
Off-Road Driving Evaluations for Persons With Cerebral Injury: A Factor Analytic Study of Predriver and Simulator Testing

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Objectives. Off-road evaluations composed of psychometric testing and simulator driving are commonly used in rehabilitation settings to assess a person's fitness to resume driving after a cerebral injury. Although the results of these evaluation methods separately provide information about ability to drive, there is no clear understanding about what is measured in comprehensive off-road evaluations as a whole. This study explored the interrelationship of perceptual, cognitive, behavioral, and operational variables that form the basis for off-road evaluations in order to determine whether there are basic dimensions underlying performance in these evaluations and to derive a small set of variables that could help in refining methods for evaluating persons with cerebral injuries.

Methods. One-hundred six persons with cerebral damage due to brain injury or cerebrovascular accident were administered a predriver evaluation that consisted of selected neuropsychometric tests. Subjects were also evaluated in a driving simulator that measured their operational responses to filmed driving situations and assessed their behaviors. Principal component analysis was used to identify manifest and latent variables contributing to the results of the evaluations.

Results. The analysis produced a model with five independent (orthogonal) eigenvectors, or factors, for this population: Higher Order Visuospatial Abilities, Basic Visual Recognition and Responding, Anticipatory Braking, Defensive Steering, and Behavioral Manifestations of Complex Attention. These factors accounted for 66.14% of the total variance in the subjects' responses to comprehensive off-road evaluations.

Conclusion. These factors were useful in understanding driving performance and the role of predriver and simulator testing in driver evaluations.

Persons who have had a brain injury or cerebrovascular accident (CVA) are often interested in resuming driving after rehabilitation. Their return to driving is encouraged by family members and society as well as rehabilitation professionals who promote independence and autonomy. However, because many persons with cerebral injury are left with residual deficits in perception and cognition that can affect safe driving, fitness to drive has to be carefully evaluated (Bardach, 1971; Galski, Bruno, & Ehle, 1992, 1993; Gurgold & Harden, 1978; Sivak, Olson, Kewman, Won, & Henson, 1981; van Zomeren, Brouwer, & Minderhoud, 1987).

Evaluating suitability for resumption of driving has been mainly assumed by psychiatrists working with occupational therapists and neuropsychologists in rehabilitation settings. On-road evaluations have been their primary and most direct method for determining fitness to

drive. However, these evaluations have the potential for causing injury and destruction of property if an unsafe driver is behind the wheel. Additionally, on-road evaluations have been criticized as lacking in objectivity and costly in time, effort, and money (Croft & Jones, 1987).

The need to enhance safety and contain costs has resulted in the development of off-road methods for evaluating driver fitness. Batteries of psychometric tests, called *predriver evaluations*, have been developed to evaluate residual deficits in perception and cognition associated with driving. Criticism of predriver evaluations as a tool to assess driving performance has focused on problems in obtaining paper-and-pencil tests that are valid measures of the skills and abilities needed for everyday driving. The development of ecologically valid tests selected on the basis of models of driving abilities has helped to mitigate this criticism and enhance the value of predriver evaluations (Croft & Jones, 1987; Engum, Cron, & Hulse, 1988; Galski, Ehle, & Bruno, 1990; Galski et al., 1992; Jones, Giddens, & Croft, 1983; Sivak et al., 1984; van Zomeren, Brouwer, Rothengatter, & Snoek, 1988; van Zomeren et al., 1987).

