Determinants of Driving After Stroke

Abiodun E. Akinwuntan, PT, MSc, Hilde Feys, PT, PhD, Willy DeWeerdt, PT, PhD, Jan Pauwels, PhD, Guido Baten, OT, Emmanuel Strypstein

ABSTRACT. Akinwuntan AE, Feys H, DeWeerdt W, Pauwels J, Baten G, Strypstein E. Determinants of driving after stroke. Arch Phys Med Rehabil 2002;83:334-41.

Objective: To identify variables that best predict a team's decision of driving ability in stroke patients from a predriving assessment.

Design: Retrospective study of a 2-year predriving evaluation.

Setting: Belgian Institute for Road Safety.

Participants: One hundred four patients with sequelae of first stroke.

Interventions: Predriving assessments and road test.

Main Outcome Measures: The suitability to resume driving based on a team decision and performance in the road test.

Results: Forty-one patients (39.4%) were judged suitable, 45 (43.3%) not immediately suitable, and 18 (17.3%) not suitable to drive. Correlation coefficients and comparisons between groups revealed that most variables had significant individual relationships with the team decision and performance on the road test. After logistic regression analysis, side of lesion, kinetic vision, visual scanning, and a road test led to the best model in predicting the team decision ($R^2 = .53$). The road test was the most important determinant ($R^2 = .42$). Multiple regression analysis showed that the combination of acuity of left and right eyes and the figure of Rey was the best subset to predict the road test ($R^2 = .28$).

Conclusion: The predictive accuracy of the team's decision is limited, and the road test is even lower. Inclusion of more real-road–related tests in the predriving assessment is necessary.

Key Words: Cerebrovascular accident; Motor vehicles; Neuropsychological tests; Rehabilitation; Vision.

DRIVING IS AN IMPORTANT part of everyday life. When a driver's license is revoked, the impact on the individual's life is often dramatic. A neurologic event such as a stroke affects driving ability.[1] Driving a motor vehicle requires a high degree of competence on many levels, including physical abilities such as mobility, vision, and hearing, as well as cognitive skills necessary to integrate and respond appropriately to multiple rapid and transient signals.[2] Stroke patients present with various physical and neuropsychologic impairments, some of which represent definite symptoms contrary to driving and others more ambiguous in nature.[3]

Studies on the assessment and training of the driving skills of people with brain damage have received attention lately because of increased awareness of the potential to drive after such brain injuries. Haselkorn et al[4] compared the records of licensed drivers both before and after hospitalization with those of nonhospitalized drivers. They found that individuals hospitalized because of a brain injury occurring from a stroke or trauma did not have an increased risk of motor vehicle crashes or driving violations. This finding was in line with previous work of Sivak et al[5] and Katz et al.[6] Gurgold and Harden[7] stated that the therapist should be able to make an early assessment of the driving potential of the handicapped with knowledge of all available aids, the physical requirements needed to drive, cognitive and perceptual deficits, and their relationship to driving. Several studies[5,8-11] have been performed with brain-damaged patients to evaluate the impact of visual, perceptual, and cognitive functions on driving. Most studies reported perceptual and cognitive functions to be related to driving performance and stressed the need for routine assessment of these functions.

Some studies have been published on the determination of the driving potential in stroke patients. Nouri et al[12] investigated the relationship between cognitive abilities and driving after stroke in 39 patients. Driving performance was assessed by using a road test that was performed on a set route including side streets, busy main roads, traffic islands, and large junctions. Cognitive tests such as cube copy, what else is in the square, road sign recognition, and hazard recognition assessing complex reasoning skills were predictive of the road test. These findings were validated in a later study by Nouri and Lincoln[13] on 40 patients. Three cognitive tests referred to as the Stroke Driver Screening Assessment correctly predicted the road test performance of 81% of patients in an experimental group study.[14] The 3 tests are dot cancellation, square matrix, and road sign recognition.

Sundet et al[3] examined the neuropsychologic measures that determined whether 79 stroke patients were allowed to drive. The neuropsychologic test battery was made up of 4 principal components: visual perception, spatial attention, visuospatial processing, and language and praxis. A discriminant analysis revealed that the Trail-Making Test (TMT) B and the Tachistoscopic Discrimination Test, with complex stimuli measuring visuospatial inattention (neglect) and speed of mental processing, respectively, had a major influence on the decision. A study by Mazer et al[1] predicted the ability to drive after stroke by using a road test, conducted first on quiet streets followed by busy boulevards and then on the highways. The predictive value of 9 perceptual tests, including Complex Reaction Timer, Motor-Free Visual Perception Test, Single and Double Letter Cancellation, Money Road Map, Bells Test, Charron Test, and the TMT-A and TMT-B, were evaluated. After a logistic regression, the Motor-Free Visual Perception Test—measuring visual perceptual skills—and the TMT-B—assessing multiple

From the Department of Rehabilitation Sciences (Akinwuntan, Feys, DeWeerdt), Department of Kinesiology (Pauwels), Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven and CARA, Belgian Institute for Road Safety (Baten, Strypstein), Brussels, Belgium.

