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Validation of an *off-road* cognitive and behavioral evaluation protocol for driving after a stroke

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ABSTRACT

Objective: People who have experienced a stroke may exhibit neuropsychological and behavioral impairments that affect their ability to drive safely. To our knowledge, there is currently no standardized, validated assessment protocol for this purpose in the Spanish context. Consequently, the aim of this research was to validate a protocol to address this need.
Methods: We conducted a comprehensive cognitive and behavioral assessment in a group of people with stroke. Different correlation analyses were carried out between the variables and the on-road score, as well as a linear regression analysis. Subsequently, serial trichotomization was performed.
Results: 45 people with stroke were evaluated. Several variables of bimanual coordination and motor planning, divided attention, visuospatial skills, executive functions, hazard prediction and dissociative driving style were related to the on-road score. The linear regression model, including the variables that correlated moderately, explained 71.8% of the on-road score ($p = 0.014$). Serial trichotomization with 4 tests (visual perception, divided attention, bimanual coordination, and hazard prediction) classified 22.72% of participants as fit and 2.72% as unfit.
Impact: This study pioneers the validation of an *off-road* assessment protocol that measures the ability to drive safely in Spanish individuals who have suffered a stroke. The results help in clinical decision-making to reduce evaluation times and to work on possible rehabilitation of altered cognitive processes to return to driving.
ClinicalTrials.gov: This study is part of the project registered under NCT 05659667.

1. Background

Driving is a highly relevant instrumental activity that supports independence, social participation, and quality of life (Devos et al., 2021; Samuelsson et al., 2021). However, it is also a complex task that requires the continuous integration of cognitive, perceptual-motor, and behavioral processes in a dynamic environment (Unsworth et al., 2019). Safe driving depends on multiple cognitive domains, including attention (Roca et al., 2011; Samuelsson et al., 2021), processing speed (Wolfe & Lehockey, 2016), perception (Castro Ramírez et al., 2006), memory (Aksan et al., 2015), executive functions (Asimakopulos et al., 2012), praxis (Fields & Unsworth, 2017).

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Hazard prediction skills, involving processing speed, executive functions, memory, and visuospatial abilities, are essential for identifying and responding to high-risk traffic events (Crundall et al., 2012; McInerney & Suhr, 2016) and are inversely associated with the likelihood of accidents (Wells et al., 2008). In addition, driving behavior and style influence safety, with maladaptive patterns being linked to reward and punishment sensitivity (Padilla et al., 2020).

1.1. *Driving assessment after stroke*

Stroke is a common neurological condition and a leading cause of long-term disability. Although survival rates have increased, up to 75% of stroke survivors experience cognitive deficits in the acute phase, and approximately 50% continue to show impairments in the chronic phase (Salvadori et al., 2022).

In the field of driving, while motor impairments after stroke can often be compensated through vehicle adaptations (Devos et al., 2011), cognitive impairments are more difficult to mitigate and represent a stronger predictor of driving performance.

Among the cognitive processes involved in driving that may be affected after a stroke, processing speed, attention and executive functions stand out, including decision-making and anticipation of events. Slower processing speed due to brain damage slows decision-making while driving (Schultheis & Whipple, 2014). In relation to attention, specifically in the periphery, studies have shown that processing information within the inner 30° predicts car accidents (Braga et al., 2018; Fisk & Mennemeier, 2006). Furthermore, drivers with stroke struggle with complex maneuvers that require simultaneous attention to surrounding vehicles (Hird et al., 2014). Deficits in selective attention and motor execution result in slower braking, increasing the risk of collisions and injuries (Lodha et al., 2021). In relation to executive functions, it has been shown that poor executive function, including inhibition and abstract reasoning, predicts driving performance issues and traffic violations post-stroke (Cardoso et al., 2014; Clark et al., 2008; Moore et al., 2025). Stroke lesions hinder the anticipation of traffic events (Hwang & Song, 2023; Steen, 2023; Sundström, 2008; Zhou et al., 2022) and show difficulties in assessing road conditions and lane changes, particularly in new and challenging situations (Devos et al., 2014; Gillen & Rubio, 2016). People with stroke can also have impaired ability to make decisions and choose the most beneficial option, as well as to properly assess risk. Furthermore, a lack of self-awareness can lead some people to overestimate their driving abilities, thereby increasing safety risks (Gasne et al., 2024). Recent research also explores the use of neuroimaging techniques to improve the identification of cognitive deficits after stroke. For instance, Zhang et al. (2025) highlight the potential of functional near-infrared spectroscopy (fNIRS) biomarkers to stratify post-stroke cognitive impairment, particularly in domains such as processing speed and executive function, which are critical for driving ability.

However, returning to driving is considered by stroke survivors and their families, as an indicator of recovery and a priority for improving their personal autonomy. Research suggests that approximately 30–50% of brain injury survivors resume driving, with the majority doing so without undergoing a formal assessment (Marshall et al., 2007; Motta et al., 2014), making them more likely to be involved in road traffic accidents than the average driver (Rabadi et al., 2010).

Considering the variability of possible alterations and their consequences for safe driving, a comprehensive and specific cognitive assessment is required to determine fitness to drive in individuals who have suffered a stroke.

Internationally, both on-road and off-road assessments have been used to predict driving performance after neurological conditions. Although on-road tests show higher predictive validity (Akinwuntan et al., 2012; Bellagamba et al., 2020; Rabadi et al., 2010; Sawada et al., 2019), with standardized on-road tests achieving a sensitivity of 81–93% and a specificity very close to 100% (Alhashmi et al., 2022; Bellagamba et al., 2020) they are costly and difficult to standardize (Bellagamba et al., 2020). Off-road tests offer a practical alternative but show variable predictive accuracy (Devos et al., 2011; Motta et al., 2014; Samuelsson et al., 2021) with an overall accuracy of 80–91% (total proportion of drivers correctly classified compared to on-road), but with sensitivities often lower than specificities, therefore, they should not be used as the sole criterion for license withdrawal (Akinwuntan et al., 2018, 2013; Anstey et al., 2020; Hines & Bundy, 2014; Kay et al., 2012). Given that driving requires the effective use of numerous cognitive processes, a combination of tests is recommended to evaluate domains essential for safe driving, as no single assessment tool encompasses all necessary functions and skills (Selander et al., 2020). Consequently, for off-road testing, the use of structured test batteries and sequential decision-making approaches, such as serial trichotomization, has been proposed to improve efficiency and accuracy, thus reducing the workload and waiting time for patients (Krasniuk & Crizzle, 2024).

