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# Influence of moving visual surroundings on walking

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*Abstract*—**Introduction: Balance is negatively influenced by optokinetic stimuli. Fall research with these stimuli has been done with standing subjects. Less is known of the influence these stimuli have on risk of falling while walking. The objective of this study was to qualitatively investigate the influence of optokinetic roll stimuli on balance during walking.**
**Methods: The 6DoF CAREN virtual reality motion base located at Doorn, The Netherlands, was used. A roll dome with in the center a rectangular structure to promote gaze fixation was projected on a semicircular wall (180 degree field of view, eye-wall distance 2.5 m). The roll dome rotated counterclockwise at 30 deg/s and the subject walked at a speed of 3.6 km/h. Qualitative aspects of gait from 10 subjects were collected.**
**Results: Subjects experienced severe gait disturbances during walking. They could not compensate for the optokinetic stimulation and risk of falling was evident.**
**Discussion: optokinetic (roll) stimuli have a large influence on the gait pattern, which affected stability and enhanced the risk of falling considerably.**

***Keywords-component; roll vection; falls; virtual reality; balance***

## I. Introduction

Aviation has enriched life with several types of illusions. Also it has given these types of illusions their sometimes illustrious names, like graveyard spiral, black hole approach or the Giant Hand illusion [1]. These illusions point towards an inadequacy of the sensory systems to adequately represent the physical movements of the aircraft. The brain tries to calculate a “best fit” from these complex non-representative data: In these situations trusting your instruments is life-saving.

Modern travel over ground has also brought societies these types of illusions, for example the “train illusion”. When sitting in a train waiting for departure, and watching a departing train on an adjacent track, one can experience a strong (yet faulty) illusion of self-motion, as if the own train departs. This perceived self-motion is called vection and the phenomenon of vection was first described by the physicist Mach in 1875 [2]. Vection can have linear and/or circular components [3].

In activities of daily life, like driving, walking and cycling, but also when picking up toys from the ground because a child “forgot” to put them in the basket, normal functioning of the senses, (sub)cortical structures and the neuromuscular system is of importance for maintaining adequate balance and orientation as the gravitational pull is omnipresent on this planet. In healthy people this might be interpreted as an effortless achievement. In the aging human however, staying upright is challenged by (accumulations of) impairments and pathology [4, 5, 6]. According to Tinetti e.a. [7] the most important biomechanical constraint on balance is the size and quality of the feet: the base of support.

Posturographic studies have given insight into the dynamic process that standing actually is. A recent systematic review on risk factors of falling in elderly by Piirtala & Era [8] showed a potential role of various aspects of mediolateral displacement of the center of position, but the results are inconclusive. Bles e.a. [9] have shown that visual stimuli, for example roll stimuli can cause a shift in the subjective vertical and cause falling. All these studies have in common that they have been performed on standing subjects. In general though people do not fall while standing still, although motion parallax, a depth cue that results from objects moving across our field of view, can positively or negatively influence stability while standing: On the edge of a cliff with a wide view and no objects nearby to induce sufficient parallax, stability is impaired [9].

Yet, for an adequate understanding of why humans fall, it is necessary to perform research in walking subjects. In this pilot study we wanted to investigate the role of visual (roll) stimuli while walking, because as Bles e.a. [9] have shown roll stimuli on their own can also cause a mediolateral displacement of the center of mass.

Literature on this subject is sparse however. To our knowledge there is only one study available that investigated the influence of visual roll stimuli on walking: Schneider e.a.

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[10] investigated the effect a virtual roll dome projected via a head mounted display has on walking 6 meters. They found that only the first few meters resulted in "initial balance responses in the roll plane".

One might hypothesize that after the first few meters an adequate corrective response takes place, but nothing is known whether or not this response is substantiated in the next meters or even minutes walking.

This pilot study aims to qualitatively investigate the effect a continuing roll stimulus has on gait stability during several minutes of sustained walking. Gaining insight in if and how people habituate to these stimuli will potentially enable the formulation of therapeutic and preventive measures concerning falling in humans with sensorimotor impairments.