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Reprint requests to Abiodun E. Akinwuntan, PT, MSc, Dept of Rehabilitation Sciences, Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven, Tervuursevest 101, B-3001 Heverlee, Leuven, Belgium, e-mail: *Emmanuel.Akinwuntan@flok.kuleuven.ac.be*.

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conceptual tracking, sequencing, and alternating divided attention—emerged as the best predictors of the road-driving evaluation.

Although previous studies indicated the importance of cognitive and perceptual abilities in driving after stroke, there is still a need for further validation. Only a few studies were performed, and in these studies, relatively small numbers of subjects were used. The studies also used different sets of tests to assess visual, perceptual, and cognitive problems. In nearly all the studies on stroke, the criterion of driving performance was based on the road test. In an editorial in *Lancet*,[15] the road test was described as the most accurate assessment of driving ability in conditions with motor disability.

In Belgium, brain-damaged patients with mental or physical dysfunction who wish to resume driving are referred to the Belgian Institute for Road Safety. The predriving assessment is conducted by a team composed of neurologists, occupational therapists, and neuropsychologists at the Center for Determination of Fitness to Drive and Car Adaptations (CARA) unit of the institute. The assessment consists of a medical examination, and visual, neuropsychologic, and road tests. The team decision, based on the following 3 categories: (1) suitable to drive, (2) not immediately suitable to drive, and (3) not suitable to drive, is made based on patients' performance in all aspects of the predriving assessment.

Many of the visual and neuropsychologic tests contained in the predriving assessment used in this study differ from tests in prior studies. To the best of our knowledge, the predictive accuracy of the decision of suitability to drive based on these tests has not been established. Thus, our aim was to identify the variable or combination of variables from the predriving assessment as performed in Belgium, which best predict the decision of driving ability in stroke patients. The decision of the assessors in the 3 categories was used as the main outcome measure. Because performances of the road tests have been used in previous studies as the main outcome measure, the variable or set of variables that best predicted the road test used in this study were also identified.

METHODS

Subjects and Procedure

The records of all patients who visited the CARA section of the Belgian Institute for Road Safety in the year 1998 and 1999 for the first time were reviewed. Patients were selected if they had a history of first stroke, possessed a valid driver's license, and had been driving before the stroke onset. Since October 1, 1998, the law in Belgium[16] made provision for patients with a visual field problem, such as hemianopia after brain damage, to resume driving based on the positive advice of an ophthalmologist. Consequently, patients with visual field problems before October 1, 1998 were excluded from the study. In all, 104 subjects were included in the study.

The patients were referred to the institute by the hospitals, insurance companies, or patients' private doctors. All patients previously completed a detailed medical questionnaire together with their doctors. Patients with specific problems at this stage went for specialist examination and performed the predriving assessment only when the specialist certified them to do so. In the institute, a neurologist first examined all the patients and this was followed by the visual, neuropsychologic, and road assessments. The average total period to conduct a full predriving assessment for 1 patient ranged between 2 and 3 hours. All assessments were completed on the same day of the evaluation; however, if patients complained of tiredness during the phases of the assessment, they were allowed to rest and continue when they felt fit to do so.

One hundred four patients were included in the study. The mean age $\pm$ standard deviation of the patients was 56.8 ± 11.9 years (range, 30–79y). The group consisted of 82 men and 22 women. Forty-five patients had a left-sided brain lesion, and 59 had a right-sided brain lesion. The interval between stroke onset and examination varied from 80 days to 3407 days ($>$9y) with a mean of 18.5 ± 20 months. The years of driving experience of the patients ranged from 6 to 63 years (mean, 34.9 ± 12.4y). There were 15 patients with a history of epilepsy; this was under control in all patients and they were without any history of an epileptic fit in the last 6 months. All but 6 patients were on medication. Thirty-seven patients had visual field problems, of which 6 had hemianopia. Sixteen of the patients had a history of aphasia.