In Spain, the assessment of fitness to drive is carried out by the Drivers' Assessment Centers based on the medical history and a psychophysical assessment through the Psycho-Technical Driving Test (Gombao-Ferrándiz & Muñoz-Menéndez, 2011; Ministerio del Interior et al., 2022). In addition, minimum medical requirements for obtaining or renewing a driving license are regulated under the Spanish General Drivers' Regulations (Real Decreto 818/2009, 2009, Annex IV).

Within the specific off-road evaluation of pathologies affecting the nervous system, such as stroke, the Protocol for medical-psychological exploration for Drivers' Assessment Centers recommends the combined use of a set of cognitive assessment instruments frequently used in clinical practice for the assessment of cognitive impairment (Ministerio del Interior et al., 2022). However, these instruments are provided as general guidance rather than as a standardized assessment battery; their selection relies on professional judgment, and evidence supporting their predictive validity for driving performance in the Spanish context remains limited. Consequently, the lack of a unified, evidence-based off-road protocol may lead to heterogeneous assessments and variable decisions across centers and professionals, highlighting the need for a standardized Spanish protocol aligned with the Drivers' Assessment Centers pathway and national regulations.

In several international contexts, the assessment of fitness to drive after stroke is embedded within post-stroke rehabilitation services rather than conducted solely through independent fitness-to-drive centers (Canadian Association of Occupational Therapists, 2017; Marshall et al., 2007). In countries such as Canada and the United Kingdom, driving evaluation and rehabilitation are commonly led by occupational therapists within multidisciplinary rehabilitation teams, using structured clinical protocols that combine off-road cognitive assessment, functional evaluation, and, when appropriate, on-road testing as part of the continuum of stroke care (Scottish Stroke Allied Health Professionals Forum, 2023; National Health Service, 2022). Similarly, in Australia, fitness-to-drive decisions following stroke are integrated into clinical rehabilitation pathways, with health professionals responsible for assessing functional recovery and readiness to return to driving (Stroke Foundation Australia, 2021). These models contrast with the Spanish system, where driving fitness is primarily assessed through Drivers' Assessment Centers operating outside formal post-stroke rehabilitation pathways (Ministerio del Interior et al., 2022; Real Decreto 818//2009, 2009), which may limit the direct transferability of international protocols and underscore the need for context-specific assessment approaches. In fact, previous research has reported limited effectiveness of Drivers' Assessment Centers in Spain in accurately evaluating psychophysical fitness to drive among individuals with underlying medical conditions and that it could be improved with more follow-up, training and connection with the regional health service (García-Fortea et al., 2016).

1.2. The present study

Despite the existence of a regulated pathway for assessing fitness to drive in Spain, the current evaluation framework presents important limitations from a scientific and clinical perspective. Although the medical-psychological exploration protocol proposes the use of cognitive instruments commonly applied in clinical settings, it does not define a standardized off-road assessment battery, nor does it establish evidence-based decision rules or test-specific cutoff points linked to driving performance. As a result, the assessment of post-stroke driving fitness relies largely on non-standardized test selection and professional judgment, with limited empirical support regarding the predictive value of these measures in the Spanish context. This gap between regulatory requirements and evidence-based assessment procedures hinders the consistent and objective evaluation of driving safety after stroke.

The present study is justified by the need to develop and validate an evaluation protocol incorporating multiple off-road tests to assess driving after a stroke (currently lacking in the Spanish context), in line with efforts undertaken by other countries such as Australia (Unsworth et al., 2019). The aim is to create a homogeneous, standardized, and validated protocol that can establish specific cutoff points for each included test, ensuring high specificity and sensitivity, as part of a serial trichotomization procedure. We hypothesize that a serial trichotomization approach combining multiple tests will improve classification accuracy (fit vs. unfit) relative to a single-test approach.

The tests selected for the protocol will enable the assessment of cognitive domains and behavioral measures associated with safe driving. Initially, perception is highlighted as a basic process. Perception allows for the identification of the state, characteristics, and dynamics of environmental elements and drivers themselves, which is crucial for managing changing visual information (Castro Ramírez et al., 2006). Alterations in the useful visual field (UFOV) or in visual attention can generate longer reaction times, limiting information processing and having negative consequences for driving (Wolfe & Lehockey, 2016). Processing speed plays a crucial role in enabling reactions (involving the use of vehicle controls and adaptations) to be carried out effectively, in accordance with each situation. Specifically, it is necessary for the individual to maintain a good level of alertness and vigilance, as well as sustained, selective, and divided attention to manage relevant elements, ignore distractions, and perform simultaneous tasks (Roca et al., 2011; Samuelsson et al., 2021).

Driving continuously demands the participation of working memory, which limits how much traffic information can be held and processed at one time, influencing situational perception, judgment, and motor response to avoid collisions (Zhang et al., 2023). A greater working memory capacity is associated with more consistent and safer driving parameters, such as better lane keeping and fewer distracted driving violations. (Broadbent et al., 2023; Louie & Mouloua, 2019; Wood et al., 2016).

Executive functions are high-level processes that allow to plan, organize, inhibit automatic responses, keep information in mind, and change strategies in new situations (Diamond, 2013; Friedman & Miyake, 2017). Driving is a complex, multitasking, goal-oriented task that demands precisely these abilities: maintaining the objective (arriving safely), monitoring the environment, making quick decisions, and adjusting behavior in real time (Hayashi et al., 2018; Pergantis et al., 2024; Walshe et al., 2017). In addition to the ability to plan the most advisable route in advance, taking into account various circumstances such as environmental and personal factors (Laffarga et al., 2026).

On the other hand, praxis would allow for the programming and execution of necessary movements (Fields & Unsworth, 2017). Motor coordination and programming appear to be important for driving the vehicle centered and at an appropriate speed (Gentle et al., 2021).

Encompassing some of these cognitive processes (processing speed, memory, executive functions, and visuospatial skills), skills related to hazard prediction stand out, namely, the ability to identify and react to road events that have a high probability of resulting in a collision (Crundall et al., 2012; McInerney & Suhr, 2016)). This is crucial for making appropriate decisions regarding maneuvers to be executed, correlating negatively with the likelihood of accidents (Wells et al., 2008). Finally, another fundamental element in driving is the driver's behavioral variables, as well as their driving style, which could range from adaptive to maladaptive behaviors. These styles have been related to risk-taking in different life domains, as well as behavioral patterns regarding sensitivity to punishments-rewards. In this regard, reckless driving styles have been associated with high reward sensitivity, and anxious driving style has been related to high punishment sensitivity (Padilla et al., 2020).

2. Methods

2.1. Design

The aim of the present study was to validate a protocol for the evaluation of the fitness to drive safely in the Spanish population after a stroke, through cross-sectional case observation.

