

A Virtual Reality System for Robot-Assisted Gait Training Based on Game Design Principles

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I. INTRODUCTION

Gait robots have become increasingly common in rehabilitation of neurological patients [1]. Virtual reality (VR) can be used to integrate therapeutic goals into gait training, and thereby improve rehabilitative gait therapy [2]. Particularly in children with cerebral palsy (CP), VR offers powerful options to combine functional and purposeful therapy within a motivating context [2, 3].

While VR applications in robot-assisted rehabilitation were recently shown to be superior to robot-assisted rehabilitation without VR [4], current developments focus exclusively on the therapeutic goal and neglect game design principles established in the gaming industry. Game design principles are tailored to maximize motivation and involvement of the user, and can therefore be expected to improve rehabilitation outcome, as motivation and active involvement in the production of motor patterns were shown to increase motor learning and retention compared to passive movement [5].

We present the newly developed game environment "Gabarello", which joins therapeutical goals derived from clinical neurology with motivating elements of game design during robot-assisted gait rehabilitation. Patient activity during gait therapy can be quantitatively measured using weighted forces measurements. Gabarello v1.0.5 modifies these measurements into game play parameters and makes use of game immersion to maintain motivation.

II. METHODS

A. Goal of the software

The software was intended to achieve the active participation of children with neurological gait disorders during robot-assisted gait training while providing long-lasting, motivating feedback in form of a computer game. The game was kept deliberately simple to account for the limitations of the patient, and ease of use by the therapist. It requires deliberate changes in exertion of the patient and thus meets therapeutic goals.

B. Hardware

The setup consisted of a virtual reality display system and a commercially available driven gait orthosis (DGO) commonly used in gait rehabilitation. The display system consisted of a 52" flat screen in front of the gait robot and a 5.1 surround sound system. The Lokomat (Hocoma Inc., www.hocoma.com) was used as DGO for locomotion training. Linear drives on hip and knee joints provided torques to the subject and assisted the locomotion on a treadmill by guiding the subject's legs along a predefined trajectory.

C. Quantifying patient participation

To quantify physical effort from a biomechanical measure, we computed weighted interaction torques (WIT) between robot and patient, recorded from hip and knee joints of both legs, using the standard Lokomat force sensors located in line with the linear guides. For each step, the interaction torques of all four joints were computed from the force recordings, weighted using the weighting function of Banz et al. [5] and summed up. The WIT has a high positive value if the patient performs an active movement which is therapeutically desired and a negative value if the patient is passive or resists the walking pattern of the orthosis. Details on the computation and their physiotherapeutic interpretation can be found in [6-8].

D. Game Design

1) *Preparatory questionnaires:* To assess subjective aspects of the robot-assisted gait training with and without VR a self-designed motivational questionnaire was used. Patients and healthy controls were asked to rate on a visual analogue scale (VAS) the extent to which they had liked the different training conditions from 0 ("not at all") to 10 ("very much").

2) *Visual game design:* The qualitative and quantitative measures were used to develop the Gabarello game, in which patients use an avatar to walk over the surface of a planet. Patient participation and motivation lead to a higher velocity of the avatar and its possibility to 'jump' within the game. The more a patient exerts him/herself, as measured by the human-interaction forces of the Lokomat, the longer the legs of the avatar become and the easier it can jump and advance. The patient receives, as is common with games, feedback on

‘success’ through a point system he/she triggers by the collection of score items. The avatar’s velocity affects the points awarded by each score items. The level design motivates the patient to deliberately change his/her exertion by making the capacity of the avatar to jump or drop conditional on the patient’s level of exertion.

The software includes a therapeutic interface which allows the accompanying therapist to modulate the degree of difficulty of the game according to observations of the patient’s state, level of exertion and progress, and where necessary to synchronize avatar and patient movements to lend cognitive support to the patient, and retain motivation.

III. PRELIMINARY RESULTS

First clinical experiences with Gabarello began in January 2010 and data collection is ongoing. While the data is still raw, we are able to make preliminary observations about motivation and gameplay immersion .

The analysis of motivation questionnaire in 45 children with and without neurological gait disorders revealed that children had fun training with VR (mean 9.19, SD 1.08) while walking in the Lokomat. With regard to generalization of the preferred

conditions 70.4% of all participants reported that they would prefer the VR for the next training sessions, while only 29.6% preferred watching a DVD.

It is possible to create games that are immersive for children and results from an fMRI study demonstrated that children are relative susceptible to the experience of presence in virtual environments [9].

IV. CONCLUSION

With regard to applied game design, the collaboration between game designers, engineers, neuropsychologists and medical doctors has shown that it is important to create interfaces in which the learning process is made enjoyable. Achieving this depends on understanding the limitations of the patients, the hard- and software to hand, and the complexity of therapy from the various disciplinary understandings. The balance between what is ‘fun’ and what are serious needs must not be lost, at the same time, a finely calibrated equilibrium is necessary for developing successful therapeutic tools. Virtual reality games as tools for extended therapy are likely of limited application where the immersive experience cannot be adequately achieved or assessed.

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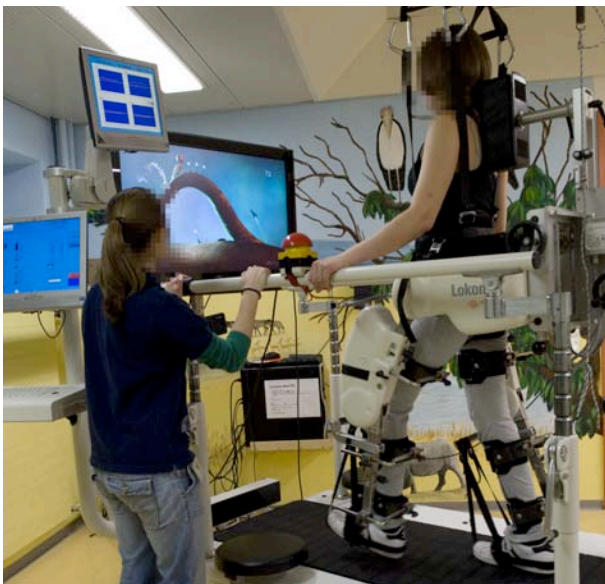


Figure 2. A patient exercising in the Lokomat gait orthosis while playing the Gabarello game



Figure 1. Screenshot taken from the Gabarello game