Measures

Visual tests. Four visual tests (monocular vision, binocular vision, stereoscopy, kinetic vision) were performed on Ergovision equipment.[a] The procedure involved the patient sitting in front of the apparatus with the forehead against the headrest. The monocular and binocular vision[17] tests are measures of the visual acuity of far vision of each eye and near vision of both eyes. Monocular vision was performed with both eyes opened but 1 eye blinded with the aid of a shutter; binocular vision with both eyes opened. The patient was asked to read 6 lines of 4 letters of the alphabet and 4 numbers on each line with decreasing type size. Testing was terminated when the patient could not read correctly 3 items on a line. For both tests, a score of 0 was recorded for patients who could not read at least 3 letters and numbers in the biggest print, and a maximum score of 6 was recorded for patients able to read all the lines.

Stereoscopy measures the depth perception of the eye. Depth perception usually requires 2 good monocular images, good merging, and good cortical integration. The test shows 5 black circles numbered from 1 to 5 placed in different planes in space. The patient was expected to give the order of the circle placements, from the closest to the farthest. The scoring range was between 0 (no correct response) and 5 (5 correct responses).

Kinetic vision acuity[17] evaluates the ability to recognize objects in movement. The test involves presenting the subject with 9 chevrons moved horizontally from left to right at 3 different speeds. The subjects were to identify whether the chevrons are directed to the left or right. A maximum score of 3 was given to patients who correctly responded to at least 8 of the 9 chevrons and 0 for patients who could identify none or 1 of the directions of the chevrons.

Neuropsychologic tests. The neuropsychologic screening consisted of 8 different tests: the figure of Rey, useful field of view (UFOV), divided attention, flexibility, visual scanning, incompatibility, visual field, and neglect. The last 6 tests are part of the battery developed by Zimmermann and Fimm[18] (Fimm-Zimmermann test). These tests were found to assess some common neuropsychologic impairments in brain-damaged patients such as divided attention, selective attention, visual searching, and scanning. Others are focused attention, binocular central visual field and perception, neglect, and lateralized reaction time.[19] The tests were performed by using the Psychologische Testsyteme apparatus.[b]

The figure of Rey[20] test, which is a copy of the Reys complex figure, investigates the perception, organization, visual inattention, and spatial abilities in brain-damaged subjects. It is made up of a complex figure, which the patient was given to reproduce. The evaluation of the drawing is obtained by using an accuracy score based on a unit scoring system; the maximum score is 36.

The UFOV has been defined as “the spatial area or visual field extent that is needed for a specific visual task.”[21,22] The first task is a center discrimination task between 2 stimuli. A picture of a car or a truck was presented at decreasing display duration (between 240–40ms in 40-ms decrements) in a box at the center of a 20-in tactile screen. After every presentation, the 2 stimuli were shown, and the subject was required to correctly identify the box that last contained the presented stimulus. The minimum threshold is scaled from 0 to 30.

The second and third tasks are a visual localization task. In addition to the stimulus, which evaluates central vision discrimination, a second stimulus (a car) appeared simultaneously in the periphery at 10°, 20°, or 30° eccentricity. The subject was to localize this car from 8 line coordinates at various degrees of radial angle (0°–315° in 45°-increments). The subject was required to correctly perform the initial center discrimination task while simultaneously locating the presented peripheral target, again at different blocs of display duration. The threshold duration was then scaled through a specific algorithm to yield another score between 0 and 30. The third task was identical to the second task, the difference being the presence of clutter in the visual field. The result also yields a score between 0 and 30. The total score is the sum of the scores for the 3 subtests, and it varies between 0 and 90. These tests were measured with the UFOV Visual Attention Analyser.[c]

The Divided Attention Test includes a visual and acoustic task. In the visual task, crosses appear in a random configuration in a 4 × 4 matrix. The patient has to detect whether the crosses form the corners of a square. The acoustic task includes a regular sequence of high and low beeps. The patient also has to detect an irregularity in the sequence in each task. Both tasks were performed simultaneously, and the patient was expected to press a button whenever the crosses form the corners of a square or when the beep sequence is irregular. Thirty-three single and 33 double stimuli were presented in total. The number of correct responses and the reaction times were recorded in milliseconds.

Flexibility was assessed by presenting 2 stimuli (letters, numbers). The stimuli were presented simultaneously and randomly on the left- or the right-hand side of a fixation point in the middle of a computer screen. The patient was expected to press the key on the side of the screen indicating the stimuli presented as quickly as possible. This was preceded by a practice trial provided to ensure that the simple alternation of response was measured with the patient’s eye still fixed on the central point. The computer recorded the number of errors committed in 100 stimuli and the reaction time in milliseconds.