2.2. Participants

2.2.1. Recruitment

The study population comprised individuals who had experienced a stroke. Participants were recruited through non-probability convenience and snowball sampling, facilitated by agreements with various rehabilitation services in public hospitals and private centres. Occupational therapists, neurologists, neuropsychologists, and rehabilitation physicians affiliated with these services informed patients about the study and invited them to participate.

2.2.2. Inclusion/exclusion criteria

The inclusion criteria for participants in this study were as follows:

- Individuals with a stroke (haemorrhagic or ischemic) in the chronic phase, i.e., at least 6 months after the event. Participants must have medical authorization to participate in the study, indicating medical stability regardless of their ability to drive.
- Age between 18 and 70 years.
- Holding a valid driver's license and having driven in the three months prior to the stroke.
- Being able to stand and having sufficient movement in at least one arm to manipulate a steering wheel, gear shift and knob smoothly.
- Participants will be excluded if they do not meet the minimum criteria required for driving by the Spanish Department for Transport (Dirección General de Tráfico, DGT) as outlined in the General Drivers' Regulations (Real Decreto 818//2009, 2009), which include evidence of epileptic seizures, hemineglect syndrome, or severe balance disorders. The remaining exclusion criteria are described in the initial screening of Table 1.

2.3. Procedure

Initially, a literature review isolated psychological, neuropsychological, and functional tests that predict post-stroke driving ability, which were subsequently vetted and refined through consensus by a multidisciplinary panel of psychometric and clinical driving experts. Investigators supplied the inclusion and exclusion criteria to recruitment centers, secured informed consent authorizing the transfer of contact details, and subsequently contacted eligible individuals to provide full study information and confirm their participation.

Participants visited the research center and, after signing the informed consent form, began the evaluation, with the collection of sociodemographic and driving data (level of expertise and frequency). Two occupational therapists specialized in driving and researchers on this project performed the initial screening and ensured that the patients met the criteria for each of the tests described in Table 1. They were then asked to drive for 15 min in a simulator to confirm the absence of intolerable pain and identify any adaptations required for the subsequent on-road test. Next, the participants were evaluated using the protocol, beginning with off-road tests and then moving on to the on-road test. The estimated time to complete the entire evaluation protocol was approximately 9 h, conducted over multiple sessions based on the participants' preferences and needs (approximately 4–5 sessions).

The *off-road* assessment was conducted by an occupational therapist specialized in brain injury and cognitive neuroscience. Meanwhile, the *on-road* assessment was performed by a driving instructor and another occupational therapist specialized in driving after a stroke. Evaluators for the *on-road* assessment were blinded to the participants' performance in the previously conducted *off-road* tests. Similarly, the *off-road* evaluator was unaware of the *on-road* assessment results.

2.4. Measurement

The *off-road* tests consist of a set of validated assessments that evaluate different processes involved in driving (See Table 2).

Table 1
Initial screening.

	Variables	Cut-off for exclusion
General Cognitive Status	• MMSE (Folstein et al., 1975)	< 24 points
Reading	• Boston Sentence Reading Test (Goodglass et al., 1986)	< 2 points
Visual Acuity	• Snellen Test (Azzam & Ronquillo, 2023)	< 0.5 binocular visual acuity < 0.1 monocular visual acuity
Pain	• Adapted Functional Pain Scale (Gloth et al., 2001)	> 3

Table 2
Off-road evaluation protocol.

Domain	Tests
Global Cognitive-motor skills for driving	• Psycho-technical driving test (Gombao-Ferrándiz & Muñoz-Menéndez, 2011)
Cognitive tests	• MiniMental State Examination (MMSE) (Folstein et al., 1975) • Visual Object and Space Perception Battery (VOSP) (Warrington & James, 1991) • Useful Field Of View (UFOV) (Ball et al., 1993; Edwards et al., 2005) • Trail Making Test (TMT) (Reitan & Wolfson, 1985) • Continuous Performance Test (CPT) (Rosvold et al., 1956) • Paced Auditory Serial Addition Test (PASAT) (Duque et al., 2012; Gronwall, 1977) • IOWA Gambling test (Bechara et al., 1994) • Five Digit Test (Sedo, 2004) • Spanish Weekly Calendar Planning Activity (WCPA-10) (Toglia, 2015); (Salazar-Frías et al., 2023) • Luria Premotor Series (Luria, 1976) • Hazard Prediction Test (Muela et al., 2021) • Risky Decision-making Test (Castro et al., 2021)
Psychological behavioral scales	• Multi-driving Styles Inventory (MDSI) (Padilla et al., 2020; Taubman-Ben-Ari et al., 2004) • Domain-Specific Risk-Taking (DOSPERT) (Weber et al., 2002) • Sensitivity to Punishment and Sensitivity to Reward Questionnaire - 20 (SPQR20) (Torrubia et al., 2001)

For each of these tests, the variables that have been shown to be related to driving performance in previous studies were used (See Appendix 1, with the description and justification of all variables).

The gold standard for assessing fitness to drive is the on-road test, which evaluates participants' driving performance in real-world conditions. Both a driving instructor and an occupational therapist specialized in driving after a stroke observed and evaluated the participants' performance based on their experience, professional judgment, and knowledge of current traffic regulations (Subdirección Adjunta de Formación Vial, Dirección General de Tráfico, 2019) (See Appendix 2). The *on-road* assessment was conducted in a vehicle adapted to the individual's needs and provided by the driving school. The test lasted approximately 40 min, beginning with driving on a low-traffic circuit and continuing on an open road with regular traffic. Prior to the assessment, participants completed a practice session of equal duration and route characteristics to familiarize themselves with the vehicle, any adaptations, and the driving tasks.

2.4.1. *"Fit"/"unfit" variable*

Following the *on-road* assessment, and similar to driving exams in the general population, the driving instructor rendered a dichotomous judgment, classifying participants as either "fit" or "unfit" to drive.

2.4.2. *On-road score*

Additionally, to provide a more sensitive measure capable of capturing variations in participants' driving ability, an occupational therapist specialized in post-stroke driving rated performance using an observation scale developed specifically for this study, cross-referencing her assessment with the instructor's judgment. Scores on this scale were determined by the number and severity of errors made in various driving tasks, such as locating and using vehicle controls (e.g., the accelerator pedal), managing different driving situations through specific maneuvers (such as overtaking another vehicle), and completing predetermined tasks with a clear objective (such as parking near a destination).

Scores on this scale ranged from 32 to 132. Preliminary analyses conducted prior to the main study identified a score of 98 as the optimal cutoff for discriminating between participants considered "fit" and "unfit" to drive. Accordingly, scores from 32 to 98 corresponded to participants classified as "unfit," whereas scores from 99 to 132 corresponded to those classified as "fit."

