The Validity of a Road Test After Stroke

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ABSTRACT. Akinwuntan AE, De Weerdt W, Feys H, Baten G, Arno P, Kiekens C. The validity of a road test after stroke. Arch Phys Med Rehabil 2005;86:421-6.

Objectives: To determine the validity of a road test performed by stroke patients in Belgium and to reestablish its reliability.

Design: Prospective study of a predriving evaluation.

Setting: University hospital in Belgium.

Participants: Thirty-eight patients with sequelae of first-ever stroke.

Interventions: Not applicable.

Main Outcome Measures: Performance in the Stroke Driver Screening Assessment (SDSA) and on a road test.

Results: Interrater reliability of the road test subitems was moderate to substantial (weighted κ range, .44–.78). Item-per-item reliability varied from moderately high (intraclass correlation coefficient [ICC]=.63) to very high (ICC=.87). The reliability of the overall performance in the road test was very high (ICC=.83). For the criterion validity of the road test, 78.9% of the subjects were correctly classified when the judgments of the principal evaluator were compared with outcomes of the SDSA. Agreement in classification between the principal evaluator and a state-registered evaluator's judgments was 81.6%. The sensitivity and specificity of the agreement were very high (80.6%) and perfect (100%), respectively.

Conclusions: The road test is a reliable and valid test of driving ability after stroke.

Key Words: Automobile driving; Rehabilitation; Reliability and validity; Stroke.

A ROAD TEST IS ASSUMED to be the most valid test of driving competence, especially after brain injury.[1] This assumption is based on the face validity of the road test and its similarity to driving itself. The road test was used as the criterion for assessing driving performance in most studies of driving after brain injury[2-6] and especially of driving after stroke.[7-12] Notwithstanding the importance of the road test, very few studies have reported on assessments of its validity.

Odenheimer et al[13] assessed the validity of a standardized 16-km (10-mile) road test in a study with 30 elderly subjects. A significant correlation was reported between a driving instructor's global scores and the 2 research raters' scores for the closed-course (r=.35, P<.05) and in-traffic (r=.64, P<.01) sections of the test. In another study,[14] the validity of a 4.4-km (2.7-mile) road test was evaluated by comparing the previous 2-year driving records of 43 elderly, diabetic, or neurologically impaired subjects with their performance during the road test. The Pearson correlation between the driving records (number of collisions/moving violations per 1600km [1000 miles] driven) and the road test scores was r equal to −.38 (P<.02). The validity of the Washington University Road Test performed on a 9.6-km (5.9-mile) road was assessed in a study that included 65 subjects with Alzheimer's disease and 58 controls.[15] Comparison (Kendall τ-b) between a certified instructor's ratings and the quantitative scores of the study investigator was .60 (P<.001). Galski et al[16] assessed the validity of another road test in a retrospective study of the driving evaluations of 23 stroke patients and 14 people with traumatic brain injury. Results showed that none of the 21 items of an off-road test and only 6 of the 26 items of the road test were significantly associated with the overall outcome of the road test.

Most of the studies that assessed the validity of the road test were performed with a heterogeneous population. This heterogeneity is not always representative of common neurologic problems that affect driving, nor is it widespread enough to include the different driving populations (novice/young, adult, and elderly drivers). Yet, it is difficult to assume that the reported validity values of the road tests are applicable to road tests in specific populations such as stroke survivors. Despite road tests being commonly used in determining driving ability after stroke, we found only 1 study[16] of the validity of a road test that was performed by stroke patients (but not exclusively). Results of that study indicated poor validity of the test.

