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Chronic Pain Rehabilitation with a Serious Game using Multimodal Input

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Abstract—**Rehabilitation for chronic pain follows a multidisciplinary approach, which despite the effort, often lacks the long term success and patients often fail to translate the skills learned in therapy to every day life. Serious games are hypothesized to support patients to self manage their complaints and keep training their physical functions by themselves, especially, when the game is controlled by the patient's own body performance. In this paper we present the implementation of a system providing multimodal input, including our own full body motion capture system, a low cost motion capture system (Microsoft Kinect) and biosignal acquisition devices to a game engine. In addition, a workflow has been established, that enables the use of the acquired multimodal data for serious games in a medical environment. Finally, a serious game has been implemented, targeting rehabilitation of patients with chronic pain of the lower back and neck. The focus of this work is on the multimodal input and how it is used in a game to support rehabilitation of chronic pain patients. A brief comparison of a marker-based full body MoCap system and Microsoft's Kinect is included. Preliminary results of tests currently underway are provided.**

Keywords- Chronic Pain Rehabilitation, Serious Games, Multimodal Input, Full Body Interaction

I. INTRODUCTION

An important goal in rehabilitation of patients with chronic pain is enhancement of a patient's level of physical fitness and normalization of activities of daily living. Many chronic pain patients have a deviating activity pattern [1], which is hypothesized to be related to inadequate coping strategies of the patient: a vicious circle characterized by decrease in physical condition, muscle strength and increase in illness and sick-role behavior [2]. To change these vicious patterns, a balanced increase of physical condition is very important, which is done during rehabilitation by following an exercise program supervised by a therapist. To increase the intensity of this exercise program or to extend the inpatient rehabilitation, the therapist can assign home exercises. These home based exercise programs are effective [3] but a low adherence to these programs is problematic [4]. It is hypothesized that by using biomedical technology in combination with information and communication technology the adherence to these home-based exercise programs can be increased.

For instance, patients can be monitored during exercising at home and can receive direct feedback provided by technology or indirectly provided by a therapist, who has remote access to patients' data via a web portal [5]. Using serious games, in addition, a motivational environment can be created. By incorporating appropriate input technologies, the game can monitor and guide the patient in his relearning process and give feedback on his movement patterns. Section III briefly describes requirements of motor rehabilitation of chronic pain patients. Based on these requirements we have identified, integrated and developed sufficient input modalities.

We have implemented a system, which enables chronic pain patients to train their motor skills in a serious game, where body movements and biosignals are monitored and provide multimodal control of the series of events in the game. Figure 1 shows our system during first evaluations with patients.

Our contributions are:

- Development of our own flexible, full body motion capture (MoCap) system and adaptation of the used algorithms to the requirements of serious games in rehabilitation, especially in the field of chronic pain rehabilitation.
- Integration of Microsoft's Kinect, a full body interaction device for conventional games. We have compared measurements of Kinect and our MoCap system to determine, if it can be used for patients practicing at home.
- Integration of a biosignal acquisition device to assess muscle activity.
- A workflow that enables us to use the acquired data for serious games.
- Implementation of a serious game targeting rehabilitation of patients with chronic pain of the lower back and neck.
- First evaluation of the technical feasibility of a serious game targeting rehabilitation of patients with chronic pain.

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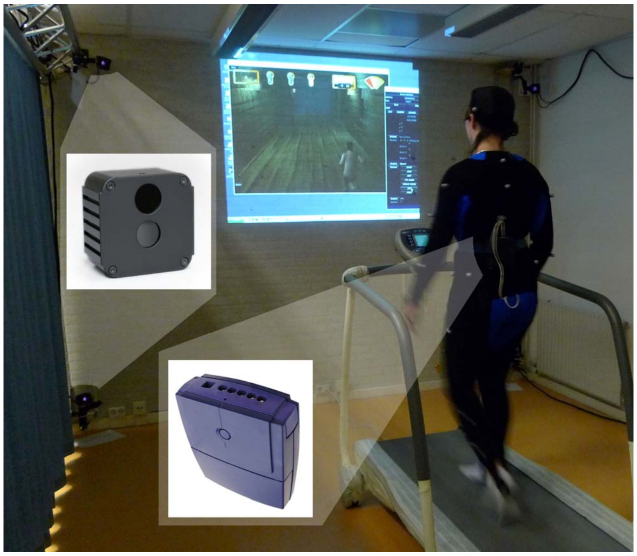

Figure 1. Our setup and serious game with magnifications of an iotracker-camera and the TMSI Mobi biosignal acquisition device.

