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Altered steering strategies for goal-directed locomotion in stroke

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Abstract: The aim of the study was to examine the effects of changing optic flow and target location on goal-oriented heading in stroke. Two subjects with stroke and two healthy older subjects participated in a mouse-driven steering task while seated and a walking steering task. In the sitting experiment, stroke subjects showed less heading errors than older subjects, while in the walking experiment they had larger heading errors than older subjects. Results support the feasibility of using a virtual reality-based task to assess steering strategies in stroke and healthy older subjects.

Keywords:(Steering, Virtual Reality, Optic flow, Heading,Focus of Expansion)

I. Introduction

Persons who have suffered a stroke have long-term difficulties in walking [1]. This can lead to an increase risk of falling and dependency while limiting participation and quality of life [2].Walking after stroke is characterized by a slow gait speed [8], poor endurance [9], and difficulties adapting to environmental constraints. In particular, stroke subjects present with difficulties reorienting their walking trajectory to head in the desired direction [4].There are many sources of sensory information that guide locomotor heading, including vision which, provides rich information about self- motion and the environment. One source of visual information used to guide walking is optic flow. When an individual moves through the environment, that leads to a radial pattern of visual motion called optic flow [3]. When walking on a straight path, the optic flow field has a radial structure with a point from which the motion radiates, known as the focus of expansion (FOE). In order to control locomotor heading, one would align the FOE with the desired goal [3, 6]. The role of optic flow in the control of locomotor heading is usually investigated by artificially changing the optic flow direction and examining the impact on the walking trajectory, or heading. This is usually done with prisms (Rushton et al.1998) or with virtual reality (Warren et al. 2001).Complex locomotor tasks, such as changing direction while walking, can be especially challenging, as they require fine movement coordination and the integration of sensory information including perceived self-motion with respect to the destination [4].We previously reported that individuals who sustained a stroke can manifest altered locomotor steering behaviors when exposed to OFs expanding from different locations [7]. It was also shown that the coordination of gaze and body segment reorientation during locomotor steering is disrupted [4] .This suggests that both perceptual and motor aspects of visuo-motor control could contribute to the altered steering ability after stroke. The purpose of this study was to examine the effect of changing target locations and foci of expansion (FOE) on steering strategies in stroke and healthy older individuals.

II. Method

Two subjects with stroke (58 and 41 years) and two healthy older subjects (68 and 66 years) provided written informed consent and participated in this study. Stroke subject's presented with a lesion in the right middle cerebral artery territory. In experiment 1, subjects were instructed to head or 'walk' toward a target in a virtual environment (VE) by using a mouse while being seated in front of large screen (1.9m X 2.7m) which displayed the VE. In experiment 2, subjects performed a similar steering task while walking over-ground at their comfortable speed and while watching the same VE in a helmet-mounted display (NVisor™). Reflective markers were placed on specific body landmarks, as described in the Plug-In-Gait model. Marker positions were recorded with a 12-camera motion capture system (Vicon™) and fed into the CAREN-3 (Motek BV) virtual reality system. Head coordinates were used to update the subject's position, in real- time, in the VE. The VE consisted of a large room (40m X 25m) with a target located straight ahead, at eye level and 7m away. The target and the FOE were initially at 0°. When, the subjects achieved a forward displacement of 1.5 m, target and FOE locations either remained at 0°or shifted randomly to $\pm 20^\circ$, for a total of 9 different conditions. The subjects were instructed to walk toward the target covering a distance of 5m after which the trial stopped.

III. Results

In general, subjects overshot and undershot the target when the FOE and target were located ipsilaterally and contralaterally, respectively. In experiment 1, they used the mouse to modify their medio-lateral position with absolute net heading errors (NHEs) within 5.2° and 44.6° for stroke and older subjects, respectively (Figure1). In experiment 2, NHEs were within 16.6° and 5.5° for stroke and older subjects, respectively, (Figure2). In other words, stroke subjects displayed larger NHEs in the walking task than healthy older subjects and less NHEs in the sitting task.

