Validity of the Cognitive Behavioral Driver’s Inventory in Predicting Driving Outcome

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OBJECTIVE. This study seeks to (a) compare Cognitive Behavioral Driver’s Inventory (CBDI) scores for clients who passed and failed a driving evaluation and for diagnostic groups (left cerebrovascular accident [CVA], right CVA, traumatic brain injury [TBI], and cognitive decline); (b) determine sensitivity, specificity, and positive and negative predictive values of the CBDI; (c) compare validity of the CBDI with other tools; and (d) identify factors associated with outcome.

PARTICIPANTS. This historical cohort study included clients with neurological conditions who completed a driving evaluation.

MEASURES. CBDI, Motor-Free Visual Perception Test (MVPT), Bells test, and driving results were extracted from the charts.

RESULTS. Mean CBDI (p < 0.0001) and MVPT (p < 0.0001) scores were significantly worse for those failing compared to passing the driving evaluation. Sensitivity of the CBDI was 62%, specificity was 81%, positive predictive values were 73%, and negative predictive values were 71%. Results varied according to diagnostic group.

CONCLUSIONS. The CBDI is not sufficiently predictive of outcome to replace a driving evaluation, and is predictive only for clients with R-CVA and TBI. Evaluation of driving should vary according to diagnosis.


Introduction

Driving a motor vehicle is an integral component of modern life and is particularly significant for the community reintegration of those with a newly diagnosed disability. Clients with neurological impairments, such as traumatic brain injury (TBI) and cerebrovascular accident (CVA), may have residual cognitive and behavioral impairments that adversely affect the ability to drive safely (Galski, Ehle, McDonald, & Mackevich, 2000; Haselkorn, Mueller, & Rivara, 1998). For these clients who are facing great changes in lifestyle and self-esteem, the loss of the ability to drive can result in a reduced level of autonomy, diminished access to community activities, and limited opportunities for socialization (Lister, 1999), as well as higher rates of depression (Marrotti et al., 1997).

The evaluation of driving ability requires an accurate analysis of the individual’s cognitive, physical, and behavioral capacities (Korteling & Kaptein, 1996). Driving is a complex task that requires the integrated use of high-level visual and cognitive functioning (Ball, Owseley, Sloane, Roenker, & Bruni, 1993; Owseley & Ball, 1993). Although it has been estimated that 90% of the informational input to the driver is visual (Simms, 1985), the task also involves the interaction of sensory and motor skills and the constant use of judgment, abstract thinking, and other cognitive perceptual abilities (Klavora, Hesgrave, & Young, 2000). Because of the multifaceted nature of the driving task, even mild impairments after TBI or CVA may have an impact on the ability to drive safely (Liddle & McKenna, 2003; Sivak, Olson, Kewman, Won, & Henson, 1981). Frequently noted problems in brain-damaged drivers include attention deficits, visual spatial impairments, slowed reaction time, impulsivity, poor judgment, and impaired executive function.
Clients with newly diagnosed disabilities are typically referred to a Driving Evaluation Service for a functional driving evaluation. In Canada, the occupational therapist is responsible for conducting these types of evaluations and providing a recommendation to the provincial licensing bureau regarding fitness to drive (Korner-Bitensky, Sofer, Kaizer, Gelinas, & Talbot, 1994). Currently, the driving assessment is composed of a pre-driver evaluation that includes the evaluation of individualized skills such as reaction time, visual perception, visual attention, and cognition, followed by an on-road functional driving evaluation. A survey of North American driving programs (Korner-Bitensky, Sofer, Gelinas, & Mazer, 1998) indicated that the most commonly used pre-driver screening tools include the Motor-Free Visual Perception Test (MVPT) (Bouska & Kwatny, 1982); Trail Making Test, Part A and Part B (Reitan, 1986); and the Cognitive Behavioral Driver’s Inventory (CBDI) (Engum, Cron, et al., 1988).