II. RELATED WORK

Our system touches many fields including serious games in rehabilitation and their design [6, 7], full body interaction in conventional games [8, 9], MoCap systems [10], skeleton calibration [11, 12] and tracking [13, 14] as well as biofeedback devices and their use in rehabilitation [15]. It is therefore beyond the scope of this paper to relate to all of them in detail. Instead we give a brief overview of work in these different areas.

A. *Serious Games in Motor Rehabilitation*

Serious games in motor-rehabilitation are still in their infancy, but have become an active research area within the last couple of years. They have been used to assist therapy following stroke, traumatic brain- and spinal cord injury and in other areas. Also the focus of therapy is very diverse, such as upper limb rehabilitation [6], balance rehabilitation [16] or rehabilitation of specific body-parts [7].

Specific requirements and design principles apply to serious games in motor rehabilitation [6, 7]. In our game, the crucial aspect of configurability to patients' abilities has been emphasized and all parameters measured by MoCap and biosignals can be adapted in addition to in-game parameters.

B. *Game Input*

Various input devices have been used to provide input to serious games in rehabilitation: from technology available in commercial gaming systems [9], to specialized input devices like a pressure mat [16], to webcams [6] and more sophisticated technologies like data gloves and magnetic tracking [17].

The trend for the input in conventional, as well as serious games goes towards full body interaction. Microsoft's Kinect [9] tracks the player's whole body and integrates this body state information into the game. Using Primesense's camera/depth sensor [8] full body interaction will be possible for some applications of serious games in rehabilitation. In section IV we conducted a brief technical evaluation comparing Kinect and our MoCap system.

C. *Full Body MoCap Systems*

As determined by our requirements introduced in the next section movement parameters of different body parts are needed and therefore full body MoCap is required. Full body MoCap, in this context, is defined as capturing the user's body in a way that allows for the reconstruction of six degrees of freedom (DOF) for every bone in a simplified skeleton model, which is available in a complete kinematic chain.

Marker based optical full body MoCap (e.g. [10]) has become a de facto standard capture technology in the movie and entertainment industry in the previous 10 years. Thereby, one or more actors wearing motion suits with retro reflective markers, are tracked by a number of cameras. All motions are computed in real time (with millimeter accuracy) and are available for further processing e.g. recording, analyzing, motion transfer to a virtual character and more. However, these have not been used as input to serious games due to numerous reasons like cost, inflexibility and complexity of operation, which are issues we are targeting with our system.

Of course, systems using other tracking technologies like markerless optical tracking or magnetic tracking exist. However, they do not achieve the same accuracy as marker based solutions and are therefore neglected in this discussion.

D. *Skeleton Calibration and Tracking*

Current commercially available full body MoCap systems rely on a predefined skeleton model with a small number of markers, which have fixed positions on the tracked subjects. This reduces the flexibility of adaptation to different patients and use for more specific applications only needing input from a part of the body.

Several methods have been proposed for the automatic calculation of a skeleton model from motion capture data. Often, they rely on the calculation of the center of rotation between bones defined in their position and rotation by three or more optical markers [12, 13, 18], or magnetic tracking [19]. In these approaches using two adjacent bones with six DOF the joint positions are calculated using a least squares fit. However, these methods require many markers or (inaccurate) magnetic tracking (with one sensor attached to each bone). The method, described in [11], suggests using a computationally more expensive algorithm, which requires less markers. We have improved the latter to be more robust and reliable.

Skeleton tracking or fitting [13] describes the process of adapting the position and the joint rotations of the skeleton model in a way, that it fits the recorded data. Little information is published on the intrinsic functionality of skeleton tracking in commercially available full body MoCap systems. Some algorithms, like the global skeleton fitting described in [13], rely on the identity of the markers to be known. However, this is a constraint, which for reasons of stability, we don't want to depend on.