In visual scanning, a target pattern, which is a square opened on the upper side, has to be detected in a 5 × 5 arrangement of the squares with an opening on the sides. The patient was to scan from the left side of the screen to the right side to detect the target pattern. The square may be present or not. One hundred stimuli were presented in total. The reaction time in milliseconds and number of correct responses as well as errors were recorded.

Incompatibility measures the ability of a subject to cope with interference. Arrows pointing to the left or right were presented on the left or right of a fixation point on the screen. The subject was instructed to press a key on the side indicated by the arrow, independent of the position of the arrow on the screen. If the side of presentation of the arrow and the direction of the arrow were in accord, the condition was defined as compatible; if otherwise, the condition was defined as incompatible. Scoring was performed by recording the reaction time in milliseconds on 57 items. The difference in the errors committed in the compatible and the incompatible situations was also calculated.

The tests for visual field and neglect were combined. In the test of visual field, a 3-digit integer appeared 92 times with a random time delay. The patient had to respond as quickly as possible whenever the number was presented. During its presentation, the 3-digit integer randomly changed its value, thus appearing to slightly flicker. The maximal time for stimulus presentation was limited to 3 seconds, after which the stimulus was judged as not seen. In the test for visual neglect, the critical stimulus (randomly changing 3-digit integer) was simultaneously masked by several other numeric stimuli that made it more complex. Reaction times were measured with 10-ms resolution. Forty-four stimuli were presented.

In both tests, the candidate pressed a button as soon as the stimulus was seen. The reaction time in milliseconds and the number of omissions on the left and the right sides were recorded. In both tests, the median reaction time, absolute difference in reaction times, and omissions were calculated. The absolute difference in reaction time was calculated by subtracting the median reaction time of the performances on the sides (left, right) of the screen. Similarly, the absolute difference in omissions was generated by calculating the difference in the number of omissions on the left and right sides of the screen.

Road test. The road test was performed either in a car with a manual transmission, automatic transmission, or with adaptations depending on the patient’s physical state. The cars were fitted with 2 sets of pedals, 1 for the patient and 1 for the assessor. The second set of pedals was to ensure safety when the driving test was in progress or during situations demanding immediate intervention. The patient was tested first on the driving skills of steering handling, coordination, control, and parking skills within the premises of the institute. Testing continued on a stretch of road around the institute with minimal traffic where skills such as road and sign recognition, positioning on the road, and gradual acceleration were assessed. The road test further progressed to a major road with medium traffic where concentration and observation of road signs and speed limits were evaluated. Other driving skills, such as respect for other road users, change of traffic lanes, and general reactions to demanding traffic situations, were assessed on a highway with dense traffic. The driving test terminated on return to the premises of the institute, parking the car, and properly turning off the engine.

Immediately after completion of the road test, the therapist scored the performance in 10 sections. The first 4 assess the motor aspect of driving ability (steering handling, coordination, control, rapidity of movement), and the other 6 sections assess the cognitive and perceptual aspects. In each section, a maximum score of 4 was given for the best performance and 0 for the worst performance. The score of the road test thus varied between 0 and 40.

Decision. The decision to drive or not was determined by the team, based on the performance on all aspects of the predriving assessment. Three categories of decision could be reached: (1) suitable to drive either with a normal car, an automatic car, or a car with adaptations; (2) not immediately suitable to drive, either for insufficient recovery time, awaiting medical advice, awaiting ophthalmologic report, or advised to go to a driving school; and (3) not suitable to drive because of poor performance on the tests.

Patients in the first category were given a letter addressed to the licensing authority for their driver’s license to be granted. The temporarily unsuitable group was requested to come back for a retest after solving the problem of which they were diagnosed.

Data Analysis

Descriptive statistics were used to document subject characteristics. The individual prognostic value of the variables in the decision to drive was first examined by comparing the scores of each of the variables in the 3 categories of the outcome. The data set contained dichotomous, ordinal, and ratio variables for which chi-square, Kruskal-Wallis, or analysis of variance (ANOVA) tests were used, respectively. When ratio variables were not normally distributed, a Kruskal-Wallis test was used as well. Post hoc analyses were performed by using the Tukey-Kramer method following ANOVA and the Wilcoxon rank sum test with Bonferroni correction following the Kruskal-Wallis test to differentiate among the 3 groups. Spearman rank and Cramer correlation coefficients were used to explore further the relationship between predictor variables and outcome. Coefficients with a P value of less than .05 were considered significant.