## II. Methods

### A. Subjects

There were 10 healthy subjects with a mean age of 27.9 (±7.0) years, who volunteered for this study. They were not receiving any medication, except for female subjects who were allowed to be on oral contraceptives.

Written consent was obtained from all subjects. The experiment carried out under the constraints of a protocol relating to experimentally-induced gait variability and had Medical Ethical Committee approval. Subjects gave informed consent and were free to withdraw at any time

### B. Equipment

The CAREN (Computer Assisted Rehabilitation ENvironment, Motek Medical, Amsterdam) facility located at the Military Rehabilitation Center in Doorn, The Netherlands is a 6 DoF motion base on which a single belt (max 18 km/h) treadmill is integrated. Directly underneath the treadmill are four force plates. A 6 meter screen encircles the motion base enabling a 180 degree field of view (average distance eye – screen was 2.5 m). Three LCD projectors, several meters above the subject, can project a virtual environment on the screen. At the level of the LCD projectors located in a square, 9 and at the level of the motion base, 3 Vicon 3D motion capture cameras are present.

Fig.1 represents the CAREN setup at the Military Rehabilitation Center in Doorn.

A virtual roll dome consisting of dots in different colors and sizes was constructed using 3D-max software. In the centre of the dome a rectangular shape was present, thus enabling a sense of verticality and promoting gaze fixation of central vision. The roll dome rotated counterclockwise at an angular speed of 30 deg/s.

Figure 1. The roll dome is projected on the 6 m semicircular 180deg. Field of vision screen (eye-screen distance was 2.5 m). Subjects walk on the treadmill and are secured in a harness. In this experiment subjects were instructed to look at the rectangular shape. This shaped did not move during the experiment, the roll dome rotated counterclockwise.

### C. Design

Prior to the start of the experiment, subjects had to familiarize themselves with treadmill walking for at least six minutes. According to Matsas e.a [11] this is necessary to eliminate initial changes in gait variability.

After a short rest period, the experimental trial started. During this trial the treadmill ran at 3.6 km/h. The virtual roll dome application was started 10 seconds after the start of the treadmill. Data was collected and after 4 minutes the rotation of the roll dome was stopped while the treadmill continued at the same speed for 10 seconds after which the treadmill gently came to a stop.

### D. Analysis

The following qualitative aspects of the potential influence the roll dome might have on gait were collected:

1. Shift of the subject to the left or right side of the treadmill (relative to the center of the treadmill) and the amount of time the subject stays on that side. The following distinction was made and was rated by the investigator: 0-25%, 25-50%, 50-75%, 75-100%.

2. The direct influence of lateroflexion of the head to the left and right respectively on gait changes was investigated (these head movements were executed on demand after two minutes of walking)

3. Immediate gait changes after stopping the roll dome after 4 minutes, as the treadmill continued at the same speed for 10 seconds.

4. The experienced tilt in degrees while walking.

## III. RESULTS

The roll dome rotated counterclockwise and all subjects experienced an almost immediate shift to the left side of the treadmill, and walked there almost the entire time during stimulus period (4 mins). Gait was remarkably changed, there was an increase in step width and/or subjects crossed their steps. Also there was leaning of the torso towards the roll stimulus. Subjects told us afterwards they felt an inability to correct for the perceived roll stimulus.

After stopping the roll dome, the treadmill continued for 10 seconds before coming to a gentle stop. All subjects, after cessation of the roll dome almost immediately shifted to the right side of the treadmill, so they overshoot the center position of the treadmill.

During the runs subjects were asked to lateroflex their head counterclockwise and then clockwise. Counterclockwise lateroflexion of the head resulted in either worsening of the perceived tilt including the corresponding gait changes or in no effect. Clockwise lateroflexion rotation of the head resulted in either worsening, no effect or lessening of tilt experience. There was however one subject in which counterclockwise lateroflexion of the head resulted in normalization of gait width and clockwise lateroflexion resulted in widening of gait width. All subjects perceived clockwise tilt of the walking surface while walking, but the variance was large ranging from 10 to 45 degrees.

