

Development of a virtual reality system to study tendency of falling among older people

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ABSTRACT

Injuries related to falls are a major threat to older persons health. A fall may not only result in an injury, but also in a decreased sense of autonomy in the persons daily life. In order to be able to prevent such falls there is a need to further understand the complex mechanisms involved in balance and walking. Here we present an immersive virtual reality system in which a person can move around, while being subjected to various events, which may influence balance and walking.

1. INTRODUCTION

Falls and fall-related injuries is a serious health problem for elderly persons (Tinetti et al 1988, Luukinen et al 1994). With age there is an increasing number of diseases present among persons in the ageing population. Neuromuscular, cognitive and vascular diseases may represent disorders contributing to poor balance and a risk of falls and injuries. Old persons also often consume numerous medications, many of which may also influence alertness, blood pressure, muscle tension, respiratory function and balance in a negative way. Here the interactions between various medication represents an important issue to consider when treating older persons with concomitant disease, bearing in mind the risk of negatively influencing motor performance with the medications. Medications which on the other hand may be vital to the individual.

Some patterns regarding risk factors for falls may be described, among these are; previous balance and gait problems, mobility factors which may include a broad range of difficulties regarding for instance transfer between furniture and wheelchair transfer or trouble bending down, visual deficits, cognitive impairments, postural hypotension, acute illness among persons in people living in institutional care, previous falls clearly increase the risk of another fall and future injuries, and the combination of several of these risk factors.

The costs, associated with fall related injuries in healthcare budgets in the industrialized world, is substantial (Zettraeus et al 1997). Costs may also involve severe social and personal suffering, however often difficult to measure, but obvious for those directly involved in the care for the affected individual.

Fall related injuries and their complications may also threaten life per se in old age (Sernbo & Johnell 1993, Center et al 1999). The presence of a fall and a fall related injury may be the first step of a downward going spiral with poor self esteem, less mobility, loss of muscle strength and sarcopenia, increased passivity and lower independency level. In general falls occur mainly during walking (Jensen et al 2002). Falls that occur while turning may even constitute an increased hip fracture risk, compared to falls related to walking in a straight line (Cumming & Klineberg 1994). During walking there are complex mechanisms involved for balance control. There is also a considerable multisensory load upon the individual at each moment. Hence it appears that there are complex mechanisms involved that decide the outcome of a fall. The risk of falling may be regarded as dependent on the individual's motor function and control, related to the environmental

demands, for the individual to handle, at any given moment. An imbalance here may leave the person at risk of fall and injury (Shumway-Cook & Woollacott 1995).

Postural control and attention are important elements to maintain balance and avoid falls. Research has shown that falls in residential care tend to occur while activities at the ward is at its greatest peak level, or while the individual is engaged in an activity or confronted with an obstacle. With age related decline in systems important for postural control, there may be competition for a limited capacity. Maintaining postural stability during frequently performed tasks, such as sitting or standing has been considered automatic, but today there is evidence that cognitive information processing is also involved. Here multisensory input during a walk change over time and there is a constant demand for corrective movements and altered strategies for maintaining balance. If the critical limits of any part or in the interactions between any of the parts in this very complex system is reached a fall may be the severe consequence. Studies have shown that the ability to correctly process multisensory input may play a role in this respect. Persons who stop walking when they are asked an everyday question are prone to falling and may even have a greater risk for future fractures (Lundin –Olsson et al 1997). Performing normally easily handled balance tasks such as standing on a foam support, may be difficult for an older person if there are simultaneous attentional demands put on the individual (Shumway-Cook et al 1997). Hence it appears that in order to take the necessary fall preventative measures one must try to understand the characteristics for each individual, and probably also undertake functional studies during walks and turns.

This complexity makes it difficult to standardize methods for testing balance and fall tendency in a everyday clinical setting, if these methods are aimed to give reproducible, comparable, measures from one time to another. Here the use of Virtual Reality may represent a new tool able to produce identical environmental scenes over and over again. Changes in weather, light and sound conditions and relations to other persons present in the real environment may be set aside. With the use of a virtual environment (VE), such conditions can be standardised and identical for a series of tests and movement measurements. The use of VE also enables the test leaders to set “critical levels” for the visual disturbances and by doing this the balance performance level for a tested individual may be estimated in the future. Here the possibility to study influences of other factors such as medications, injuries, limb restrictions and more may also be tested and evaluated within such a technical system.

