Crossing *iVRoad*: A VR application for detecting unilateral visuospatial neglect in poststroke patients

Sebastian Wagner, Bernhard Preim, Patrick Saalfeld
Department of Simulation and Graphics
University of Magdeburg
Magdeburg, Germany
{wagner, bernhard, patrick}@isg.cs.uni-magdeburg.de

Julia Belger
Day Clinic of Cognitive Neurology
University of Leipzig
Leipzig, Germany
julia.belger@medizin.uni-leipzig.de

***Abstract*—This paper presents the immersive virtual reality (VR) application *iVRoad* for the detection of unilateral visuospatial neglect in right hemisphere poststroke patients. With our immersive VR tool, it is possible to perform realistic road crossing in a safe environment using a head-mounted display (HMD). We present and discuss the virtual environment (VE) for an upcoming study with neglect patients, a broad range of neurological patients and a healthy control group. Our aim is to determine whether extrapersonal neglect can be reliably diagnosed in the chronic phase using VR with the help of various measured values (task completion time, errors, head rotations, eye tracking).**

Keywords—stroke, neglect, rehabilitation, virtual reality

I. INTRODUCTION

The perception and spatial representation of us in the surrounding environment is a fundamental requirement for the execution of nearly all activities of daily life. However, for patients with unilateral spatial neglect (USN) following acquired brain lesions the ability to perceive or respond to objects, persons, or events contralateral to the damaged hemisphere is impeded. This leads to severe limitations in active participation in everyday life [1]. USN constitutes to be a prevalent disease with about three to five million patients every year [2]. In the acute stages after right hemisphere stroke, approximately 82 % of the patients are affected by visuospatial neglect [3]. More than one year after the incident, about one third of the patients will have a chronic form of neglect [4]. In neglect research, it has been criticized for a long time that too little research into neglect's transferability into patients' activities of everyday life has been conducted [5]. Furthermore, conventional assessment methods lack sensitivity, "as they contain mainly non-functional tasks performed in near-extrapersonal space, using static, two-dimensional methods" [6, p. 1]. Especially in the chronic phase, conventional paper-and-pencil tasks might miss USN symptoms [7].

The usage of the realistic immersive VR task provides the potential to diagnose this type of USN with an ecologically valid tool in a safe environment: crossing a road virtually. Another typical characteristic is the pathological failure to recognize the cognitive impairment associated with a circumscribed brain damage (anosognosia). Our objective is to investigate if the use of VR in performing virtual road crossing helps patients to become more aware of their own deficits. This incident could help patients to perform compensation techniques more effectively. The use of VR is particularly promising for the implementation of dangerous or too complex scenarios, which are difficult to address in daily clinical routine. Parameters of the system can be adapted to the patient under completely controllable conditions.

II. RELATED WORK

There is promising research on road scenarios to assess USN. However, most of it is based on non-immersive VR and non-natural input devices (e.g. mouse or keyboard). Navarro et al. [8] used a desktop-based system to investigate the behavior and performance of USN patients in realistic road crossing tasks. They compared task completion times, errors and head rotations of USN patients in contrast to patients without USN and a healthy control group. In almost all measures they found significant differences between the three groups and, as expected, patients with USN performed worst. However, using a normal display reduces the level of immersion and user behavior may be different from using an HMD. Kim et al. [9] report indications for the ability to assess extrapersonal neglect in road crossing tasks using an HMD. However, they used more abstract tasks which differ from real road crossing, where the users have to decide if they want to cross the road before they start. The task was designed to protect the avatar that is standing on the road from approaching cars. The users had to press a mouse button when they noticed an approaching car to secure the avatar.

III. SYSTEM

Our goal is to create an immersive VE that allows to assess extrapersonal neglect by presenting a realistic road crossing task using an HMD. The VE was developed in the Unity game engine. The HTC Vive, including audio strap, is used to present the environment. For the interaction with the environment the HTC Vive Controller is used. In addition, our system records eye movements to investigate if there are differences in the attention paid to one side of the body.

Our VE consists of two approximately 600 m long parallel two-lane roads in a fictional urban environment separated by a public square (see *Fig. 1*). The user is positioned in the middle of the road on the sidewalk. The distance to the other side of the road is 6.75 m. This distance is composed of a lane width of 3 m each and a distance of 0.75 m on the sidewalks. Typically, when using an HMD, the user is in the first person's perspective within the scene. The most natural way to perform a virtual road crossing task would be to walk in the real world.

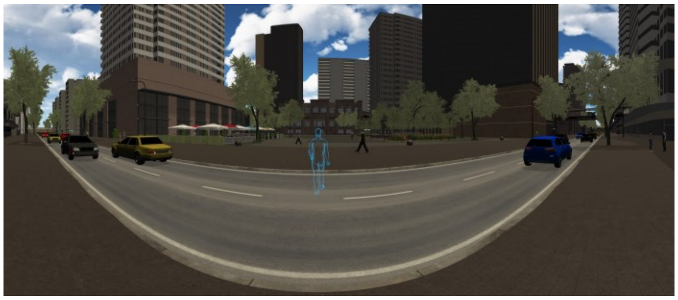

Fig. 1: Panoramic image of the *iVRoad* application with the virtual avatar crossing the road from users' first-person perspective.

