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Body position in virtual reality - balancing support for patients with neuropathy

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Abstract: Patients with limited sensorimotor abilities often suffer from balancing problems or to find the correct body position. However, correcting the body posture can prevent serious secondary diseases. Digitization tools offer the potential to achieve better therapeutic outcomes through new training scenarios. In this subproject, the correlation of instructions and visualization in virtual reality (VR) will be focused to train patients with neuropathy. For this purpose, a technical setup with a sensor concept in VR embedded in a motion capture system will be realized and a measurement and evaluation procedure for different test scenarios to measure the workload will be presented.

I. Introduction

People who suffer from polyneuropathy - a disease of the peripheral nervous system - often have balance problems. The fact that serious secondary diseases can be avoided by correct body positioning is shown by the example of the diabetic foot syndrome (DFS), a neuropathological secondary disease in diabetes. In this clinical picture, the patient does not feel any pain reactions in the feet. That is the reason why a correction of the body posture in this case is hardly possible. Due to the lack of feedback, coordination and balancing ability of the patients are severely limited and can lead to unpleasant wounds. The so-called "Charcot foot" means that the foot breaks in, which can be avoided by a correct body posture.

I.I. Research background

Overall aim of this project is to develop a personalized orthosis for patients with DFS. In this subproject a biofeedback system will be developed that actively supports the patient in using the foot orthosis. VR is used to train patients with the biofeedback system.

I.II. Research objective

Scientific studies proved that the influence of visualization in VR has a statistically significant effect on balance behavior [1]. To investigate the influence of visualization the body in VR more detailed, different visualization scenarios are developed for a user study. The results of the study are intended to provide information on how the visual influence of body perception in VR affects balancing behavior. The developed visualization scenarios should be used for therapy purposes to improve the coordination of patients. In the first step user studies with healthy participants are conducted in an adapted immersive training environment. Measurement data will be recorded, based on the deflection data of a balance board and body posture.

II. Material and methods

To assess postural stability, either the Clinical Test of Sensory Interaction on Balance (CTSIB) [2] or the Sensory Organization Test (SOT) [3] are commonly used in practice. The use of CTSIB provides a quick and economical procedure which use a 6-step test to provide a subjective assessment of the three balance systems (visual, somatosensory, and vestibular). The SOT includes an apparatus-based computer-aided balance measurement, which is used in posturography to determine the Center of Gravity (COP) by using a force plate [4]. However, SOT is a space-consuming and expensive method, so a mobile system with force plates was presented [5], which demonstrates evaluation using SOT through the use of a VR environment. Further scientific studies show that the use of force plates can be applied for multidimensional assessment of postural control [6]. Own investigations are conducted to find out, if it is possible to assess stability while standing in VR without force measurement data.

II.I. Technical set up

A motion capture system from OptiTrack is used to record and visualize the human body and the balance board. In the laboratory we use 16 cameras of the type Prime^X 13W, which track active and passive markers based on infrared illumination (wavelength of 850 nm). The resolution used is 1280x1024 pixels, with a frame rate of 240 fps. With the program Motive 3.0 the detected 2D object data are reconstructed to 3d points, from which the necessary skeletons and rigid bodys can be created. During the entire study, the participants wear motion capture suits with 49 markers, which are grouped into a skeleton (Template: Baseline and Passive Fingers). Eight additional markers are attached to the outer edge of the MFT Challenge DISC 2.0 balance board at an angle of 45 degrees. This allows the balance board to be captured as a rigid body. An HTC Vive Pro 2 with wireless VR adapter is used as a head-mounted display (HMD). Six markers were also attached to the HMD for tracking. The Unity software version 2020.3.41f1 is used to program the VR environment and visualizations. Fig. 1 shows the structure of the system.

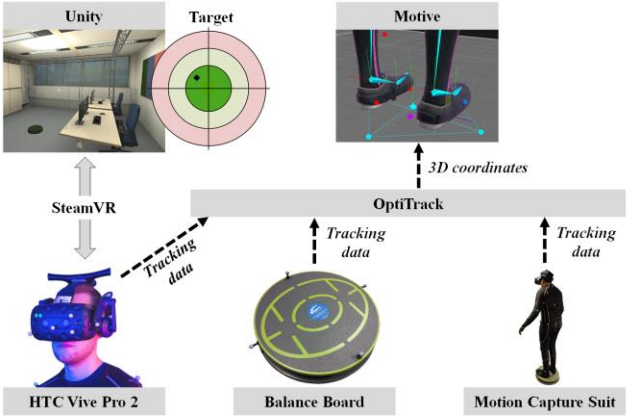

Figure 1: Overview of the technical process chain of the system

II.II. Study design and evaluation methods

To investigate the effects of body balancing in VR quantitative methods of human-computer interaction (HCI) for evaluation are used. To evaluate the effectiveness of the system, the NASA Task Load Index [7] is applied with 6 items to generate subjective data in form of the workload. This assessment tool determines individualized feedback on the mental, physical and temporal demand during the tasks, as well as information on the performance, effort and frustration of the participants. Each item is rated on a subscale from 0 (very low) to 20 (very high). A pairwise comparison is used to weight the items and by summing up the scores an overall workload index is calculated (ranging from 0 to 100 points).

To assess the balancing ability with objective data, the deflection of the board is recorded over the entire time course of the study, using the markers attached on the board. The coordinates of the board deflection are used to describe the balance in X-direction anterior-posterior (transverse axis of the body) and Y-direction medial-lateral (sagittal axis of the body). To verify the functionality of the system, a preliminary study was conducted with 5 participants. The procedure of the study is to complete 8 randomized tasks in a defined time of 30 seconds for each task. The participants perform the tasks in different visualization forms (surfboard, skateboard, hoverboard and laboratory), in each case with and without the representation of their own body. The COP axis projected from the marker data is visually displayed with a circular dot on a target. The target serves as visual feedback at eye level and shows the users their balance behaviour by the deflection of the board in real time. The target is divided into three circular zones (green, yellow and red colour feedback) which describe the deflection of the board between 0 to 3,69 and 3,7 to 7,39 and 7,4 to 11 degrees.

III. Results and discussion

The evaluation of the NASA-TLX shows for all participants that the workload in tasks without visualization of the body is described as very high (mean 85 ± 6 points). The tasks with a visible representation of one's own body limbs decrease the workload index (mean 69 ± 7 points). According to the participants, the task with own body representation and target visualization leads to less mental effort and less frustration. The self-assessment of the balance performance was also rated much better by all participants. The analysis of the quantitative data showed that the four of the participants had more difficulties in the tasks surfing and flying. The significance of the results needs to be determined accurately in a follow-up study with at least 32 subjects - estimated according to Lehr's Rule of 16 [8] - using analysis of variance (ANOVA).

By continuously recording the board deflection in the X and Y directions, it is possible to determine the success rate in the balancing task. The total time that the participants has spent continuously in one of the three target areas is decisive for assessing the success rate. The classification can be divided into "good" (green area), "medium" (yellow area) or "poor" (red area). 3 participants achieved a rating of "good" (68%, 61% and 55% of the total time spent in the green target) and 2 participants achieved a rating of "medium" (52% and 45% of the time spent in the yellow target).

IV. Conclusions

The investigations with the system have shown that it is possible to assess postural stability while balancing in VR through tracking. With these findings, follow-up studies with a representative number of participants will be conducted to examine the statistical influence between visualization and body perception.

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