow down a vehicle in the game (D). The last exercise was converted to steering a vehicle or changing a viewing perspective in the game by bending all fingers, holding the position and flexing towards the desired direction (E). To make navigation more intuitive the navigation interactions are performed with both hands simultaneously.

Usability & Engagement pilot study

To assess engagement for the designed system its usability was evaluated. Usability responds to the dimensions effectiveness, efficiency, engagement and error tolerance and the ease of learning (Quesenbery, 2010, p. 81). Being interested in the engaging effect of our framework, we regard effectiveness, efficiency and error tolerance as basic conditions that are measured to verify

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unobstructed engagement. Quantitative and qualitative methods were used for that by measuring usability factors, mapping participant emotions, and evaluating the game plot and the designed gamified hand gestures. To measure these aspects, relevant system parts were designed in an initial simulated way with 3 tasks.

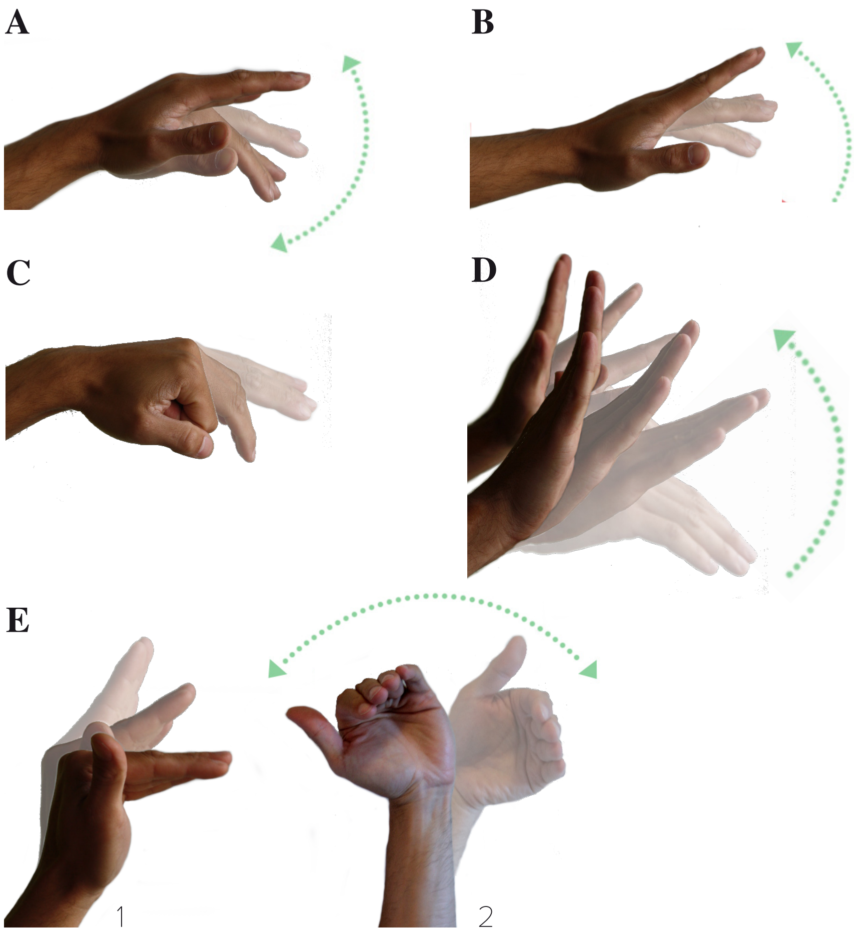

Figure 4. Gamified rehabilitation interactions

1.Taking a hand measurement, with the Leap motion device. 2. Setting up the system for home therapy and 3. Play a game (Mario world) with the Leap motion as input device and operate it with the redesigned rehabilitation exercises (fig. 5). The pilot study was conducted with 10 participants. An evaluation questionnaire was used to measure usability factors and therapy engagement through the gamified hand interactions and the designed game. Thinking aloud during the simulation and open-ended questions on the subjects' experience with the digital practice system and his thoughts on the game plot were used to obtain more qualitative insights. For qualitative data analysis, participant answers were coded, clustered and summarized while preserving the content.