In Belgium, the road test is the most important predictor of a group decision on driving resumption by stroke patients. The test is based on performance in a predriving assessment administered at the Center for Determination of Fitness to Drive and Car Adaptations (CARA) unit of the Belgian Road Safety Institute.[17] The reliability of assessing overall performance in the road test was moderately high (intraclass correlation coefficient [ICC]=.62) and very poor to perfect reliability was found for its items.[18] However, the validity of the road test has never been established. It was, therefore, our purpose in this study to evaluate the validity of the road test performed by stroke patients in Belgium. The study was also designed to reestablish the test's reliability following recommendations and suggestions of the reliability study.[18]

METHODS

Participants

All stroke patients admitted to a rehabilitation hospital in a 9-month period and who were not older than 75 years were told the purpose of this study, its procedure, and its duration. Those who agreed to participate in the study signed informed consent documents. All subjects were between 6 and 15 weeks post-

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Table 1: Descriptive Characteristics of the 38 Subjects

Variables	Descriptive Statistics
Sex, n (%)	
Male	31 (81.6)
Female	7 (18.4)
Age (y)	
Mean ± SD	53.9±12.8
Range	24–73
Side of lesion, n (%)	
Right	20 (52.6)
Left	16 (42.1)
Bilateral	2 (5.3)
Type of stroke, n (%)	
Ischemic	26 (68.4)
Hemorrhagic	12 (31.6)
Driving experience (y)	
Mean ± SD	32.1±12.7
Range	6–50
Distance traveled (1000km/y)	
Mean ± SD	21.7±12.0
Range	5–60
Hemi- or quadrantanopia, n (%)	
Yes	10 (26.3)
No	28 (73.7)
Visual acuity, n (%)	
20/20	22 (57.9)
20/25	12 (32.6)
20/30	4 (10.5)

stroke; in Belgium, people with functional impairment after stroke are encouraged not resume driving until 6 months after onset. For this reason, subjects who participated were specially insured. The inclusion of subjects earlier than the 6-month waiting period was done to ensure a variety of driving performances. The medical ethics committee of the University Hospitals of the Katholieke Universiteit Leuven, Belgium, approved the study protocol.

Thirty-eight (31 men, 7 women) first-ever stroke subjects with an average age of 53.9 years who were actively undergoing rehabilitation in the University Hospital Pellenberg, Leuven, Belgium, were included (table 1). Twenty subjects had right-sided lesion, 16 had left-sided lesion, and 2 had bilateral lesion. Twenty-six (68.4%) and 12 (31.6%) of the subjects had ischemic and hemorrhagic stroke, respectively. Most of the subjects had more than 15 years of driving experience (mean ± standard deviation [SD], 32.1±12.7y) and drove about 21,700±12,000km/y on average. Five subjects had quadrantanopia and another 5 had hemianopia. The latter 5 were certified by an ophthalmologist to be capable of performing the predriving evaluations. Twenty-two (57.9%) subjects had binocular visual acuity that corresponded to 20/20. Subjects with corrective glasses or lenses performed the tests of visual acuity and other evaluations by using the appropriate corrections.

Evaluations

All subjects performed a battery of off-road tests and an on-road test, with a rest of about 45 minutes between the off- and on-road evaluations.

Off-road tests. Experienced psychologists from CARA administered to all subjects a modified version of the Stroke Driver Screening Assessment (SDSA) battery,[10] made up of the dot cancellation test,[19] square matrix (direction and compass) test, and the road sign recognition test. The dot cancellation test is a measure of attention and concentration in which subjects are instructed to cross out all groups of 4 dots on an A4 paper. The numbers of uncrossed groups of 4 dots, groups of dots other than 4 crossed, and the time spent (maximum, 15min) were documented. The square matrix test consists of the direction and compass subtests. Each subtest involves matching a card that contains pictures of 2 vehicles traveling in different directions to 1 of 16 squares arranged in a 4×4 matrix in a maximum of 5 minutes. Arrows (direction test) or 1 painted arm of compasses (compass test) pointing in the directions of travel of the vehicles depicts the correct square for each card. A correctly placed card earns 2 points. Scores of performance in each test range from a minimum of 2 points (obtained from an example) to a maximum of 32. The road sign recognition test contains 19 cards with different traffic signs and another 12 cards, each with a picture suitable for a particular traffic situation. The subject is instructed to match each of 12 cards from the 19 traffic sign cards to the most appropriate traffic situation card in a maximum of 3 minutes. One point is awarded for each correctly matched pair of cards, which results in a range of 0 to 12 possible points. For the square matrix and road sign recognition tests, driving picture changes and traffic signs in the original SDSA verison[10] were modified to make them applicable to the traffic style in Belgium.