Although studies indicate an association between scores on the pre-driver paper-and-pencil tests with on-road driving evaluations, results have been inconsistent. Poor performance on the MVPT and Trail Making Test, Part B, was associated with a large increase in the rate of failing the road test (Mazer, Korner-Bitensky, & Sofer, 1998), whereas a follow-up study across six driving evaluation sites in Canada and the United States concluded that the MVPT does not have sufficient predictive validity to independently predict on-road driving results (Korner-Bitensky et al., 2000). To provide a more complete and objective evaluation, a perceptual and cognitive test battery was developed and found to correctly classify participants in more than 80% of cases (Nouri & Lincoln, 1992).

Computer-based testing has several potential advantages over the traditional paper-and-pencil tools. Time and cost-effectiveness in a driving evaluation program may be maximized with the use of computerized tools. Tests are scored quickly and accurately, results are rapidly reported, and immediate feedback is provided (Green, Green, Harrison, & Kutner, 1994). A computerized neuropsychological test battery has been designed specifically to aid rehabilitation professionals in assessing the cognitive and behavioral skills integral to the safe operation of a motor vehicle. The CBDI (Engum, Cron, et al., 1988; Engum, Lambert, Womac, & Pendergrass, 1988) has been standardized, and norms and decision-making rules have been developed (Engum, Lambert, & Scott, 1990; Engum, Lambert, et al., 1988) for both clients with brain injury and normal control clients (Engum & Lambert, 1990; Engum, Lambert, & Scott, 1990; Lambert & Engum, 1990). These findings have been summarized and published in a comprehensive manual (Engum, Lambert, & Bracy, 1990). The CBDI was intended to provide clinicians with a tool that evaluates complex visual and cognitive skills related to driving—that is, one that discriminates efficiently between persons with neurological impairments who recovered sufficiently to operate a motor vehicle and persons whose residual disabilities render them unfit to drive (Antrim & Engum, 1989). It has high internal reliability (Cronbach’s alpha of 0.95) and test scores are highly related to on-road driving performance (Engum, Cron, et al., 1988; Engum, Lambert, & Scott, 1990). Engum and colleagues (Engum, Cron, et al., 1988) demonstrated that 95.5% of participants with brain injury who passed the CBDI were found capable of operating a motor vehicle safely, whereas all participants who failed the CBDI were assessed as unfit to drive. In 1990, Engum and colleagues (Engum, Lambert, & Scott, 1990) performed validity studies using a double blind analysis, whereby both the psychologist performing the CBDI and the driving instructor conducting the on-road test rated driving ability (pass or fail). Validity studies were conducted by comparing normal control participants with 215 clients with neurological conditions. There was a significant correlation between CBDI outcome (pass, fail) and the psychologist’s judgment based on CBDI performance (pass, fail) (Engum, Lambert, & Bracy, 1990).

Driving evaluation programs serve a wide range of clientele, with the most common medical conditions being TBI, CVA, and age-related changes in functioning (Korner-Bitensky et al., 1998). Whereas driving evaluation programs typically use the same battery of tests and procedures to evaluate all clients, it is unclear whether this process is equally effective for all diagnostic groups. Studies have detected differences in driving abilities and in the rate of success on the driving evaluation according to the client’s condition (Fisk, Owsley, & Pulley, 1997; Quigley & DeLisa, 1983; van Zomeren et al., 1987).

The administration of perceptual and cognitive tests is costly and time consuming, and their value to the driving evaluation process is not well understood. Although pre-driver screening tools may never be adequately predictive to eliminate the need for a road test, the information they provide is crucial to focusing the driving evaluation and determining safety and potential on the road. In addition, the usefulness of the CBDI for clients with various conditions and how it compares to other typically used measures is not known. The overall purpose of this study was to examine the usefulness of the CBDI as an evaluation of driving ability in clients with a variety of neurological conditions. Specifically, this study was designed to: (a) compare the mean CBDI scores for those who passed and
failed the on-road driving evaluation in clients with neurological conditions and in the most commonly seen diagnostic groups (left CVA, right CVA, TBI, and cognitive decline), (b) determine the sensitivity, specificity, and positive and negative predictive values of the CBDI for the group as a whole and for the diagnostic groups, (c) compare the validity of the CBDI with other commonly used pre-driver screening tools, and (d) identify the demographic and clinical factors associated with on-road driving outcome for clients with neurological conditions.