To examine the value of the several variables in the prediction of the decision (3-point ordinal scale), a logistic regression analysis was used. Univariate regression analysis was first performed including only 1 variable in the model. Only significant variables were then included into a multivariate regression analysis. Correlation analysis and factor analysis were used to explore high interrelationships between predictor variables. The combination of variable scores that provided the most accurate prediction of the road test was also determined. For this, a multiple regression analysis was used. In both logistic and multiple regression analyses, the best predictive model was determined in a stepwise manner by omitting variables from the model on the basis of significance testing and the best subset selection method. The best model with all the significant predictor variables ($P < .05$) was retained for each of the outcome variables.

In logistic regression analysis, significance testing of the regression coefficients of the predictor variables was based on the Wald chi-square statistics. In multiple regression analysis, the distribution of the error term was inspected and the data set was examined for possible problems involving outliers, influential points, and multicollinearity.[23] All statistical procedures were performed with the SAS system.[d]

RESULTS

Of the 104 patients, 41 (39.4%) were found suitable to resume driving; 33 could drive a normal car, 2 were recommended to use an automatic car, and 6 an adapted car. Among the patients found suitable to drive, 9 had no restrictions, whereas others were only suitable to drive for 12 (n = 31) and 6 (n = 1) months, respectively. The patients with restrictions were requested to come back after the specified duration for a retest. Forty-five patients (43.3%) were found not immediately suitable to drive. They were either to wait for further recovery (n = 10), to undergo further medical examination (n = 6), or to go to a driving school for training (n = 29). Eighteen of the patients (17.3%) were found not suitable to drive.

Comparison Between Categories of Driving Decision

Inspection of general data in the 3 categories of decision revealed that the variables of age, interval between onset of stroke and examination, driving experience, and visual field problem ($P < .005$) were significantly different between the groups. All aspects of the visual test battery (P-value range, .008 to <.0001) were significantly different between the 3 groups. Also, nearly all variables of the neuropsychologic test (P value range, .04 to <.0001) differed significantly between the groups except for errors in the flexibility test ($P = .06$), omissions with target in visual scanning ($P = .23$), and difference in errors in incompatibility test ($P = .41$). The flexibility scores were borderline significant. This was probably because of the small number of subjects who performed this test. The kinetic vision test, figure of Rey, UFOV, reaction time in scanning, absolute difference in reaction time of visual neglect, and the road test were significant at the 1 per 10,000 level ($P < .0001$) between the categories of decision.

Between-group comparisons revealed that the variables of age and driving experience (Tukey-Kramer test, $P < .05$) and interval between onset of stroke and examination (Wilcoxon rank sum test with Bonferroni correction, $P < .0167$) differentiated the subjects found either suitable or not immediately suitable to drive from the subjects found not suitable to drive. The visual tests, with the exception of acuity of the left and right eyes, differentiated between subjects found suitable to drive and those not suitable to drive (Wilcoxon rank sum test with Bonferroni correction, $P < .0167$). The acuity of the left and right eyes test differentiated between subjects found suitable to drive and those found either not immediately suitable to drive or not suitable to drive. For all neuropsychologic tests, significant differences were found between the patients in the first 2 categories of decision and the not suitable to drive category (Tukey-Kramer test, $P < .05$; Wilcoxon rank sum test with Bonferroni correction, $P < .0167$). The road test differentiated between all the 3 groups (Tukey-Kramer test, $P < .05$). Subjects found suitable to drive performed markedly better compared to the other 2 categories.

Relationship Between the Predriving Assessment and Outcome Variables

Further relationships between the predriving assessment and the decision to drive as well as the road test were explored. The Spearman rank-correlation coefficient (r_s) was used for the ordinal and ratio variables and Cramer coefficients for the nominal variables (table 1). More general parameters, with the exceptions of gender, side of lesion, and aphasia, were significantly associated with the group decision and varied between .10 and −.36. Correlation coefficients of all items of the visual test battery were found to be significant. Kinetic vision showed the highest association with group decision ($r_s = .43$). Most of the neuropsychologic tests, with the exception of median visual reaction time in divided attention, flexibility (median reaction time, error), and omissions in scanning with target and difference in errors in the incompatibility test, correlated significantly with the decision to drive. The highest associations were found for the figure of Rey ($r_s = .42$), UFOV ($r_s = .43$), correct response in divided attention ($r_s = .40$), mean reaction time in scanning ($r_s = -.41$), and absolute difference in reaction time in visual neglect ($r_s = -.43$). The road-driving test showed the highest association with the final group decision ($r_s = -.67$).

With few exceptions, a similar pattern in the level of association was found between the predriving assessments and the road test itself. All general parameters except gender and epilepsy correlated significantly with the road test. Again, all items of the visual tests showed significant correlation coefficients with the road test. Median reaction times in divided attention and flexibility tests, as well as the absolute difference in omissions in the visual field test, were the only items in the neuropsychologic tests that did not correlate significantly with the road test.