In an alternative approach, as used in [12], a rigid clique (or body) is placed on each bone-segment. These cliques, consisting of three or more markers with fixed distances, can be used to derive position and orientation of the bone. As described in [14] these can also be trained dynamically. However, this approach depends on the markers to be fixated on rigid structures and four markers per bone, limiting applicability.

E. *Biofeedback in Rehabilitation*

In recent years biofeedback has become increasingly important as a non classical user interface. Especially in medical applications, where users' biosignals are of vital importance, various sensors have been integrated and used for feedback to patients and medical personnel [15]. In serious games, however, they have been mainly used to measure engagement and excitement [20]. Furthermore, collecting data as a side product of a serious game might help increase efficiency and applicability of existing technology.

F. *Workflow in existing Serious Game Systems in Rehabilitation*

Most serious game systems in rehabilitation have not evolved above prototype stadium and tests with a few patients or healthy subjects. Therefore, often a closed workflow is missing, which should reach from (1) calibration of input to (2) configuration of the game to (3) gameplay to (4) patient feedback and finally (5) medical evaluations. One system, which has been established in many clinics and studies, is RehaCom [21]. It provides such a workflow. However, it is limited to cognitive rehabilitation and standard input devices (mouse/joystick). In our system we have established such a workflow, which should enhance efficiency throughout the evaluation process.

III. REQUIREMENTS OF CHRONIC PAIN REHABILITATION

According to cognitive-behavioral models [2, 22], patients with chronic pain are in a vicious circle of maladaptive pain-related cognitions (i.e. fear of movement), coping strategies (i.e. avoiding physical activities) and physical disuse. Therefore, therapeutic activities performed in pain rehabilitation practice, focus on changing these cognitions and increasing physical functioning. An important way to do this is by letting patients experience and execute physical exercises. Exercises commonly used in chronic pain rehabilitation focus on:

- Mobility and coordination by activities that focus on increased range of motion, increased velocity and smoothness of the motion.
- Improving a patient's physical conditioning by endurance exercises like walking.
- Relaxation of muscles by exercising both total body relaxation as well as local muscle relaxation.

Changing motor functioning is considered a dynamic process. Subjects need to become aware of their inadequate functioning during daily life and need to learn skills to change it. Subsequently, they need to be motivated to develop intentions to change and then actually change. So, besides monitoring physical performance, feedback on this performance in serious games is important.

IV. SYSTEM OVERVIEW

Our setup comprises of an infrared optical tracking system, a biosignal acquisition device, a number of software components performing different tasks in the MoCap and data processing pipeline and a serious game.

A. *Hardware Setup*

1) *Professional MoCap Setup*

The tracker used for our motion capture system is an iotracker [23], which is a passive marker based infrared optical motion tracking system. It was primarily built for collaborative virtual reality and augmented reality applications, but is also well suited for motion capture. Commodity hardware is used to minimize the cost and calculations are performed on PC workstations, while no additional electronics is required. Iotracker cameras are shutter synchronized and stream digital video to the tracking workstation at an update rate of 60 Hz. To make (only) the passive markers visible in the camera images the cameras are equipped with infrared strobe lights and optical band pass filters. The application "iotracker server" calculates the 3D positions from camera images. Measurements indicate low latency (20-40ms), minimal jitter (RMS less than 0.05mm), submillimeter location resolution and an absolute accuracy of ±0.5cm. For a more detailed description of the marker tracking performance please refer to [23].

2) *Low Cost MoCap Setup*

In addition to iotracker, we have integrated Microsoft's Kinect as an alternative low cost MoCap system. Kinect has been designed as a natural user interface using gestures instead of controllers to provide input to conventional games. As opposed to our system, it uses only one camera for tracking and works without markers. Instead, a dot pattern is projected onto the environment and user(s) by an infrared laser. Projected points are traced by the camera. Projector and camera are positioned at a certain calibrated distance from each other within the Kinect casing. Therefore, the dots recorded in the camera image and the original pattern can be used to reconstruct a depth image. The depth image in turn is used to calibrate and fit a human skeleton model, resulting in a skeleton pose. In addition, from skeleton poses over time gestures can be recognized using the middleware layer "Flexible Action and Articulated Skeleton Toolkit" (FAAST) [24]. Together with the skeleton pose gestures can be used within a game. Accuracy of Kinect is limited by the resolution of the camera and by the fact that one perspective is used.

