

# Driving Skills in Elderly Persons With Stroke: Comparison of Two New Assessment Options

Peter Klavora, PhD, Ronald J. Heslegrave, PhD, Margaret Young, OT, CDRS

**ABSTRACT.** Klavora P, Heslegrave RJ, Young M. Driving skills in elderly persons with stroke: comparison of two new assessment options. *Arch Phys Med Rehabil* 2000;81:701-5.

**Objective:** To compare the effectiveness of two methods of assessing off-road driving skills that claim to predict on-road driving fitness of persons with stroke.

**Method:** Fifty-six persons with stroke (age 44 to 82yrs; mean, 60.2yrs) completed the 2 off-road driving assessments along with standard clinical and on-road driving tests.

**Main Outcome Measures:** Linear stepwise regression on 4 variables of the Dynavision Performance Assessment Battery (DPAB), the Cognitive Behavioral Driver's Inventory (CBDI) variable (composite score), and the variables of age, gender, and lesion side.

**Results:** A 4-minute endurance subtest from the DPAB was superior to the CBDI in predicting success/failure in the on-road driving test (75%). However, success on both the 4-minute endurance subtest from the DPAB and the CBDI tests significantly improved the prediction of on-road success. If participants passed the CBDI and the endurance test from the DPAB, they also passed the on-road assessment.

**Conclusion:** Driving fitness of elderly persons with stroke can be assessed with reasonable accuracy using off-road tests, minimizing the expense and risk associated with on-road assessments in this population.

**Key Words:** Cerebrovascular disorders; Off-road driving assessment; Automobile driving; Dynavision; Rehabilitation.

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**M**ANY PERSONS who have had a neurologic event such as cerebrovascular accident (CVA) wish to resume driving.<sup>1,2</sup> Occupational therapists working with stroke patients face the challenge of determining if the person is ready and capable of returning to the road. Behind-the-wheel evaluations, although likely the best way to ascertain whether a client will be safe behind the wheel, are often prohibitively expensive. They require expensive equipment (a car) and specially trained evaluators, and carry high liability.<sup>3</sup> Medical insurance in Canada typically does not pay for evaluations or driver rehabilitation. Many rehabilitation programs are looking for a reliable way to screen a person's ability to resume driving by using some form of off-road perceptual cognitive assessment.

The problem facing therapists is whether reliable assessments exist that can predict how a patient would perform behind the wheel.

A need exists for better and more effective off-road driving assessments for persons with deficits stemming from a CVA.<sup>4,6</sup> While an on-road driving assessment by a certified driving instructor is often considered essential in determining whether a person should resume driving after stroke, on-road assessments have serious limitations other than cost. For instance, on-road assessments measure overt driving behavior—such as proper steering control and rear-view mirror checks—but fail to identify subtle (or covert) psychological and psychomotor impairments that affect these fundamental skills.<sup>4,5</sup>

Off-road driving assessments may more clearly identify the driving capacities of persons with stroke. Such assessments may include combinations of psychophysical and perceptual/cognitive tests and driving simulators.<sup>4,7-9</sup> While some researchers argue that the most informative and predictive off-road tests of driving fitness evaluate visuocognitive abilities (the use of visual and reasoning skills, visual memory, etc), visual attention, visual scanning, simple and complex visual reaction time, and visuomotor coordination,<sup>9,10</sup> there is limited good data to compare the predictive validity of off-road assessment tests for screening individuals for on-road assessments.<sup>11</sup> The purpose of the present study was to assess the predictive validity of 2 off-road driving assessment tests—the Cognitive Behavioral Driver's Inventory (CBDI) and the Dynavision Performance Assessment Battery (DPAB).

The CBDI<sup>12</sup> is comprised of 27 tests of visual skills related to driving. It has high internal reliability (Cronbach's  $\alpha = .95$ ),<sup>12</sup> and test scores derived from it are highly related to on-road driving performance. In one study,<sup>13</sup> 95.5% of subjects who passed the CBDI also passed the on-road assessment and 100% of subjects who failed the CBDI either were not allowed to do an on-road test or failed the on-road assessment. The CBDI has also been standardized and decision-making rules have been created based on subjects' scores.<sup>14</sup> Although the work by Engum and colleagues<sup>14</sup> appears to be comprehensive, their findings have yet to be verified by other researchers.