Table 1: Correlation Coefficients Between Predictor Variables and the Final Group Decision to Drive and the Road Test

Predictor Variables	N	Final Group Decision r_s	Final Group Decision C	Level of Significance	Road-Driving Test r_s	Road-Driving Test C	Level of Significance
General data							
Age	104	−.31		†	−.34		‡
Gender	104		.17	NS		.09	NS
Side of lesion	104		.10	NS		.23	*
Onset-examination interval	104	−.36		‡	−.33		‡
Driving experience	104	−.32		‡	−.28		†
Visual field	104	−.32		‡	−.26		†
Epilepsy	104	−.24		*	−.13		NS
Aphasia	104	−.17		NS	−.29		†
Visual tests							
Acuity of the left eye	104	.37		‡	.32		‡
Acuity of the right eye	104	.34		‡	.40		‡
Acuity of the left and right eye	104	.35		‡	.44		‡
Stereoscopy	104	.29		†	.21		*
Kinetic vision	104	.43		‡	.27		†
Neuropsychologic tests							
Figure of Rey	99	.42		‡	.48		‡
UFOV	99	−.43		‡	−.38		‡
Divided attention	84						
Correct response		.40		‡	.39		‡
Median visual reaction time		−.15		NS	−.07		NS
Flexibility	42						
Median reaction time		−.09		NS	−.28		NS
Error		−.24		NS	−.41		†
Scanning	93						
Mean reaction time		−.41		‡	−.40		‡
Omissions with target		−.18		NS	−.27		†
Incompatibility	74						
SD reaction time		−.28		*	−.26		*
Difference in error		−.12		NS	−.24		*
Visual field	100						
Median reaction time		−.33		‡	−.25		*
Absolute difference in reaction time		−.23		*	−.28		†
Absolute difference in omissions		−.26		†	−.14		NS
Visual neglect	101						
Absolute difference in reaction time		−.43		‡	−.38		‡
Absolute difference in omissions		−.34		‡	−.21		*
Driving Test							
Road test	104	−.67		‡			

Abbreviations: r_s, Spearman rank-correlation coefficient; C, Cramer coefficient; NS, not significant.
* $P < .05$.
† $P < .01$.
‡ $P < .001$.

Prediction of Driving Decision

To identify the set of variables that had the best predictive value as to the driving decision, a logistic regression was performed. In a univariate logistic regression, gender, aphasia, divided attention median visual reaction time, flexibility median reaction time, omissions with target in scanning, and the incompatibility tests were not found significant and were dropped for the multivariate regression analysis. Flexibility was also not used because of the small number of subjects. Factor analysis and intercorrelation analysis revealed a very high relationship between driving experience and age; therefore, only age was included. Although side of lesion was not significantly associated with outcome in this study, it was included because of its proven importance in previous studies.[1,3,24,25]

The multivariate analysis revealed that a combination of 4 variables—side of lesion, kinetic vision, scanning, and the road test—led to the best model in predicting outcome (table 2); R^2 was .53. The road test was the most significant predictor. A logistic regression including the road test alone produced an R^2 of .42. The odds ratio for a 5 unit increase in the driving test performance was 2.02, implying that those who improve by 5 points on the road test were 2 times more likely to be found suitable to drive.

Figure 1 shows the performance of subjects in the road-driving test according to the final group decision in the 3 above-mentioned categories. With the road test, scores can vary between 0 (worst performance) to 40 (best performance). The scores of those found suitable to drive (mean ± standard error [SE], 34.5 ± 1.5) were clearly higher compared with the

Table 2: Selected Model by Logistic Regression in Predicting the Final Group Decision

Variables	Parameter Estimate	SE	Wald Chi-Square	*P*	Odds Ratio
Intercept 1	−3.16	1.58	3.99	.05	
Intercept 2	.45	1.52	.09	.77	
Side of lesion	−1.23	.52	5.55	.02	.29
Kinetic vision	.81	.32	6.51	.01	2.25
Scanning	−.16	.08	4.15	.04	.85
Road test (5 units)	−.14	.03	28.55	.00	2.02

NOTE. N = 93, R^2 = .53.

scores of those found not immediately suitable (mean ± SE, 20.4 ± 1.4) and not suitable to drive (mean ± SE, 12.9 ± 2.4).

Prediction of the Road Test

Because the road-driving test was shown to be the most important determinant of the final group decision, a multiple regression analysis was generated to evaluate which tests could best predict the road-driving test itself. The results showed that the combination of acuity of the left and right eyes and the figure of Rey were the best subset to predict the road test. However, only 28% of the variance was explained by the 2 tests (table 3). The figure of Rey alone accounted for 24% of the variance.