Driving simulators have also been regarded as a potential means for assessing fitness to drive (Boydston, Kessel, Henson, & Miller, 1980; Cimolino & Balkovec, 1988; Galski et al., 1990, 1992; Kent, Sheridan, Wasko, & June, 1979; Quigley & DeLisa, 1983; Reger, McGloin, Law, Spence, & Claus, 1981). Their promise as an assessment tool has rested on the assumption that simulators approximate actual behind-the-wheel driving in their appearance as well as in their requirements for handling and operating (i.e., face validity, fidelity). There have been relatively few studies on the usefulness of simulators in a rehabilitation setting to predict behind-the-wheel performance (i.e., passing or failing an on-road driving evaluation) (Galski et al., 1993; Gouvier et al., 1989; Hale, Schweitzer, Shipp, & Gouvier, 1987; Kewman, Seigerman, Kintner, & Chu, 1985). A review of the literature revealed no studies that examined the specific skills and abilities required in simulator performance.

This study explored the interrelationship of perceptual, cognitive, behavioral, and operational variables that form the basis for off-road evaluations. It was designed to determine whether basic dimensions underlying performance in typical off-road evaluations exist and to derive a small set of distinctive variables for use in developing a parsimonious method to evaluate drivers who have been cerebrally compromised.

Method

Subjects

One hundred six persons who met the following criteria were selected for this study: (a) cerebral compromise due

to traumatic brain injury (TBI) ($n = 63$) or CVA ($n = 43$); (b) licensed drivers 17 years of age or older; (c) referral by a physiatrist to Kessler's occupational therapy department for a complete driving evaluation; (d) visual acuity of at least 20/50; and (e) freedom from medical conditions or medications that would impair motoric ability, cause sedation or drowsiness, or compromise performance and safety. All subjects had residual deficits from their cerebral injuries and were interested in resuming driving after completing physical rehabilitation.

The sample was not dichotomized by diagnosis (i.e., TBI, CVA) or stratified by age because our research focused on the relationship between driving performance and cerebral functioning or dysfunctioning regardless of causation or etiological determinants. Subjects ranged in age from 17 to 87 years ($M = 47.09 \pm 19.64$ years) and in driving experience from 0 to 69 years ($M = 25.04 \pm 19.38$ years). Time since TBI or CVA ranged from approximately 1 week to 110 weeks ($M = 11.64 \pm 17.19$ weeks).

Instrument and Procedure

All subjects were administered the predriver evaluation, which was a battery of psychometric tests shown to measure the perceptual and cognitive abilities that predict behind-the-wheel driving performance (Galski et al., 1992; Gurgold & Harden, 1978; Sivak et al., 1981; van Zomeren et al., 1987). These tests included the following:

- Measures of visual scanning, attention, and information processing speed (i.e., Trail Making Test, Part A [Reitan, 1985], Double Letter Cancellation Test [Lezak, 1979])
- Visuospatial perception, visuopraxis, and visual memory (i.e., Visual Form Recognition Test [Benton, des Hamsher, Varney, & Spreen, 1983], Block Design Subtest of the Wechsler Adult Intelligence Scale-Revised [WAIS-R, Wechsler, 1981], Rey Osterreith Complex Figure Test [Osterreith, 1944])
- Planning-problem solving (i.e., Raven's Progressive Matrices [Raven, Court, & Raven, 1985]; Porteus Maze Test [Porteus, 1965])

Administration and scoring of these tests followed recommended procedures. Approximately 1.5 hours per subject were required for the predriver evaluation.

After completing the predriver evaluation, the subjects underwent a simulated driving evaluation with the Doron L225 Driving System/Analyzer.¹ Each subject was seated in the simulator and provided an opportunity to become familiar with the equipment. Twenty-three sub-

¹Manufactured by Doron Precision Systems, Inc., PO Box 400, Binghamton, New York 13902.

jects needed adaptive controls, such as steering knobs and left-foot accelerators, to compensate for extremity weakness. Instructions about operating the simulator and responding to the films were provided by the occupational therapist evaluator who had no knowledge of subjects' performance on the predriver evaluation.

Three films—*Good Driving Strategies*, *Threat Recognition*, *Evasive Action*—were selected from a six-film array purchased as a package from the simulator manufacturer. The films were representative of those used in typical simulator evaluations conducted in rehabilitation settings, particularly by users of the Doron simulator, and had been used in previous research related to driving outcomes (Galski et al., 1992, 1993). All films were similar in that they required subjects to respond to driving situations projected onto a 12-ft screen at the time of testing, but they varied in the nature of the situations depicted.

