

# WuppDi! – Supporting Physiotherapy of Parkinson’s Disease Patients via Motion-based Gaming

Oliver Assad, Robert Hermann, Damian Lilla, Björn Mellies, Ronald Meyer, Liron Shevach, Sandra Siegel, Melanie Springer, Saranat Tiemkeo, Jens Voges, Jan Wieferich, Marc Herrlich, Markus Krause, Rainer Malaka

Digital Media, TZI, University of Bremen

## Abstract

The Parkinson’s disease is a neurodegenerative disorder with a range of symptoms such as slowness, rigidity, resting tremor (trembling), and an impairment of postural balance leading to disturbance of gait and falling. Continuous exercises are an effective strategy to maintain the patient’s movement abilities, slowing down the progression of the disease. Self-directed exercises in addition to supervised physiotherapy sessions are not only beneficial, but necessary. This paper presents an approach to support Parkinson’s disease patients in their daily exercises using the playful context of different motion-based digital games adapted from physiotherapy.

## 1 Introduction

Parkinson’s disease (PD) is a degenerative disorder that affects the nervous system (Goodwin et al., 2008). Symptoms such as immobility (freezing of movements, low movement speed and amplitude), resting tremors, uncoordinated movements and concentration problems are usually associated with the disease, heavily influencing the patients’ quality of life (Morris, 2000).

Exercises and training are useful to slow down the degenerative process, with a chance of bringing back lost skills (Goodwin et al., 2008; Faherty et al., 2005). In general PD affects elderly people. Surveys show that in average one out of 1000 people over the age of 65 and one out of 100 people over the age of 75 are suffering from it.

Besides medication, physiotherapy is the most important part in slowing down the progression of the disease and helping patients to stay agile (Deane et al., 2001). However, in order

to improve their abilities, the patients also need to invest time and effort to exercise at home. A problem is that not every patient has the motivation to do so. In this case people can use exergames to motivate themselves for regular training at home in order to complement collaborative training and professional physiotherapy.

One existing commercial and very popular example of using games for complementary training is the Nintendo Wii console (Yim & Graham, 2007). Another example is the Playstation EyeToy. Both are in general easy to handle and cheap to purchase. Yavuzer et al. (Yavuzer et al., 2008) showed in their studies that the integration of the EyeToy into daily exercises could help to make them more enjoyable, resulting in raising the patients' motivation. Also, in the field of stroke rehabilitation, patients can improve their physical fitness with simple motion-based games (Kiili & Merilampi, 2010). However, the existing commercial and non-commercial games are not necessarily considering the PD patients' abilities. Therefore these games are limited in many terms for usage in therapy.

WuppDi is a collection of five motion-based mini-games, aiming to motivate PD patients to exercise at home. The WuppDi collection was developed in close collaboration with the patients. Therefore the focus lies on the integration of the following three main aspects: movement, coordination of movement and the improvement of concentration. To ensure that the design and development of these aspects meet the needs and abilities of the PD patients, a close contact with subject matter experts was established and data and suggestions were gathered during frequent evaluation sessions.

## 2 Related Work

For more than two decades the gaming industry introduced new interaction technologies beyond conventional input methods (e.g. mouse and keyboard). They offer possibilities of interaction that can be used to assess the player's motor as well as cognitive activity (e.g. capacity of memory) and to facilitate the augmentation of physical and cognitive tasks in the context of games (Krichevets et al., 1995).

Traditional rehabilitation approaches have the disadvantage that the patient has to be motivated to perform repetitive exercises. But those are indispensable to achieve the goal of the physiotherapy by means of the repetition of different task-specific exercises (Burke et al., 2009).

Thus, several researchers anticipated that games have a motivational impact due to their entertaining capabilities (Burke et al., 2009; Flores et al., 2008). Most notably the WiiMote device enabled physical interaction. It was assessed as suitable therapy device for the elderly (Jung et al., 2009). Furthermore, the Wii platform offers a variety of motion-based games with different requirements of motor control and visual spatial demands (Deutsch et al., 2008), which might not be suitable for rehabilitation purposes in the application area of PD.

Additionally, the EyeToy platform offers a low-cost gaming environment that is adaptable for rehabilitation purposes. In contrast to the WiiMote the EyeToy is based on video capture

technology without the requirement of a handheld device that needs to be learned first. According to this a study revealed that ten healthy elderly (Age: 59-80) found the platform easy to operate and enjoyable (Rand et al., 2004).

An individual case-study showed that a variety of commercial motion-based games (The EyeToy: Play 2 games bundle) have a positive effect on the rehabilitation of post-stroke patients, but games not intended for therapeutic use have limitations in terms of accessibility, i.e. they could be too difficult to be performed even at their lowest levels (Flynn et al., 2007).



