Assessing the Gaming Experience of an Applied Game for Rehabilitation of the Arm and Hand Function: A Feasibility Study

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Abstract The present pilot study assessed the feasibility, in terms of gaming experience, of using a first prototype of a self-developed mixed-reality system for rehabilitation of the arm and hand function. Results showed that the hybrid game approach is well accepted by Cerebral Palsy children and adults with stroke/acquired brain injury. Further research is needed to improve the current prototype and to investigate the clinical value of the applied game.

1 Introduction

A common problem in children and adults with neurological injuries is a limited upper extremity function [1]. However, functional arm movements, such as reaching, and hand movements, like a cylinder or tweezers grip, are essential for the performance of activities in daily living.

During rehabilitation, an important aim is to stimulate the improvement of the arm and hand function. Serious gaming can play an important role in achieving this goal, since gaming has a lot of elements which may be useful to promote recovery of lost skills, such as repetition, intensity, feedback, motivation and training at the individual level [2].

Although commercially available game systems are increasingly used within rehabilitation, these systems may be less adequate since individual adaptability to physical and cognitive limitations is not possible. This is necessary to train on the patients' own level in a motivated way [3].

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Therefore, an mixed-reality system, named HandsOn, was explicitly designed for rehabilitation of the arm and hand function. By linking reaching, grasping and releasing of a physical object to the control of a game, an intensive, motivating and meaningful training is accomplished. Moreover, this hybrid approach not only provides a very intuitive task-specific training, but also results in a very natural form of sensory feedback, e.g. touch, proprioception and eye-hand coordination. This direct feedback is essential in relearning a motor task.

The aim of this pilot study was to investigate the feasibility of a first prototype of the HandsOn game, by assessing the gaming experience.

2   Materials and Methods

2.1   Design

A pilot feasibility study was conducted in Roessingh Centre for Rehabilitation, Enschede, the Netherlands. All participants received two game sessions of 30 min within one week, replacing a conventional session aimed at upper extremity functioning. A questionnaire was completed by all participants immediately after the second therapy session.

2.2   Participants

Participants of the study involved Cerebral Palsy (CP) children in the age of 7–12 years and adults between 30 and 70 years with stroke or acquired brain injury (ABI). All participants had a limited upper extremity function with at least the ability to grasp and release an object.

No approval of the Medical Ethical Committee was needed for this study, since the study did not fall under the Dutch Medical Research Involving Human Subjects Act. All participants signed an informed consent prior to the start of the study.

2.3   HandsOn Game

The HandsOn game was developed for the CP population, via an iterative design process with user input of CP children in the age of 7–12 years, aimed specifically at training the function of the arm and hand function (Fig. 1). The hardware consists of a projector, projecting the virtual environment on a table, a Kinect sensor, tracking the physical objects by estimating the depth and color information of the scene, and a PC, which makes the setup very low cost. In the game a spaceship is

Fig. 1 HandsOn prototype: setup (*left*) and virtual environment (*right*)

attacked by farm animals, which must be blocked by the participant by placing a physical object on the animals' path to the spaceship. The choice of the objects, existing of different shapes, sizes and colors, determines the grasp, hand movement and/or wrist movement that has to be made by the participant. In addition, in hand object manipulation and cognitive training can be achieved by using colored blocks that have to be matched onto colored targets.

To change the speed and number of animals coming into the playfield, the therapist can choose between different difficulty levels (easy-medium-advanced).

2.4 Outcome Measures

The gaming experience of all participants was assessed via a questionnaire with Likert rating scales to assess Enjoyment (4 items), Frustration (2 items), Environment (graphics and sounds; 3 items), Game play (scenario and rules; 4 items) and Control (4 items). These factors and items were derived from the Core Elements of the Gaming Experience Questionnaire (CEGEQ) [4]. On a 5-point Likert scale all participants indicated to what extent each statement was true for them (0 = minimum score; 3 = neutral score; 5 = maximum score). An average score was calculated for each factor.

In addition, all participants were asked to give the HandsOn game a grade (0–10) and to note the three most positive and negative aspects of the game.

2.5 Data Analysis

Descriptive statistics were used to calculate the average scores for each factor and grade (mean (SD)).

3   Results

3.1   Participants

Table 1 shows the characteristics of the 15 included participants. The mean time after injury for the stroke/ABI group was 11.9 weeks (SD = 8.0).

3.2   Outcome Measures

Positive scores on Enjoyment, Frustration, Control, Environment and Gameplay were found in both groups (Fig. 2). In addition, the game was rated high by the CP group (mean 9.0; SD 0.7) and the stroke/ABI group (mean 8.0; SD 0.96).

As positive aspect of the HandsOn game, the CP group mentioned the exciting story of the game. The stroke/ABI group appreciated that, besides their arm and hand function, also their cognitive function can be trained by the game. Furthermore, both groups liked the control of the game by using physical objects.

Technical issues when playing the HandsOn game (e.g. bad reaction of the game on movement registered by the Kinect sensor) and the absence of additional game environments were most often mentioned as negative aspects by both groups. Additionally, the most severely affected individuals in the stroke/ABI group (physically and/or cognitively) reported that the game was too hard to play.

Table 1 Participant characteristics

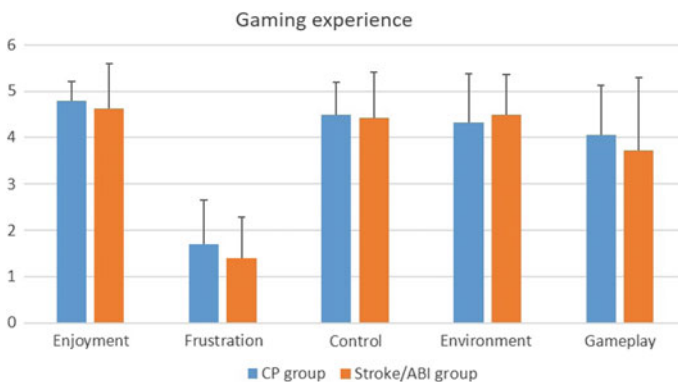| Group	N	Gender (M/F)	Age (years; mean (SD))	Affected side (L/R)
CP group	5	4/1	9.8 (1.6)	1/4
Stroke/ABI group	10	6/4	60.6 (12.3)	5/5

Fig. 2 Gaming experience

4   Discussion

The goal of the present study was to get a first insight into the feasibility of a first prototype of the HandsOn game in clinical practice. Although this prototype was originally designed for CP children, the present findings showed that both groups were very positive about the use of this hybrid game approach. This was reflected by the high gaming experience scores and high grades.

However, the suggestions for improvement need to be addressed in the further development of the HandsOn game. The difficulty and game play must be adapted to the patients' abilities to enter a state of complete focus and immersion and to avoid frustration [3]. Furthermore, the technical issues related to the game control need to be solved. In addition, different game environments need to be created, to train the same underlying deficits in a changing and challenging environment, resulting in many repetitive movements [5].

Further work is ongoing to improve the technical development of the HandsOn prototype, based on the current feasibility study. Subsequently, a study is planned that investigates the clinical value of the applied game in relation to conventional upper extremity therapy, in terms of motivation, intensity of training and upper extremity function.

5   Conclusion

The results of this study showed that the use of an applied game for rehabilitation of the upper extremity function in both CP and stroke/ABI population is very well accepted.

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