Methods

Study Design

This is a historical cohort study. The medical charts of all eligible participants were reviewed and the results from the CBDI, MVPT, Bells test, and the on-road driving evaluation were extracted. Demographic information, including gender, date of birth, language, condition, date of diagnosis, and level of verbal expression and comprehension were also recorded.

Participants

All clients with a diagnosis of a neurological condition who completed testing at our Driving Evaluation Service as part of their regular clinical intervention between January 2000 and March 2003 were included in the study. Commonly, referrals to the service are made if one or more treating clinicians are concerned about the motor, perceptual, or cognitive functioning of their client. Although the majority of referrals are for individuals receiving inpatient or outpatient rehabilitation services at our center, referrals may be received from other rehabilitation centers, acute care hospitals, and private physicians. Clients with medical conditions that legally precluded them from driving (e.g., visual homonymous hemianopsia, a primary visual impairment inadequately improved by corrective lenses, class IV cardiac status, uncontrolled seizures) were not eligible. In addition, those participants who received their road test more than 75 days after the screening evaluation were excluded.

Measures

The evaluation procedure consisted of two components: a pre-driver screening session and an on-road driving evaluation. The pre-driver session included the perceptual and cognitive testing and took approximately 1.5 hr to complete. The test order was consistent, with the MVPT administered first, followed by the Bells test, the CBDI subtests, and last, the CBDI computerized tests. Approximately 1 week later, clients received the on-road test, which typically lasted 2 hr for those with TBI and 1 hr for all other diagnostic groups. The tests were administered as part of the routine clinical driving assessment. All measures were directed by experienced occupational therapists who followed the standard administration procedures for each evaluation. The same occupational therapist administered both the pre-driver and on-road components. The following measures were included in the study:

Cognitive Behavioral Driver's Inventory. The CBDI (Engum, Cron, et al., 1988; Engum & Lambert, 1990) was designed to assess the cognitive and behavioral skills required for driving. It includes four components of Bracy's Computer Assisted Cognitive Rehabilitation (Bracy, 1985) that are completed on the computer: visual reaction differential response, visual reaction differential response reversed, visual discrimination differential response II, and visual scanning III. Also included in the scoring are results from the Wechsler Adult Intelligence Scale—Revised Picture Completion and Digit Symbol subtests; Trail Making Test, Part A and Part B; brake reaction test; and an examination of visual fields (Keystone Perimeter Field of Vision, Keystone View, 2200 Dickerson Road, Reno, Nevada 89503). It takes approximately 1 hr to complete. The software calculates standard scores with a mean of 50 and a standard deviation of 10. The total score generated is called the General Driver's Index (GDI28) and consists of the average of the 27 standard scores and the scatter variance. The GDI28 provides the best single estimate of driving ability by classifying clients as passing (47 or less), borderline (48 to 51), or failing (52 or greater), with higher scores reflecting greater levels of dysfunction.

Motor-Free Visual Perception Test. The MVPT (Bouska & Kwatny, 1982) is a standardized paper-and-pencil test of visual-perceptual skills in five areas: spatial relations, visual discrimination, figure–ground discrimination, visual closure, and visual memory. A maximum score of 36 indicates no errors. The time required to complete each item is noted and the average time per item is calculated. Total test time is approximately 20 min. Normative data is available for adults aged 18 to 80 years.

Bells Test. The Bells test (Gauthier, Dehaut, & Joanette, 1989) is a complex paper-and-pencil test of selective attention and visual scanning. The test sheet contains 35 bells embedded within 264 distracters. Participants are asked to circle each bell that they see. The score is the total number of bells circled and the time it took to complete the task. The test takes about 10 min to complete.