In the introductory film (*Good Driving Strategies*), subjects were required to respond to general traffic situations by appropriately braking, accelerating, and steering the simulator. The simulator automatically tabulated the number of errors in braking, steering, accelerating, controlling speed, and signalling.

In the films that depicted danger by international road symbols, an impending crash, or other hazardous situations (*Threat Recognition*, *Evasive Action*), subjects were again required to respond by appropriately braking, accelerating, and steering. The simulator automatically tabulated subjects' failures to appropriately brake and steer and measured the distance traveled between the onset of the danger symbol and the initiation of the defensive maneuver on valid attempts.

Additionally, during the simulator evaluation, the occupational therapist scored behaviors shown to correlate with driving performance (Galski et al., 1992) as present or absent. Observation focused on four behaviors:

1. Distractibility—the inability to sustain attention because one is drawn to unimportant or irrelevant stimuli (e.g., trivial noises and events, thoughts)
2. Inattention—the lack or diminished awareness of visual stimuli in a field of vision
3. Mental slowness—the inability to think with customary or appropriate speed (e.g., long latency between stimulus and response, hesitation in responding)
4. Difficulty in following directions—the inability to conform driving behaviors or actions to instructions

Evaluation in the simulator required approximately 1 hour per subject for completion.

Data Analysis

SYSTAT, version 5.0, was used to perform a principal

component analysis of neuropsychometric test scores, simulator scores, and observed behaviors (Wilkinson, 1990). Other variables with potential effects on performance, such as age and time since injury, were also included in the analysis. Kaiser's Stopping Rule (Kaiser, 1960) for extracting the number of eigenvectors was also applied in this analysis; specifically, components with an eigenvalue of 1.00 or greater were retained in the analysis, a conventional practice designed to eliminate factors that account for less variance than any of the original variables individually (Bryant & Yarnold, 1995). Varimax rotation was used to attain a simple factor structure while retaining independence between eigenvectors and to simplify the interpretation of central dimensions tapped by the eigenvectors.

Results

The data analysis produced a model with five independent (orthogonal) eigenvectors, or factors, that accounted for 66.14% of the total variance in subjects' responses to comprehensive off-road evaluations (see Table 1). These factors—Higher Order Visuospatial Abilities (HOVSA), Basic Visual Recognition and Responding (BVRR), Anticipatory Braking, Defensive Steering, and Behavioral Manifestations of Complex Attention (BMCA)—were defined by constituents, with factor loading coefficients of $r = .60$ or higher. This stringent criterion for classifying a variable as a constituent worthy of consideration in the interpretation of the eigenvector goes beyond the research convention of $r = .30$ or higher in order to maximize the shared variance between variable and eigenvector and facilitate interpretation of central dimensions (Bryant & Yarnold, 1995).

Performance on three of seven neuropsychometric test scores loaded together on the HOVSA factor, with moderate to high correlations (units correct on the Rey-Osterreith Complex Figure Test, raw score on the WAIS-R Block Design Test, errors on Raven's Progressive Matrices). Age was also a moderate-sized HOVSA determinant; however, closer scrutiny revealed a moderate-sized zero-order correlation ($r = .60$) only with performance on one neuropsychological measure (i.e., errors on Raven's Progressive Matrices). Age did not load significantly on any other factors. All HOVSA variables accounted for 16.35% of the total variance.

Two neuropsychological test scores (errors on the Double Letter Cancellation Test, errors on the Visual Form Recognition Test) and one of the simulator variables (braking distance in the *Evasive Action* film) loaded on the BVRR factor, with moderate-sized correlations. This factor accounted for 15.56% of the total variance.

