

A reliable low-cost platform for neglect Virtual Rehabilitation

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Abstract—Neglect syndrome is characterized by a selective impairment of spatial exploration sensible to cognitive rehabilitation. We show here how an effective rehabilitation system for neglect can be obtained using a web-cam, a PC and a TV display or a video projector. The patient is guided to explore the space, included the neglected hemispace, by a specifically designed game that requires the patient to reach targets with an increasing level of difficulty. Rewards display and audio output feed-back make the game even more attractive. We also report significant improvement on spatial exploration and everyday activities in one patient with chronic neglect, after a single intensive treatment with the described system. Besides improving the patients reported a positive attitude towards the system throughout the entire rehabilitation period.

Keywords—component; virtual reality rehabilitation, patient tracking, neglect, serious games design.

I. INTRODUCTION

Neglect is characterized by the inability to interact with stimuli located in the side of space contra-lateral to the brain lesion [1]. Virtual Reality (VR) integrating behavioral and cognitive training in a daily life scenario by means of controlled tasks [4], has been used to rehabilitate this syndrome [2-3] as an alternative to the classic approaches. VR allows training at home, where patients feel more comfortable and can choose the most appropriate time window to exercise themselves accordingly to their *ecological rhythm*. Finally, computerized game-like methods represent a powerful tool to train participants, providing regular feedback and also motivation to endure practice. However, none of the available systems is suitable for at home rehabilitation at the moment.

The fast improvement of real-time video processing techniques has opened new possibilities, making rehabilitation at home a possible scenario. Here, we show how an effective rehabilitation system can be obtained using a web-cam, a PC and a TV display or a video projector. The final goal is to enable patients to train at home independently, although with tight connection to the hospital, thus facilitating intensive rehabilitation for prolonged periods. We have termed this platform *DuckNeglect* from one of the stimuli adopted.

II. DESCRIPTION OF DUCKNEGLECT

As shown in Fig. 1, the patient (1) comfortably sits on a chair (or in his wheelchair), with a white curtain or a white

wall behind him. He watches a projection screen (2), or a TVscreen, positioned at 3m distance. A virtual scene is projected onto this screen by a projector (3). A web cam (4) is positioned below the screen aimed at the patient's face and upper part of the body. This is connected to a host PC (5) that processes the video input and generates the output for the projector. The Eye-toy web-cam used costs about 50 Euros making the platform potentially suitable for massive diffusion.

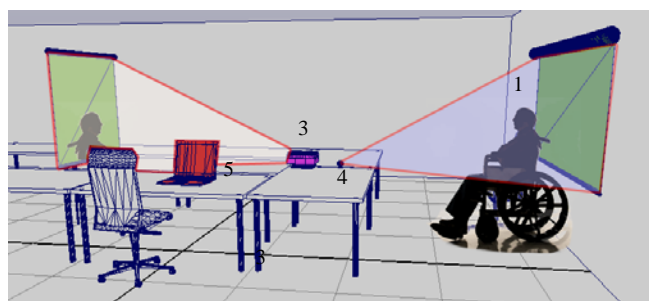


Figure 1. The architecture of Duck neglect as used in the first pilot test: 1 – patient; 2 – display (screen); 3 – projection screen; 4 – web-cam; 5 – host PC.

The game engine loops through three steps at 30Hz. First the image from the web-cam is acquired and processed to extract the patient silhouette from the background through thresholding. The silhouette is then pasted over the virtual scene that constitutes the game background and lastly the composited scene is displayed (Fig. 2). Calibration is carried out before rehabilitation starts to determine the optimal threshold that separates the subject from the background. Afterwards, the patient is asked to step in and to position himself to match his face and trunk into a model silhouette shown on the display. He is also asked to reach the borders of the displayed image with his arms, to confirm that the positioning is correct. If the patient's head is too high or low, the projector height is regulated accordingly. In case of lateralized paralysis, patients use the unaffected arm only.

Proper lighting is needed to obtain optimal background-foreground segregation: the combination of neon and external bright light may cause not optimal background-foreground segregation that leads to a display of an incomplete silhouette.

The game engine detects collisions between hands and virtual objects. The hand trajectory is also recorded during the game, to assess patients' spatial exploration strategies. The

whole software application has been developed under an OpenSource paradigm to maximize the software diffusion.

We developed a visual search game [5] in which the patient is instructed to hit with his unimpaired hand one or more targets avoiding distractors. The hit target disappears from the screen as soon as an OK symbol is displayed (Fig. 2). A nice beep signal is played and the patient's score is increased and displayed. Targets are randomized and balanced between the left and right side and the upper and lower regions of the visual field. They appear in a pleasant scenario chosen randomly among few scenarios designed to recall pleasant environments usually related to nice times in everyday life. Soft and calm music is played accordingly to the scenario creating a more natural environment.

The exercises progress in terms of levels of complexity that is due to the number of targets to be hit. When one level is completed, the next level adopts a different background scenario to avoid becoming boring. The exercises progress also in terms of degree of difficulty that depends on visual (targets blinking) and/or auditory (spatially lateralized beeps) cues. These are automatically activated after a ten second interval during which patients rest.