3) *Biosignal Acquisition Devices*

We have integrated two biosignal acquisition devices into our system (Gtec g.MOBIlab and TMSI Mobi [25]). Both biosignal devices have a number of sensors including electroencephalography (EEG), electrocardiogram (ECG), electromyography (EMG), galvanic skin response (GSR), respiration and others. For our purposes in chronic pain rehabilitation we are primarily using EMG, while other sensors would be easy to activate.

B. Workflow

In order to successfully use a MoCap system for serious games in rehabilitation, it is important to have a workflow that can be easily handled. An overview of the workflow can be seen in Figure 2. The main steps are (1) skeleton calibration (2) skeleton/marker tracking (3) motion data transformation (4) game configuration (5) game play (6) feedback and evaluation. The numbers in Figure 2 indicate these steps.

Before the games session can be started, the patient has to be equipped with the necessary sensors. In case of chronic pain rehabilitation, this includes the markers for MoCap (placed on a motion suit similar to the one shown in Figure 1, as well as electrodes for EMG.

In the first step a skeleton model has to be generated and adapted for each new patient. Using a separate tool, the “skeleton calibration assistant”, from the marker positions alone, a skeleton model is calibrated fully automatically. To execute the algorithm the user has to perform some initial calibration movements often referred to as the “Gym motion” [13, 26]. For a successful calibration the user moves the joints of interest to their full extent for about 15-20 seconds. For practical use with patients, the skeleton calibration assistant shows movement sequences, which have proven to work well. However, no restrictions are imposed on the Gym motion except that it has to start in the T-Pose[27].

Out of the skeleton models generated from the sequences, the assistant automatically selects the best for further processing; however, the therapist is able to override this selection manually. The evaluation of the skeleton is based on the joint optimization cost of a skeleton. Finally, the choice of a skeleton is acknowledged and is automatically labeled with bone names by comparison with a predefined template. This is important in order to map the joint angles to the avatar in the game. The labeled skeleton is then handed to the tracking software and the calibration assistant is being closed. The MoCap module of the iotracker loads the skeleton and starts the MoCap process waiting for the games to connect. The skeleton tracking module, responsible for fitting the skeleton to the 3D positions of the markers in each frame, is integrated within the iotracker server. The module loads the skeleton model file and optimizes the internal representation, so it can faster find a fit in the tracking data. The product of this step is angles for all joints of the skeleton model plus the position and orientation of the skeleton in 3D space. We consider this to be the “raw” MoCap data. For further use of input data often specific information has to be retrieved (e.g. positions of specific limbs, movement velocities, filtered EMG data). To transform and extract this data from the “raw” data produced by the iotracker server and the biosignal acquisition devices described in subsection A, we are using an additional software layer. For this layer OpenTracker [28] is used, which is a multi modal data flow framework and connects the input devices and provides a common interface to the game engine. Within OpenTracker we can easily manipulate and extract data from the “raw” tracking data provided by the iotracker. In addition, we can filter and preprocess data that are read from the biosignal acquisition device. Within OpenTracker we are using standard functionality like filters and a number of customized nodes to calculate specific values required within the games. Examples for extracted data used in the serious game described in section V include (1) walking speed, which is calculated from the stride length (2) reaching height, which is calculated from the position of a hand, (3) turning velocity of the head, which is calculated from the rotation of the neck-joint and the time stamps, (4) root mean square of the high pass filtered EMG data and others.