Another off-road driving evaluation uses Dynavision, an apparatus designed to test and train visual scanning, peripheral visual awareness, visual attention, and visuomotor reaction time across a broad, active visual field. Dynavision also requires execution of visuomotor response sequences, basic cognitive skills (short-term memory), and physical and mental endurance. The apparatus has a high test-retest reliability with intraclass correlation coefficients for 3 tasks ranging from .88 to .97.<sup>15</sup> The DPAB task set imposes psychomotor performance demands that are fundamental to driving, but are frequently deficient in persons with stroke. These tasks yield both quantitative values (number of hits or number of digits correctly identified) and qualitative aspects of performance, such as the level of attention and the extent to which peripheral vision and correct scanning strategies are properly used, along with other variables.

From the University of Toronto (Klavora, Heslegrave), University Health Network (Heslegrave), and Bloorview MacMillan Centre (Young), Toronto, Ontario, Canada.

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Reprint requests to Peter Klavora, PhD, Faculty of Physical Education and Health, University of Toronto, 55 Harbord Street, Toronto, Ontario M5S 1A1, Canada.

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One recent pilot study<sup>16</sup> found that the performance score on several Dynavision tasks differentiated between persons who passed or failed the on-road driving assessment. Informal observations also suggested that performance on a particular Dynavision task could predict whether an individual would pass a driving assessment (personal communication, M. Warren, 1996).

The primary purpose of the present study was to compare the effectiveness of the CBDI and DPAB to predict success on on-road driving tests by persons after stroke. A secondary purpose was to validate independently the CBDI technology.

## METHODS

### Participants

To participate, patients had to be at least 6 months poststroke, diagnosed with visual scanning or visual attentional problems, have a brain insult of vascular etiology or documented by computed tomography and clinical findings, and be recommended for an on-road driving assessment at the Bloorview MacMillan Centre in Toronto. While the second inclusion criterion clearly biases the sample toward participants with documented visual problems and may be less representative of the entire population of persons with stroke, these patients were selected so that follow-up rehabilitation studies using the CBDI and DPAB rehabilitation strategies could be conducted. Potential participants were excluded if they showed an unstable medical condition (ie, heart failure, uncontrolled seizure, uncontrolled diabetes), brain stem injury, recent or current history of psychiatric or substance abuse problems, poor vision, dementia, physical inability to execute motor sequences, current participation in a visual skills rehabilitation program, or no history of having a driver's license.

Over a 2-year period, a pool of 471 persons with stroke met the inclusion/exclusion criteria and were approached to participate in the study, but only 56 persons (34 with unilateral right hemispheric damage, 18 with unilateral left hemispheric damage, and 4 with bilateral involvement) volunteered to complete the two off-road driving skill assessments, which were not a standard requirement at the center. Reasons for not participating were mostly pragmatic (could not devote the extra time, health reasons, perception that extra tests might interfere with on-road assessment, etc). The 56 participants ranged in age from 44 to 82 years (mean = 60.2) and included 46 men and 10 women.

### Off-Road Assessment Instruments

**Cognitive Behavioral Driver's Inventory (CBDI).**<sup>12</sup> The CBDI includes 21 measures derived from a computerized driving simulation, 4 pencil-and-paper psychometric tests, and 3 independent peripheral tests (break reaction time, left and right perimetry). Together, these tasks assess visual, perceptual, and cognitive tasks, such as attention, concentration, reaction time, rapid decision making, visual scanning, and visual alertness. The CBDI test battery can be administered in 1 to 1.5 hours.

