The Effectiveness of Driving Simulators on Driver Retraining and Assessment with TBI/Stroke Survivors

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Disciplines
Occupational Therapy

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The Effectiveness of Driving Simulators on Driver Retraining and Assessment with TBI/Stroke Survivors

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Date: 10/31/2011
Review date: 10/2013

CLINICAL SCENARIO:
One of the activities many TBI and stroke survivors wish to return to after receiving their injury is driving; however, their ability to drive has often been impaired. Safety has become the main issue in assessing driving ability as on-road tests may not always be feasible with this population due to cognitive impairments. Driving simulators are a safe way to assess and retrain driving skills in TBI and stroke survivors. In addition to safety, simulators are also able to provide a wide range of driving scenarios with varying traffic that an evaluator would not be able to control for on an on-road test.

Many of the TBI and stroke clients are physically fit to drive but lack the cognitive processing for safe driving. Because they are physically able to drive, many will continue to do so regardless of negative advice from professionals. A driving evaluation done with a simulator could add some weight to the clinician’s advice in discouraging unsafe clients from driving. On the other hand, if clients are so determined to drive contrary to clinical recommendations, a safe way to retrain and build their driving abilities is needed so that at least they have the skills to drive.

FOCUSED CLINICAL QUESTION:
How effective are driving simulator programs on driver assessment and retraining in comparison to other training programs and assessments with TBI/stroke survivors?

SUMMARY of Search, ‘Best’ Evidence appraised, and Key Findings:

- Five research articles covering various driving simulator programs were selected for analysis.
- The article deemed as “best evidence” was written by Devos et al. (2010). It discussed a follow-up of a randomized control study that looked into finding differences in driving performances after five years between stroke survivors who underwent driving simulator training and those who partook in cognitive rehabilitation therapy for driving. The study also looked at the difference at five years in depression rates between those of the participants who returned to driving and those who gave it up. Study indicated that after a short term follow-up of six months, participants who received simulator training showed much more improvement than those who received cognitive rehabilitation. After five years, however, the difference between groups was negligible. Driving status at the five year follow-up did not correlate with severity of depression when factoring in age and other health conditions.
• Cox et al. (2010) also looked at the feasibility of using a driving simulator program for re-training. This study focused on military personnel with TBI as its population. It was found that the participants who received simulator training had improved driving performances with lower risky driving and road rage scores.

• Study done by Lew et al. (2005) investigated the validity of using driving simulator and road test assessments to predict long term driving performance in TBI survivors. The simulator was able to distinguish between the control group of healthy participants and TBI survivors as an initial test of the simulator. Driving scores on the simulator significantly correlated with long term community driving performance. Simulator evaluations identified information about the person’s driving skills that did not show up in the road test. It was concluded that driving simulators can add more information to the road test.

• Bedard, Parkkari, Weaver, Riendeau, & Dahlquist (2010) tested the validity and reliability of a driving simulator assessment by comparing it to an on-road evaluation and neuropsychological tests. Correlations were moderate to high between the simulator and the neuropsychological tests. There was also a significant correlation between the on-road test and the simulator. Study also showed high interrater and intrarater reliability for evaluators’ scoring on the simulator.

• Patomella, Tham, & Kottorp (2006) examined the validity of the P-Drive assessment when evaluating people with stroke on a driving simulator using Rasch analysis. The study showed that P-Drive using a simulator was successful in differentiating participants based on driving skill.

**CLINICAL BOTTOM LINE:**

In addition to being able to physically operate a car, driving also involves higher cognition and visual skills that may not be present after a person has received a stroke or TBI, thus making it a safety risk to assess stroke/TBI survivors who want to return to driving. These studies have shown that a driving simulator is a valid tool for evaluating and retraining clients with stroke or TBI.

**Limitation of this CAT:** This critically appraised topic has been peer-reviewed by another independent person. This paper was created by a second year MOT student, and the research is not exhaustive.