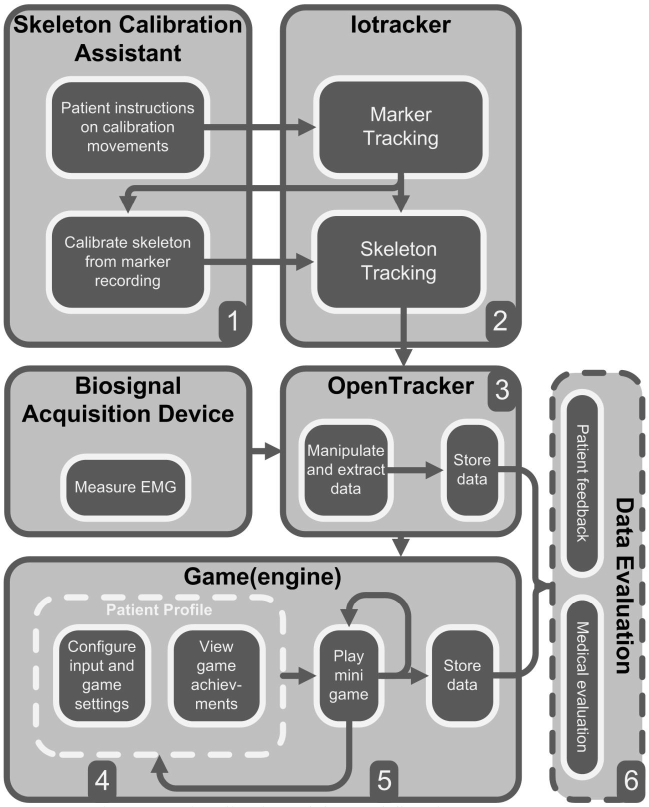

Figure 2. Visualization of the workflow in our system.

In addition to live manipulation of the data, OpenTracker is also used to write measured “raw” and extracted data to files for later evaluation by the therapist.

Finally, the preprocessed input data is sent to Unity3D [29]. Unity3D is a game engine and editor with a rapidly growing user base. We have implemented a network

Figure 3. Our MoCap system and two of the mini games during the preliminary testing. „Face of Chronos“ (left), „Three Wind Gods“ (right)

interface to connect it to OpenTracker/iotracker (using TCP sockets and XML messages). Therefore, the games can be run on machines other than the tracking PC. When a patient first logs on to the game, a profile is created. The game can be configured individually to each patient's needs by calibrating goals and baselines. This is meant to measure (calibrate) the player's physical vantage point in the various exercises and use this information to set the difficulty of the game.

Then the therapist or patient can select the mini game, which should be played. After he has finished the configured tasks the game returns to an overview scene, where the patient can take a look at his game achievements. If the configured settings don't provide the right amount of challenge (e.g. the patient makes faster progress than expected), the therapist can adjust them easily for the next session. Following each games session the therapist and patient take a look at the data stored in the patient's profile to determine the progress and issues that have to be worked on.

V. A SERIOUS GAME FOR PAIN REHABILITATION

Finally, we want to introduce the prototype of a serious game that has been implemented to make use of the multimodal input. It is intended to assist rehabilitation of patients with chronic pain of the lower back and the neck and preliminary tests with a limited number of patients have been conducted.

Supported therapy goals are (1) physical reconditioning, (2) improved reaching ability (3) reduced level of muscle activation of the Trapezius muscle after task (4) increased cervical range of motion (CROM) and increased smoothness of movement.

To achieve these therapy goals three separate mini games have been developed. They are embedded within an adventure setting, linking the games with a common story line. In that story the player arrives with his ship at a deserted island and discovers the remains of an ancient civilization. Pictures of test users playing the mini games can be seen in Figure 3.

The ship is the base of the patient. While on the ship, the game can be configured individually to each patient's needs and abilities by calibrating goals and baselines for the mini games.

During the mini games the player can collect items, which can be seen in an inventory. When the player has collected enough items he is rewarded by unlocking the next part of the story, which should provide additional motivation.

During game play the three mini games provide game feedback (scores, collected items) as well as visual, auditory and textual feedback on the patient's performance and results. Furthermore, after every session, therapist and patient view the patient’s progress, by having a look at the patient's profile. In this profile objective data, recorded during gaming, about the reaching ability, cervical range of movement and the level of muscle activation during gaming are presented. After the last game session the physical fitness of the patients is assessed. After this assessment the patient is informed about his progression of physical fitness induced by playing the serious game. An overview of the mini games, their clinical goals and input data used is listed in Table I.