**Dynavision Performance Assessment Battery (DPAB).** The DPAB is comprised of four independent tasks performed on the Dynavision board. The participant is required to press buttons sequentially in random locations in a broad visual space according to a set of programs (fig 1). The main performance variable is the number of correct responses (hits) obtained under various conditions. A liquid crystal display near the center of the board can display random digits for brief, preset 1-second exposure periods. Thus, the more complex Dynavision tasks combine simple cognitive tasks (detecting and

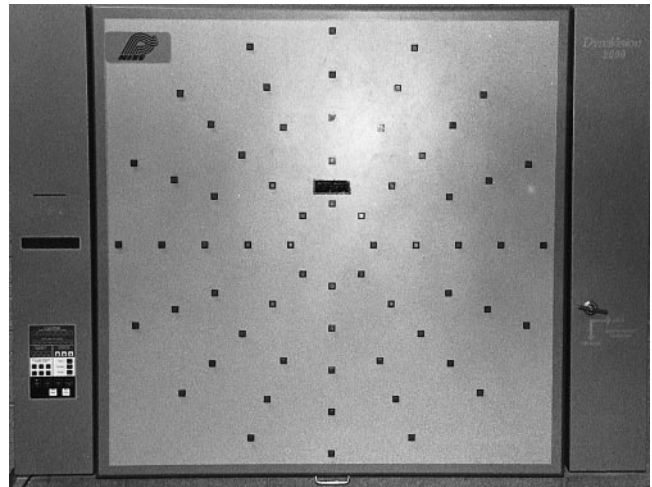


Fig 1. The Dynavision consists of a large (120cm × 165cm × 25cm) wall-mounted board housing 64 small square (2cm × 2cm) buttons fitted with lights arranged in a pattern of five nested rings.

recalling digits) with physical tasks (striking buttons). A more detailed description of the Dynavision apparatus can be found in Klavora and coworkers.<sup>17</sup>

### Procedure

The CBDI and DPAB tests were administered before the Centre's standard clinical and on-road evaluations were conducted. According to the Centre's standard protocol, the clinical evaluation was conducted by an occupational therapist specializing in driver rehabilitation. The therapist reviewed health and driving history, performed a physical/functional assessment as it pertained to driving, and administered a battery of visual screening tests, including tests of visual acuity, peripheral vision, distance judgment, and night vision skills. Reaction time was tested by means of a steering wheel and gas/brake apparatus; the "rules of the road" were also reviewed.

The on-road assessment used a dual-controlled General Motors car equipped with dual brakes and adaptive driving equipment, such as a left foot gas pedal, steering spinners, and extra mirrors. The person being assessed started driving in a quiet residential area and progressed to more complex traffic situations, including lighted intersections, 4-lane roadways, and more demanding traffic. There were a minimum of 8 right turns, 12 left turns, and 3 alternative standardized routes depending on the client's level of performance. Terrain changes were added as needed to assess areas such as trunk balance on long S turns. The route included 2-, 3-, and 4-way stops, traffic circles, lane changes, and parking procedures.

The safe/unsafe outcome of the on-road assessment was based on the demonstration of such skills as knowledge and application of road rules, problem-solving, visual processing speed, and risk perception. If the client responded well to coaching after a long absence from driving (due to hospitalization, rehabilitation, license suspension, or medical condition), lessons could be recommended. If the client was unaware of the shortcomings in his or her driving ability, more recovery time could be recommended before lessons or re-testing, or it could be suggested that driving be permanently discontinued.

### Pass/Fail Criteria

Both off-road tests were used to predict pass/fail outcomes on the on-road driving test. For the CBDI, we used a composite

pass/fail cutoff score of 47. This score is supplied by the manufacturer as part of the software and is based on a combination of 28 separate tasks from the CBDI test battery. All performance results are converted to standard scores and the computed average represents the composite score using healthy previously defined norms from the population. A score below 48 is scored a pass; 48 to 51 is ambiguous (borderline); and a score of 52 or higher is considered unsafe.

We based the pass/fail criteria for each of the four DPAB tasks on the scores that yielded the best distinction between subjects who passed or failed the on-road driving test in a previous study of 10 persons with stroke (5 passed, 5 failed).<sup>16</sup> The pass/fail criteria were consistent with those used at the Eye Foundation of Kansas City, University of Missouri (personal communication, M. Warren, 1996). For the simplest DPAB task (SDT), subjects responded in a self-paced manner for 60 seconds; the pass criterion was 50 responses/min. For the more difficult DPAB task (DDT), the pass criterion was 40 responses/min. In this task, the subject responded for 60 seconds to lights that were randomly illuminated for only 1 second. If the subject gave no response within this time period, another light was illuminated elsewhere on the board. Errors of omission were critical for this task. The third DPAB task was similar to the DDT condition, but more complex (CDT). It involved the identification of a 1-digit number presented simultaneously while completing the DDT task. The instructions emphasized the correct identification of the digits presented every 5 seconds over a period of 60 seconds. The criterion for a pass on this test was 30 correct responses/min. The final DPAB task was an endurance task (EDT), which was identical to the SDT except for an extended duration of 4 minutes; the criterion for success was defined as 195 correct responses over the 4-minute period.