**SEARCH STRATEGY:**

Terms used to guide Search Strategy:

• **Patient/Client Group:** TBI/Stroke Survivors

• **Intervention (or Assessment):** Driving Simulator

• **Comparison:** Other driving evaluations and training programs

• **Outcome(s):** Driver Retraining and Assessment
### Databases and sites searched

<table>
<thead>
<tr>
<th>Databases and sites searched</th>
<th>Search Terms</th>
<th>Limits used</th>
<th>Date Searched</th>
<th># Found</th>
<th># Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>CINAHL</td>
<td>Driving and Simulation</td>
<td>Full Text; Academic Journals</td>
<td>09/2011</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Simulator and Stroke</td>
<td>Academic Journals 1 repeat</td>
<td>09/2011</td>
<td>13</td>
<td>1</td>
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<tr>
<td>MEDLINE</td>
<td>Driving AND Simulator AND Stroke</td>
<td>Full Text; Evidence Based Medicine Reviews 3 repeat</td>
<td>09/2011</td>
<td>3 repeat</td>
<td>0</td>
</tr>
</tbody>
</table>

### INCLUSION and EXCLUSION CRITERIA

- **Inclusion:**
  - Full Text
  - Academic Journals/Evidence Based Reviews
  - Studies looking into viability of using driving simulators as assessments
  - Studies looking into the validity of using driving simulators as retraining tools for participants with TBI or stroke.

- **Exclusion:**
  - Studies that did not include a simulator for testing.
  - Studies done on the effects of miscellaneous conditions on driving performance.

### RESULTS OF SEARCH

5 relevant studies were located and categorised as shown in Table 1 (based on Levels of Evidence, Centre for Evidence Based Medicine, 1998)

**Table 1:** Summary of Study Designs of Articles retrieved

<table>
<thead>
<tr>
<th>Study Design/ Methodology of Articles Retrieved</th>
<th>Level</th>
<th>Number Located</th>
<th>Author (Year)</th>
</tr>
</thead>
</table>
BEST EVIDENCE

The following study/paper was identified as the ‘best’ evidence and selected for critical appraisal.


Reasons for selecting this study were:
- This study gave the highest level of evidence in answering the clinical question.
- There are two follow-ups done, one at 6 months and another at 5 years.
- Fitness to drive at follow-up was determined by using multiple tests including: medical, visual, neuropsychological, and on-road tests.
- Participants received driving training from the same therapist.
- Study incorporated the use of a simulator for driver retraining.
- Use of statistical significance in reporting results.
- Driving evaluators were blinded to which group participants were in.

SUMMARY OF BEST EVIDENCE

Table 2: Description and appraisal of Effect of simulator training on fitness-to-drive after stroke: A 5-year follow-up of a randomized controlled trial by Devos et al. (2010).

| Aim/Objective of the Study/Systematic Review: | The initial study done in 2005 looked at effects of simulator training on driving ability for participants with stroke. This was done by comparing a driving simulator program to a cognitive rehabilitation therapy program. The purpose of this follow-up is to see the long term effects over 5 years of the driving simulator program and the cognitive rehabilitation therapy on driving performance in participants with stroke. This study looked to compare the results of both training programs. |
| Study Design: | 5 year follow-up of a Randomized Control Trial. Participants were measured at pre-test, post-test, 6 month follow-up, and 5 year follow-up. |
| Setting: | The study did not specify where the driver training programs took place; however the participants were recruited from the Rehabilitation Center of the University Hospital Leuven, Belgium where they received traditional rehabilitation therapy in addition to the driver training. |
| Participants: | There were 83 total participants at the initial part of the study and they were randomly assigned to an intervention group (Simulator Group, n=42; Cognitive Group, n=41). Only 61 of those 83 consented to partake in the 5 year follow-up (Simulator Group, n=30; Cognitive Group, n=31). Both groups had similar drop-out rates and no significant differences were found between baseline characteristics such as age (p=.83), sex (p=.55), education (p=.96), side of lesion (p=.08), type of stroke (p=.54), Barthel index (p=.62), and fitness-to-drive decision (p=.47). Participants in the RCT were recruited from Rehabilitation Center of the University Hospitals Leuven, Belgium while they were patients. The inclusion criteria for participants were as follows: participants needed to have medical documentation of a stroke; stroke had to have happened within the past 3 months; participants had a driver’s license prior... |
to stroke; and they must have been active drivers prior to stroke. Exclusion criteria included the following: if participants were older than 75; if they had any seizures within the past 6 months; or if they had severe aphasia.

