# Affordable Driving Simulation for Use in a Rehabilitation Setting: Preliminary Findings

Yuval Naveh, Penina Weiss, Navah Z. Ratzon

**Yuval Naveh,** MSc, OT, Department of Occupational Therapy, Bayit Balev Hospital; Maccabi Health Care Services, Bat Yam, Israel. TMN Driving devices. yuval.naveh@gmail.com

**Penina Weiss,** PhD, OTR, CDRS, Occupational Therapy Department, Rabin Medical Center- Beilinson Campus, Petach-Tikva; Occupational Therapy Department, Sackler Faculty of Medicine, Tel Aviv University, Israel. pninavi@clalit.org.il

**Navah Z. Ratzon,** Occupational Therapy Department, Sackler Faculty of Medicine, Tel – Aviv University, Israel. navah@post.tau.ac.il

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## Abstract

Over the past decade virtual reality has developed from basic three dimensional (3D) interactive programs running on sophisticated computers to immersive programs running on modern laptops. One of the most promising applications is the simulation of driving scenarios for the evaluation and treatment of executive functions related to driving. However, most software applications in this field are too expensive for most clinicians. In this study two PC Windows-based programs that simulate driving scenarios were compared to determine whether it was feasible to use a low cost driving program in a driving rehabilitation clinic and whether the perceived presence of the lower priced (off-the-shelf) program was experienced as less immersive. Our specific goals were: (A) to examine the perceived presence experienced while using each of the two simulators; and (B) to examine the subjective impression of participants regarding the use of these programs. Nine certified occupational therapists volunteered to compare their perceived presence while using the simulators and report their subjective impressions of each program. Our findings indicated no major differences between the two programs with respect

to most of the parameters measured. Thus, it appears that an off-the-shelf inexpensive program has the potential to be used for driving rehabilitation. However, further investigation is required due to the small sample size and use of healthy participants recruited for the current preliminary study.

# Introduction

Virtual reality (VR) is a technology which allows a user to interact with a computer-simulated environment. Virtual environments (VE) are primarily visual experiences displayed either on a computer screen or through special stereoscopic displays. Rizzo and Buckwalter (1997) suggested that "VE offers the potential to develop human testing and training environments that allow for the precise control of complex stimulus presentations in which human cognitive and functional performance can be accurately assessed and rehabilitated" (p.123). With recent improvements in VR technology, driving simulators seem to offer a promising alternative to on-road methods of driving assessment. Lee, Lee, Cameron, and Tsang (2003) argue that low cost PC-based driving simulators, made possible by the current advances in personal computer technology, have better face validity than traditional psychometric tests. In addition, these simulators have been found to be a safe and cost-effective means of testing performance under different driving situations. Moreover, although simulators are not perfect surrogates for the on-road setting, research findings have indicated that people's performance in a simulator is similar to their performance on the road (Bédard, Riendeau, Weaver, & Clarkson, 2011).

Despite these potential advantages, very few studies have assessed the subject's sense of presence and the ecological validity of the simulators, and none have attempted to identify affordable simulators appropriate for use by clinicians or that could enable virtual training in one's own home.

## Driving Simulators and On-Road Assessment

A number of studies have addressed the relationship between simulated driving and on-road driving assessments. Wang, Zhang, and Salvendy (2010) demonstrated that intensive simulated driving intervention can improve novice drivers' abilities to deal with hazardous situations and that these abilities were maintained after the training period. de Winter et al. (2009) found similar results when using simulated driving programs for training before a driving test. Additionally, Shechtman, Classen, and Mann (2009) found that driving errors made when attempting to negotiate turns in the simulator can be generalized to the road under the same testing conditions. Finally, Devos et al. (2009) showed that driving simulators were superior to conventional cognitive training in rehabilitation of impaired on-road driving skills of individuals with mild deficit due to stroke. Overall, driving simulators have been shown to be extremely useful clinically, providing a safe and economical alternative for driving training among traumatic brain injured patients, as well as for assessing the driving performance of older adult drivers (Akinwuntan et al., 2005; Lee, Cameron, & Lee, 2003).