### Data Analysis

The analyses were performed on the composite score of the CBDI and on the subtests of the DPAB, because the latter lacks a composite score. To predict success in the on-road driving assessment, the results of the two tests, the CBDI and the DPAB, were examined separately.

A linear stepwise logistic regression model was used to predict the on-road test safe/unsafe outcomes. The following 8 independent variables were included in the model: 4 variables of the DPAB test battery (for criteria, see Pass/Fail section above), the CBDI variable (composite score), and the variables of age (>60yrs and <60yrs), gender, and lesion lateralization.

## RESULTS

Table 1 summarizes the ability of the 2 off-road instruments to predict estimates of on-road driving success, showing the general accuracy rate as well as the distribution of errors (false positives and false negatives). Accuracy refers to correct predictions from the off-road assessments (those that were predicted to pass and did pass and those that were predicted to fail and did fail). False positives refer to those that were predicted to pass but failed; false negatives are those that were predicted to fail but passed.

The CBDI's ability to predict accurately success or failure was 66%. In this test, and indeed in all tests used in this study, there was a much greater likelihood (30%) of a false negative outcome (those who fail the CBDI but pass the on-road driving test) than a false positive outcome (4%) (those who pass the CBDI but failed the on-road driving test).

For the DPAB, results of the SDT were identical to the CBDI test results; the accuracy rate for the prediction and pass/fail

**Table 1: Prediction of On-Road Driving Success and of Error Distribution, by Off-Road Assessment Instruments**

Tests	Accuracy	Errors	
		False Positives	False Negatives
CBDI	66%	4%	30%
SDT	66%	4%	30%
DDT	68%	4%	28%
CDT	68%	4%	28%
EDT	75%	7%	18%
SDT and EDT	77%	7%	16%
CBDI and EDT ( <i>n</i> = 12)	100%		

Abbreviations: CBDI, Cognitive Behavioral Driver Inventory; SDT, simple (self-paced) Dynavision task; DDT, difficult (device-paced) Dynavision task; CDT, complex Dynavision task; EDT, endurance Dynavision task.

outcomes on the on-road test was 66%. Also, the false negative bias was identical. Interestingly, while the accuracy and false positives and false negatives were identical, different subjects contributed to the identical findings. In other words, the 37 (of 56) correct predictions of passing or failing based on the CBDI were a different set of 37 subjects than the set that passed the SDT.

For the DDT and CDT, the prediction accuracy rate was 68% with the number of false positives unchanged, but the number of false negatives decreased to 28%. For the EDT, the prediction accuracy rate was 75%, with fewer false negatives (18%), but slightly more false positives (7%). Since the EDT is simply an extended version of the SDT, the question was raised, Would passing both the SDT and the EDT influence the predictive power? Table 1 suggests that when the SDT and EDT scores were combined, the predictive value of the EDT alone increased by 2% and of the SDT alone by 11%. The SDT and EDT in combination decreased the number of false negatives of the EDT alone by 2% and of the SDT alone by 14%.

Combining the results from both the CBDI and DPAB yielded the best predictive outcome for the on-road driving assessment. Of the 16 subjects who passed the CBDI, 12 also passed the EDT task. All 12 went on to do well on the final on-road driving test. Significantly, the combined analyses yielded no false positives—none of the participants who failed both the CBDI and the EDT tasks passed the on-road test.