When discrepancies occurred between the occupational therapist's score and the instructor's classification, priority was given to the instructor's judgment, as this professional was responsible for the final driving eligibility decision within the assessment process. In such cases, scores were adjusted to remain consistent with the instructor's classification (e.g., participants classified as "fit" by the instructor were assigned a minimum score of 99).

2.5. *Statistical data analysis*

Once the assessments were corrected, the data were tabulated and cleaned. Subsequently, the assumption of normality was verified using the Shapiro-Wilk test ($p < 0.05$). Descriptive statistics were used for sociodemographic, clinical, and driving experience data for the entire group, using means and standard deviations. In addition, means and standard deviations were also reported for cognitive and behavioral variables and the on-road score, differentiating between fit and unfit groups.

Initially, a bivariate correlation was performed between each participant's *on-road* scores and the variables in the off-road tests (Spearman's correlation), as well as age as a potential confounding variable. Variables with a correlation coefficient (r) greater than 0.39 were included in a linear regression model where the *on-road* score was also the variable to be predicted. This threshold was selected based on established and empirically grounded guidelines for interpreting correlation magnitudes (Kleinbaum, Kupper, and Muller, 1988), which also corresponds approximately to the 75th percentile of applied research effect sizes according to Lovakov and Agadullina (2021). Participants' *on-road* scores were compared across groups defined by their gender and driving experience using a

Mann-Whitney *U* test for gender and a Kruskal-Wallis test for driving experience. Variables with $p \leq 0.05$ were also included in the linear regression model. To accurately estimate regression coefficients, standard errors, and confidence intervals, two participants were required per predictor variable in the model (Austin & Steyerberg, 2015).

Additionally, to validate a sensitive protocol contributing to the clinical decision-making process, a serial trichotomization was conducted (Gibbons et al., 2017). For each predictive test after linear regression, a ROC curve analysis was performed based on the criteria of "fit" or "unfit," and the area under the curve (AUC) was calculated. The variables used in the regression model that achieved an acceptable AUC > 0.7 were included. Subsequently, the variables were ranked from the smallest to the largest gray area (% indeterminate participants). Using these results, cutoff points reflecting 100% sensitivity and 100% specificity for each test were selected (or the highest sensitivity/specificity that can be achieved) and a serial trichotomization was carried out. With these cutoff points, the participants were categorized into two groups for the first test: pass (scoring above the cutoff point with 100% specificity or the highest specificity that can be achieved) and fail (scoring below the cutoff point with 100% sensitivity or the highest sensitivity that can be achieved). Those whose scores lay between both cutoff points proceeded to the next test and were reassigned to the categories until the final test was reached.

3. Results

A total of 45 post-stroke drivers were included in this study. Fig. 1 shows the participant selection flowchart. Table 3 summarizes the sample's descriptive data, including sociodemographic and clinical information, as well as driving experience.

Due to participants' medical conditions and the length of the evaluation protocol, not all participants *(n* = 45) were able to complete all the tests. Forty individuals completed more than 80% of the tests, three completed between 70% and 80%, and two completed between 60% and 70%.

The following table (Table 4) shows the mean scores, standard deviation, and maximum and minimum scores for participants who were found fit or unfit to drive according to the driving instructor's judgment.

The on-road score was influenced by gender ($U = 113$; $p = 0.017$) and was significantly higher in men (*Mean* = 100; *SD* = 17.8) than in women (*Mean* = 84.4; *SD* = 20.8). However, no statistically significant differences were found between the three groups regarding driving experience ($U = 53$; $p = 0.221$).

For the first step, correlations were performed between the on-road score and the neuropsychological test variables, as well as age. As the on-road score did not follow a normal distribution (Shapiro–Wilk test, $p < 0.01$), Spearman correlation analyses were conducted. The Spearman correlation coefficients and associated *p*-values for each variable are presented in Table 5.

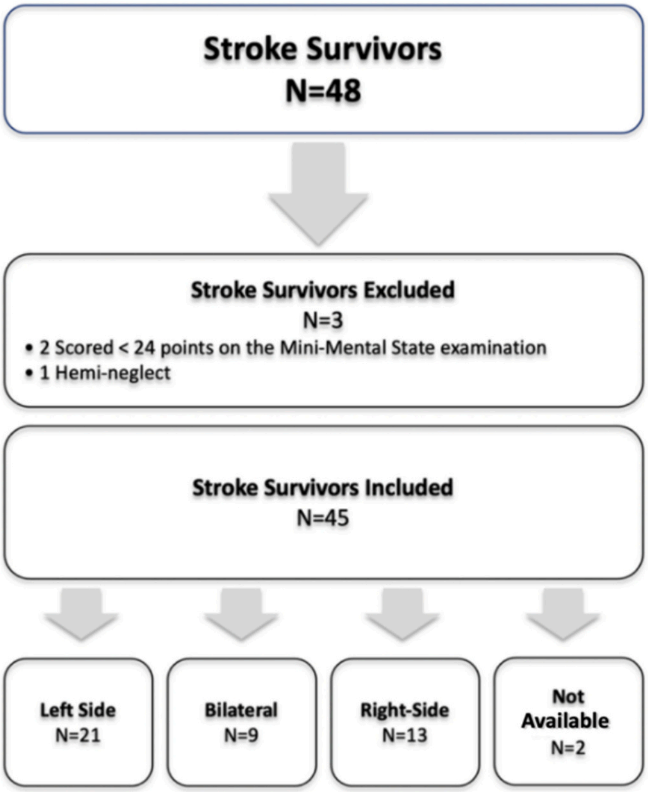


Fig. 1. Participant selection flowchart.

Table 3
Descriptive data of the sample of participants with stroke (n = 45).

		Mean	*Median*	*SD*
Age		56.3	60	12.2
Months since stroke		18.4	11	16.0
		Frequency	*(%)*	
Gender	*Male*	32	71.7%	
	Female	13	28.3%	
Education	*Basic*	14	31.1%	
	Intermediate	13	28.9%	
	Higher	18	40%	
Driving experience	*Novice*	0	0.0%	
	Intermediate	4	8.9%	
	Experienced drivers	41	91.1%	
Diagnosis	*Hemorrhagic*	17	38.6%	
	Ischemic	27	61.4%	
	NA	1		
Lesion lateralization	*Bilateral*	9	20.9%	
	Right	13	30.2%	
	Left	21	48.8%	
	NA	2	2.2%	

Note. NA = Not Available.To determine the driving experience variable, the following criterion was established: “Experienced drivers” were defined as drivers with more than 8 years of experience who drive at least twice a week, and “novices” as drivers with less than 8 years of experience who drive less than twice a week (Castro et al., 2019). Those with over 8 years of experience but without frequent driving fell into a third, intermediate category. The participants were asked to report the frequency of their driving in the year prior to experiencing the stroke.