On-road driving evaluation. The on-road driving evaluation is based on the standard test procedure used by the provincial licensing board in Quebec, Canada. The on-road driving evaluation is conducted by the same occupational
therapist who administers the perceptual tests. An experienced driving school instructor, who is unaware of the results of the perceptual testing, directs the evaluation. For those with physical impairments, the vehicle is equipped with adaptations such as a spinner knob and a left accelerator. Clients are oriented to the driving school car and to any adaptations needed to compensate for physical deficits. The driving instructor provides specific instructions to the client while directing him or her on a standard route. The occupational therapist sits in the rear seat and rates driving performance. The 17-km (10.5-mile) course begins on quiet streets and then proceeds to busy boulevards and highways. All driving evaluations are conducted during daylight hours and take approximately 50 min to complete. An assessment form is completed by the occupational therapist, documenting the clients’ strengths and weaknesses. Subscales include the use of controls, maneuvering, specific driving skills—such as visual exploration and response to traffic signals—and general driving skills, including decision-making, planning, and tolerance. Once the evaluation is completed, the occupational therapist reviews the client’s driving behaviors, knowledge, application of driving regulations, and ability to maneuver the vehicle safely and determine whether the client has passed, has failed, or requires driving lessons. Interrater reliability for the overall categorization of pass and fail on the on-road evaluation was assessed by two occupational therapists on five clients and agreement between them was found to be 100%.

Potential confounding variables. Demographic and clinical information were recorded, including gender, age, language spoken for the evaluation, presence of comprehension and expression difficulties, diagnosis, time since diagnosis, and time between the pre-driver testing and on-road testing.

Data Analysis

Individuals were classified according to their on-road evaluation outcome, either pass, fail, or recommended lessons. Those who were recommended lessons were grouped with the fail group, because they were, at the time of testing, deemed not sufficiently skilled to obtain a driving license. Descriptive statistics were used to document the general characteristics of the participants. T-tests were used to compare the mean test scores on the CBDI, MVPT, and Bells tests for those who passed and those who failed the on-road driving evaluation for the group as a whole, as well as for four homogeneous diagnostic groups (left CVA, right CVA, TBI, and cognitive decline). There were insufficient numbers to examine other less common diagnostic groups independently.

Tables were created in which on-road driving outcome and CBDI score were dichotomized into pass or fail. Sensitivity, specificity, and positive and negative predictive values were calculated for the entire group and for each of the four diagnostic groups. Initially, the cutoff value suggested by the CBDI test was used, with borderline and fail ratings collapsed together. For the purposes of this analysis, participants with scores >47 were classified as failures and ≤47 as a pass.

To identify the best cutoff score on the CBDI for our sample, Receiver Operating Curves (ROCs) were generated and different cutoff values were analyzed. ROCs determine the accuracy of a screening test (CBDI) according to how well the test separates the groups into those who pass and fail the road test. Because it is most important to identify persons who will fail an on-road driving evaluation to prevent needless and dangerous on-road testing, priority was given to obtaining a high sensitivity.

Logistic regression analyses were performed to determine the combination of tests (CBDI, MVPT score and time, Bells test) that best predicts pass and fail on the driving evaluation. Univariate analyses were first performed and all possible combinations of the tests were examined. Diagnostic testing was conducted to determine whether collinearity was present. Demographic (age, gender) and clinical (comprehension, expression, and time since diagnosis) characteristics were added one at a time to the best model of tests to determine any potential confounding or interaction. To examine the impact of different conditions on the results, all analyses were repeated for those with left CVA, right CVA, TBI, and cognitive decline separately. All data analyses were performed using the SAS statistical software, Version 8.1.

Results

The study included 172 participants: 28 with left CVA, 20 with right CVA, 58 with TBI, 23 with cognitive decline (Alzheimer’s disease, early dementia, undiagnosed cognitive deficits), 25 with other cerebral vascular disease (bilateral CVA, cerebellar CVA, subarachnoid hemorrhage, aneurysm), 7 with multiple sclerosis, and 11 with other neurological disorders such as Parkinson's disease, meningitis, Charcot-Marie-Tooth disease, tumors, and Guillain-Barre syndrome. Clients were tested on the road an average of 1.8 weeks (SD = 1.9) after the pre-driver assessment. The demographic and clinical characteristics of the study participants are presented in Table 1.

Road test outcomes show that 93 (54.1%) participants passed their driving evaluation, 59 (34.3%) failed, and 20 (11.6%) were recommended lessons and a reevaluation.
Results for participants in different diagnostic groups indicate the rate of failure (fail and lessons) as 46.4% for left CVA, 55.0% for right CVA, 27.6% for TBI, and 82.6% for those with cognitive decline.