### Predicting Road Test Outcome

None of the possible interactions were statistically significant. The absence of interaction effects indicated that a main effects model should be fitted to the response frequencies. The nonsignificant residual chi square (3.1583 with 6 *df*, *p* = .6756) indicates that the main effects model fits the data. An analysis of the maximum likelihood estimates confirms that scoring well on the CBDI and EDT tasks is associated with a higher probability of passing the on-road evaluation. The positive weighting (1.7153) for the CBDI indicates that drivers scoring 47 or less on the CBDI had a substantially higher probability of doing well on the road test. Similarly, the positive weighting for the EDT (2.0672) indicates that scoring 195 or higher on the DPAB endurance task was associated with a substantially higher probability of passing the on-road test. The negative intercept (−0.9916) indicates that participants who scored more than 47 on the CBDI and less than 195 on the EDT were more likely to perform poorly on the on-road evaluation.

Given the support for the main effects model, table 2 shows the impact of the main effects. To reduce the total number of

variables entered into the stepwise regression, a  $p < 0.3$  level of significance was used in the initial analysis. This procedure reduced the number of explanatory variables to those shown in table 2. From this analysis, two variables (the EDT of the DPAB and the CBDI) were found to be significant at  $p < .05$ . It is these variables that we discuss further in the present report.

The predicted on-road failure probabilities and the corresponding odds ratios (table 3) indicated that participants who scored 47 or less on the CBDI were 5.56 times more likely to pass the on-road test than subjects who scored more than 47 on the CBDI. Participants who scored 195 or better on the EDT were 7.90 times more likely to pass the road test than drivers who scored less than 195. Finally, participants who scored 47 or less on the CBDI and 195 or more on the EDT were 43.93 times more likely to pass the on-road test than were drivers who scored more than 47 on the CBDI and less than 195 on the EDT. This finding is not surprising given that not one of the 12 participants who scored 47 or less on the CBDI and 195 or better on the EDT were unsuccessful on the on-road evaluation.

## DISCUSSION

The present study suggests that off-road simulation tests are useful in predicting on-road success/failure in drivers after stroke. Of the various predictors of on-road driving success that were entered into the stepwise logistic regression, only the EDT of the DPAB and the CBDI significantly predicted on-road outcomes of drivers poststroke. Lesion lateralization, gender, and age variables did not account for significant independent variance in the outcome of success in the on-road assessment beyond that accounted for by the EDT and CBDI. Our sample's bias toward more right hemisphere CVAs and more males may have reduced our ability to obtain a clear finding with respect to lateralization and gender, and the psychomotor performance differences on these tasks may account for most of the variance otherwise attributable to age.

The finding that age did not enter the prediction equation was surprising, because age can have a deleterious effect on cognitive functioning. Given the neurophysiologic and neuropsychologic decline often associated with aging, it is not surprising that age exacerbates the severity of psychomotor and cognitive functioning of persons experiencing stroke.<sup>18-20</sup> It may be that driving tests are less sensitive to age than the standard neuropsychologic measures used in other studies.

Although the results from the DPAB were only slightly superior to those from the CBDI with respect to predicting on-road success, practical and budgetary advantages may exist for using the DPAB over the CBDI. The testing time for all 4

Table 2: Main Effects of the Stepwise Logistic Regression Model

Source	$\chi^2$	Probability
Intercept	5.5597	.0184
EDT	8.8059	.0030*
CBDI	3.7419	.0531*
SDT	.3581	.5496
DDT	.0361	.8493
CDT	.3113	.5769
Age	.6168	.4322
Gender	.5362	.4640
Lateralization	.0969	.7555

Abbreviations: EDT, endurance Dynavision task; CBDI, Cognitive Behavioral Driver Inventory; SDT, simple (self-paced) Dynavision task; DDT, difficult (device-paced) Dynavision task; CDT, complex Dynavision task.

\* Significant at  $p < .05$ .

Table 3: Odds Ratios for the CBDI and EDT Variables

	CBDI = Fail EDT = Fail	CBDI = Pass EDT = Fail	CBDI = Fail EDT = Pass	CBDI = Pass EDT = Pass
Estimated probability	.2706	.6734	.7457	.9422
Odds ratios	1	5.56	7.90	43.93

Abbreviations: CBDI, Cognitive Behavioral Driver Inventory; EDT, endurance Dynavision task.