DISCUSSION

This study sought to determine the predictive value of the set of variables contained in the predriving assessment performed at CARA, Belgium, in the decision of the driving ability of stroke patients who wished to resume driving. Many variables had individual predictive values both for the final group decision and the road test, as shown by the comparison of means, medians, or frequencies, and the correlation coefficients. Further examination of these results showed that the neuropsychologic tests differentiated mainly between those found not suitable to drive and the 2 other categories. On the other hand, the subjects found suitable to drive performed much better in the road test. These findings suggest that subjects in the not immediately suitable to drive category performed well in the neuropsychologic tests but rather badly in the road-driving test. This was probably because of poor compensatory mechanisms during driving. It is possible to compensate by driving slowly or by using road safety margins during poor visibility (tactical) and not driving during peak hours or by not driving at all (strategic).

Michon[26,27] described the following 3 levels of cognitive driving hierarchy: operational, tactical, and strategic. The operational level, which involves execution of basic driving actions such as steering control and brake application, demands coping with risks and is time dependent. The tactical level was described as a risk-taking level, which is, on the average, time dependent. It involves in-traffic decisions like speed adaptation and use of headlights during poor visibility. The strategic level of driving is not time dependent but entails accepting risk such as the decision to drive, what time to drive, and route planning.

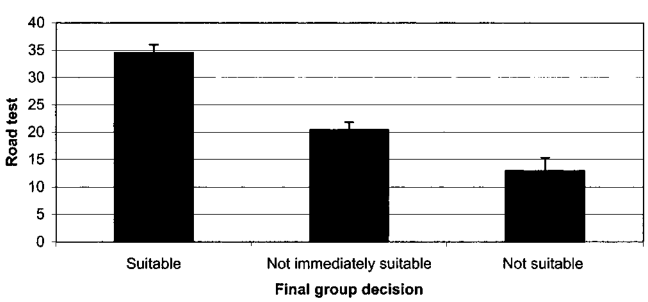

Fig 1. Mean performance in the road test according to the 3 categories of decision.

Table 3: Selected Model by Multiple Regression Analysis for the Prediction of the Road Test

Variables	Parameter Estimate	SE	*t*	*P*
Intercept	−25.65	9.04	−2.837	.006
Acuity of left and right eye	2.84	.94	3.024	.003
Figure of Rey	1.19	.31	3.882	.0002

NOTE: N = 99, R^2 = .28.

In multivariate analysis, a combination of side of lesion, kinetic vision, scanning, and the road test had the best predictive ability for the decision to drive. The road test was found to be the most important determinant of the variables. In predicting the road test, figure of Rey, and acuity of both eyes emerged as the combination with the best predictive ability.

There was no significant association between the number of patients with left- or right-sided brain lesion and the decision to drive in univariate analysis. This was also found in other studies.[1,3,25] Nevertheless, side of lesion was retained in the logistic regression analysis. This implies that when combined with other variables, side of lesion provided additional information. Inspection of individual data revealed that of the 9 patients who scored poorly in the road-driving test and were found suitable to drive, 7 had left-sided brain lesion and only 2 had a right-sided brain lesion. In contrast, 7 of the 8 patients who scored extremely poorly in the road-driving test and who were not suitable to drive had a right-sided brain lesion. Right brain-damaged stroke patients have been found to have more visual problems than their left brain-damaged counterparts.[3]

The kinetic vision test measures the ability of the patient to recognize objects in movement. It is logical that this test is an important determinant because driving requires recognizing objects around and on the road, which always appear to be moving. Data showed that only 5 of the 41 patients who were found suitable to drive scored poorly in the kinetic vision test. On the other hand, only 1 of the patients who were found not suitable to drive performed well. The acuity of both eyes also was an important indicator because only 1 of the patients who were suitable to drive had a poor binocular visual acuity. In New Zealand, inadequate visual acuity was the only explicit legal ban on driving and was the single main reason for a fail-reassess recommendation.[9] These results, however, contrast with the finding of Nouri et al[12] who found that the tests of vision and visual fields were not related to driving performance.

Among the neuropsychologic tests, scanning mean reaction time, figure of Rey, and visual neglect showed to be important indicators of driving performance. Scanning is an examination that assesses the capacity of active exploration of the visual field. It is a complex performance that involves several specific functions such as eye movements, visual neglect, and mental processing. Unimpaired sustained attention (concentration) is necessary for a good performance. The figure of Rey is a test of visual inattention and spatial abilities. These results agree with the study by Nouri[12] who reported that the cognitive tests that appear to be highly related to driving performance are those that involve complex reasoning. Sundet et al[3] also found test variables measuring neglect and speed of mental processing as significant predictors of driving ability among stroke patients.