Although there were also significant correlations with the variables UFOV-Subtest 3, PDT-Multiple Reactions (reaction time and number of errors), PDT-Bimanual Coordination (number of errors), PDT-Decision Making (reaction time), Premotor Series-Graphic Alternations, S-WCPA-10 Rules followed and MDSI-Dissociated, these did not reach a correlation coefficient > 0.39, thus they were not included in the regression analysis.

For the linear regression analysis, the following cognitive variables were included in the model: UFOV-Subtest 2 ($r_s = -0.550$), PDT-Bimanual Coordination (Time spent in error) ($r_s = -0.553$), Premotor Series-Motor Series ($r_s=0.412$), Premotor Series-Reciprocal Coordination ($r_s=0.515$), VOSP-Progressive Silhouettes ($r_s = -0.393$), and Hazard Prediction Simple Trials ($r_s=0.463$) and Invalid Trials ($r_s=0.446$). Additionally, the sociodemographic variables of gender and age were incorporated due to their significant influence on driving performance, although age did not achieve a correlation coefficient greater than 0.39. All assumptions for the regression analysis were met: linearity, independence (Durbin-Watson statistic = 2.09), homoscedasticity (Breusch-Pagan $p = 0.445$), normality (Shapiro-Wilk $p = 0.185$), and non-collinearity (FIV < 10 for all predictor variables).

The regression model was significant ($t = 2.248$; $p = 0.039$) and explained 71.8% of the variance in the On-Road score. Table 6 shows that both gender and PDT-Bimanual Coordination (Time spent in error) were the two variables found to be significant within the model.

Regarding the trichotomization process, the variables used in the regression model that achieved an acceptable AUC >0.7 were included. Therefore, the variables Premotor Series – Motor Series (AUC = 0.682) and Hazard Prediction - Invalid Trials (AUC = 0.669) were discarded. Premotor Series - Reciprocal Coordination was also discarded, as it had a 100% indeterminate population. The trichotomization process managed to categorize 11 patients into Fit/Unfit after the entire process (See Fig. 2).

4. Discussion

Driving is a common and crucial activity for most adults; however, it is also a complex task that requires the proper functioning of various cognitive and behavioral functions, which may be affected by the sequelae of a stroke.

Off-road tests assess the cognitive skills required for safe driving and therefore contribute to the final decision on fitness to drive (Bennett et al., 2016; Selander et al., 2020), although they do not always predict the ability to drive accurately (Devos et al., 2011; Motta et al., 2014; Samuelsson et al., 2022). However, these tests have great relevance in practice, since they are less expensive in terms of both resources and time (Kay et al., 2012).

Given that driving requires the effective use of multiple cognitive and behavioral processes, it is recommended to use a combination of tests that address the essential domains for safe driving, since no single assessment instrument can cover all the necessary functions and skills (Selander et al., 2020). Thus, designing and validating a comprehensive off-road assessment protocol for people with stroke is highly valuable in the initial assessment and in the design of personalized rehabilitation programs, especially when there is no access to a simulator or adapted vehicle.

This study evaluated different cognitive, behavioral, and personality tests which assess traits that could affect safe driving in a sample of people with stroke.

In the present investigation, the on-road score was correlated with a range of cognitive tests that have been shown to be related to driving, such as the Psychotechnical Driving Test. This test is the assessment traditionally used in driver training centers to evaluate

Table 4
Descriptive statistics for participants' fit and unfit for driving in the cognitive, personality, and on-road scoring tests.

Variable	Fit				Unfit			
	N	*Mean*	*SD*	*Min–Max*	*N*	*Mean*	*SD*	*Min–Max*
General cognitive-motor skills for driving								
PDT Focused attention RT	20	85.4	36.0	31–180	23	83.8	30.8	56–198
PDT Focused atenttion Errors	20	3.95	7.67	0–29	23	1.48	2.94	0–13
PDT Multiple reactions RT	20	145.0	39.7	75–249	23	169.0	41.4	103–229
PDT Multiple reactions Errors	20	4.9	4.56	0–13	23	8.22	5.25	2–20
PDT Anticipation speed	20	26.9	14.4	8–70	24	25.0	15.9	9–70
PDT bimanual coordination Time Spent in error	20	5666	3094	521–10,740	24	7891	2060	3661–10,752
PDT bimanual coordination Errors	20	33.5	18.4	2–69	24	47.3	21.5	11–79
PDT Decision making % Correct responses	20	86.5	8.78	72–100	24	87.4	8.53	75–100
PDT Decision making RT	20	108.0	40.7	53–213	24	120.0	26.9	84–176
Cognitive Tests								
General cognitive screening								
MMSE	21	28.5	1.47	25–30	24	28.6	1.14	26–30
VOSP Progressive silhouettes	20	7.45	2.68	4–13	24	9.67	2.01	6–13
VOSP Locating numbers	20	9.1	1.12	6–10	24	8.5	1.47	6–10
Attention and processing speed								
UFOV2	20	61.2	68.6	24–320	20	122	103	29–400
UFOV3	20	157	81.6	68–363	20	210	112	76–469
TMTB - Time	19	137	93.8	36–404	23	134	76.6	61–391
CPTX	21	−0.41	2.28	−7-1	24	−0.59	1.58	−5-1
CPTAX	21	−0.81	3.68	−16-0	23	−0.05	0.92	−2-0
Mnesic abilities								
PASAT Correct responses	11	52.3	4.1	44–60	16	45.4	7.56	27–56
Executive Functions								
IOWA	21	−10.6	31.3	−82-60	24	−12.3	35.5	−96-44
5D Inhibition PC Time	16	42.9	30.4	2–99	22	36.7	20.6	2–80
5D Flexibility PC Error	16	42.2	31.3	1–90	22	33.3	27.8	1–75
S-WCPA-10 Total Strategies	20	5.45	3.12	0–11	22	5.64	1.76	2–8
S-WCPA-10 Rules followed	18	4.17	1.25	1–5	22	3.59	0.96	2–5
S-WCPA-10 Accuracy	19	5.11	2.45	0–8	22	4.64	2.42	0–9
Motor Planning								
PremotorS-MS	21	2.71	0.64	1–3	24	2.08	1.02	0–3
PremotorS-RC	21	3.05	1.4	0–4	23	2.04	1.43	0–4
PremotorS-GA	21	1.71	0.46	1–2	24	1.29	0.62	0–2
Hazard Prediction								
Hazard Prediction-Simple trials	19	85.0	11.9	61–100	12	73.1	14.9	46–100
Hazard Prediction-Valid trials	19	70.4	14.8	46–92	12	65.4	13.3	38–92
Hazard Prediction- Invalid trials	19	59.5	17.7	30–84	12	48.1	18.3	7–76
Risk Acceptance								
RDM Test %	19	68.4	13.8	50–90	15	60.7	17.1	30–80
Psychological and behavioral scales								
MDSI Agresive	18	1.79	0.93	1–4	24	1.71	0.69	1–3
MDSI Reckless	18	1.71	0.65	1–3	24	2.09	0.76	1–4
MDSI Anxious	18	1.86	0.95	1–4	24	1.95	0.79	1–4
MDSI Careful	18	4.98	0.69	3–6	24	4.91	0.65	3–6
MDSI Dissociative	18	1.5	0.51	1–3	24	1.76	0.51	1–2
MDSI Distress Reduction	18	3.24	1.24	1–5	24	3.51	0.95	1–5
DOSPERT Ethical	17	4.89	1.98	1–7	24	5.51	1.74	1–7
DOSPERT Financial	17	4.12	1.9	1–7	24	4.81	1.71	1–7
DOSPERT Financial Gambling	17	5.12	2.52	1–7	24	5.64	2.07	1–7
DOSPERT Recreational	17	4.45	1.88	1–7	24	4.97	1.81	1–7
DOSPERT Health Safety	17	5.21	2.03	1–7	24	5.56	1.69	1–7
DOSPERT Health Safety	17	3.49	1.36	1–6	24	3.42	1.07	1–5
SPSRQ20 S-Punishment	17	2.16	0.63	1–3	23	2.13	0.52	1–3
SPSRQ20 S-Reward	17	1.85	0.6	1–3	23	1.85	0.38	1–2
On-road score								
On-road Score	21	112	8.18	99–122	24	81.4	15	60–98