Considerations of avoiding falls while using the system was discussed throughout the project. Virtual systems has been used successfully for a number of applications, such as exposure to heights, virtual spiders and hostile avatars, all used in a manner safe for the tested individual, a safety that may not have been possible in real life. Safety while testing was also an issue in the development of this virtual reality system as a tool for testing and evaluating balance and walking. Here it is possible to expose an individual to events, that would represent a dangerous element for causing an injury in real life, or something that is impossible to do in real life (for instance tilting of the VE). When using this system a trained professional accompanies the test subject at all times. Emphasis was also made during the experiments to make the subjects feel safe when exposed to various parts of the equipment at first and then for the system in general. The tested individuals was also screened for simulator sickness using the simulator sickness questionnaire SSQ (Mc Cauley & Sharkey 1992).

2. METHODS

2.1 Method

We describe the development of a system to assess how attention demanding and unexpected events influence a person’s capacity to control balance and movement using a virtual environment (VE).

The technical system was divided in two parts, hardware and software. The hardware in the system consists of a V8 head mounted display (HMD) in which the computer graphics is presented in colour on a screen for each eye. There is also a tracker system (Ascension Motion Star) that provides a magnetic field and provides tracker data from sensors attached to the test person.

Two SGI computers were being used to generate computer graphics and collect data from the motion tracker system. The participant was during the trial equipped with the Ascension Motion Star tracker system, with nine motion sensors (figure1). The software consists of the image generation of the VE and the management and visualization of motion tracking data. Here data from the walks can be visualised by the representation of a skeleton on the screen with trackers trails set at desired length to enhance the visual assessment of the movements. Tracker data in 3D was also being collected during the experiments in real time. All the software used in the experiments is developed at VRlab in Performer

[<http://www.sgi.com/developers/devtools/apis/performer.html>], and OpenGL [www.opengl.org].

This system enables immersive virtual reality where the subject may perceive as being part of the environment. What this means here is that the individual, while being in the VEm can look around in any direction and still be surrounded by only computer generated images, presented for each eye in such a way that these generated images appear to be the real thing - the surrounding world.

2.2 *The environment and individuals tested*

The VE was an immersive 3D model of a market in the centre of Umeå city, well known to the participants who all lived in this community. The VE shows the ground materials in the city square, as well as representations of all the surrounding buildings plants and other objects. Colours are presented to look like the real downtown of the city. As the individuals tested the environment they all felt familiar to the city presented as being the city of Umeå, known to them before.

The VE is however short of other virtual persons (avatars). Connected to the VE was the control system through a TCP/IP network connection. This enabled the control system to manipulate the VE in all regards, such as the start and stop of the events.

Individuals tested; due to the nature of this study, being the first of its kind, using very advanced technical tools, we wanted to include both young and old individuals, since we had received input that the system may be too complex for older individuals. In this preliminary pilot study eight persons (age 23 to 80) participated, after being asked for voluntary consent. They all had good balance performance on traditional clinical tests, and being ADL independent, they were also independent walkers. All participants also lived in their own home in the local community.

Emphasis was made that each tested person should feel as safe as possible during the experiments. For this reason time was given for the subject to get acquainted with the equipment. By for instance being given the chance to try walking around with the sensors alone without the HMD. A test leader (trained personnel) was also walking beside the subjects at all times, ready to grasp, but never holding on to, a hip belt with safety handles. This hip belt was used at all times while being part of the walking part of the test session. This was done in order to ensure that no injuries were caused while the individuals were being tested. Some of the subjects also expressed a feeling of safety just by knowing that there was someone walking beside them while they were performing the tests. On the other hand no instructions were made as to what was going to happen regarding the disturbances (the events) in the VE. The individuals tested was also allowed to walk in their own pace. This was important since the character of this study was that of a pilot study performed to make initial observations in this recently developed system and to collect background data, and to test the systems usability.

During the experiments, each person walked on a normal floor and was visually fed the familiar environment in the HMD and was exposed to different unexpected events, such as a virtual snowfall and tilting of the VE (fig 1).

3. RESULTS

There were technical difficulties evident during the experiments. External magnetic fields were present in one building and prevented the use there. The triggering of the events at the right time was another issue. In order for the test persons to have a chance to experience them as being events and not just system errors there had to be a certain timing involved. Here previous experiences in each individual may also have played a role. The virtual snowfall is such an event that may be perceived as a malfunctioning screen or a system error to someone not used to snow.

The positive results found was that the system could be used to influence walking among the participants while data was being collected. In general there was the feeling of being safe and well taken care of during the experiments. This was especially encouraging since an effort had been made to generate such a feeling before starting the experiments. The safety issues was a part of the study protocol in this manner. Evident disturbances of balance and walking pattern such as changes in speed, stride length and balance reactions like slipping were observed (table 1).

We also found that the system could be used for both with younger and older test subjects. Here no particular difference was observed regarding handling of the equipment or tolerating the system among the participants. However one must remember that the number of subjects in this study is not large enough to provide any clear evidence. For this reason we have chosen to present data from each individual as seen in table 1.