The road test was the most important determinant of the group decision, which stresses the importance of an actual driving test. The road-driving test may seem a more valid evaluation, still, the test remains subjective because there are no standardized methods of scoring. Galski et al[11] showed that the validity of the individual items of a road test in the prediction of a pass or fail classification outcome was poor despite the face validity of the test. In a review study, Fox et al[28] emphasized the importance and need for a standardized, reliable, and valid road test after brain impairment.

Although the variables found in our study agree with findings of some studies,[3,9,11] other studies[5,12-14] have identified different specific cognitive and perceptual abilities, such as reasoning ability and spatial perception, as predictive of driving in stroke patients. However, it is difficult to compare the findings of our study with those of most other studies because of the different cognitive and perceptual tests contained in the predriving assessments. The outcome measures used in the other studies were also different. In some studies,[1,12-14] the performance during the road test itself was used as the outcome. In our study, the decision of the suitability to resume driving as determined by the assessing team on the basis of performance during the predriving assessment was used as the main outcome measure.

The importance of visual and neuropsychologic abilities in driving after stroke found in this and some other studies[1,3,12,13] is comparable with the findings in other neurologic groups. In patients with Parkinson's disease, slowness of cognitive processing, including visual processing, choice reaction time, visual perception, and memory, was identified as the major factor affecting driving.[29] In the study by Fitten et al,[30] the tests of memory, visual tracking, and mental state best predicted driving ability in subjects with mild Alzheimer's disease and vascular dementia. On the road, eye movements distinguished between the 2 groups with the Alzheimer's disease subjects, showing less visual scanning abilities than the vascular dementia group. Increased reaction time distinguished between patients with and without accidents after Huntington's disease in the study by Rebok et al.[31]

The finding of our study revealed a moderate predictive accuracy. The multivariate coefficient of determination (R^2) in predicting the final group decision was .53. The accuracy of predicting the road test was even lower ($R^2 = .28$). This may imply that other factors that were not measured, such as patient personality, use of adequate adaptations, or condition of vehicle used during testing, might have influenced the patient performance or team decision. The small number of patients in the fail (not suitable to drive) group ($n = 18$) compared with the other 2 groups ($n = 45$, $n = 41$) might have contributed to the low predictive accuracy as well. The composition of the predriving assessment, particularly the visual and neuropsychologic tests, thus warrants further study. More specific road-related tests could be included and redundant tests eliminated.

This study has some limitations. It is a retrospective study with the principal focus of determining the predictive value of a predriving assessment on the driving decision as used in Belgium. This inherently has some implications that may have influenced the results. The retrospective design led to a highly variable sample and some missing data especially in the tests of flexibility and incompatibility. The selection of tests for the predriving assessment was made based on face validity. It is therefore possible that some of the tests may not be appropriate predictors of driving performance. The predriving assessment also contained many vision and reaction-related tests (time, correct response). Although good vision and accurate reaction are necessary and important for safe driving, they are significantly affected by age. Furthermore, the reliability and validity of the road test was not established, and this might have influenced the predictive accuracy for both the team decision and the road test. To our knowledge, no previous study has been performed to prove the road test.

CONCLUSION

Many stroke survivors wish to return to driving. However, the varieties of predriving assessments for stroke patients vary between countries, just as do the laws concerning returning to driving. This study evaluated the value of the predriving assessment in a team decision's prediction regarding driving competence after stroke as it is performed in Belgium. The results showed some association between many of the general and medical parameters and visual and neuropsychologic tests with decision to drive, but the road-driving test was the most important determinant. The predictive accuracy of the team decision and especially of the road test was limited.

It is therefore suggested that other tests more closely related to road situations be performed in a predriving screening program and some emphasis should be put on the administration, reliability, and validity of the road test. It is our intention to develop a short and concise predriving assessment with a high predictive accuracy. It will provide information on aspects of driving, which can be used to improve driving performance after stroke.

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Suppliers

a. Essilor, 1 Rue Thomas-Edison, 94028 Creteil Cedex, France.
b. PSYTEST, version 1.02c; Psychologische Testsysteme, Den Hemigärten 27, D-52134 Herzogenrath, Germany.
c. Model 2000, version 2.1a (multilingual); Visual Resources Inc, 1733 Campus Plaza, Ste 15, Bowling Green, KY 42101.
d. SAS Institute Inc, SAS Campus Dr, Cary, NC 27513.