**Intervention Investigated:** On top of their standard rehabilitation for stroke, participants received 15 hours of driver training over a 5 week period, 3 times a week, and for 1 hour a day. All participants were trained by the same therapist.

**Control (Cognitive Rehabilitation Therapy):** Participants were educated on problem-solving skills, visuospatial skills, planning, memory training, road sign recognition, and route finding using various shelf/board games. They would perform cognitive tasks related to driving such as route finding on a map (Akinwuntan et al. 2005). Road sign recognition was exercised by using 40 picture cards with different traffic scenarios.

**Experimental (Driving Simulator Program):** Participants first spent 2-3 hours getting acquainted with the simulator. After the warm-up, participants underwent a pre-driving test (different from pre-test evaluations, determining whether or not the person was fit to drive) in which number of collisions, pedestrians hit, excessive speed, traffic light faults, total faults, and run-time were recorded (Akinwuntan et al. 2005). Participants then received comments on their performance. Training then commenced using twelve different 5 km courses on the simulator program. Participants were able to train driving abilities such as: lane tracking, speed control, anticipation, road sign recognition, hazard perception, and overtaking maneuvers. Skills were first trained in typical on-road traffic on the simulator, and then with added difficulty as the participant progressed. The post-drive test was administered the 5th week of training which mirrored the pre-drive with the exception of a different simulator course being used.

**Outcome Measure (Primary and Secondary)**
All measures were done at pre-test, post-test, 6 month follow-up, and 5 years follow-up. The assessments were carried out by neuropsychologist and driving evaluation experts of the Center for Evaluation for Fitness-to-Drive and Car Adaptations (CARA) Department of the Belgian Road Safety Institute, Brussels. The primary outcome measure of fitness to drive was determined by the health professional team at CARA based on medical, visual, neuropsychological, and on-road testing. This team consisted of a physician, a psychologist, and an occupational therapist (Akinwuntan et al. 2005). Secondary outcomes looked at were driving status, comorbidity, rates of depression, kilometers driven per year, and number of self-reported traffic tickets and accidents.

- **Medical Tests**
  - MRI and CT scans: used to determine if the person had a stroke
  - Barthel Index: Used to determine amount of impairment of the participant.
    Consists of 10 items with total scores ranging from 0-100 that measure person's ability to perform ADL’s. The higher the score, the more functional the person is.

- **Visual Tests**
  - Unspecified Monocular, Binocular, and Kinetic Vision Tests: assessed participant’s ability

- **Neuropsychological Tests**
  - Useful Field of View (UFOV): tests speed of mental processing, divided attention, and selective attention.
  - Stroke Driver Screening Assessment: looks at attention, visuospatial abilities, and executive functioning.

- **On-road Test**
  - Test Ride for Investigating Practical fitness-to-drive (TRIP) checklist: items were scored on a 4-point scale (0-3).
- **Depression Test**
  - **Hospital Anxiety and Depression Scale**: 14 item assessment with a 4-point Scale (0-3). Items are marked either as ‘A’ for anxiety or ‘D’ for depression. Adding up similar items together for scores: 7 and below=normal; 8-10=mild; 11-15=moderate, 16 and above=severe.

