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[DC] VR Simulation as a Motivator in Gait Rehabilitation

Negin Hamzeheinejad*
Human-Computer Interaction, Julius-Maximilians-Universität Würzburg, Germany

ABSTRACT

Gait rehabilitation is a necessary process for patients suffering from post-stroke motor impairments. The patients are required to perform repetitive practices using a robot-assisted gait device. Repeated exercises can become extremely frustrating and the patients lose their motivation over time. In my PhD research, I focus on Virtual Reality (VR) as a medium to improve gait rehabilitation in terms of enjoyment, motivation, efficiency, and effectiveness. The objective is to systematically investigate different factors, such as the presence of a trainer, interactivity, gamification, and storytelling in a two-step process. First, by evaluating the applicability of different factors for the clinical use with healthy subjects. Second, by evaluating the effectiveness of the VR simulation with patients with gait deficits, especially stroke patients in collaboration with a [country] clinic.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality

1 RESEARCH INTEREST AND BACKGROUND

Stroke patients with gait impairments are required to perform a considerable amount of exercises to induce neuro-plastic adaption and functional recovery [2]. With regard to observational data, the number of repetitive movements that patients perform in the traditional therapy are typically restricted [3]. Even though robot-assisted therapy (see Fig. 3) provides the possibility for a high-dosage and high-intensity therapy, patients require motivation and excitement in order to perform the exercises regularly in a clinical surrounding and to preserve a successful rehabilitation outcome [1]. As one possibility to improve the method for gait rehabilitation, the implementation of VR usage has been proposed, in order to reduce the perception of exertion and increase the stimulation of patients. VR is capable to enhance gait and balance rehabilitation when combined with traditional rehabilitation methods [5]. Shema and colleagues presented that the mobility of experienced patients improved, and the risk of fall was reduced by including a Virtual Environment (VE) in a treadmill training program [6]. VR can provide multi-modal sensory stimulation with a variety of interesting artificial environments during exercises which provides benefits for neurorehabilitation. Most of the previous work used a limited notion of VR (e.g., low immersions, and interactivity).

2 OBJECTIVES AND GOALS

The main goals of my PhD project are: (1) to develop and systematically investigate Virtual Reality Rehabilitation (VRR) programs with regard to their applicability for the clinical use by altering factors that may impact their acceptance, and, (2) to investigate their impacts on the motivation of the patients to perform therapy sessions regularly, as well as on the efficiency and effectiveness of the rehabilitation.

*e-mail: negin.hamzeheinejad@stud-mail.uni-wuerzburg.de

Figure 1: Calming virtual environments that provoke escapism for the patient and suppress the clinical context.

2.1 Factors to Investigate

Even though previous works investigated methods for VRR, several directions require further investigation.

(1) The neural activity in the mirror neuron system was shown to be triggered when a person observes a motoric action. Activating this system by imitating performed actions may support motor rehabilitation [4]. Therefore designing a virtual trainer that performs periodic gait movement could improve the rehabilitation outcome.

(2) The social behavior of the trainer should be considered as a virtual trainer needs to provide a similar sense of motivation and excitement compared to a physical human trainer, and thus the virtual agent needs to be highly sophisticated in terms of visual communication and humanness.

(3) Storytelling and gamification can keep the patients motivated over time. The development of a VE that includes storytelling features could impact on the enjoyment of the patients during therapy. By strolling in the environment, exploring a nature simulation, and listening to background information, patients could be kept far from reality and clinical environments. Therefore, storytelling could promote escapism and presence. In addition, the VR stimulation can provide gamified tasks with different difficulty levels in order to engage the patients in their therapy sessions.

(4) Real-time feedback for the patients could be provided by visual modifications of their own (virtual) body in VR, i.e., by visually changing the color of the legs in accordance to the force evoked by the patient.

3 FIRST RESULTS

In the first study, I compared a physical with a virtual trainer as well as the impact of escapism provoking VE's on enjoyment, motivation, sickness, and effect. A VE to provoke escapism was developed that consisted of grassland, a forest, and a beach scenery (see Fig. 1), including animated animals and ambient sounds. Additionally, the virtual trainer was placed in the VE in order to provoke mirror neuron activity by performing periodic movement and motivation by displaying motivational speeches through voice (see Fig. 2). 45 healthy students (22 females) participated ($M_{age} = 21.82$, $SD_{age} = 1.84$) and were assessed for three consecutive days (i.e., 135 trials were assessed). The participants were assigned to one of four conditions (Non-VR no trainer, Non-VR with a trainer, VR no trainer, VR with a trainer). Participants were asked to walk 1000 steps on a crosstrainer in a speed of 40 steps per minute, while their motion was tracked through VIVE controllers and in the VR conditions, they were immersed with the VIVE head-mounted display. A metronome was used to level their speed.