**Driving Simulators and Psychometric Off-Road Measures**

Driving is a complex task requiring a range of cognitive and psychomotor abilities including memory, judgment, motor control, decision making, attention, and executive function (Freund, Gravenstein, Ferris, Burke, & Shaheen, 2005). Studies have shown that psychometric tests could not predict driving ability (Van Zomerenm, Brouwer, Rothengatter, & Snoek, 1988) and Freund et al. (2005) claimed that no single cognitive assessment is adequate for the assessment and evaluation of a person's driving capability. However, some researchers have suggested the inclusion of the Mini Mental Status Examination, the Rey-Osterrieth Complex Figure Test and Trail Making Tests A and B in the occupational therapy off-road driver evaluation (Unsworth, Lovell, Terrington, & Thomas, 2005). For active older drivers correlations were found between the STIMSIM model 400 (Systems Technology Incorporated, Hawthorne, CA) and the clock drawing test (Freund et al., 2005).

**Driving Simulators and Self-Awareness Variables (impulse control and reaction time)**

One of the major prerequisites for safe driving is the ability to correctly perceive and interpret the current traffic situation and consider these elements in planning and controlling one's driving behavior (Baumann & Krems, 2007). Despite the seemingly apparent complexity of the task, individuals with brain injury are less aware of the effects of their deficits on their driving ability (Fleming & Stong, 1999). In another study, the behaviors of experienced and inexperienced drivers who were trained within a virtual "risky scenario" were compared to inexperienced young drivers who did not undergo this virtual scenario. The results of inexperienced drivers who underwent virtual training and those of experienced drivers differentiated measurably from those of the young inexperienced drivers who didn't train on the virtual scenario (Fisher et al., 2002).

Although the advantages described and the wide acceptance that using VEs is an effective and motivating tool, the rehabilitation team faces a challenge to find an off-the-shelf VR system that would enable achievement of the goals stated, yet affordable by the typical clinical facility. A still greater challenge is to find motivating intervention tools that a client could afford to acquire for home-based therapy (Rand, Kizony, & Weiss, 2004). Therefore the aim of this study was to compare two PC Windows based programs that simulate driving scenarios and verify whether a low cost off-the-shelf driving simulator would be feasible for use in a driving rehabilitation clinic. Certified occupational therapists volunteered to participate in the study. Our specific goals were: a) to examine the perceived presence experienced while using the two simulators, and b) to examine the subjective impression of each program, before acquiring knowledge about the technical specifications of each one.

## Methods

### Participants

Nine healthy certified practicing occupational therapists volunteered to participate in this study. This sample including six females and two males, aged 28 - 42 (mean age= 35; SD=4.3), undergoing their masters' degree or clinical guidance course in the occupational therapy department at the Sackler Faculty of Medicine in Tel-Aviv University. All participants had a driving license for the last 14.6 (5.5) years and drive 1.65 (0.4) hours per day.

### Instrumentation

**Apparatus.** The standard paradigm comprised a desktop 350-Mhz Pentium IV processor with 256-Mb Ram and a 128-Mb ATI. A radeon graphics card was used. The two PC-based computer simulation programs compared were the STIMSIM Drive™ (http://www.stisimdrive.com) and the 3-D Driving School (http://www.3dfahrschule.de/uk_index.htm). The STIMSIM Drive™ Ver 2.04.02 was developed for use in rehabilitation, and cost an average of US 10,490$ that including 10 hours of phone/fax/email support. In contrast, the 3-D Driving School program was developed to teach basic driving skills, and cost on average 18,00-21,50 €.

The main properties of the STIMSIM Drive™ are:

- Scenario replay and a wide range of data collection capabilities.
- A module for simulating driving under the influence of substances, such as alcohol.
- A driver assessment and training system.