- **Interviewing**: used to determine kilometers driven per year, number of self-reported traffic tickets and accidents and driving status.

**Main Findings**: In the simulator group, 18 of 30 (60%) were considered fit to drive, while 15 of 31 (48%) in the cognitive group were considered fit to drive at the 5 year follow-up. The $X^2$ statistic was used to compare the participants’ fitness to drive between and within the two groups. Percentage of those in the simulator and cognitive groups respectively who passed the driving evaluation was consistent over the 6 months and 5 years follow-up; however, proportion of participants passing between intervention groups was not significant at 5 years (p=0.09).

Furthermore, a generalized estimating equation (GEE) analysis, which is used to find correlations between parameter, was done to compare the effects of the two training programs over time. It was found that the probability of passing the driving evaluation was greater at 5 years follow-up than at pre-training (p<0.0001). The analysis revealed that the effects of intervention over time were not significant for either groups (p=0.45), as the proportion of participants who passed was similar for both groups at 6 months and 5 years. Also, the difference in success rates between the groups over time were not significant (p=0.36).

Cause for the 10 drop-outs (5 from each group) during training was not directly related to the training. High drop-out rate at 6 months were determine to have occurred randomly and did not have a significant effect on the study, as there was no significant difference between the median improvement on the on-road test from pre-training to post-training between the 11 drop-outs from the simulator group and the 10 from the cognitive group. It was hypothesized that because patients were recruited in their acute phase of treatment, they may have miscalculated the difficulty of resuming driving. Drop-outs at 5 years occurred for the following reasons: medical complications, death, refusal, and missing contact information.

<table>
<thead>
<tr>
<th>Fitness to Drive Decisions</th>
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<tbody>
<tr>
<td>Pre-training (n=83)</td>
</tr>
<tr>
<td>cognitive simulator</td>
</tr>
<tr>
<td>Pass</td>
</tr>
<tr>
<td>4 (10%)</td>
</tr>
<tr>
<td>Fail</td>
</tr>
<tr>
<td>37 (90%)</td>
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</tbody>
</table>


Of the 61 participants, 34 (56%) were still driving at 5 years. Participants who gave up driving were significantly older and had lower Barthel scores, more comorbidity, and higher depression scores than participants who were still driving. Of those still driving, 7 reported comorbidity that might hinder their driving performance, while, 14 of those not driving reported comorbidity. Those who stopped driving exhibited more depressive symptoms at 5 years than at baseline (p=0.02); however, when adjusting for age and Barthel index score, the effect of driving status on severity of depression was not significant (p=0.36).

<table>
<thead>
<tr>
<th>Driving Status and Participant Characteristics at 5 Years Follow-up</th>
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<tbody>
<tr>
<td>Actively Driving (n=34)</td>
</tr>
<tr>
<td>Age, years (mean ± SD)</td>
</tr>
<tr>
<td>Barthel Index, median</td>
</tr>
<tr>
<td>Comorbidity (yes/no)</td>
</tr>
<tr>
<td>HADS (depression)</td>
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Other secondary findings:
- Participants drove less per year than before stroke (measured in km)
- No increased risk of accident involvement at 5 years when compared with before stroke
- Participants did report receiving more traffic tickets at 5 years than pre-stroke

Original Authors’ Conclusions: The study concluded that the driving simulator training does have favourable effects for retraining patients with stroke in an in-patient setting when compared to cognitive therapy at 6 months. The simulator speeds the recovery of driving abilities, as observed up to 6 months, but as time goes on, its effects minimize. At 5 years follow-up, there was no significant benefit of the simulator training on a person’s fitness to drive although the simulator group still had a higher percentage that passed. In addition, those who discontinued driving were older, scored lower on the Barthel Index, had more comorbidity, and higher depression scores than those who continued driving. Driving status did not seem to directly influence level of depression when age and disability was accounted for. The authors also felt that fitness to drive should be determined by multiple tests instead of just an on-road one. Using more tests further validates the decision of whether or not a person is fit to drive. Five of the 44 complete cases did not pass at the 6 month follow-up but did at the 5 year mark, showing that driver training needs to be included in later rehabilitative phases.