Braking action that resulted from an immediate response to environmental cues (i.e., braking distance, per-

Table 1
Factor Analysis of Variables Associated With Off-Road Evaluations

Test or Measure	Factor				
	HOVSA	BVRR	AB	DS	BMCA
Neuropsychological tests					
Rey-Osterreith Complex Figure Test					
Units correct (copy)	-0.723 ^a	-0.131	-0.281	-0.104	-0.079
Change score (copy-recall)	-0.542	-0.598	-0.075	0.117	-0.032
Trail Making Test, Part A					
Time (sec)	0.290	0.592	0.235	0.124	0.154
Double Letter Cancellation Test					
Errors	0.280	0.603 ^a	0.160	-0.125	0.178
Visual Form Recognition Test					
Errors	0.241	0.649 ^a	0.036	0.152	0.333
Block Design Test (WAIS-R)					
Raw score	-0.680 ^a	-0.462	-0.205	-0.137	-0.095
Potterus Maze Test					
Test age	-0.527	-0.499	-0.113	-0.197	-0.207
Raven's Progressive Matrices Test					
Errors	0.730 ^a	0.384	0.231	0.044	0.194
Observed behaviors					
Distractability	0.374	0.003	0.135	-0.073	0.736 ^a
Inattention	0.070	0.010	0.006	0.196	0.818 ^a
Mental slowness	0.031	0.341	0.181	-0.149	0.726 ^a
Difficulty in following directions	-0.015	0.389	-0.010	0.316	0.665 ^a
Simulator rests					
<i>Driving Strategies</i> film					
Signalling (% errors)	0.428	0.150	0.127	0.268	0.537
<i>Evasive Action</i> film					
Steering (% valid attempts)	-0.357	-0.074	-0.243	-0.765 ^a	-0.071
Steering (distance)	0.069	0.065	0.072	0.786 ^a	0.118
Braking (% valid attempts)	-0.031	-0.304	-0.679 ^a	-0.433	-0.056
Braking (distance)	0.046	0.660 ^a	0.357	0.272	-0.064
<i>Threat Recognition</i> film					
Steering (% valid attempts)	-0.300	-0.520	-0.473	-0.115	-0.245
Steering (distance)	0.351	0.373	0.312	0.312	0.274
Braking (% valid attempts)	-0.365	-0.157	-0.775 ^a	-0.073	-0.169
Braking (distance)	0.287	0.174	0.762 ^a	0.057	0.060
Age	0.628 ^a	0.092	0.146	0.303	0.184
Percentage of total variance	16.353	15.560	11.447	9.324	13.455

Note. AB = Anticipatory Braking; BMCA = Behavioral Manifestations of Complex Attention; BVRR = Basic Visual Recognition and Responding; DS = Defensive Steering; HOVSA = Higher Order Visuospatial Abilities; WAIS-R = Wechsler Adult Intelligence Scale-Revised.

^aHighest factor loading.

centage of valid attempts at braking the simulator during the *Evasive Action* and *Threat Recognition* films) loaded with moderate-sized to large-sized correlations on the Anticipatory Braking factor, which accounted for 11.45% of the total variance.

Steering action that required anticipation and evasion of potentially dangerous driving situations (i.e., steering distance, percentage of valid attempts at steering during the *Evasive Action* film) loaded with large correlations on the Defensive Steering factor, which accounted for 9.32% of the total variance.

All observed behaviors—distractibility, inattention, mental slowness, difficulty in following directions— but none of the neuropsychological test variables and simulator variables, loaded on the BMCA factor, with large to very large correlations. This factor accounted for 13.46% of the total variance.

Discussion

The findings confirm that comprehensive off-road evaluations commonly used in rehabilitation settings, which include predriver evaluations and simulator tests, are measuring many simple and complex abilities that have been related to behind-the-wheel performance and provide meaningful information about a person's fitness to resume driving after cerebral injury. Furthermore, it was found that these abilities are reducible to a set of five basic factors, which accounted for a major portion of subjects' responses to off-road tests and helped to address the question of what is being measured in off-road evaluations.