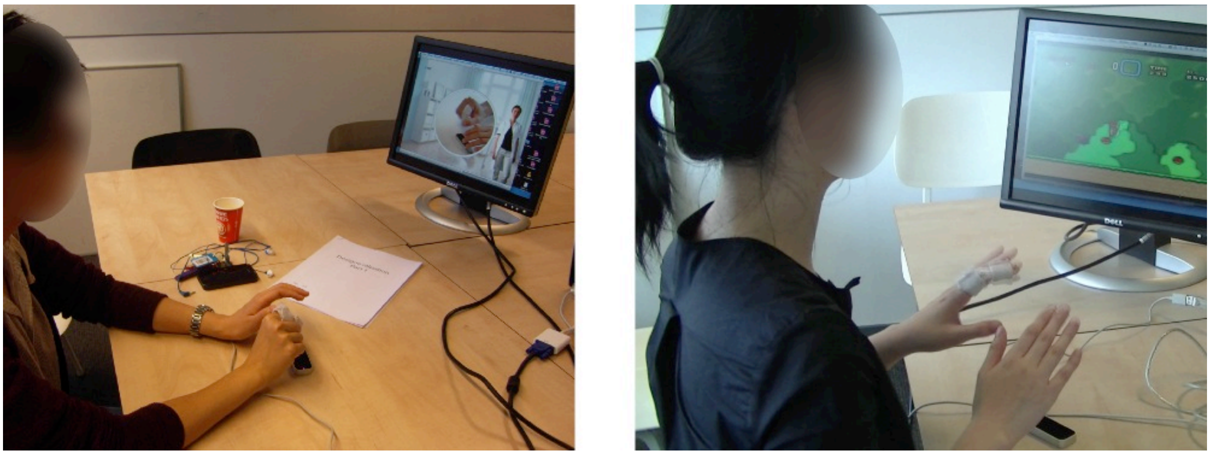

Figure 5. Left: taking a measurement; right: game interaction simulation

Results

Real life activities as exercising interactions

The insights from the hand splinting intervention with the future possible-self stimulus (fig. 3) revealed that patient concerns and the levels of inconvenience with different activities differ greatly, according to personal interest and life goals. A generalization of one or more specific activities that appeal to the majority was not possible. However, daily activities were identified as real-world relevant and formed into categories for the future practice design by clustering similar concerns. These categories are:

1. Daily life skills: doing dishes, getting dressed, grocery shopping, withdrawing cash

2. Work related skills: typing an email, performing work-specific tasks, using a pen

3. Travel and mobility skills: cycling, driving a car, taking the train

4. Hobbies: playing an instrument, sporting

5. Social activities: going to a bar, interacting with people, playing with children

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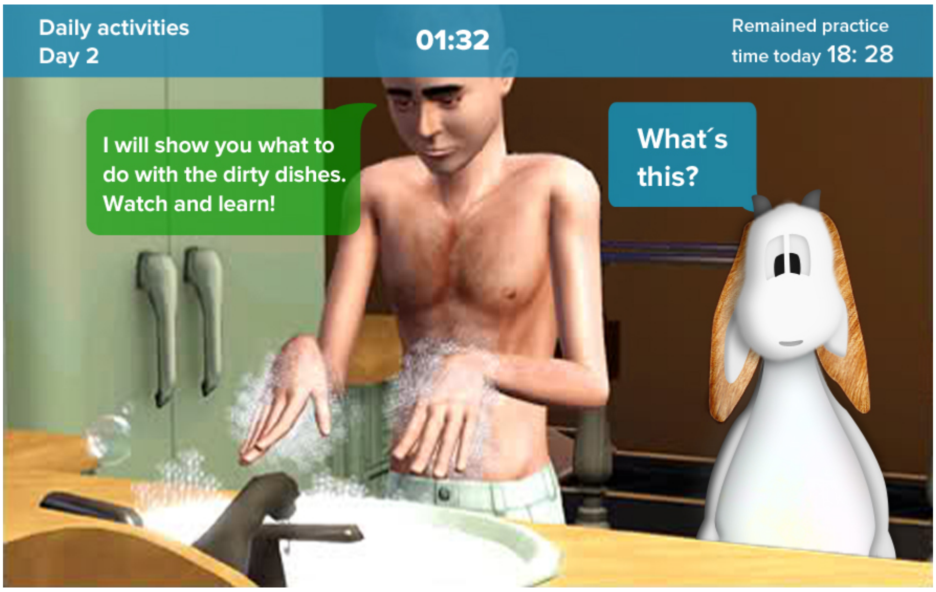

Figure 6. Game content simulation, Teaching the patient avatar how to clean dishes.