Critical Appraisal: In this follow-up, 27% of the participants were not accounted for, which may have altered the results of the study. In addition, only 44 out of the 83 participants went through all 4 evaluations (pre-test, post-test, 6 month follow-up, and 5 year follow-up). Another limitation was that the simulator training was not compared to on-road training. It would be interesting to see which one provides more carryover of skills. Also, 4 out of the 44 complete cases had their licenses reinstated at 6 months but had it taken away at 5 years. This backwards trend may have also skewed the results and should be looked into further.

Validity
Methodology: The following measures were deemed as valid and reliable: the Barthel Index, Useful Field of View test, Test Ride for Inventory Practical fitness-to-drive checklist, and the Home Anxiety and Depression Scale. The study failed to mention what visual tests they used and whether or not they were valid or reliable.

Sample: The adequate sample size for this study was determined by estimates from a previous study. The adequate size was 72, but to account for drop-outs, the authors increased the size to 83. However, drop-outs exceeded expectations and there were less than 72 participants for the two follow-ups. The previous study showed that 72 was the minimum needed in order to obtain an 80% chance of identifying an effect size of 0.5 between groups in the on-road test using an alpha level of 0.05.

Bias: The same therapist was used for both driver training groups and was not blinded to the study. If the therapist was leaning towards one intervention over the other, then that could skew the results.

PEDro score: 7/10

Interpretation of Results: The study did provide proof that driving simulator training is able to increase the driving skills of stroke survivors, with improvements seen up to 6 months. After a
long term period of 5 years it seems that improvements are negligible. This finding corresponds with other studies reviewed in this CAT in validating the simulator as a driver training tool.

**Summary/Conclusion:** This study provided good evidence of the validity of using simulators for driver retraining with stroke survivors. Although there was a large drop-out rate for the follow-up, between the pre- and post-training tests, the sample size remained above 72, which was the minimum amount needed. It did show that the effects of the simulator on improving driving skills were not long term. However, it would be interesting to see if the simulator training was done later in the person’s recovery or for a longer period of time, as some participants did go from fail to pass between the two follow-ups. The study also used on-road as well as off-road tests to measure participants’ fitness to drive, which it pushed to be the standard for evaluation. A couple of participants went from passing to failing in between evaluations, which needs to be further investigated.

It is also good to note that 5 participants were driving without a license. One of those participants chose to continue driving in spite of contrary advice at 6 months and 5 years. Another resumed illegal driving after the 6 months but was deemed fit to drive at 5 years. The 3 others obtained valid licenses after the 6 months but failed to renew them before the 5 year follow up. Two of them passed at five years and one failed. Clinicians should stress the legal and financial consequences of driving illegally in addition to the safety issue. This may also show that if people are really determined to drive, they will. In order to ensure safety, they must undergo driver retraining.