Based on the study by Nouri and Lincoln,[10] pass and fail scores were generated for each subject according to a discriminant function predicting driving ability after stroke. When the *pass* score of a subject is higher than the *fail* score, the subject is predicted to be found fit to resume driving and vice versa. The accuracy of the SDSA in predicting driving fitness of stroke patients was reported as 81%.[11]

On-road test. The road test was conceptualized by experienced traffic safety and assessment experts and performed on a standardized 17-km (10.4-mile) road similar to the test route in Brussels. The road test was performed in an adapted automatic transmission car fitted with double brake and gas pedals to ensure safety. The test always started on the premises of the University Hospital Pellenberg and proceeded to a village near the hospital that has average vehicular and human traffic. The test then progressed to busier roads and eventually on to the highway before terminating back at the hospital. A complete road test lasted 45 minutes on average.

Three assessors, including a principal (CARA) evaluator, research investigator, and state-registered evaluator, assessed performance in the road test. All assessors were involved in a pilot evaluation that included 10 stroke patients. The pilot evaluation was conducted to standardize the road test and the criteria for judging driver performance. That evaluation also offered the state-registered evaluator, who assesses persons applying for a new driving license in Belgium, the opportunity to gain experience in assessing stroke patients.

Based on outcome of the pilot study, a checklist from the Test Ride for Investigating Practical Fitness to Drive: Belgian Version[20] (TRIP), was adapted and shortened to 13 items containing 49 subitems. Each subitem was scored on a 4-point scale a ("bad" performance equal to 1, "insufficient" performance equal to 2, "sufficient" performance equal to 3, "good" performance equal to 4). A minimum score of 49 points indicated the worst performance and a maximum of 196 points signaled a faultless performance. The principal evaluator, who was always seated in the front seat with the subject, and the research investigator—seated behind the subject—completed the adapted TRIP checklist during the test. However, in a few, but potentially dangerous situations during the test, the principal evaluator, who was also responsible for safety, took control of the vehicle and scored the subject's driving performance

Table 2: Mean, Median, and IQR Performances on the SDSA and Road Test as Judged by the Principal Evaluator, Research Investigator, and State-Registered Evaluator

Assessments	Mean ± SD	Median	IQR (Q1–Q3)
SDSA			
Dot cancellation time (s)	569±230	528	367–795
Dot cancellation errors (range, 0–213)	29±39	16	2–40
Dot cancellation false positives (range, 0–412)	0.7±1.5	0	0–0
Square matrix direction (range, 0–32)	23±12	31	12–32
Square matrix compass (range, 0–32)	15±10	15	8–21
Road sign recognition (range, 0–12)	5±3	5	3–7
Road test			
Principal (CARA) evaluator (range, 49–196)	134±57	136	82–185
Research investigator (range, 49–196)	121±56	126	58–177
State-registered evaluator (range, 10–40)	27±7	28	22–32

Abbreviations: Q1, 25th percentile; Q3, 75th percentile.

immediately after the test. After each test, the principal evaluator decided whether a subject was (1) fit to drive, (2) temporarily unfit to drive, or (3) definitively unfit to drive. Only subjects who are judged fit to drive after the predriving assessments can resume driving. Consequently, a "fit to drive" decision became a pass decision and "temporarily unfit to drive" or "definitively unfit to drive" became a fail decision.