Note: PDT = Psychotechnical driving test; RT = Reaction Time; MMSE = MiniMental State Examination; VOSP = Visual Object and Space Perception Battery; UFOV2 = Used Field of View Test Subtest 2 (divided attention); UFOV3 = Used Field of View Test Subtest 3 (selective attention); TMTB – Time = Trail Making Test subtest B Time; CPTX = Continuous Performance Test Part X; CPTAX = Continuous Performance Test Part AX; PASAT Correct Responses = Paced Auditory Serial Addition Test Correct Responses; IGT = Iowa Gambling Test; 5D Inhibition PC Time = Five - Digit Test

Inhibition Score. Time percentile score; 5D Flexibility PC Error = Five - Digit Test Flexibility Score. Error percentile score; S-WCPA-10 = Spanish Weekly Planning Calendar Activity – 10; PremotorS-MS=Premotor Series-Motor Series; PremotorS-RC = Premotor Series-Reciprocal Coordination; PremotorS-GA = Premotor Series-Graphical Alternations; Hazard Prediction test = %; RDM Test = Responses Risky Decision Making Test; MDSI = Multi-driving Styles Inventory; DOSPERT = Domain-Specific Risk-Taking; SPSRQ20 S-Punishment = Sensitivity to Punishment and Sensitivity to Reward Questionnaire. Sensitivity to Punishment; SPSRQ20 S-Reward = Sensitivity to Punishment and Sensitivity to Reward Questionnaire.

Table 5

Correlation coefficients and p value for each cognitive and behavioral variable and the on-road score.

		On-Road Score	
		r_s	*p*
Age		−0.308	0.040*
Psychotechnical driving test	PDT Focused attention RT (*n* = 43)	−0.068	0.664
	PDT Focused attention Errors (*n* = 43)	0.000	0.999
	PDT Multiple reactions RT (*n* = 43)	−0.329	0.0361*
	PDT Multiple reactions Errors (*n* = 43)	−0.350	0.021*
	PDT Anticipation speed (*n* = 44) 3 VA	0.082	0.596
	PDT bimanual coordination Time spent in error (*n* = 44) 4TE	−0.553	<0.001***
	PDT bimanual coordination Errors (*n* = 44)4NE	−0.371	0.013**
	PDT Decision making % Correct responses (*n* = 44)5PA	−0.002	0.989
	PDT Decision making RT (*n* = 44)5TR	−0.337	0.025*
MMSE	MMSE (*n* = 45)	−0.036	0.813
VOSP	Progressive silhouettes (*n* = 44)	−0.393	0.008**
	Locating numbers (*n* = 44)	0.190	0.217
UFOV	Subtest 2 (*n* = 40)	−0.550	<0.001***
	Subtest 3 (*n* = 40)	−0.320	0.044*
TMT	Time subtest B (*n* = 42)	−0.147	0.355
CPT	Subtest X (*n* = 45)	0.241	0.111
	Subtest AX (*n* = 44)	0.154	0.317
PASAT	Correct responses (*n* = 27)	0.313	0.114
IOWA	NET score (*n* = 45)	−0.083	0.589
Five Digits	Inhibition Score. Time percentile score (n = 38)	−0.161	0.335
	Flexibility Score. Error percentile score (*n* = 38)	0.085	0.612
S-WCPA-10	Total Strategies (*n* = 42)	0.158	0.319
	Rules followed (*n* = 40)	0.330	0.037*
	Accuracy (*n* = 41)	0.080	0.619
Premotor Series	Motor Series (n = 45)	0.412	0.005*
	Reciprocal Coordination (n = 44)	0.515	<0.001***
	Graphical Alternations (*n* = 45)	0.296	0.048*
Hazard Prediction	Simple (*n* = 31)	0.463	0.009**
	Valid *n* = 31)	0.302	0.099
	Invalid (*n* = 31)	0.446	0.012*
RDM Test	RDM Test % (*n* = 34)	0.016	0.927
MDSI	Agressive (*n* = 42)	−0.034	0.833
	Reckless (*n* = 42)	−0.207	0.189
	Anxious (*n* = 42)	−0.174	0.270
	Careful (*n* = 42)	0.195	0.216
	Dissociative (*n* = 42)	−0.383	0.012*
	Distress (*n* = 42)	−0.065	0.682
DOSPERT	Ethical (*n* = 41)	−0.009	0.954
	Financial (*n* = 41)	−0.012	0.942
	Financial Gambling (*n* = 41)	0.1234	0.445
	Recreational (*n* = 41)	−0.108	0.5
	Health Safety (*n* = 41)	0.061	0.706
	Health Social (*n* = 41)	0.142	0.375
SPSRQ-20	Sensitivity to Punishment (*n* = 40)	−0.177	0.273
	Sensitivity to Reward (*n* = 40)	−0.114	0.483