Figure 1: The Frog Prince game

### 3 Field Tests and Participatory Design

From an early state on, a regular meeting with the PD patients was involved in the design process of the WuppDi game in order to meet their requirements. A participatory process was followed in which field tests were performed under uncontrolled conditions with a various number of patients. Therefore a contact with the Bremen regional group of the “Deutsche Parkinson Vereinigung” (German Parkinson Association) was established. They organize regular group therapy meetings for their members, whereby the participation in such sessions offered the possibility to identify tailored game mechanics.

In an initial session commercial off-the-shelf games that feature motion-based interaction were evaluated with the target group (e.g. Wii, EyeToy). The outcome of first observations was that on the one hand the patient's were attracted to those games based on physical interaction. On the other hand these tests revealed the fact that the games are not necessarily suitable for the target group.

The problems were in general related to the fast gameplay speed, visual overload, too complicated game-design and the need for a very fast response time. Nonetheless some aspects of game design were identified which facilitated the design process of WuppDi.



Figure 2: The Cinderella game

## 4 Concept and Design

WuppDi is a collection of five mini-games that were adapted from five different fairy tales. The games are named after their fairy tale counterparts, which are *Der Froschkoenig* (English: The Frog Prince), *Aschenputtel* (Cinderella), *Die Sterntaler* (The Star Money), *Ali Baba* and *Die Bremer Stadtmusikanten* (Town Musicians of Bremen).

In the following section, some important aspects that were considered in the design process of WuppDi will be discussed.

**Simplicity:** Due to their age, a lot of people in the target group are reserved about new technology and not very proficient in using computers or gaming systems. Some also have problems with their memory and to remember instructions. Therefore, WuppDi was designed with a simple interface that is easy to use even without the attendance of a consulting expert.

**Familiarity:** The overall theme of fairy tales was chosen to break the barrier of the technology use mentioned earlier by introducing a familiar theme. Yet, since it could be played at home, elderly people could also play it with their younger grandchildren whom are familiar with the theme as well.

**Rhythm:** Observing physiotherapy sessions it was noticed that music and rhythm immediately motivated patients to start moving. Research has shown that using auditory cueing has positive carryover effects (Lim et al., 2005; del Olmo et al., 2006; Rubinstein et al., 2002). In some of the games the gameplay is aligned to the rhythm of the background music. Players can reach a higher score when they stay in the rhythm.

**Feedback:** In several field tests it was observed that multiple ways of feedback are beneficial to support the players' perception of their progress. Therefore a combination of visual and auditory feedback was included in the WuppDi games. It is also important to give the

player a positive feeling while playing, which in turn supports the motivation. Hence, constant positive feedback and rewards were supplemented.

**Variety:** Since PD patients undergo different symptoms and are in different states of the disease, it is impossible to design a single game that suits every patient's needs. Thus, WuppDi features several mini-games with different levels.

## 5 Game Mechanics

Besides motion training as the most prominent aspect the games feature concentration and coordination training as well. The game mechanics are to a certain extent based on input gathered from the already mentioned physiotherapy and field test sessions.



Figure 3: The Ali Baba game

### 5.1 Movement

In the game mechanics, movement of the player is the most important element. The ability to do controlled movements is what most of the Parkinson's patients are lacking in various degrees. Therefore, the movement patterns that the player needs to do are built upon observations from physiotherapy sessions.

It was figured out that large amplitude movements are beneficial for the patients (Farley & Koshland, 2005). Consequently they were enhanced in the WuppDi games. To illustrate, in the single player game *Froschkoenig* the player's goal is to steer a frog avatar through a pond and collect rewarding items (Figure 1) In order to do so, the player has to emulate swimming movements (i.e. moving one hand to steer in a specific direction, or moving both hands simultaneously to swim forward).

Another example is the *Aschenputtel* game. This mini-game, which is playable by up to three players, encourages the player to imitate movements displayed by a 3d character according to music rhythm. To mirror the movements of the avatar correctly appearing notes have to be hit. Hereby a bonus is possible when the notes are touched in the predetermined rhythm (Figure 2).

## 5.2 Concentration

Since PD is usually affecting elderly people, concentration- and mind-training was also implemented in the WuppDi collection.

The *Ali Baba* game is developed for this aspect (Figure 3). To open a door and find a hidden treasure the player has to remember a colour sequence. This sequence is displayed by glowing coloured buttons. In order to open the door step by step the player has to memorize the sequence and press the buttons in the same way that was shown before. By every round the sequence is getting longer and thus more difficult.