VI. EVALUATION

A. Technical Evaluation: Comparison of Iotracker and Kinect

We conducted a brief technical evaluation of Microsoft’s Kinect. An iotracker setup would be too expensive for home use and also too difficult to handle by a patient. Therefore, the patient could continue playing the game using Kinect.

TABLE I. MINI GAMES, THEIR MEDICAL RATIONALE AND THE MOCAP DATA USED

Game name	**Mini games overview**		
	Game description	***Clinical goal***	***Input data***
Temple of Magupta	The player runs through an ancient temple, collects artifacts and avoids obstacles.	Physical reconditioning, increase walking speed and walking time	Movement rate
Face of Chronos	The patient climbs a mountain by extending the arms upwards until the next hold is reached and collects artifacts placed on holds.	Increase reaching ability, velocity and smoothness of the motion, relaxation of the trapezius muscle after reaching	Position of the hand, movement characteristics of the arm (path, velocity), muscle activity of the left and the right trapezius muscles (EMG)
Three Wind Gods	The player imitates a series of head movements executed by fictive characters.	Increase cervical ROM, velocity and smoothness of cervical motion	Measures of cervical ROM and current rotation (Flexion/extension, Right/left bending, Left/right rotation), movement velocities, movement acceleration

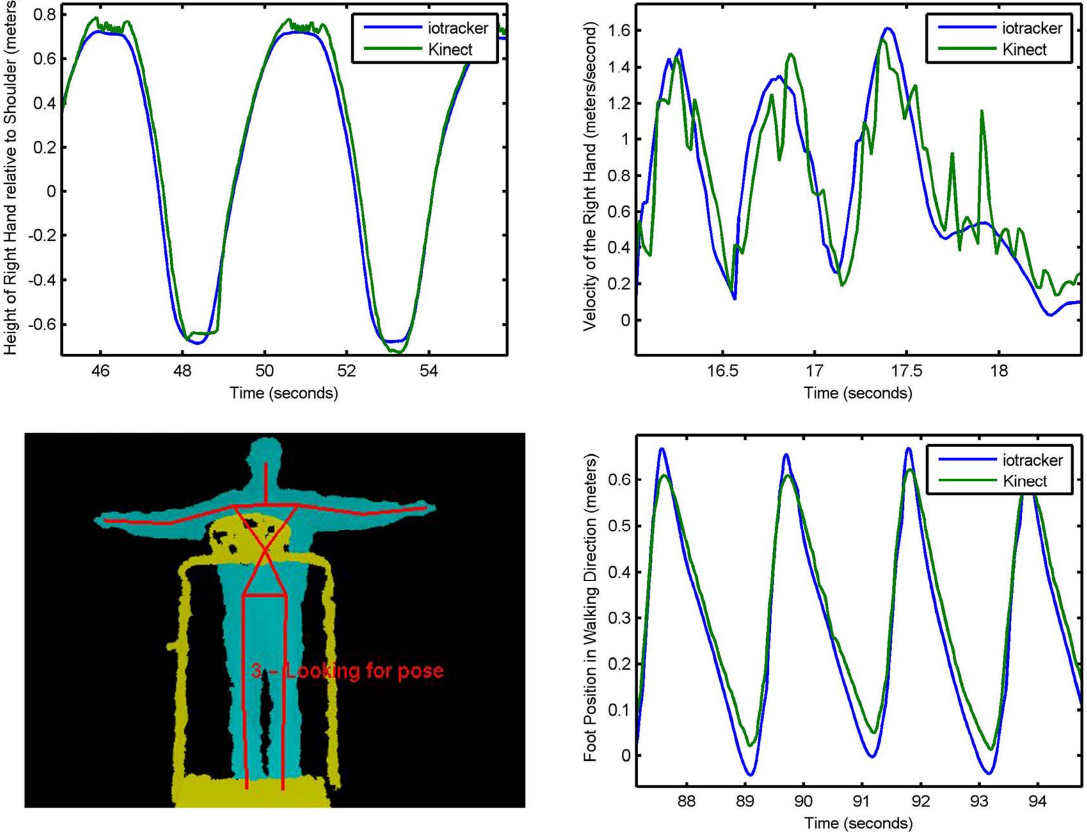

Figure 4. Comparison of measurement between iotracker and Kinect/FAAST. Handposition and velocity (upper row). Treadmill and testuser with skeleton model visualized by FAAST during the walking measurements (lower row left) and foot positions in walking direction (lower row right)

To compare our MoCap system with Kinect we have recorded unfiltered movement data simultaneously with both systems. We ran iotracker and Kinect on two different workstations connected by local area network.