The first factor, HOVSA, was coalesced by predriver tasks that require complex visuospatial abilities, particularly the capacity to appreciate the spatial aspects of static visual material, organize the visuospatial information into

a percept, and use the image as the basis for a specific response (e.g., copying a complicated visuographic design, constructing dimensional block designs of increasing complexity, using analogic reasoning to identify complex visual patterns embedded in an array). It was not surprising that visuospatial abilities emerged as a factor; many neuropsychometric tests tapping various aspects of this ability have been shown to be important determinants of driving performance (Bardach, 1971; Galski et al., 1992; Sivak et al., 1981; van Zomeren et al., 1987). However, the emergence of the tests around this central factor and the magnitude of explained variance associated with overall results of off-road testing emphasize the primary importance of considering a person's ability to perceive and organize complex visuospatial material when evaluating driving performance.

The finding that age loaded only on the HOVSA factor suggests that chronological age is an important consideration when using neuropsychometric tests to evaluate the visuospatial abilities of persons who are cerebrally compromised. It also suggests that the HOVSA factor is more sensitive to age-related changes in performance than the other factors. However, although the results of many neuropsychometric tests are sensitive to differences or variations in age, it may be misleading to conclude that age per se entirely explains the loading on the HOVSA factor. Review of the correlation matrix for HOVSA variables showed that age had a meaningful, moderate-sized correlation only with the results of one neuropsychometric measure (errors on the Raven's Progressive Matrices). This finding is consistent with research that has shown a linear decrease in performance on this test with older age (Burke, 1985; Orme, 1966). But most of our subjects were not elderly; therefore, the elderly subjects would have been expected to solve more than the simple problems by analogic reasoning if age was a primary determinant of their test performance. The fact that the younger subjects made errors like the older subjects suggests that age may function as a moderator variable in a situation that measures deterioration in perception and cognition due to natural losses of brain capacity over time or to TBI (Costa, Vaughan, Horwitz, & Ritter, 1969; Denes, Semenza, & Stoppa, 1978; Villardita, 1985).

The BVRR factor coalesced around the subjects' ability to select a simple visual stimulus from a small bed of potential distractors and to use the information to perform an uncomplicated action (e.g., cancel two specific alphabetical letters embedded in an array of letters, recognize simple visual forms, step or do not step on the simulator's brake at an intersection). Inherent in both off-road tests was the fact that the BVRR appeared as a read-and-react, simple-choice paradigm characterized by relatively low cognitive demands—global scanning or minimally focused attention to identify simple, visually presented stimuli and

selecting a response from several alternatives to meet the demands of simple tasks (e.g., choose to brake, choose not brake). Subjects with functionally intact visual scanning, attentional and information processing abilities, and basic visuospatial perception were relatively unchallenged by the demands of tasks loading on the BVRR factor to produce a learned response when there was a match between an environmental stimulus (the cue) and its mental representation (the template). On the other hand, subjects experiencing attentional and visual processing difficulties made excessive errors on these tasks (e.g., inappropriate brake use, incorrect letter cancellations).

The Anticipatory Braking factor was determined by a single driving action, namely, braking the simulator when real danger was imminent and withholding the use of brakes when no impending danger was evident. This factor was manifested by measures of accuracy and timeliness in anticipating and reacting to a perceived danger, that is, the percentage of valid attempts at braking in response to situational cues in the two complex films (*Evasive Action, Threat Recognition*) and estimated distance that the simulator travelled from the onset of the danger signal to its stopping. More than simply making the car (simulator) stop in response to a fixed, unchanging stimulus (e.g., stop sign, red traffic light), the integration of basic perceptual abilities and higher order cognitive abilities seemed to be necessary for accuracy and speed of anticipatory braking in a dynamic, changing environment. For example, subjects required (a) relatively intact visual scanning and attention to preview the scenes projected on the simulator's screen; (b) recognition of visual patterns and their association with danger through previous learning (e.g., driving experience) when real driving scenarios were used in the simulator or through new learning when presented with symbols of danger; (c) executive functioning, such as abilities for planning, making decisions, directing an action, and handling novel or demanding situations; (d) visuomotor coordination in executing the braking response; and (e) speed of mental processing to read and evaluate the situations, choose a response from an available repertoire, and carry out the action within moments of the time that the potentially dangerous situation came into sight.