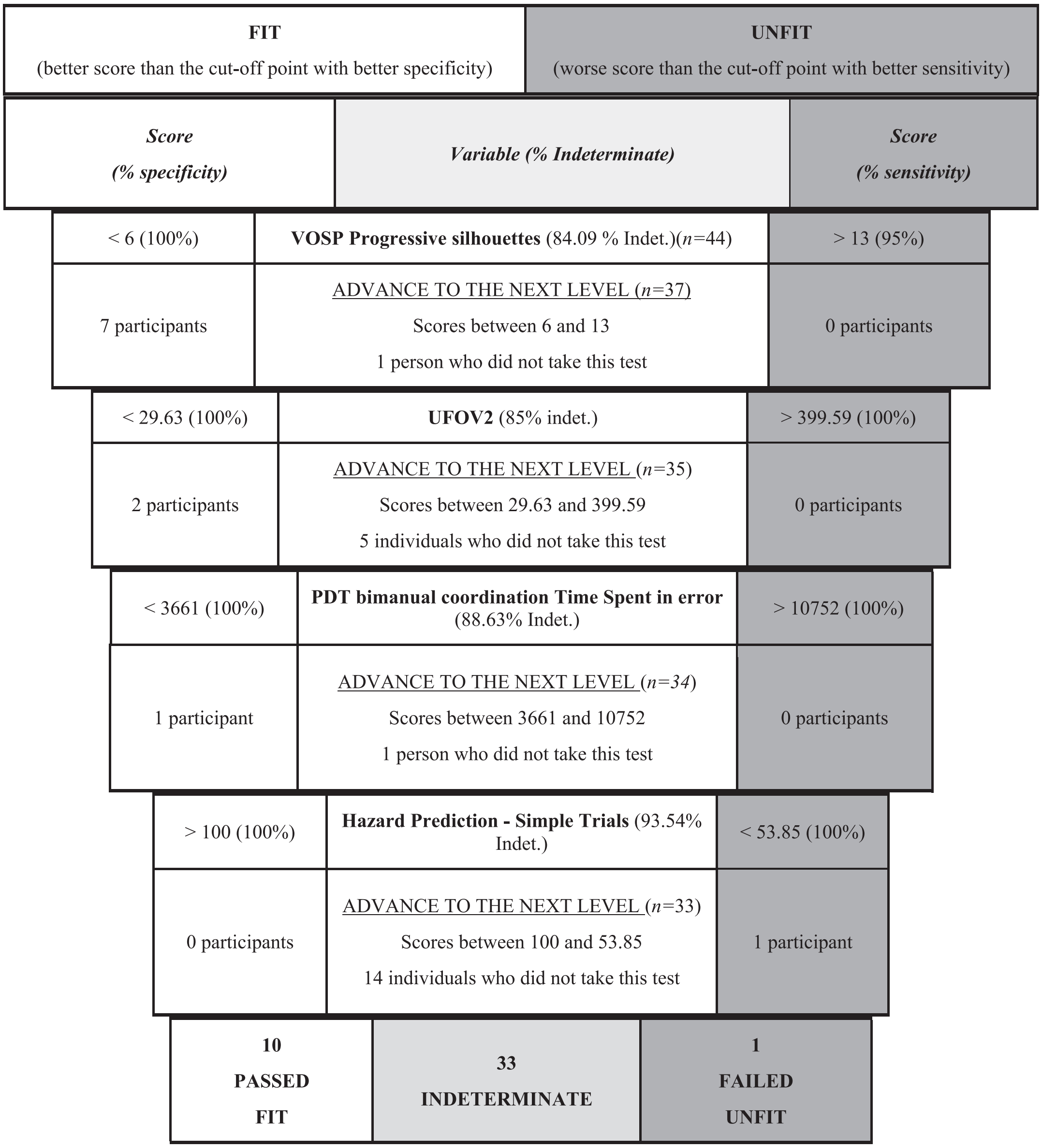
Note: * = p < 0.05; ** = p < 0.01; *** = p < 0.001; PDT = Psychotechnical driving test; RT = Reaction Time; MMSE = MiniMental State Examination; VOSP = Visual Object and Space Perception Battery; UFOV=Used Field of View Test; TMT = Trail Making; CPT = Continuous Performance Test; PASAT = Paced Auditory Serial Addition Test; IGT = Iowa Gambling Test; S-WCPA-10 = Spanish Weekly Planning Calendar Activity – 10; Hazard Prediction test = % Responses Risky Decision Making Test(RDM); MDSI = Multi-driving Styles Inventory; DOSPERT = Domain-Specific Risk-Taking; SPSRQ20 S-Punishment = Sensitivity to Punishment and Sensitivity to Reward Questionnaire.

psychophysical aptitudes. Therefore, assessing its predictive capacity for safe driving in people with stroke is essential. In this study, the multiple reactions test and bimanual coordination test were moderately correlated with the on-road score. In relation to the predictive power of the multiple reactions test, it is useful to note that this test has shown a high discriminatory capacity between healthy people and people with dementia (Badenes Guía et al., 2007), due to the cognitive impairments that these individuals may also present. Unlike the study by Badenes Guía et al. (2007), in our study, we found that the PDT Bimanual Coordination test significantly

Table 6
Regression analysis. Dependent variable: on-road score.

Predictor	*t*	*p*
Constant	2.248	0.014
Gender: Male/Female	3.015	0.008
Age	−1.069	0.301
PDT bimanual coordination Time spent in error	−2.511	0.023
VOSP Progressive silhouettes	0.452	0.658
UFOV2	−0.604	0.555
Premotor Series- Motor Series	0.750	0.464
Premotor Series - Reciprocal Coordination	−0.508	0.619
Hazard Prediction- Simple Trials	1.495	0.154
Hazard Prediction- Invalid Trials	−0.114	0.911

Note: PDT = Psychotechnical driving test; RT = Reaction Time; VOSP = Visual Object and Space Perception Battery; UFOV2 = Used Field of View Test Subtest 2 t; Hazard Prediction Test (Simple and Invalid trials).