The main properties of the 3-D Driving School program are:

- Different types of training grounds, such as big city or cross-country driving.

- Driving during various environmental conditions, including rain, snow and night time driving.
- A fleet of vehicles suitable for training for different driver license classes.
- It can be implemented with or without the use of a driving supervisor's instruction.
- A diploma is presented at the end of each level accomplished.

The car control for the STIMSIM was provided by a Microsoft SideWinder steering wheel with force feedback and accelerator/brake foot pedals. In contrast, car control for the 3D-Driving School program was based on the Logitech MOMO steering wheel and accelerator/brake foot pedals. The participants were seated comfortably on a regular chair positioned in front of the steering wheel and screen.

**Evaluation of presence.** Presence was measured by the Presence Questionnaire (PQ) translated from Witmer and Singer (1998). The PQ assesses different aspects of presence such as: involvement/control; natural, interface quality and resolution. The level of presence is rated on a scale from 1 (low) to 7 (high). The Questionnaire was freely translated by the first author specifically for this protocol.

**Subjective parameters.** Subjective parameters were examined through a rating scale developed for the purpose of this study. The specific parameters measured were the ability to control the driving simulator and to control the environment. The rating scale for each parameter was designed to match the scale used in the PQ. Thus, scores ranged from 1 (least favorable) to 7 (most favorable).

**Objective parameters.** These included background data on the programs, as listed in Table 1.

Table 1
A Comparison bBetween the STIMSIM and the 3D Driving School Simulators

| Parameter | STIMSIM | 3D Driving school |
|---|---|---|
| Price | US 10,490$ | 18,00 € - 21,50 € |
| Included support | Yes (10 hours) | No |
| Extra technical support needed | Yes | No |
| Number of allowed installations per license | 1 | 14 |
| Free evaluation that can be downloaded from the internet | No | Yes. A basic version for a limited time |
| Available for practicing at home at a reasonable price | No | Demo version available on the internet |

**Procedure**

A specific route was selected for each of the participants in each of the simulators. The sequence in which the driving simulators were experienced were counterbalanced. That is, five participants experienced the STIMSIM first and then the 3D-Driving School, whereas the order was reversed for the other four. Immediately after driving the predefined route for 10 minutes, each subject completed the PQ, to record their subjective impression of the simulators and their preferred simulator. The objective parameters (Table 1) were also provided to the subjects after they experienced the driving simulators.

**Data analysis**

Due to the small number of participants, the data obtained from the PQ and the subjective questionnaire were examined through the use of descriptive statistics.

# Results

Our findings verify the similarity between these two PC based programs for most of the parameters measured. The main findings demonstrated that the mean scores for the Driving School was higher than the STIMSIM in three parameters: the sense of "being there" in the virtual environment (3.6 ± 1.14 vs. 2.75 ± 1.5), the potential for use for treatments in an occupational therapy setting (4.2 ± 0.4 vs 3.25 ± 0.9), and subjects had less discomfort while using the simulator (2.2 ± 0.8 vs 4 ± 1.0). Results of the remaining parameters were found to be similar.

Table 2
Descriptive Statistics of the PQ and the Subjective Questionnaire

| Factor | SIMSIM | | Driving School | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| How much did you enjoy yourself during the experience? | 4.5 | 1.0 | 4.0 | 1.0 |
| How much did you have a sense of "being there" in the virtual environment? | 2.75 | 1.5 | 3.6 | 1.14 |
| How well did you succeed in the mission? | 2.25 | 0.5 | 2.0 | 0.7 |
| To what extent did you feel as though you were actually controlling the driving simulator? | 1.75 | 0.5 | 2.0 | 0.0 |
| To what degree did you have the feeling of control on the vehicle? | 3.25 | 0.95 | 3.2 | 1.3 |
| Does the simulator have potential for use in evaluating driving skills in an occupational therapy setting? | 3.0 | 0 | 3.2 | 1.0 |
| Does the simulator have potential for use for treatments in an occupational therapy setting? | 3.25 | 0.9 | 4.2 | 0.4 |

| | | | | |
|---|---|---|---|---|
| Does the simulator have potential in clinical setting? | 3.5 | 0.5 | 4.0 | 0.7 |
| Did you feel any discomfort while using the simulator? | 4.0 | 1.0 | 2.2 | 0.8 |
| Ease of use | 3.8 | 1.69 | 4.3 | 0.8 |