The data from Kinect was streamed to the iotracker PC, where time-stamped values were written to file. For movements typically used in the mini games we then compared significant parameters between the two MoCap systems. In addition we test played two of the mini games by using Kinect. Although both systems work within the infrared spectrum of light, the systems did not negatively affect each other's measurements.

The mini game "Face of Chronos" is primarily using the player's hand positions and parameters derived from these. We started comparing the reaching height relative to the torso, as reported by both systems. Figure 4 shows the height values of the right arm as they are used within the game. Measurements show good conformance except that the hand position calculated by Kinect extends slightly larger (about 5 to 7 cm). This is due to the fact that the hand position is defined slightly different in both systems. Also for Kinect jitter in positional data is clearly visible in the extreme positions. Jitter also strongly disturbs the velocity, which we calculated on a frame by frame basis. Figure 4 shows a comparison of velocity graphs. Since velocity is being used to determine smoothness of motion this is considered problematic for our application.

Due to the positional differences, latency between the systems could not be exactly determined. However, aligning the extreme positions of the movements we have estimated the delay to be somewhat below 100 milliseconds. Taking into account the latency of 20-40 ms of our system and that the abovementioned network transmission adds a few milliseconds, overall latency of Kinect is estimated to be around 100ms.

The mini game "Temple of Magupta" is primarily using walking movements. Therefore, we have taken a look at variations of foot positions in the walking direction, while walking on a treadmill, which are used to calculate the stride length and walking speed consecutively. The Kinect sensor was placed in front of the treadmill, creating a difficult scenario in which the player was partly occluded by the treadmill's structure and foot positions could only be calculated from depth information. A visualization of the setup's depth image provided by FAAST can be seen in Figure 4. Once Kinect properly recognized the player within the structure, it performed rather well for our purpose. Iotracker reported larger values for stride length compared to Kinect. That could be caused by different definitions of foot positions (a comparison of foot positions is shown in Figure 4). Jitter is again recognized to be stronger than in our system and even stronger than for the hand positions. Nevertheless, Kinect provides useful measurements for our purpose.

The mini game "Three Wind Gods" mainly relies on neck rotations, which have not been implemented in FAAST yet. Therefore, we could not evaluate these measurements nor test that mini game. However, from the technical limitations of calculating rotations from an RGB image alone we expect rather inaccurate measurements.

Overall Kinect works surprisingly well as an alternative MoCap system used to control our game targeted at rehabilitation of chronic pain patients. Our tests have shown that it correctly captures some of the exercises used within the game. Two of the mini games were playable, although with certain restrictions. Kinect, however, can't measure all required parameters and lacks accuracy required for others, especially with regard to a medical evaluation.

B. Evaluation Design

At RRD premises the motion capture system and the game environment have been installed. In this environment the patients can play the game, after being instructed and while being monitored by a therapist.

For the evaluation an iotracker system and TMSI MOBI as described in section A are being used. A video projector is used to display the game content to the patient, while the therapist has her own control monitor. Figure 1 and Figure 3 show this setup. For the mini game "Temple of Magupta" the patient has to walk on a treadmill.

The currently ongoing evaluation is planned for at least 15 patients with chronic pain in the neck/shoulder or lower back region. It focuses on getting insights in patients' expectations and experiences with serious games as well as in the changes induced in physical and cognitive status of the patients. In a period of 4 weeks a patient is asked to visit the RRD premises up to eight times.

During the first visit the patient is handed questionnaires to determine pain intensity, level of disabilities and expectations. Also the physical fitness is assessed with a 6 minutes walking test. Then the system is calibrated for the patient, the baselines set and the patient introduced to the game. In the following four weeks the patient will repeatedly be playing the game in up to 8 separate sessions. Each therapy unit has an approximate overall duration of 45minutes (15 minutes preparation / 30 minutes gaming). After the last session the patient is again handed a questionnaire to evaluate pain intensity, level of disabilities and expectations. In addition, usability and user experience are assessed. Finally, the physical fitness is assessed as done prior to the evaluation.