## 5.3 Coordination

Besides motion training in general, WuppDi also consider training accuracy and coordination.



Figure 4: The Star Money game

This could clearly be illustrated through the example of *Sterntaler*. In this game it is possible to play with one or two players in different game modes. In the first mode the player has to perform horizontal arm movements to collect falling star coins (Figure 4). In the second mode the player has to move his hands according to a path of star figures that appears on the screen. Paths are generated randomly and appear in ellipsoid shapes. The last mode combines both game modes. Here one player has to move his arms according to the path of stars, while the other player has to catch the falling star coins.



Figure 5: The Town Musicians of Bremen game

The game *Die Bremer Stadtmusikanten* focuses on the coordination between both hands by assigning tasks to be done successively with one hand after the other. The voices of the town musicians are trapped in bubbles, which are moving across the screen. The objective is to first stop the bubbles with a net steered by the left hand and then destroy the bubbles with a needle controlled by the right hand. By freeing the voices the player gives the ability to sing back to musicians. Therefore wide movements with both hands is necessary (Fig. 5).

## 6 Discussion

The WuppDi game collection addresses the purpose to provide a game environment for Parkinson's patients to support their self-directed exercises complementary to physiotherapy. A replacement of physiotherapy was not considered as the games don't offer the possibility of intervention as in case of supervised therapy.

Instead of that the objective of the game design was the enrichment of the games with auditory and visual cues to assure proper motion sequences adopted from physiotherapy exercises.

During the initial phase of user testing, video-capture technology based on available hardware was identified as an intuitive input method useable for the PD patients. In addition, this available hardware offers the advantage of home-based use due to its low cost.

However, one limitation is that unintended movements could not be excluded completely (e.g. the player chooses an uncomfortable position in order to adapt to the game). In consideration of the fact that PD varies in progression and symptoms individually, several aspects could hinder the patients in terms of user interaction. For example, coordination deficits might limit the affected person to fulfil precise movement exercises (e.g. hand-eye coordina-

tion). Thus, auditory cues (e.g. rhythm) were applied to generate additional stimuli. Further limitations affect the capability to perform large amplitude movements due to rigidity or a decreased range of movement.

Those potential limitations of the target group are essential in terms of the level of difficulty and the challenge within the game. Firstly, the challenge is an important aspect in terms of motivation. Secondly the games' goals have to be accomplishable, demands should not out-balance the users capabilities to prevent frustrations. To do so appropriate levels of difficulty are necessary, capabilities of the unimpaired are not a proper measure in this case. Furthermore the feedback design should prevent further potential frustrations. Therefore the users achievements are accentuated.

Finally, another beneficial aspect of the WuppDi games collection applies to the symptom of the freeze phenomena. Motion freezing is reported as an episodically reduction of the patients movement capabilities for a limited span of time (Nieuwboer et al., 2007). This phenomenon might be induced by stress. A study already addressed to this issue concluded that the intensity of freezes could be reduced through regular training. In theory, suitable exercises might be helpful in that case to overcome the freezes. This was also anticipated as a beneficial outcome / purpose of our games by the Parkinson patients' involved in our design process.

## 7 Conclusion and Future Work

This paper presented a collection of motion-based games that are designed to be an extension to existing physiotherapy addressing PD. The WuppDi collection contains five mini-games, which are meant to be played at the patients' homes. A simple webcam is used to detect the motion-input. Thus, a portable system is provided that can be deployed on most of the existing hardware.

In preliminary user tests it was determined that the games attract elderly people and can be used as a motivational factor to encourage training at home. The games address different capabilities, namely motion-, concentration- and coordination-training. They provide a set of various exercises realized in different tasks that are presented in the common theme of fairy tales.

Up so far the games were not evaluated under controlled conditions. Currently an evaluation based on questionnaires and video analysis is being conducted. A subsequent long-term study of daily use is still an open request to prove the efficiency of the games and their validity in terms of physiotherapy.

In terms of adaptability and the degree of difficulty the games currently only provide pre-definitions, it could be anticipated that with user-specific movement measurements an individual tailored game play could be achieved.

Furthermore the use of webcam-based technology might not be appropriate to generate a meaningful feedback channel on the quality of the users performed motions. This techno-



logical limitation might be solved by adaptation of advanced time-of-flight or structured light approaches. These provide user interaction in spatial depth and therefore accurate tracking of the user and his movements performed (e.g. skeleton tracking, full-body tracking).

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### **Contact Information**

Research Group Digital Media, University of Bremen, Email: sg10all@tzi.de