Development of a Portable Virtual Reality Driving Interface to Retrain Drivers with Spinal Cord Injury

Lisa K. Simone, Ph.D. [1], John A. Simone[2], Roman Mitura[3], Dean Klimchuk[3], Maria T. Schultheis, Ph.D.[1]
[1]Kessler Medical Rehabilitation Research and Education Corp (KMRREC), West Orange, NJ.
[2]Virginia Tech, Blacksburg, VA [3] Digital MediaWorks, Inc., Kanata, Ontario, Canada

Objective

To design and build an accessible Virtual Reality (VR) driving simulator to help individuals with Spinal Cord Injuries relearn driving skills in a safe environment.

Research goals:
Evaluate to see if the additional training using VR can reduce the number of evaluator-led training sessions and increase "return to driving."

Development goal:
To create VR driving simulator hardware with adaptive equipment that is low cost, portable, and easily deployable to a wide range of sites including rehabilitation centers, doctor's offices and outpatient facilities.

Rationale and Requirements

Examples of Existing VR Simulators with hand controls

I Actual Car Simulators
The most common configuration uses an actual car or the front half of a car containing the driver's compartment, appropriate adaptive equipment, and a large projection screen.
(Ku, J. H., Jang, D. P., et al. (2002). Development and validation of virtual driving simulator for the spinal injury patient. Cyberpsychol Behav 5(2): 151-6.)

Limitations: Costly, Not portable, Not readily available to all patients

II Desktop Simulators
The desktop VR simulator has a hand controls option which is a module under the steering wheel that only mimics the mechanical control of the foot pedals, reducing the realism of the system.
(Simulator Systems International, Tulsa, OK, and Sim-Drive Canada, Cochrane, Alberta)

Limitations: Lack of realism

Conclusions
- Simulators have been used successfully with SCI
- Limitations hinder the clinical application and use

Requirements for the System

Feedback on the design was received from the SCI Consumer Advisory Board and from 2 focus group sessions (total of 10 individuals with SCI) organized for this project.

The VR simulator must meet the following requirements:

Clinical
- Ability to measure driving parameters such as steering and brake reaction time, range of motion, lane position, speed, and distance to obstacles (including collisions).
- Very small lag between user input and simulation display update to avoid simulator sickness.

Physical
- Must maintain familiar steering wheel/foot pedal configuration for realism
- Portability (light weight, compact)
- Low cost
- Use of clinically recommended adaptive driving equipment
- Fully adjustable steering wheel/hand control unit (height, tilt, telescoping functions)
- Appropriate clearance for wheelchair access

Design

The VR driving simulator is PC-based using 1 or 3 flat screen displays, which can be large or small depending on cost and space issues. The simulator consists of 3 sub systems: Hardware, Interface, and Virtual Environment Software systems.

Hardware:

Steering wheel – From a 1987 Cadillac Deville, with full telescoping and tilt functionality.

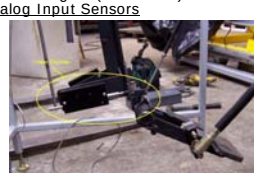
Adaptive Equipment – Hand controls for acceleration and braking + spinner knob and tri-pin.

US Digital USB-based Data Acquisition System
- 3 encoders
- 4 digital input signals (turn signals, gear shifter, ignition switch)

The Interface:

Digital Inputs
Switch positions available from 3 wiring harnesses from the steering column.
- Ignition switch (Harness C)
- Gear shift (Harness B)
- Turn signal (Harness A)

Analog Input Sensors



Linear encoder for each foot pedal (500 counts per inch on depression) position.

Rotary encoder for steering wheel position (1/3 degree resolution).

Virtual Environment Software:

High speed data acquisition provides real-time position and switch information to the virtual environment software (by Digital MediaWorks, Inc.) up to once every millisecond.

Commercial Area

Residential/School Area

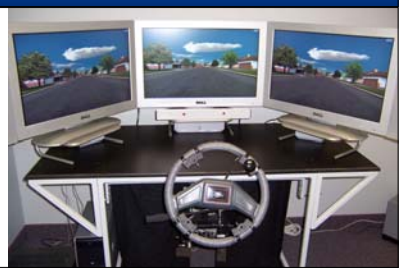
Highway Area

Operation

The operation of the VR driving simulator is identical to that of a real car.

- The brake pedal (using the hand controls) is depressed
- Ignition is turned to start the car
- Shifter is put into gear

The software constantly monitors all the hardware parameters. When the user turns the key, the simulator "starts" the virtual car and places it in drive. When the participant accelerates, the virtual car accelerates and the virtual environment reacts to every action that the participant makes.



Current Status

This unique driving simulator system contains actual driving components to provide a realistic driving experience at a lower cost than full car simulators, and is more realistic than desktop models.

This unique system is:
- Portable (can be unbolted into 4 manageable pieces)
- Less expensive ($2000 w/o monitors)
- Realistic: actual steering wheel, turn signals, shifter, hand controls
- Hardware and interface are completed; integration with software in progress
- Clinical trials are beginning

Future Directions

Flexibility for the Future
The data acquisition interface is reconfigurable; additional analog and digital inputs can be easily plugged into the USB interface in order to capture additional physical or physiological parameters such as grip force and pedal force.

Long Term Goals
We intend to make manufacturing recommendations based on the results of this study to identify the critical hardware configurations that are needed in a final production system.

Acknowledgments: Funding provided by The New Jersey Commission for Spinal Cord Research (NJCSCR) and the Henry H. Kessler Foundation.

Donations of auto equipment, hand controls, mechanical design, and labor were received from Price AutoWreckers (Bridgewater, NJ), Drive Master (Fairfield, NJ), and Spadix Technologies, Inc. (Middlesex, NJ).

For additional information, please contact Maria T. Schultheis [redacted] or Lisa K. Simone [redacted]