In addition to the data obtained by the questionnaires and the assessment of physical fitness, the movement data (reaching ability, muscle activation of the Trapezius muscle and CROM) recorded by the game during all gaming session are evaluated.

Results will be evaluated on progress made during the 8 individual sessions. We will study the learning curve of patients using serious games to train motor skills. Therefore, we will compare the baseline with follow up results to investigate whether the game induces a change in physical condition and in patients' cognition of physical activity.

C. Evaluation Results

Six pain patients are already included in the evaluation; 2 male and 4 females. The average age of these patients is 58 years (SD 3 years). All patients reported pain complaints in neck/shoulder or (lower) back with an average pain intensity of 62 (SD 11) during the last month, assessed by a Visual Analogue Scale (0= no pain at all and 100= as much pain as possible) [30]. All six patients visited RRD premises in a period of 4 weeks and trained with the Playmancer game during 4 to 6 sessions. Patients were after limited instruction able to play the game. The Playmancer system was technical stable and usable during the treatment of pain patients.

The primary objectives of this first evaluation focus on user experiences (satisfaction, usability and emotional engagement) and clinical changes (pain intensity/disability and health status). The preliminary data on user experience of our first six participants show that patients were very positive about the game. They evaluated the game with an average score of 7.5 (SD 0.8) on a scale of 0 (negative) to 10 (positive). These six patients were also very positive about the usability of the game assessed by the System Usability Scale (SUS) [31]. They rated the usability good (average SUS score 82 (SD 9) of a maximum score of 100). The first patients enjoyed playing the game (average enjoyment score 17 (SD 3) of a maximum score of 21) assessed by the enjoyment scale of the Core Elements of Gaming Experience Questionnaire (CEGEQ) [32]. Patients stated to be not frustrated by the game during game play (average frustration score 1 (SD 1.2) of a maximum score of 14) assessed by the frustration scale of the CEGEQ.

Based on the data of 6 subjects it is hard to give an impression about the clinical change induced by playing the Playmancer game. The average pain intensity score of these 6 patients before gaming (baseline) was 62 (SD 11) and decreased to 52 (SD 22) after four weeks of gaming (T0). A change of 13 on a pain VAS would be considered to be clinically significant [33]. On pain disability, assessed by the pain disability index [34], the sum score dropped slightly from 30 (SD 15) at the beginning to 28 (SD 18) at T0 (maximum possible score of 70). The physical health status of these first patients was assessed by the six minutes walking test (6mwt) [35]. At baseline the average walking distance was 460 (SD 78 meters), at T0 the walking distance has increased slightly to 476 (SD 52) meters. When we look at an individual level; the walking distance of three participants stayed stable, while it increased for the other three patients with respectively 37, 40 and 94 meters.

TABLE 2. PAIN INTENSITY, DISABILITY AND PHYSICAL FITNESS AT BASELINE AND T0 (N=6)

	Pain intensity (VAS)	Disability (PDI)	Physical fitness (6MWT)
Baseline	62 (11)	30 (15)	460 (78)
T0	52 (22)	28 (18)	476 (52)

VII. CONCLUSION

In this paper, we presented our system providing multimodal input for serious games in rehabilitation. We described the integration of our newly developed, flexible, full body MoCap system, along with biosignal acquisition devices, into a game engine. In addition, we have integrated and tested Microsoft Kinect as an alternative low cost MoCap system and compared it with our system. Finally, we have developed a serious game focusing on the motor rehabilitation of chronic pain patients, which is a new target group of serious games. We presented a well designed workflow of serious games in practice, which can be handled easily. This workflow includes calibration, patient configuration, game play, feedback and evaluation.

Preliminary results stated that the Playmancer game is technical stable and usable during the treatment of pain patients. Patients were positive about the game and enjoyed training with the Playmancer game. On clinical change there is a positive trend of decreasing pain intensity score and disability scores and an increase on walking distance after a gaming / training period of 4 weeks.

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