The state-registered evaluator, seated behind the principal evaluator, assessed performance during the road test by completing a checklist of 10 predefined components of driving by using a 4-point scale similar to the TRIP test. This evaluator also gave an overall judgment of pass or fail. The judgment was based on the total number of bad and insufficient judgments and not on the total score from the completed checklist.

Data Analysis

We used descriptive and inferential statistical analyses of mean, SD, and frequency distribution to document subject characteristics. We explored relationships between the variables of sex, age, side of lesion, type of stroke, driving experience, average kilometers driven per year, and the total scores in the road test as judged by the principal evaluator. For data sets that contained nominal variables, we used the point biserial correlation coefficient and when data sets contained ratio variables, the Pearson correlation coefficient was used. Mean, SD, median, and interquartile range (IQR) of performance in the various assessments were derived to examine the distribution in our subject population.

Interrater reliability in scoring the subitems (4-point ordinal scale) was evaluated by comparing the judgments of the principal evaluator with scores given by the research investigator by using the weighted κ. Values of weighted κ from less than 0 to .20 were considered as poor, from .21 to .40 as fair, from .41 to .60 as moderate, from .61 to .80 as substantial, and from .81 to 1.0 as almost perfect.[21] The ICC was used to determine the interrater reliability in scoring the items and overall performance in the road test. ICC values below .40 were considered low, between .40 and .59 as moderate, between .60 and .79 as moderately high, and .80 or above as very high.[22]

The criterion validity of the road test was determined by comparing the pass or fail outcome of subjects' performance in the SDSA with those of the road test, as judged by the principal evaluator. We calculated the Pearson correlation coefficient to determine the relation between the total score given by the principal evaluator and that given by the state-registered evaluator. The concurrent validity of the road test was determined by comparing the principal evaluator's pass-fail judgment with that of the state-registered evaluator. We also determined the test's sensitivity and specificity by comparing the proportions of subjects who were judged as having passed or failed by the state-registered evaluator and by the principal evaluator. All statistical procedures were carried out with the SAS system.[a]

RESULTS

The variables of sex, age, side of lesion, type of stroke, driving experience, and the average number of kilometers driven per year showed no statistically significant correlation with the overall performance in the road test, as assessed by the principal evaluator. From these results, it was evident that there were no subgroups in our subject population, and therefore further results were based on the total group performance.

Subjects' performances in the component tests of the SDSA and road test as judged by the principal evaluator, research investigator, and state-registered evaluator also showed that the distribution of the population was not skewed (table 2). The only exception was in a section of the dot cancellation test (false positives).

Reliability

Scoring agreement at the subitem level (table 3) between the principal evaluator and the research investigator was moderate to substantial. The values varied between a weighted κ equal to .44 (observation of the blind angle) and weighted κ equal to .78 (lane keeping without distraction at a speed $<$50km/h). Thirty-two subitems of the road test showed substantial reliability. Most subitems (3 and 4, respectively) of items 5 (anticipation and perception of signs) and 7 (joining the traffic stream) showed moderate reliability. Two of the 9 subitems of item 11 (turning left on a major road) and all 8 subitems of item 12 (visual communication and behavior) also showed moderate reliability.

The interrater reliability of the road test items (table 4) varied between moderately high and very high. As expected from the reliability of the subitems, the item of visual communication and behavior showed the least reliability (ICC=.63). Items 1, 3, 6, and 8 were very highly reliable (ICC$\geq$.80), with item 8 (mechanical operations) showing the highest reliability (ICC=.87). The interrater reliability of the overall performance in the road test was also very high (ICC=.83).