It was found that enjoyment degraded for each day of the assessment. In general, VR had a higher enjoyment level; however, VR without the trainer had a significantly higher enjoyment compared to VR with the trainer. This could be explained due to simple performance and lack of socio-motivational behavior of the virtual trainer. In addition, the assessment of a situational motivation scale, which asked the participants to take the perspective of the patients, revealed that VR in both conditions had higher scores compared to the Non-VR conditions. Therefore, VR is able to increase the intrinsic motivation of the patients. Observations on perceiving user experience presented that VR medium was higher in novelty. However, the novelty level dropped throughout the study which shows that a novelty effect might be just due to a first use of the simulation. In fact, this might be due to the repetitive content of the simulation, and therefore interactivity, gamification, and alternating content may improve the results. Additionally, stimulation and efficiency were significantly higher in Non-VR with the trainer condition compared to without the trainer, while as in VR the trainer decreased such ratings. It could be speculated that the virtual trainer was not sophisticated enough, i.e., not evoking a similar "human" connection than a physical trainer which is why the scores were decreased. The physical response of the exercise measured at 0, 25, 500, and 1000 steps. With regard to the result, heart rate increased up to 500 steps and then gradually decreased for all conditions, however, heart rate dropped in VR conditions in comparison with Non-VR conditions. Most importantly, there were no undesirable side effects or simulator sickness recorded in three days of study.

Figure 2: The virtual trainer used in the study. The trainer acted using motivational speeches but did not have social contact.

4 Conclusion

In this paper, reviewed recent approaches using VR in gait rehabilitation. In the first investigation, the VR system providing the landscape scenery to inspire the walking activity in combination with the use of the virtual trainer was investigated. Results of this first assessment demonstrated that even though enjoyment decreased for the day of assessment, VR conditions had a higher rate compared to Non-VR conditions. In addition, VR is capable of increasing the motivation of the patients based on the measurement collected from the participants in the perspective of the patients. The results further showed that the simulation is applicable for a clinical test. In the remainder of my PhD, I will investigate these research questions:

- **RQ1: How can the participants stay motivated throughout the gait therapy?** I plan to improve enjoyment and motivation.

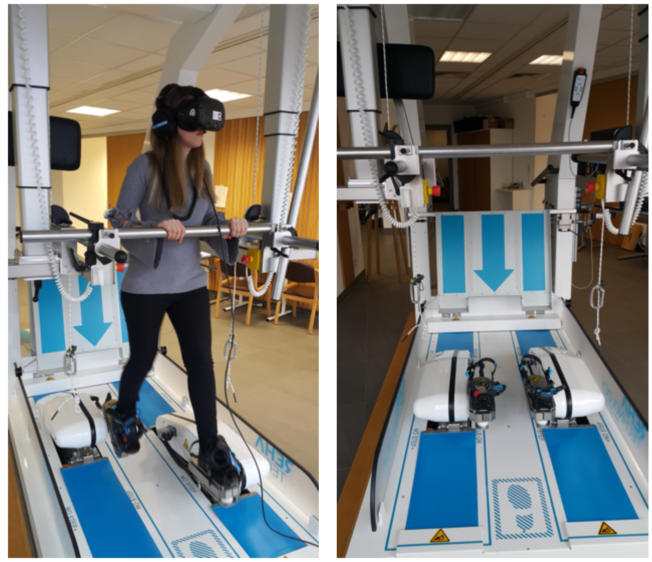

Figure 3: VR system (HTC Vive) used on a gait robot (left). Gait robot-assisted training device at the clinic (right).

  For this purpose, I will develop a VR game that provides gamified tasks with different difficulty levels. Moreover, I plan to design a VE that tells "background story".

- **RQ2: How can I activate the mirror neuron system?** I plan to enhance the virtual agent with social cues (e.g., eye contact, facial expression, and small talk), and compare levels of sophistication of the agent on their impact on enjoyment and motivation. One major point of investigation to this regard is whether additional social connections may increase the effect of the mirror neuron system activation for the participants.

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References

[1] M. C. Howard. A meta-analysis and systematic literature review of virtual reality rehabilitation programs. *Computers in Human Behavior*, 70:317–327, 2017.

[2] G. Kwakkel. Impact of intensity of practice after stroke: issues for consideration. *Disability and rehabilitation*, 28(13-14):823–830, 2006.

[3] C. E. Lang, J. R. MacDonald, D. S. Reisman, L. Boyd, T. J. Kimberley, S. M. Schindler-Ivens, T. G. Hornby, S. A. Ross, and P. L. Scheets. Observation of amounts of movement practice provided during stroke rehabilitation. *Archives of physical medicine and rehabilitation*, 90(10):1692–1698, 2009.

[4] F. Maeda, G. Kleiner-Fisman, and A. Pascual-Leone. Motor facilitation while observing hand actions: specificity of the effect and role of observer's orientation. *Journal of neurophysiology*, 87(3):1329–1335, 2002.

[5] D. C. Porras, P. Siemonsma, R. Inzelberg, G. Zeilig, and M. Plotnik. Advantages of virtual reality in the rehabilitation of balance and gait: Systematic review. *Neurology*, 90(22):1017–1025, 2018.

[6] S. R. Shema, M. Brozgol, M. Dorfman, I. Maidan, L. Sharaby-Yeshayahu, H. Malik-Kozuch, O. Wachsler Yannai, N. Giladi, J. M. Hausdorff, and A. Mirelman. Clinical experience using a 5-week treadmill training program with virtual reality to enhance gait in an ambulatory physical therapy service. *Physical therapy*, 94(9):1319–1326, 2014.