Usability & engagement

Regarding effectiveness; efficiency and error tolerance as positively fulfilled (fig. 7), we present and discuss engagement more in depth.

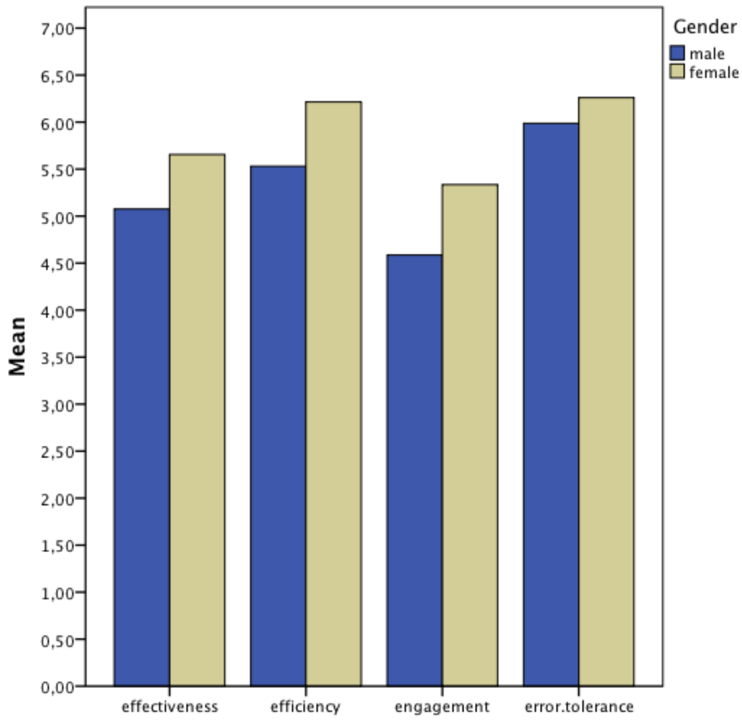

Figure 7. Results of usability evaluation

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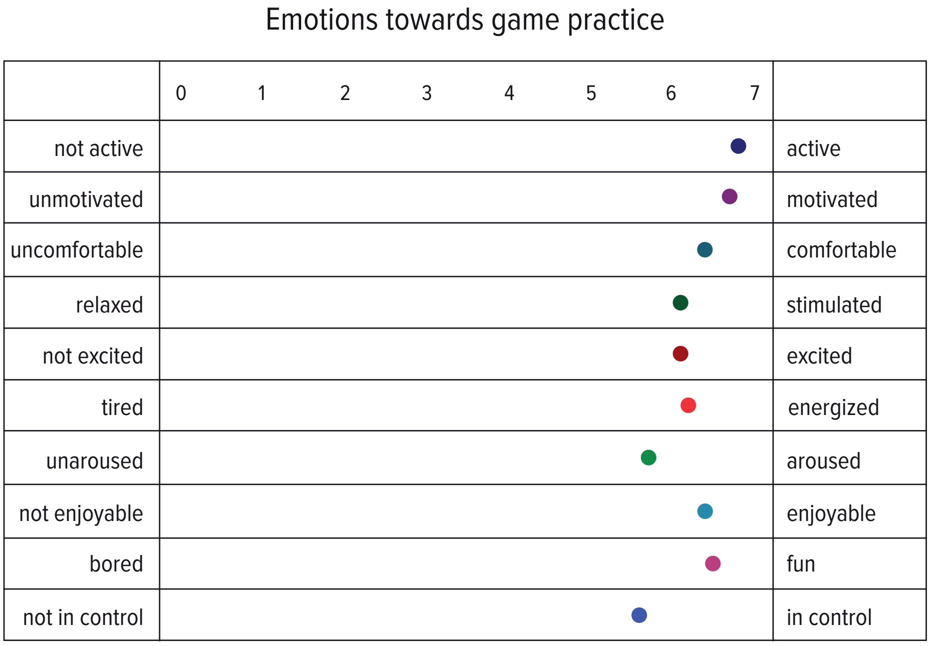