We heavily relied on scripting language to define the game, in terms of scenes, targets, distractors, scoring and reward system that can be modified simply by modifying a text (XML) file.

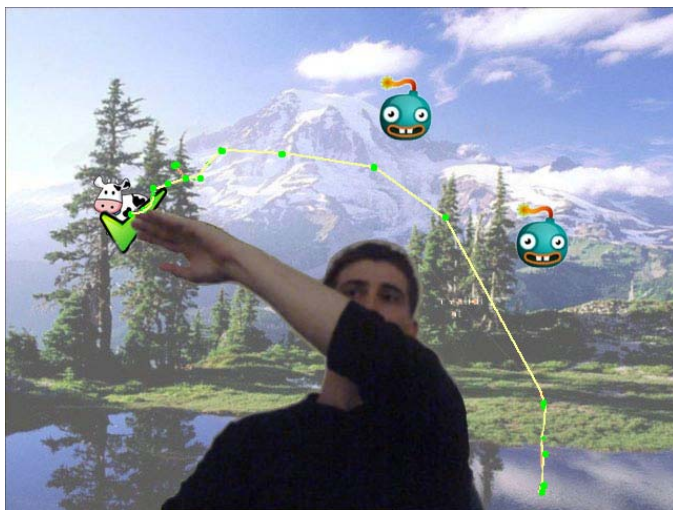


Figure 2. The patient pasted inside the virtual rehabilitation scenario. Notice that he is touching a stylized cow, that represents one of the targets of this particular game. A green checksign is shown upon collision. The logged hand trajectory is also shown superimposed.

III. RESULTS AND DISCUSSION

Patient IB is a 65 years old right handed male, with a severe left chronic Neglect following an extensive right fronto-temporal haemorrhagic lesion in 2009. He accepted to be trained with DuckNeglect at the Department of Computer Science for one month, half an hour a day for five days a week. After the treatment IB showed an improvement of his global cognitive function (Mini-Mental State Examination, Attentional Matrices). Furthermore his spatial Neglect ameliorated as demonstrated by a classical neuropsychological

assessment for selective spatial deficits administered before and after the treatment. For instance at the line bisection task where IB was asked to sign the center of a line, he showed left sided Neglect before rehabilitation while performed within the normal range immediately after. Concerning his performance at the videogames he became progressively more accurate and faster as the number of distractors hit reduced together with his reaction times with audiovisual cues, independently of the complexity level of the game, and the side of the space. As an additional remark, several everyday life activities (such as newspaper reading) have been reported as improved by his family and himself. Finally, IB was always comfortable during the training never showing to be tired or bored.

We remark two particular elements: the background music made the patient more comfortable than a complete and impersonal silence and it may have played a role in rehabilitation [6]. Moreover, we observed that IB was greatly disturbed when unable to see his complete silhouette on the screen, while was interested and elicited by seeing his arm and hand operating in the virtual space tracking the targets. This behavior is an “uncanny” valley effect [7] and suggests that a fully displayed silhouette in VR, enhances the feeling to be plunged in a real environment.

The DuckNeglect belongs to the emerging field of serious games, and it is a “hands free” interaction system without relevant constraints on the patient. In this domain, the Gesturetek IREX commercial system [8] represents the state of the art for rehabilitation. However, it is costly and cannot be tailored to different pathologies. Our preliminary data encourage the implementation of such low cost VR systems that easily may become suitable for massive at home rehabilitation.

The future integration of this kind of rehabilitation systems at home with clinical monitoring in the hospital, as explored for instance by the EU financed Fitrehab project [9], will make more flexible and economic, and therefore sustainable by National health providers, also long lasting rehabilitation.

REFERENCES

- [1] .M. Heilman, E. Valenstein, and R.T. Watson "Neglect and related disorders" *Semin Neurol* **20** 463-70, 2000.
- [2] U. Castiello, D. Lusher, C. Burton, S. Glover, and P. Disler, “Improving left hemispatial neglect using virtual reality”, *Neurology*, 62, June 2004 pp. 1958-1967.
- [3] J.Kim, K.Kim, D.Y.Kim, W.H. Chang, C.I. Park, S.H. Ohn, K. Han, J. Ku, S.W. Nam, I.Y. Kim, S.I. Kim "Virtual environment training system for rehabilitation of stroke patients with unilateral neglect: crossing the virtual street" *Cyberpsychol Behav* **10** 7-15, 2007.
- [4] F.D. Rose, Brooks B M, Rizzo A A, "Virtual reality in brain damage rehabilitation: review" *Cyberpsychol Behav* **8** 241-62, 2005.
- [5] Bowen A, Lincoln N B, 2007 "Cognitive rehabilitation for spatial neglect following stroke" *Cochrane Database Syst Rev* CD003586
- [6] A.D. Patel, Music, Language, and the Brain, Oxford University Press, 2008.
- [7] J. Seyama, R.S. Nagayama, The Uncanny Valley: “Effect of Realism on the Impression of Artificial Human Faces”, *Presence*, Vol. 16, No. 4, August 2007, pp. 337–351.
- [8] <http://www.gesturetekhealth.com/products-rehab-irex.php>
- [9] <http://www.innovation4welfare.eu/287/subprojects/fitrehab.html>