### Table 3: Characteristics of included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention investigated</th>
<th>Comparison intervention</th>
<th>Outcomes used</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patomella, A., Tham, K., &amp; Kottorp, A.</td>
<td>To test the validity of the P-Drive assessment tool when used with a simulator for participants with stroke. Specifically looked into participant and item goodness of fit.</td>
<td>N/A</td>
<td>P-drive assessment</td>
<td>P-drive was shown to have good person response and item internal scale validity when used with a simulator. P-drive was also able to distinguish participants based on driving ability. P-drive did show to be a more accurate measure of the driving ability of those with low to moderate driving ability when using the simulator.</td>
</tr>
</tbody>
</table>
| Bedard, M., Parkkari, M., Weaver, B., Riendeau, J., & Dahlquist, M. (2010) | Looked at the validity and reliability of using a driving simulator to measure driving performance. | Statistically compared to neuropsychological tests that had been known to predict safe driving and also to on-road testing. | Trail Making Tests A and B  
Useful Field of View (UFOV)  
Demerit points recorded by evaluator for simulator and on-road testing. | The correlation between the neuropsychological tests and the simulator was shown to be moderate to high. The demerit points system, when used on the |
| Lew, H., Poole, J., Lee, E., Jaffe, D., Huang, H., & Brodd, E. (2005) | To determine the predictive validity of a driving simulator evaluation for driving performance in participants with TBI. | Statistically compared to a group of healthy participants with no instance of TBI on the simulator, as well as the TBI group’s scores on an on-road evaluation. | Simulator Performance Index (SPI)  
Driver Performance Inventory (DPI)  
Report of Infarctions |
|---|---|---|---|
| Cox et al. (2010) | Looked at the possibility of using a driving simulator in rehab for military personnel with TBI to improve driving skills. Also looked at the amount of road rage and risky driving of participants. For the simulator group, the control group received standard rehabilitation treatment only at the facility. They were measured on their driving performance on the simulator afterward and also took the road rage and risky driving. | The control group received standard rehabilitation treatment only at the facility. They were measured on their driving performance on the simulator afterward and also took the road rage and risky driving. | Road Rage Questionnaire  
Cox Assessment of Risky Driving Scale (CARDS)  
Simulation Adaptation Syndrome Scale |

The simulator was able to distinguish between the control and TBI groups; however, there was found to be no correlation between the simulator and the road test. DPI scores were lower on the simulator than on the road test. The results of no correlation could be due to the fact that 1 participant had a good simulator score and failed the on-road test, while another participant had the lowest score on the simulator but passed the on-road test. These two participants may have skewed the results.

All 5 of the 7 driving performance variables from examiner’s observations had significantly improved for the simulator group upon post-test. None of the

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| simulator sickness was evaluated. | tests. | Examiner observation of driving performance based on 7 driving variables, using a 5-point scale | changes were significant for the control group. The control group exhibited a non-significant increase in scores on the road rage and risky driving tests, while the simulator group demonstrated a significant reduction in scores on those tests. Also, no one from the simulator group had any reported simulator sickness during any of the drives. |

**IMPLICATIONS FOR PRACTICE**

- The reviewed studies show that driving simulators do have a place in assessing and retraining TBI/stroke survivors.
- Driving simulators are a safe way to assess and retrain TBI/stroke survivors. In addition, they can provide a number of driving scenarios in which the evaluator can control the amount of traffic. Comparing that to an on-road test in which the evaluator cannot control the flow of traffic and may have a limited driving area.
- Simulators are very expensive and may not be cost-effective for a small facility.
- They also do not provide the actual context/environment in which people actually drive that on-road training and evaluations provide.
- Some clients (often older adults) may be at risk for simulator sickness, in which case the use of a simulator would be out of the question. Facilities serving older adults may not want to purchase a simulator. On the other hand, facilities with military clientele may want to look into purchasing a driving simulator as soldiers are routinely put through simulators for military training.
- To avoid simulator sickness, gradual orientation to the machine before starting treatment is suggested.
- May want to think about adding other tests such as the simulator in evaluating a person’s fitness to drive in addition to the on-road test.

**EDUCATION**

- Continuing education should be provided for the use of driving simulators as assessment and retraining tools for occupational therapists, as well as other professionals including driving instructors, physicians, and insurance providers.
- Driving simulators should be presented as an option for TBI/stroke survivors who want to return to driving and display the potential to do so.

**FUTURE RESEARCH**

- Further studies need to be done comparing simulator training to on-road training for TBI/stroke survivors.
- More research could address at what phase in treatment would it be optimal to start driver retraining for TBI/stroke survivors.
- The amount of driver retraining needed for the different levels of brain injury would be good to look into as it could be tied into amount of treatment that will be reimbursed.
REFERENCES