Based on the possible motoric impairments that a patient may have, this would not be possible for all patients. In addition, the movement in VR leads to a high degree of uncertainty, especially for untrained and impaired persons. A further factor that speaks against this variant is that in the clinical environment there is usually not enough space available for such tasks. Another possibility would be moving the avatar by using, e.g., a controller in the VE. However, one of the main reasons for cybersickness is a discrepancy between the vestibular and the visual sense, which could arise when the user is moving in the virtual world, but stands still in the real world [10]. Furthermore, crossing the road in the first-person perspective could lead to discomfort when vehicles are approaching the user [11]. Therefore, a virtual avatar (see *Fig. 1*) was chosen that crosses the road automatically with a constant speed of 1.45 m/s after the user pressed the trigger button of the controller. The speed is based on Morgenroths [12] observation of the walking speed of 6000 Germans. Meanwhile, the camera position of the user remains unchanged at the sidewalk in the first-person perspective and the user can watch the result of their crossing decision. After each road section, the user's camera position is automatically teleported to the next road. This interaction is easy to perform and can also be achieved by most patients with motor impairments. Ambient sound is given in form of a constant city-like background noise and typical vehicle noises to support the immersion and give an additional indication of approaching cars. In addition, the user receives a feedback sound for successful or failed crossings. In comparison to previous studies, we want to present the patient with different traffic situations by varying the traffic situation with three difficulty factors based on traffic psychology research [13] (vehicle speed, gap size between vehicles and the driving direction). This enables an analysis of the factors and their influence on the task difficulty of the participant groups. Thus, it is possible to ensure an adaptable difficulty for a future training. The patients' task is to put a letter in a mailbox on the other side of the two parallel roads and return to its starting point. This ensures that vehicles appear from both the impaired and the less affected half of the body (i.e. left side). The variation of speed and distance between vehicles requires a faster response depending on the situation and results in varying traffic situations. After the user has thrown in the letter, the user's perspective turns 180 degrees during a short black screen and the user begins his return path. The system allows us to differ between safe and unsafe road crossings as well as accidents. A safe road crossing means that the time between leaving the lane and the approaching vehicle is longer than 1.5 s (based on Simpson et al. [14]). If the time is shorter than 1.5 s, but the avatar is successfully crossing the road, we count this as an unsafe crossing. If there is a collision between the approaching vehicles and the 1-meter corridor in the lane the avatar is crossing, it is counted as an accident. This is not displayed to the patient, since the screen is previously faded to black.

IV. Discussion

With the help of our immersive VE and the evaluation of task time, errors, head rotations and eye tracking, we aim at reliably recognizing extrapersonal neglect, especially in the chronic phase. We are currently planning a clinical pilot study to investigate the feasibility of our environment and the potential of our VR environment to make neglect patients aware of their deficits. Afterwards, it would be possible to use our system with patients in the long term to investigate potential benefits in the daily life transfer. The patients could learn compensation techniques in VR by performing an ADL in a safe virtual and ecologically valid environment.

References

[1] L. J. Buxbaum, M. K. Ferraro, T. Veramonti, A. Farne, J. M. D. P. Whyte et al., "Hemispatial neglect: Subtypes, neuroanatomy, and disability," Neurology, vol. 62(5), pp. 749-756, 2004.

[2] M. Corbetta, M. J. Kincade, C. Lewis, A. Z. Snyder and A. Sapir, "Neural basis and recovery of spatial attention deficits in spatial neglect," Nature neuroscience, vol. 8(11), p. 1603, 2005.

[3] A. P. Stone, P. W. Halligan and R. J. Greenwood, "The incidence of neglect phenomena and related disorders in patients with an acute right or left hemisphere stroke," Age and Ageing, vol. 22(1), pp. 46-52, 1993.

[4] H. O. Karnath, J. Rennig, L. Johannsen and C. Rorden, "The anatomy underlying acute versus chronic spatial neglect: a longitudinal study," Brain, vol. 134(3), pp. 903-912, 2010.

[5] G. Kerkhoff and T. Schenk, „Rehabilitation of neglect: an update," Neuropsychologia, vol. 50(6), pp. 1072-1079, 2012.

[6] T. Ogourtsova, P. S. Archambault and A. Lamontagne, "Exploring barriers and facilitators to the clinical use of virtual reality for post-stroke unilateral spatial neglect assessment," Disability and rehabilitation, pp. 1-9, 2017.

[7] J. Rengachary, G. d'Avossa, A. Sapir, G. L. Shulman and M. Corbetta, "Is the posner reaction time test more accurate than clinical tests in detecting left neglect in acute and chronic stroke?" APMR, vol. 90(12), pp. 2081-2088, 2009.

[8] M. D. Navarro, R. Lloréns, E. Noé, J. Ferri and M. Alcañiz, "Validation of a low-cost virtual reality system for training street-crossing. A comparative study in healthy, neglected and non-neglected stroke individuals," Neuropsychological rehabilitation, vol. 23(4), 597-618, 2013.

[9] D. Y. Kim, J. Ku, W. H. Chang, T. H. Park, J. Y. Lim et al., "Assessment of post-stroke extrapersonal neglect using a three-dimensional immersive virtual street crossing program," Acta Neurologica Scandinavica, vol. 121(3), pp. 171-177, 2010.

[10] J. J. LaViola Jr, "A discussion of cybersickness in virtual environments," ACM SIGCHI Bulletin, 32(1), pp. 47-56, 2000.

[11] I. Feldstein, A. Dietrich, S. Milinkovic and K. Bengler, „A pedestrian simulator for urban crossing scenarios," IFAC-PapersOnLine, vol. 49(19), pp. 239-244, 2016.

[12] O. Morgenroth, „Zeit und Handeln: Psychologie der Zeitbewältigung," W. Kohlhammer Verlag, 2008.

[13] A. Dommes, V. Cavallo, F. Vienne and I. Aillerie, "Age-related differences in street-crossing safety before and after training of older pedestrians," Accident Analysis & Prevention, vol. 44(1), pp. 42-47, 2012.

[14] G. Simpson, L. Johnston and M. Richardson, "An investigation of road crossing in a virtual environment," Accident Analysis & Prevention, vol. 35(5), pp. 787-796, 2003.