DPAB tests is about 15 to 20 minutes (including rest intervals between various tasks), with the longest test (EDT) lasting only 4 minutes. In comparison, the CBDI requires 1 to 1.5 hours to administer, which can be difficult for persons with disabilities. It is also expensive to administer, increasing the cost of the evaluation, which is often an out-of-pocket expense for the client. Dynavision also has low maintenance costs and allows an unrestricted number of tests without additional cost. In comparison, the CBDI test battery requires a computer facility and is sold on a license-to-use, pay-per-run basis.

Compared with the CBDI test battery that was designed and marketed to predict driving performance of brain-injured persons,<sup>13</sup> Dynavision is a less obvious screening tool, since it was not created to evaluate driving performance. However, the Dynavision apparatus has been used as an evaluation and treatment tool for over 10 years and almost 100 occupational therapy clinics in the United States use it to evaluate and treat the effects of visual, cognitive, and motor impairment after brain injury. However, little research has been conducted to date to validate its use in the rehabilitation and off-road testing of persons with stroke.<sup>16,17</sup>

The goal of this study was to compare the two off-road testing devices and to define their accuracy in predicting on-road driving performance. Since research has not identified an off-road test battery that accurately predicts on-road success of persons with stroke, the best strategy for occupational therapists may be to administer both the CBDI and Dynavision tests. The real value, however, would be in those clinics that do not have driving programs and CBDI software, but do have a Dynavision device. In those clinics, persons with stroke could be screened on Dynavision to determine whether they would be candidates for referral to a driver rehabilitation program.

Like the CBDI, which has been used in planning therapeutic interventions aimed at restoring functional skill and enabling clients to resume driving at a later stage,<sup>12</sup> the DPAB can also be used in a rehabilitation setting to improve the abilities of individuals.<sup>16,17</sup> Although it remains to be shown that persons with stroke can improve these abilities and that learning Dynavision tasks positively transfers to driving skills, clearly a device is needed both to screen stroke patients for driving ability and to provide rehabilitation intervention.<sup>4,6</sup> Further research should be conducted using more homogeneous populations to validate these effects for both screening and rehabilitation, thus establishing the most relevant criteria for these purposes. However, it cannot be discounted that the heterogeneity of participants in the present study (in terms of age, gender, and hemispheric involvement), as well as the low participation rate from the larger sample, may have biased the present findings.

Our findings do not provide strong support for the previously reported conclusion that the CBDI predicts on-road driving success. Engum et al<sup>13</sup> demonstrated that 95% of the subjects receiving passing scores on the CBDI were found capable of operating a motor vehicle safely, while all subjects who failed

the CBDI test were assessed as unfit drivers. Our results showed that 34% of participants were misclassified based on the criterion score supplied by the manufacturer. The discrepancy in prediction between the 2 studies may be from differences in subject populations. Engum et al<sup>13</sup> used brain-injured patients whose diagnoses included stroke and other injuries (spinal, trauma, etc), whereas our study used only persons with stroke. In addition, a high percentage of their subjects were unable to take the on-road test, while all participants in the present study took the on-road test. This may indicate a difference in philosophy regarding when an on-road evaluation is indicated, or perhaps simply that the necessary adaptive driving equipment was not available. A somewhat greater disability in their population is also possible.

### CONCLUSION

The likelihood of passing on-road driving evaluations, which are expensive and can be dangerous to administer, can be predicted with relatively high accuracy and validity from more easily administered and less expensive off-road simulation tests that measure the ability of individuals to perform the essential psychomotor skills related to driving. When the complex tasks from the CBDI driving simulation were compared with the simple psychomotor and visual scanning tasks of the DPAB, most DPAB tasks were equally accurate in predicting on-road performance, although the 4-minute endurance test yielded the greatest predictor accuracy (78%). When the requirement for off-road testing success was made stricter by requiring subjects to pass both the CBDI and endurance tests, all who passed both tests were successful on the on-road test.

Further studies are necessary to determine how important on-road evaluations are to drivers' psychological adjustments to changes in driving performance and license status. A client-centered philosophy requires careful consideration of those drivers who would be denied the privilege of driving based on a computer assessment when, in fact, their driving performance may be safe and reliable.

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