Validity. For the criterion validity, there was 78.9% agreement in the classification (pass or fail) of subjects' driving performance when judgments by the principal evaluator were compared with the outcome of performance in the SDSA (table 5). Seven of the 13 subjects who were classified as "pass"

Table 3: Scoring Agreement of the Road Test at the Subitem Level Between the Principal Evaluator and the Research Investigator

Item	Weighted κ	95% CI
1.1	.78	.63–.94
1.2	.75	.59–.90
2.1	.66	.49–.84
2.2	.64	.44–.83
2.3	.64	.45–.83
2.4	.66	.48–.85
2.5	.70	.53–.86
3.1	.73	.56–.90
3.2	.71	.54–.88
4.1	.66	.49–.82
4.2	.68	.52–.84
5.1	.59	.41–.77
5.2	.59	.41–.77
5.3	.61	.43–.78
5.4	.60	.42–.77
6.1	.74	.61–.87
6.2	.69	.55–.83
6.3	.60	.45–.75
7.1	.67	.50–.83
7.2	.53	.33–.74
7.3	.47	.28–.66
7.4	.62	.44–.79
7.5	.58	.40–.77
7.6	.58	.40–.76
8.1	.72	.56–.88
8.2	.74	.58–.89
9.1	.67	.49–.85
9.2	.66	.48–.85
10.1	.64	.48–.80
10.2	.64	.48–.80
11.1	.63	.44–.82
11.2	.47	.26–.67
11.3	.62	.45–.79
11.4	.62	.44–.80
11.5	.50	.30–.69
11.6	.67	.52–.83
11.7	.63	.46–.79
11.8	.66	.49–.82
11.9	.64	.47–.82
12.1	.52	.34–.70
12.2	.52	.34–.70
12.3	.54	.36–.72
12.4	.51	.32–.70
12.5	.44	.24–.64
12.6	.47	.27–.67
12.7	.47	.28–.67
12.8	.48	.28–.68
13.1	.66	.48–.84
13.2	.69	.53–.85

Abbreviation: CI, confidence interval.

according to the SDSA were judged to have passed by the principal evaluator. Two subjects were classified as "fail" by the SDSA but were judged to have passed by the principal evaluator.

The correlation (r) between the total score by the principal evaluator and the total score from the state-registered evaluator was .80 ($P<.001$).

In establishing the concurrent validity, there was 81.6% agreement in the classification (pass or fail) of subjects' driving

Table 4: ICCs and 95% CIs for the 13 Items and Overall Performance on the Road Test From Comparisons Between Evaluations of the Principal Evaluator and Research Investigator

Item	ICC	95% CI
1. Position on the road (<50km/h)	.83	.70–.91
2. Lane changing	.77	.60–.88
3. Distance from car ahead at <50km/h	.80	.65–.89
4. Speed in areas with limit (<50km/h)	.79	.61–.89
5. Anticipation and perception of signs	.74	.56–.86
6. Mechanical operations	.87	.67–.94
7. Joining the traffic stream	.75	.54–.87
8. Position on the road (>50km/h)	.82	.69–.90
9. Distance from car ahead at >50km/h	.75	.56–.86
10. Speed in areas with limit (>50km/h)	.78	.58–.88
11. Turning left on a major road	.77	.56–.88
12. Visual behavior and communication	.63	.33–.80
13. Quality of traffic participation	.76	.59–.87
Overall performance	.83	.65–.92

performance when the judgments of the principal evaluator were compared with the judgments of the state-registered evaluator (table 6). Judgments of the principal evaluator classified in the fail group 29 of the 36 subjects classified by the state-registered evaluator in that group, which corresponded to a sensitivity of 80.6%. Results showed that 9 (23.7%) subjects passed the on-road test according to the principal evaluator while 2 (5.2%) subjects passed the on-road test according to the state-registered evaluator. All subjects judged as "pass" by the state-registered evaluator also passed according to the judgments of the principal evaluator, which corresponded to a specificity of 100%.