For the group as a whole, the mean test scores on the CBDI and MVPT (score and processing time) were significantly worse for those who failed as compared to those who passed the on-road evaluation (see Table 2). When comparing scores for the specific diagnostic groups, the test scores that discriminated between those who passed and failed differed according to diagnosis (see Table 2).

The sensitivity of the CBDI in detecting failure, using the suggested CBDI cutoff of >47, was 62%, indicating that the CBDI accurately classified only 49 of the 79 clients who failed the driving test. Specificity was 81%; the CBDI correctly identified 75 of 93 clients who passed the on-road evaluation. Positive and negative predictive values of the CBDI were 73% and 71%, respectively. Because the primary clinical concern is to accurately detect those who are unsafe drivers, when selecting a cutoff, priority was given to accurately detect failures. Results of ROCs analysis indicated that the value yielding the best combination of sensitivity and specificity for the group was 45. With the CBDI cutoff of >45, the sensitivity was 86.1% and specificity was 55.9% (see Table 3). The results also indicate that this is the best cutoff value for each of the specific diagnostic groups, except for the TBI group, where a lower cutoff (43) would better detect failures (see Table 3).

Results of univariate logistic regression analyses indicate that the CBDI score (β = 0.33, p < 0.0001), MVPT score (β = 0.23, p < 0.0001) and MVPT time (β = –0.27, p < 0.0005) were significant predictors of on-road outcome. In multivariate analyses, once the CBDI was included, no other test scores provided significant additional information, and the addition of demographic and clinical variables did not improve the model.
cal factors revealed that none of the factors significantly contributed to the model. The coefficient of –0.33 represents an odds ratio of 0.72, denoting that for every increase in the CBDI score of 1 point, the likelihood of passing the on-road test is reduced by .72. The best logistic regression models for the group as a whole and for each of the diagnostic groups are presented in Table 4. Results for those with left CVA indicate that no one evaluation or combination of evaluations was significantly associated with on-road outcome. Only time since diagnosis was significant, with those tested longer after CVA having an increased chance of passing the on-road test. CBDI scores alone significantly predicted driving outcome for those with right CVA and for participants with TBI. None of the evaluations or factors included in this study was significantly associated with driving outcome for the group with cognitive decline.

### Discussion

Individually, the CBDI score, MVPT score, and MVPT time were significant predictors of on-road outcome for the group of clients with neurological conditions seen in our driving evaluation program. In multivariate analyses, the CBDI was found to be the most predictive tool, with the MVPT and Bells tests offering no additional information over that provided by the CBDI. Using the cutoff value specified by the creators of the CBDI tool did not provide the best results for our sample. After evaluating all possible cutoff values, it was determined that the sensitivity of the test to detect failure improved when using a lower cutoff value of >45.

This study set out to examine the evaluation procedures for clients with various neurological conditions. Given the different impairments associated with different conditions, clinicians have often believed that certain tests are more or less useful for some clients. The study findings provide a guide for clinicians to identify the most accurate and efficient screening procedure for clients with various conditions. Although the findings indicate that different approaches may be required to accurately address the specific needs of each diagnostic group, several of the groups in this study were quite small and cannot provide definitive recommendations. The CBDI is a significant predictor of driving outcome in those with right CVA and TBI. In clients with left CVA and those with cognitive decline, none of the tests that were included in this study accurately predicted on-road outcome. This finding can be explained by

### Table 4. Logistic Regression: Pass/Fail on the On-Road Driving Evaluation

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>Standard Error</th>
<th>χ²</th>
<th>p</th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBDI</td>
<td>–0.33</td>
<td>0.06</td>
<td>31.28</td>
<td>&lt; 0.0001</td>
<td>0.72</td>
<td>0.64–0.81</td>
</tr>
<tr>
<td>Left CVA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time since diagnosis</td>
<td>–0.48</td>
<td>0.20</td>
<td>5.89</td>
<td>0.02</td>
<td>0.62</td>
<td>0.42–0.91</td>
</tr>
<tr>
<td>Right CVA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBDI</td>
<td>–0.61</td>
<td>0.28</td>
<td>4.93</td>
<td>0.03</td>
<td>0.54</td>
<td>0.32–0.93</td>
</tr>
<tr>
<td>TBI</td>
<td>–0.24</td>
<td>0.10</td>
<td>5.63</td>
<td>0.02</td>
<td>0.79</td>
<td>0.64–0.96</td>
</tr>
</tbody>
</table>