Similar to the determination of the Anticipatory Braking factor, the Defensive Steering factor was determined by another simulator-based driving action, namely, steering away from imminent danger or holding the simulator's course in the absence of impending danger. This factor was revealed in the same manner as the Anticipatory Braking factor through measures of accuracy and timeliness in anticipating and reacting to danger (i.e., percentage of valid attempts at steering away in response to situational cues and the estimated distance the simulator trav-

elled from the appearance of danger to turning of the steering wheel). However, although anticipatory braking abilities were measurable in films that used realistic road scenes as well as signs and symbols of danger, defensive steering emerged as an important variable only in the film depicting perceptually and cognitively challenging real-world scenarios (*Evasive Action*). This finding suggests that although both anticipatory braking and defensive steering are primary, if not the only means for averting realistically imminent danger, anticipatory braking may be the dominant response. Such a conclusion makes intuitive sense

- if braking to avert danger is seen as a basic, more natural response because it is vehicular-related behavior acquired earlier than defensive steering (i.e., children learn to brake their toy cars, bicycles, or inline skates before learning to go around danger);
- if braking is understood as a behavior that is repetitively reinforced by immediate tension reduction when a driver who brings the vehicle to a stop after averting danger is at least temporarily relieved of perceptual, cognitive, and motoric demands to continue operation of the car;
- if defensive steering, which is regarded by experts as the quintessential ability for safe driving, is viewed as a skill that takes years of experience to acquire and is, therefore, used by fewer drivers;
- if defensive steering is considered a more complex action because although it results in avoidance of imminent danger, it does not relieve the driver from pressure to continue operation of the vehicle in a dynamic environment (e.g., driving at various speeds in or out of various spatial planes [i.e., different traffic lanes or the same lane with rapidly changing intervehicular distances] after being cut off on the highway by another driver coming from the far-left lane).

Additionally, this finding suggests that subjects' responses could have been influenced by the demand characteristics of the different films (i.e., they have different perceptual and cognitive demands that result in different response tendencies). This impression was supported by the fact that braking and steering, the variables which formed the basis for evaluation in the simulator, had loadings on factors that varied in significance depending on the particular film. Specifically, neither of these variables emerged as significant factor loadings on the *Driving Strategies* film, whereas the steering variable emerged as significant on the *Threat Recognition* film, and both variables emerged as significant on the *Evasive Action* film.

The fifth factor, BMCA, coalesced around subjects' behaviors that were observed during simulator performance. Because performance was associated with their

ability to maintain purposeful behaviors and pay sufficient attention to complete the simulator tasks, BMCA seemed to primarily reflect cognitive resistance to interference or distraction and the absence of behavioral inappropriateness (e.g., impulsivity, which often results from problems in attention).

Recommendations

Off-road evaluations measure simple and complex abilities associated in earlier research with behind-the-wheel driving. However, a significant percentage of performance-related variance (i.e., 34%) remains unexplained by the perceptual, cognitive, behavioral, and simulator determinants used as the basis of this study. Additional research is necessary to determine whether there are other meaningful driving abilities or variables related to driving performance, such as risk-taking tendencies, topographical perception, route-finding ability, and body schema orientation, that can be measured in an off-road format (Boyd & Sautter, 1993; Shaw, 1971).