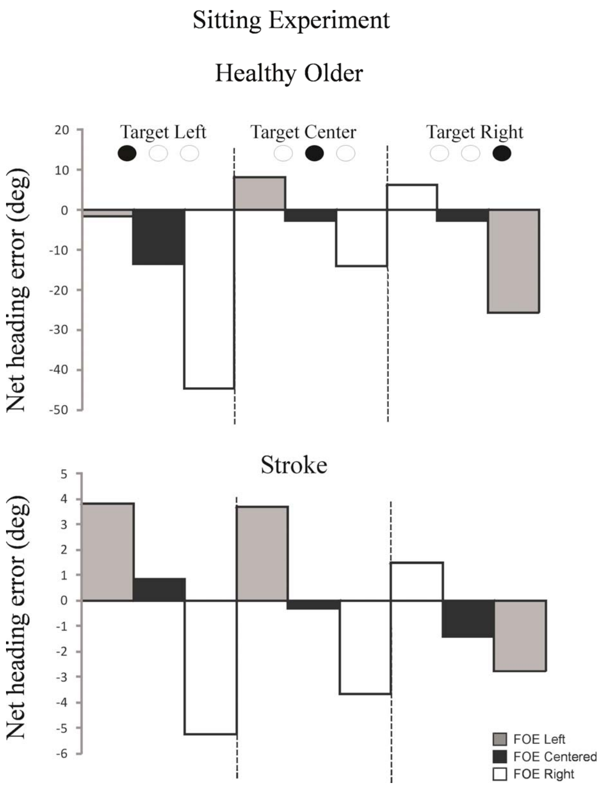

Figure 1: Mean net heading errors in the sitting steering tasks across target and focus of expansion (FOE) locations in stroke and healthy subjects.

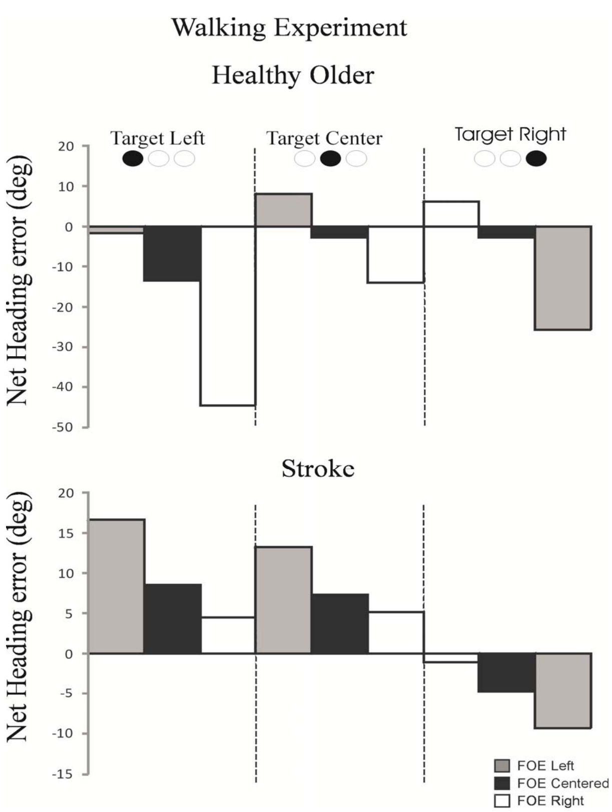

Figure 2: Mean net heading errors in the walking steering tasks across target and focus of expansion (FOE) locations in stroke and healthy subjects.

IV *Discussion and conclusions*

The contrasting results between the sitting and walking experiments suggest that post-stroke locomotor steering strategies are predominantly affected by gait-related sensorimotor impairments. An altered integration of the multiple sources of sensory information experienced during walking may also be cause. The task in experiment 1 (sitting)

The larger heading errors experienced by the older subjects in the mouse experiment in sitting, however, was not anticipated. Such large heading errors may be explained by a difficulty in using modified visuomotor rules [10] to transform small mouse displacements into large translations in the VE.

Limitations of this pilot study include the small sample size and the age difference between groups. The fact that the display differed between the sitting and walking task does not alter the comparison of the older adults and stroke subjects' performance. Altogether, these results support the feasibility of using a virtual reality-based task to assess steering strategies in stroke and healthy older subjects

Future directions for research include assessing heading perception in stroke and examining the effects of specific brain area on control locomotor steering and heading

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