Figure 8. Mapped user emotions after game play

The mapped user emotions towards the game practice are positive overall and indicate high engagement (fig.8). This accounts to the redesigned hand movements that were reported to be rich in experience, fun, intuitive and meaningful, due to Leap Motion. Users reported being motivated to practice regularly, as they felt physically active and challenged through the intergartion of the hand exercises into a game. More accurate and interactive feedback in comparison to standard practice helped patients to increase their awareness for their injury and the necessity to recover. The twice-occurring knowledge transfer enabled patients to immerse themselves into the game world by transferring existing knowledge and revalidating their own skills within the game context. However, two participants were concerned that the game might exceed the capabilities of their injured hand, causing pain while playing. Although game plot and patient avatar were reported to be very likeable, two participants were concerned with the seriousness of the game, considering the possibility of exercising at work.

Discussion

We have developed a framework and validated the usefulness of its parts for design by hand exercise interactions, playfulness and possible selves. Our approach can be expected to lead to greater certainty in evaluating outcomes, as described by Lyles *et al* (2014).

Engagement through playful hand rehabilitation interactions

We assumed that interactions designed for rehabilitation practice should divert from the effort of the exercise itself and instead emphasize the patient's abilities in the future. Meaningful tasks derived from life situations afford this condition and will increase patient awareness and

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motivation to exercise regularly as described by Flores *et al,* (2008). Gamifying rehabilitation exercises enhanced engagement with therapy by creating playfulness. In an initial empirical evaluation of the framework we found that meaningful play revolves around the principles of challenge and feedback. Play will emerge from the relevance of the presented game challenge and the patients` intentions of exercising in relation to feedback for their actions that a game makes available to them. We have fulfilled this by presenting patients with relevant daily activities and provided feedback in form of an outlook to regaining skills, through a gamified practice with a future-self avatar. This means that in applying our framework we were able to shift the perception of rehabilitation practice from a boring physical effort to a playful challenge. Our gamified interactions may stay constrained to a set of hand movements but will stimulate motivation for long-term exercising as long as they fulfill motor recovery requirements (McCallum, 2012) and present the benefits for exercising towards future abilities (Jacobs *et al,* 2013). Ryan and Deci (2000) and Ryan *et al* (2008) have, however, shown that there are possible limitations to the amount of engagement, when a patient's competence is exceeded. Also Flores *et al* (2008) point out that the physical and the game challenge both need to be dynamically adapted to the patient´s progressing motor skills in order to guarantee motor improvement and remain engaging. Further research into the exact criteria for a game should look into that.

Engagement through possible selves

The introduced concept of a future-self avatar mediated therapy objectives and the positive outcomes of long-term exercising. It linked the progress in the game world (avatar skills) to the influence it will have on patient skills in the real world (fig. 1, part 1). This was achieved by addressing real patient concerns as they enhance the motivation to practice (Jacobs *et al,* 2013). However, personal preferences to game characters need to be considered and (personalized) motor rehabilitation systems designed that appeal to different patients in order to increase involvement as shown by Koda and Maes (1996).

Conclusion

Our new framework for persuasive game design provides directions for the design of gamified rehabilitation practices by making those more experiential through meaningful interactions and play. This increases patient motivation to exercise and enhances engagement with rehabilitation therapy. In order to validate whether our framework can significantly increase patient motivation towards rehabilitation exercises, quantitative research is needed to achieve greater generalizability. To conclude, we have shown that playful interactions that are designed in relation to the patient´s life context while fulfilling motor rehabilitation requirements, change the perception of rehabilitation practices from being boring to being exciting and fun, by shifting the focus from a repetitive physical effort to a playful challenge. This led to an increased engagement with rehabilitation treatment and will foster daily exercise. Our next steps will be to validate this framework and its game components further.

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