Meaningful use of information gleaned from off-road evaluations requires that evaluators consider the *combination* of specific neuropsychometric test results obtained from (a) predriver evaluations; (b) simulator measures of steering and braking as responses to perceptually complex and cognitively challenging films; and (c) specific behaviors, particularly those sensitive to alterations in complex attention. If evaluators rely on less than the combination of results from all these sources, they explain less variance associated with overall performance in off-road testing and, therefore, reduce their capacity to evaluate a person's ability to resume driving after cerebral injury.

Simulators, such as the commonly used Doron model, tap abilities that are helpful in evaluating overall performance and provide a face-valid context for observing important driver-related behaviors. However, what simulators assess is not readily apparent to evaluators who, if they follow the standard protocol for use, are looking at general measures of performance (e.g., stopping distances, steering-braking errors). The simulator does not reveal the reasons for errors in performance that can result from variation in deficits from person to person. This kind of information is revealed only by results of the neuropsychometric tests administered in the predriver evaluation.

Absent or vague knowledge about specific deficits and their relationship to simulator performance has two important consequences. First, persons with major driving-related deficits that are not readily apparent in simulator performance may be incorrectly passed in testing, or, alternatively, capable persons with deficits that are relatively unimportant to real driving may be failed on the examination. Second, absent or vague knowledge can result in recommendations for persons to be placed into driver train-

ing programs, either in a simulator or in an automobile, that are typically general in nature and not focused on remediation of identifiable deficits. Generic retraining programs may be an inefficient and more costly use of clinic and road time than deficit-specific retraining programs. Evaluations would be improved by (a) developing simulators that provide detailed information about both the nature and extent of specific neuropsychological deficits and performance on specific driving tasks, (b) establishing the relationship of these determinants to simulator and behind-the-wheel driving, and (c) using this information as a basis for developing efficient retraining programs.

Although driving films have generally authentic appearances and face validity, they do not necessarily capture the true perceptual, cognitive, and behavioral demands of real-world driving or reflect the varying requirements from situation to situation (i.e., different abilities may be necessary for congested city driving in inclement weather and leisurely country driving on a sunny day). Consequently, evaluators' inferences about a person's fitness to drive may be incorrect or erroneously based on incomplete information if a film's demand characteristics are not known. If films continue to be the medium used with simulators, standards for performance must be developed for every filmed scenario on which a simulator evaluation is based.

There is a need to explore the generality of these findings, that is, to compare the results of relevant neuropsychometric tests and simulator performance as well as the behavioral observations of persons with cerebral injury to those of other populations (i.e., new or elderly drivers, drivers with dementia). Confirmatory factor analysis, using the factor structure derived in this study as a model for evaluating goodness of fit, lends itself to this effort. It is hypothesized, however, that the factors underlying this model would be confirmed in other populations because driving performance seems to be related to cerebral functioning or dysfunctioning rather than to other variables, such as age, years of driving, or diagnosis, alone.

Simulators need to be redesigned and improved in a number of ways in order to avoid misuse and errors in interpreting results. Specifically, although simulators typically used in rehabilitation settings may approximate real-world driving, they are not interactive and, therefore, do not adequately capture the feel and experience of actual driving. Applications of current technology, such as high-fidelity simulators used in aviation or virtual reality, in the rehabilitation setting may considerably improve the simulation of driving (e.g., by enhancing the perception of vehicular motion or the tactual and kinesthetic sensations associated with gradations of braking and steering; increasing the field of view; allowing drivers to view and experience the consequences of actions, such as swerving

to avoid a dog in the road) and the outcome of off-road evaluations.

Conclusion

Comprehensive off-road driving evaluations, including pre-driver evaluation, simulator tests, and behavioral observations, are being used to measure abilities associated with behind-the-wheel performance. The abilities underlying off-road evaluations were reducible to five primary (orthogonal) factors that can be used as a basis for understanding what is measured in off-road evaluations and in determining a person's fitness to drive after cerebral injury. ▲

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