None of the subjects, but one experienced nausea and dizziness. Discontinuation of the experiment after 1 minute was needed with one subject that got nauseated. This subject continued to experience increased nausea and finally vomited. Afterwards she told us she was prone to motion sickness.

## IV. DISCUSSION

This is the first experiment that investigated the role of visual roll stimuli on gait during prolonged walking and perceived vection while walking.

We have shown that, in walking subjects, visual roll stimuli have a very strong influence on gait pattern and stability, and this effect lasted the entire stimulus time. Our results are in contrast with results of Schneider e.a. [10] who only saw an influence of visual roll stimuli the first meters of walking, but they only measured for the distance of six meters.

We observed that our test subjects walked on the left side of the treadmill for a prolonged period of time. Jahn e.a [12], who used prism spectacles and therefore created a distortion of optic flow, observed a deviation of the gait towards the optic flow. Thus, the direction of visual stimuli seems to be important for the directional control of locomotion.

Interestingly, after cessation of the stimulus when subjects kept on walking all showed an "overshoot" to the right side of the treadmill. Tanahashi e.a. [13] who investigated the effect of visual simulated roll motion on vection and postural stabilization in standing subjects, observed also an overshoot of the center of position towards the contralateral side of the roll stimulus after discontinuation of their experiment. Also during their experiment inclination of the body and head was present and worsened when there was perceived vection. The results of our experiment that focused on walking subjects are in accord with that of Tanahashi e.a. [13]. There seems to be a potential of generalization of "balance data" acquired from stance to walking.

The reason for the overshoot is not known [13], but in our opinion there might be a sound explanation for the inclination of the bodies towards the side of the roll. The counterclockwise stimulus results in clockwise vection, a continuous falling of the body towards the right together with a shift of the subjective vertical to the left, for which one compensates, resulting in a body inclination to the left, in the direction of the stimulus. This explains the temporary shift in the perceived vertical in walking subjects.

From the perspective of falling in elderly it is noteworthy to remark the inability of subjects to adequately correct for the roll stimulus. Also joint mobility, muscle strength and adequate sensory input are of importance. All these factors influence stability and subjects with small limits of stability are prone to falls [14]. In clinical practice decreased joint mobility, sensory input and muscle strength can arise in critical illness neuropathy or diabetes for example. Other factors influencing postural performance are movement strategies (ankle or Center of Mass strategies), the sensory environment (dim-lit conditions e.g.), postural orientation (verticality), dynamics of control during gait and cognitive resources (dual tasking e.g.) [5, 15, 16]. Also, there seems to be a role for extra-ocular muscles proprioception in spatial localization and visuomotor behavior, but this is still a matter of debate [17]

According to Peterka [18] depending on the circumstances "reweighing" of sensory information takes place, to retain upright stance. This means that for example in dimly lit conditions more weight is put on vestibular information.

On the other hand, it has been observed that patients with balance impairments of various origins try to compensate for these impairments by increasing the weight given to the visual information. Consequently, these subjects are at risk if they are in an environment with optokinetic stimuli that challenge a correct orientation [19]. Examples of such optokinetic stimuli might be experienced through a startled flock of birds, or an entering train while standing/walking close to the edge of the platform. Walking in a crowd is also often reported by patients as having an (almost) immediate effect on walking stability and is therefore a situation they try to evade as much as possible. Similar balance problems in these situations are reported by elderly people.

The conclusion is that reliable visual information in elderly subjects and vertigo patients is of utmost importance to maintain adequate balance. This means that architects should take this increased visual weighing of sensory information in these subjects into account in designing the daily environment of these subjects. Moreover, since these subjects are often not aware why they suffer from balance problems, they should get some therapeutic training about the importance of reliable and consequently also of unreliable visual orientation information for postural stabilization, and perhaps they should even get fall training

In view of the large influence of these stimuli it also illustrates the necessity to apply well calibrated motion stimuli in a virtual reality system such as the CAREN system: short visual-vestibular delays may result in postural destabilization.

As a final remark it must be mentioned that projecting a virtual scenery on a 180 degrees field of view screen with a treadmill on a motion base is a valuable experimental tool to investigate the relationship between visual (optokinetic) stimuli, walking and risk factors of falling.


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