Figure 1. Setup of the HMD and sensors.

Two persons experienced symptoms of cyber sickness, with a SSQ score above 25 points. Measurements of walking time was being made, here walking with sensors only did not affect walking time. A striking finding on the other hand was that while walking in VE the persons generally walked more slowly. Among the events there seemed to be some difference as to the degree of impact on walking and balance. Virtual tilting of the environment had an impact on balance performance, and the system could provoke fall tendency by using this event among the test subjects. This effect was not seen in a virtual snowfall, an event that for some individuals went by without any observed impact on walking and balance. All individuals tested here had an experience of snow previously.

Table 1. Observed balance reactions while walking in VE with and without events.

	80	74	72	69	34	26	23	23
age	80	74	72	69	34	26	23	23
sex	F	M	M	F	M	F	F	F
Walking track without events	*							
Walk 1 with events	**	*	*		*	*	*	*
Walk 2 with events	**	*	*	*			*	*

* balance reaction, ** close to falling

4. DISCUSSION AND CONCLUSIONS

This study represents our first pilot attempt to perform immersive virtual reality for the assessment of balance and walking, during events which may provoke falls. The results and conclusions must therefore be viewed with extreme caution, since the number of test persons is small and this is the first study performed. As mentioned above, evident disturbances of balance and walking pattern such as changes in speed, stride length and balance reactions like slipping were observed. We found evidence for cyber sickness, with a SSQ score above 25 points for two test subjects.

There also seemed to be differences in walking speed when the subjects were immersed in the virtual environment. Here, walking with sensors, but without the HMD did not affect walking time, but in VE the persons generally walked more slowly. Why this phenomenon occurs with slowing of the walking speed in our system still remains to be elucidated. One possible explanation is the limited field of view that the V8 HMD provides. Here the peripheral vision normally gives important cues to balance during walking that are no longer present while the person is immersed in the VE with the HMD. There may also be other technical issues involved such as how the VE corresponds to the real world during walking. It oftentimes may be so that there are imperfections as to how a subject perceives the forward motion in VE as compared to the normally experience of moving forward when walking down the street. Maybe there is a need here to optimise the system further and evaluate the results from future studies.

Virtual tilting of the environment was the event disturbance that had the strongest impact on balance performance, and by using this visual disturbance fall tendency could be provoked. Initially the idea was that this tilting of the VE should give the feeling of actually falling while standing up. However the event rather seems to provoke fall tendency or even falls, and gives the impression that the world is leaning or tilting. The fall itself seems to generate when the tested individual tries to compensate for the abnormality generated by the computers during the tilting of the world.

The VE system was tolerated well also among older test subjects, important for its tentative use for this age group. The model needs further development, possibly by using smaller and cheaper personal computers in the nearby future, by making use of a cordless tracker system, and by finding methods to calculate and measure the observed balance reactions.

Other ways to improve the system would be by adding interactive avatars. Such interactions while measuring movements in immersive VR might add more information on the interplay of the capacity to process higher cognitive functions while maintaining a balance task, and final balance performance during such a task. By the use of different kinds of avatars and by adding sounds in the future emotion reactions may also be added as a further complication in this model.

The system clearly holds a potential for making repeated measurements in a standardized manner, a prerequisite for its clinical use, as an instrument for testing and evaluation. The system may in the future also be used as a training tool, set at different levels of difficulty, to fit individual needs. Much in the same way clinical rehabilitative training is individualized today.

Tested individuals could be provoked to having balance reactions and some also came close to falling. Still by taking certain precautions, such as careful information, and using a hip safety belt, we managed to avoid falls during the study. Still it is important to remember that the tested individuals were all independent walkers with good balance performance on clinical balance testing. When testing patients with a previous history of falls and possibly also concomitant disease even more precaution in order to avoid falls is probably needed.

Another strategy of model development is to make the VE simpler, with fewer objects, but still enough to challenge and support the tested subjects. Here the development of a virtual corridor is well under way. In such a model methods to improve the measurements of each step is desired, both regarding stride length, and pace, but also regarding weight distribution and pressure. This model holds the potential for testing both expected events, that is events that allows the test person to plan ahead, and beforehand decide on a walking strategy for instance, and to test how an individual may react to unexpected events, that is an event that takes place while the test person is already performing a task with his or her movement strategy in progress. The event then calls for immediate corrective reactions in order to avoid a fall. Here the sum of multisensory input and this added level of difficulty may end up competing with limited brain and neuromuscular capacity, to maintain walking and balance. Here the virtual environment instrument may be important to find persons at risk of falling on an early stage in order to possibly undertake fall preventative measures as soon as possible.

Acknowledgements: The KK Foundation, The Knut and Alice Wallenberg Foundation, VLL, Umeå Universitet

5. REFERENCES

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