DISCUSSION

One purpose of this study was to reevaluate the reliability of the road test performed in CARA (a unit of the Belgian Road Safety Institute) by stroke patients who want to resume driving. The reliability of the road test subitems (weighted κ range, .44–.78) was moderate to substantial. The road test items also showed moderately high to very high reliability values (ICC range, .63–.87). The reliability of the overall performance in the road test was very high (ICC=.83). Other studies[13-15,23] have also reported similar reliability values for the road tests. These results are better than those from the earlier reliability study[18] and from another study of the test's reliability when performed by older drivers and assessed by using another version of the TRIP test.[20]

The improved reliability of our road test may be attributed to experience gained by the principal evaluators and the research investigator in using the adapted TRIP checklist in the evaluation of the road test. It could also be the result of a conscientious application of the recommendations of the earlier reliability study.[18] In the previous study, few subjects performed poorly during the road test, resulting in a skewed distribution.

Table 5: Comparison of Outcome on the SDSA With Judgment by the Principal Evaluator

	SDSA, n (%)	
Principal (CARA) evaluator, n (%)	Fail	Pass
Fail	23 (60.5)	6 (15.8)
Pass	2 (5.3)	7 (18.4)

Table 6: Comparison of Judgment by the State-Registered Evaluator With Judgment of the Principal Evaluator

	State-Registered Evaluator, n (%)	
Principal (CARA) evaluator, n (%)	Fail	Pass
Fail	29 (76.3)	0 (0.0)
Pass	7 (18.4)	2 (5.3)

This was attributed to the fact that the study included only patients who came to CARA for the predriving evaluation at least 6 months poststroke and were confident of a good performance in the road test. In this study, subjects were included during the rehabilitation phase, which offered the possibility of a better distribution of scores, as seen in the performances reported in table 2. Second, 2 assessors accompanied and assessed the real-life driving performance of the subjects. Previous studies[14,18,23] have shown that road tests have better reliability when assessed under similar conditions. Third, the item of visual behavior and communication that was difficult to evaluate because of methodologic problems in the previous study[18] was redefined and was now assessed under the same condition. Although this item still showed the poorer reliability (ICC=.63), the value is a marked improvement over its outcome (ICC=−.01) in the earlier study.[18]

The closed course part of the road test, which was assessed in the earlier study,[18] was not included in this study because it is predominantly used to determine whether candidates can progress to driving in a real traffic situation. It does not influence the evaluator's judgment of the overall driving performance. It also showed only weak correlation when compared with the in-traffic section or overall driving performance in other studies.[13,16]

The main focus of this study was to establish the validity of the road test performed by stroke patients in Belgium. The content validity of the test was addressed by the participation of experts and driving instructors in the design, planning, and implementation of the various aspects of the road test. For the criterion validity, 78.9% of subjects were correctly classified as "pass" or "fail" when the judgments of the principal evaluator were compared with the pass or fail outcome of the SDSA. The SDSA was shown to be predictive of driving ability after stroke,[11] even when it was adapted for use in the traffic situation in Sweden and Norway.[24] It was therefore logical that we chose the SDSA to establish the criterion validity of the road test.

The correlation between the driving performance total scores by the principal evaluator and the state-registered evaluator was high (r=.80). Agreement in the classification (pass or fail) of subjects' overall performance in the road test between the 2 evaluators was 81.6%. The sensitivity and specificity were 80.6% and 100%, respectively. However, results also showed that subjects who failed the principal evaluator's assessment would also fail the state-registered evaluator's assessment, whereas subjects who earned a pass from the principal evaluator had only a 22.2% probability of passing as judged by the state-registered evaluator.

Seven subjects were classified as pass by the principal evaluator but failed in the judgment of the state-registered evaluator (table 6). Six of the 7 had problems with positioning on the road and speed control at the beginning of the test but improved as the test progressed. The state-registered evaluator scored performances of these items as "bad" and, coupled with 1 or 2 more insufficient scores in other stages of the test, the subjects were judged as having failed. However, improvements and safety responsibility during the course of the test might have had important roles in the principal evaluator's global judgment of the driving performance.

CONCLUSIONS

Our findings show that the reliability of the road test performed by stroke patients in Belgium is high. Apart from the face validity and similarity between the road tests and the driving performance, it is a valid test of driving ability after stroke.

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