PDDanceCity: An Exergame for Patients with Idiopathic Parkinson's Disease and Cognitive Impairment

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Abstract

In this contribution, we present PDDanceCity, an adaptive exergame controlled with a USB dance mat or a Wii Balance Board. PDDanceCity includes cognitive training geared towards cognitive enhancement in patients with Parkinson's Disease (PD) without or with Mild Cognitive Impairment (PD-MCI) or Dementia (PDD). The game is available as prototype and will be further developed in the context of the BMBF-Financed KMU-Innovativ Project PDExergames.

1 Introduction

Parkinson's Disease (PD) is a neurodegenerative malady caused by the progressive degeneration of dopaminergic neurons in the substantia nigra pars compacta. The clinical diagnosis of PD is typically determined by motor symptoms (slow movements, rigidity, hand tremor), but cognitive dysfunction is also common (Aarsland, Brønnick, & Fladby, 2011; Muslimović, Post, Speelman, & Schmand, 2005). Once cognitive impairment can be objectified, it is called Mild Cognitive Impairment in PD (PD-MCI), which is a risk factor for further cognitive decline into PD Dementia (PDD), which is characterized by cognitive symptoms in at least two domains (e.g. memory, executive function) which causes dysfunction of activities of daily living. Although classic PD is mostly pharmacologically treated with dopaminergic replacement therapy, there is no strategy to prevent cognitive decline in PD patients or approved pharmacological approach to treat PD-MCI at the moment (Weintraub et al., 2016). However, recent research suggests that cognitive function can be improved through cognitive training in patients with PD (Leung et al., 2015; Petrelli et al., 2014). It is also discussed that a combined treatment of cognitive and physical training seems to be a good option (Rahe

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et al., 2015). A particular benefit of a combined therapy could be that transfer effects, that is, both a cognitive improvement from physical movement (Hindle, Petrelli, Clare, & Kalbe, 2013) as well as positive effects of cognitive training in physical symptoms, for example, freeze of gait (Walton, Shine, Mowszowski, Naismith, & Lewis, 2014).

The therapeutical potential of exergames as an extension of traditional cognitive and motor training for PD is currently being explored (Bloem, de Vries, & Ebersbach, 2015; Kalbe & Folkerts, 2016; Leung et al., 2015), but so far, only one randomized clinical study has been performed (Barry, Galna, & Rochester, 2014). Some findings point towards improvement in balance (Harris, Rantalainen, Muthalib, Johnson, & Teo, 2015) as well as cognition (Ogawa, You, & Leveille, 2016). Previous works underlines the need of further research into improving current exergames. To the knowledge of the authors, there is no available exergames program adapted to the needs of PD patients with but also without MCI or dementia.

Thus, the goal of this study, as well as the PDExergames project, is to develop an exergame-based therapy for patients with PD, PD-MCI, or PD-PDD that combines both physical movement and cognitive tasks.

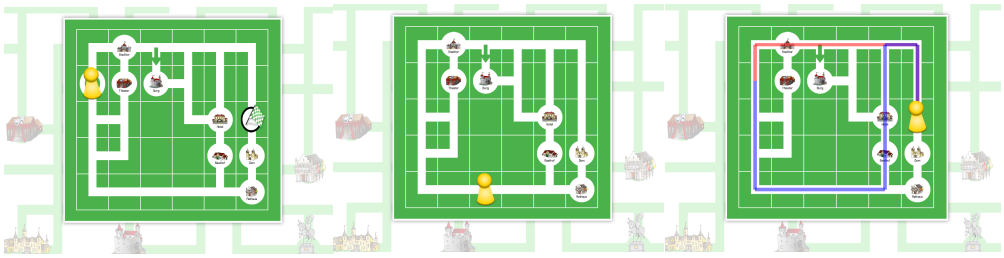
2 Concept and Implementation

In PDDanceCity, the patient is presented with a randomly generated city map, a modified version of the "city plan game" of the cognitive training program "NEURO*vitalis*" (Baller, Kalbe, Kaesberg, & Kessler, 2009) in which two-dimensional movements in the vertical and horizontal axes are possible. The patient starts at a randomized point and has to reach a goal, marked with a green racing flag (Figure 1a). After a few seconds, the flag disappears and the patient has to start moving towards the goal. The patient is able to move up/down and left/right, as long as his current position in the map allows it, by pressing the respective area of a USB dance mat or leaning on a Wii Balance Board. The map presents several landmarks (e.g. Monument, church, library) as well as one-direction alleys and dead ends (Figure 1b).

To avoid frustration and negative reinforcement, there is no time limit, and the caretaker can show the location of the goal again as often as required. Once the patient has reached the goal, two lines (blue and red) show the traveled and minimum distance paths. Relevant parameters, such as time taken, steps and difference between the traveled and ideal paths are stored for future analysis (Figure 1c).

This game concept presents several advantages in comparison with traditionally used PD training concepts. Firstly, it is a game specially designed for patients with PD, PD-MCI or PD-PDD, combining a cognitive task (mentally drawing a path in an urban environment with disappearing goals, training visuospatial and memory/ working memory functions) with the traditional motor task (alternatively moving the feet in four directions), in contrast with previous works which focused on commercial games such as Wii Sports. This permits us to collect relevant game parameters as well as user data to better adapt the task to the patient's skills, as well as monitor his progress. Additionally, the integration of the sensors of the Wii

Balance Board allow us to obtain data on the patient's balance control, an important factor risk for falls in patients with PD.



(a) (b) (c)

Figure 1: Graphic Interface of PDDanceCity

3 Outlook

In the future, we plan to expand the Exergame PDDanceCity with further interaction methods, such as speech, hand controls with the Leap Motion sensor, which may be used to train fine motor skills, as well as medical-grade ergometers. Following the work from Göbel & Hardy (Göbel, Hardy, Wendel, Mehm, & Steinmetz, 2010; Hardy, Dutz, Wiemeyer, Göbel, & Steinmetz, 2015) in the field of adaptive exergames, we will also include an adaptation algorithm that adjusts the difficulty of the game in three different levels: 'Easy' (no dead ends, simple paths with no intersections, the path is shown for the first 5 seconds), 'Medium' (intersections are present, no path is suggested) and 'Difficult' (the goal fades out after a few seconds, there are complex intersections and dead ends, and diagonal movement is possible). Difficulty adaptation will be performed on a user basis depending on the saved parameters of previous sessions, and will allow the caregivers to monitor the patient's progress.

To further modify the domains trained and the cognitive load necessary, further cognitive tasks such as distractions (city sounds played in the background) and acoustic and visual cognitive stimuli to which patients have to respond, or which they have to remember (for example passing by a given number of houses) will be included.

In parallel, we will have to address the safety issues of physical PD rehabilitation, for example, the patients should be able to hold themselves at any given time.

Finally, we plan to perform acceptance tests with patients in PD patients including those living in nursing homes, and evaluate its effectivity compared to the currently applied rehabilitation methods within the framework of the PDExergames Research Project[1].

[1] www.pdexergames.de

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