It should be noted that the 3D Driving School program requires the use of driving wheel buttons to activate "turn signals" when changing direction and adjusting mirrors whereas this option was not provided in the STIMSIM. The use of the buttons did not complicate usage as described by the higher values obtained for the parameter of ease of use in the 3D Driving School (4.3 ± 0.8) versus the values for the same parameter after experiencing the STIMSIM (3.8 ± 1.69). Moreover, on average, subjects reported discomfort more often while using the STIMSIM (4.0 ± 1.0) than when using the 3D Driving School (2.2 ± 0.8).

## Discussion

In the current study two PC Windows-based programs that simulate driving scenarios were compared. The purpose of the study was to determine whether a low cost driving program would be feasible for the use in a driving rehabilitation clinic, and assess whether the perceived presence using the lower priced (off-the-shelf) program was experienced as less immersive. The results showed very similar experience of perceived presence and similar subjective impressions regarding both simulators.

The use of simulators in driving evaluation, instruction, rehabilitation and training is an under explored area and research in this field points to the relevance and importance of the use of this medium (Akinwuntan et al., 2012; Backlund, Engström, Johannesson, & Lebram, 2010).

Advantages of using driving simulators for the evaluation and training of driving capabilities include safety issues, time savings, space and equipment considerations, cost efficiency and accurate documentation. The use of driving simulators may be especially appropriate for use in driving rehabilitation programs, since the on road driving assessment among persons with various disabilities is quite risky. Give that the responses of individuals with disabilities are often unpredictable, on-road assessments can endanger all persons in the vehicle as well as other drivers on the road. In contrast, the simulator provides a safe environment for the initial evaluation of driving skills. This does not eliminate the need for an on-road evaluation but better prepares the driving rehabilitation specialist and driving instructor as to the behaviors and skills that should be carefully observed and may prove to be hazardous (Unsworth, 2007).

In regard to training, the simulator again provides a safe environment in which to retrain and integrate cognitive and motor skills, such as reaction time and visual scanning. This top-down process may afterwards be implemented in the actual on-road training, which represents the next step in the rehabilitation process of the disabled (Cox et al., 2010).

In our pilot study, the findings indicated that occupational therapists showed a tendency to prefer an "off the counter" driving simulator such as the 3D-Driving school that has the potential to serve as an affordable and available for use in an occupation therapy setting.

We believe that the future of virtual environment driving simulators relies on the ability of clinicians to afford it, as well as whether they are appropriate for use by clients for training in the comfort of their homes. This is an extremely important factor, since it is vital to perform an enormous amount of repetitive training to learn these new skills.

Currently, flight simulators have become so sophisticated that the highest approved category of simulators do not require any actual flight time for training pilots who are preparing for their ability to fly a new and different type of airplane (Tong & Galanis, 2010). Thus, given the rapid technological advances nowadays, it is possible that driving simulators will soon be an essential part of the equipment of every occupational therapy rehabilitation unit.

**Summary**

This study represents a preliminary survey to determine whether the perceived presence of an affordable off-the-shelf driving simulator would be similar to that experienced in a much more expensive program. According to the reports of the study participants, the current study findings indicate that this is indeed the case. Therefore, it is possible to consider the use of this affordable tool by occupational therapists working in rehabilitation settings. If future research findings will validate those of the current study among clinical populations, this could pave the way for expanding the use of affordable driving simulators in occupational therapy rehabilitation programs.

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