Note. CBDI = Cognitive Behavioral Driver's Inventory (Engum, Cron, et al., 1988); CVA = cerebrovascular accident.
the fact that the CBDI does not specifically evaluate all important deficits that affect driving in these clients. Lesions in the right hemisphere likely result in deficits in visual-spatial skills that are crucial for driving, such as visual scanning of the environment, use of space, awareness of traffic conditions, planning, and shifting attention to deal with complex situations.

Left hemisphere lesions often produce deficits in verbal and visual-spatial sequencing abilities, which are not evaluated in depth by the CBDI. However, performance on CBDI tasks may be slightly slower but not inaccurate, particularly in the weeks immediately after sustaining a CVA.

Elderly persons experience declines in the sensory system, perceptual skills, and cognitive functioning. For those who have been identified with cognitive decline or suspected early dementia, performance on a computer may be an inaccurate method of evaluation. Many elderly persons are unfamiliar with the computer and the additional anxiety associated with performing in this new situation may impair performance on the CBDI tasks.

In addition, the impact of impairments associated with central nervous system damage—such as excessive risk-taking behavior, poor judgment, confusion, emotional instability, and reduced frustration tolerance—is known to affect on-road driving outcome, but may be inadequately addressed by the CBDI tasks.

In fact, the CBDI assesses only a portion of the skills necessary for driving. Driving is described by Michon’s model (Michon, 1985) as a hierarchical structured task involving three levels of cognitive control: operational, tactical, and strategic. According to this model, the CBDI evaluates mostly skills at the lowest level, the operational level. This level is concerned with immediate vehicle control tasks such as accelerating, braking, and steering. It relies largely on automatic action patterns as well as reaction time, attention span, information processing speed, and visual-spatial ability. The other two levels, the tactical and strategic levels, however, are assessed by the on-road evaluation but not necessarily on the CBDI. The tactical level is concerned with maneuvers and the negotiation of common driving situations such as curves, intersections, and entering the traffic stream, which involve executive functions. The strategic level involves general trip planning, such as selecting a mode of transportation or evaluating the risks.

Although the same occupational therapist administered the pre-driver and on-road tests as part of his or her clinical practice, this should have had little impact on the study results. Because this study was conducted retrospectively, the evaluators were not aware of the purpose of the study at the time they were conducting the evaluations and would have had no reason to be biased toward scoring the evaluations similarly.

Possible factors that may have reduced the association found between the CBDI scores and on-road performance are limitations related to the administration of the CBDI. Administering the CBDI requires additional skills, over and above those addressed by the evaluation. Those with fine motor coordination difficulties, hemiplegia, or other motor impairments are at a disadvantage for those tasks requiring rapid reaction time and accuracy. For those tests that are not able to be administered, the CBDI gives a default score of 50 (borderline range), providing a wrong estimation of actual performance. Participants with aphasia who have difficulty following written or verbal instructions also may not be accurately assessed by the CBDI.

In addition, the CBDI was measured against the standard on-road test currently used in our clinical setting. Although the route and procedures are standardized, changes in road conditions, weather, and the presence of hazardous events cannot be controlled. The on-road outcome is determined subjectively by the evaluator based on the findings from the evaluation. The lack of a reliable and validated on-road test may have contributed to a reduced association between CBDI outcome and the on-road result.

Conclusion

Although the CBDI scores are, on average, worse in those who fail the on-road test, they are not sufficiently predictive of driving outcome to allow for the elimination of the on-road test. A universal approach to driver evaluation may not provide the most accurate and clinically relevant information. The study findings suggest that different pre-driver tests are needed to give a precise indication of driving abilities and impairments for clients with different conditions. To provide an efficient and effective method of driver evaluation, specific testing for different diagnostic groups appears to be necessary. These results are an initial step in attempting to determine the best approach for each of our clients.

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