FIT (better score than the cut-off point with better specificity)	**UNFIT** (worse score than the cut-off point with better sensitivity)

Score ***(% specificity)***	***Variable (% Indeterminate)***	***Score*** ***(% sensitivity)***
< 6 (100%)	**VOSP Progressive silhouettes** (84.09 % Indet.)(*n*=44)	> 13 (95%)
7 participants	ADVANCE TO THE NEXT LEVEL (*n*=37) Scores between 6 and 13 1 person who did not take this test	0 participants
< 29.63 (100%)	**UFOV2** (85% indet.)	> 399.59 (100%)
2 participants	ADVANCE TO THE NEXT LEVEL (*n*=35) Scores between 29.63 and 399.59 5 individuals who did not take this test	0 participants
< 3661 (100%)	**PDT bimanual coordination Time Spent in error** (88.63% Indet.)	> 10752 (100%)
1 participant	ADVANCE TO THE NEXT LEVEL (*n=34*) Scores between 3661 and 10752 1 person who did not take this test	0 participants
> 100 (100%)	**Hazard Prediction - Simple Trials** (93.54% Indet.)	< 53.85 (100%)
0 participants	ADVANCE TO THE NEXT LEVEL (*n*=33) Scores between 100 and 53.85 14 individuals who did not take this test	1 participant
10 **PASSED** **FIT**	**33** **INDETERMINATE**	**1** **FAILED** **UNFIT**

Fig. 2. Trichotomization process for classifying participants as fit or unfit to drive, based on tests arranged from the smallest to the largest gray area (percentage of indeterminate participants).

explains the on-road score, to a greater extent than the multiple reactions test, and allows for a greater discrimination of the ability of people with stroke to return to driving. This fact may be influenced by the cognitive-motor problems in one half of the body that people with stroke may specifically present (Kim et al., 2021).

On the other hand, a moderate correlation was also found between the on-road score and the visual perception test: VOSP-Progressive Silhouettes. This perceptual test demonstrated its discriminatory ability between fit/unfit in people with stroke. In this regard, previous studies have assessed these visuoperceptual abilities and their relationship with driving with other tests such as the cube copy test (Nouri & Lincoln, 1992) or the Clock Drawing Test (CDT) (Gibbons et al., 2017; Yamin et al., 2024), which also involve praxis abilities (more strongly related to cognitive-motor aspects) and visual organization. Our study did not include a praxis test, although combining it with motor programming tests, which were included, would complement the assessment to address these processes. In this sense, all the subtests included in the Premotor Series were moderately related, with the exception of the graphic alternations, which were weakly related.

Regarding attentional abilities, the test that was moderately correlated with the on-road score was the UFOV subtest 2 (divided attention), which also showed good discriminatory ability between fit and unfit patients. These data support previous studies that have related this divided attention subtest to the ability to qualify as fit in driving tests, both with a real vehicle on the road in the stroke population (George & Crotty, 2010; Mazer et al., 1998) and with a simulator (Motta et al., 2014).

Although moderate correlation coefficients were not achieved, and it was therefore not included in the regression analysis, the S-WCPA-10 variable "Rules Followed" was also significantly related to the on-road score. This S-WCPA-10 variable can be analyzed as the result of the combination of working memory and inhibitory control, when having to manage information in a traffic situation, avoiding prohibited actions. These processes could be included within the executive functions, which have been shown to be strongly related to risky driving behaviors (Pergantis et al., 2024).

To date, no previous studies with stroke patients have included tools for assessing hazard prediction ability in conjunction with other cognitive and behavioral tests. Therefore, to validate this protocol, we included the Hazard Prediction Test. This naturalistic task within the driving context measures a driver's situational awareness and involves the perception, understanding, and projection of a situation (Castro et al., 2014). The study by Sasaki et al. (2019) demonstrated that scores on a hazard perception and prediction test were lower for participants with stroke compared to healthy participants, indicating impairment at this level in this population. As the data from the present study show, this test has demonstrated its discriminatory ability for fit/unfit drivers with stroke.

Among the driving style and behavioral tests, only the MDSI dissociative style score showed a significant correlation with the on-road score, but it did not reach the threshold of >0.39 for inclusion in the regression analysis. The Multidimensional Driving Style Inventory's dissociative style describes drivers who mentally "disengage" and drive on autopilot; this trait, identified in the original validation of the questionnaire, is associated with attention lapses and increased road accidents (Taubman-Ben-Ari et al., 2004). After a stroke, many people exhibit sustained deficits in selective attention and motor precision that delay braking and increase driving errors, reflecting a specific vulnerability to driving with their mind wandering (Lodha et al., 2021). Therefore, stroke survivors may exhibit—or be enhanced by—a dissociative style, as the same attentional and motor lapses that prolong braking time facilitate driving in automatic mode and, with it, the risk of lapses and accidents.

Regarding the serial trichotomization process, it can be observed that, from the initial group of 44 participants, only 10 (22.72%) were classified as fit. The remaining 34 individuals did not pass the threshold established to be considered fit, but only one of them (2.72%) failed outright. The majority of cases (33 individuals, 73.33%) were within a gray range, suggesting that, although they did not pass the initial evaluation, they could benefit from rehabilitation programs to improve their performance and potentially regain their ability to drive.

In line with Gibbons et al. (2017), this study reaffirms that it is not possible to predict driving aptitude with 100% accuracy using a single cognitive test. Although the obtained ROC curves showed areas under the curve (AUC) ranging from 0.713 to 0.769, which indicate an acceptable discriminatory capacity to predict who would fail a practical driving test, these results are not robust enough to make definitive decisions. The AUC values provide an overall summary of the quality of the tests (Weaver et al., 2014); however, relying exclusively on a single tool increases the risk of misclassifying drivers. Therefore, the serial trichotomization process used here improves the selection of cascade tests for administration in clinical settings requiring the evaluation of stroke patients who do not have extensive time resources, thus streamlining the process (Bédard et al., 2025).

For example, although VOSP was the most accurate of those evaluated (classifying 7 participants as fit), only the Hazard Prediction single trials clearly identified one participant as unfit. These limitations underscore the need for more comprehensive strategies, such as serial trichotomization, which, in this study, was able to predict driving test passing for 22.72% of participants. In comparison, individual tests were able to classify fit participants in 0–15.9% of cases. This multidimensional approach could be key to reducing the number of drivers requiring practical road tests, thus optimizing resources in the clinical fitness-to-drive assessment process.

These results highlight the importance of developing multidimensional assessment protocols that combine different instruments and approaches to more accurately assess driving ability after a stroke. Such protocols would not only allow for a more comprehensive assessment, but would also help identify specific areas where stroke patients require rehabilitation, allowing for the design of personalized programs to facilitate their safe return to driving.

4.1. Limitations and further research

The absence of similar previous studies in the Spanish context shows the need for research in this area and also implies several limitations. Firstly, the judgment of driving instructors, occupational therapists and psychologists regarding the participants' driving performance is based on their experience, professional judgment, and knowledge of current traffic regulations (Subdirección Adjunta de Formación Vial, Dirección General de Tráfico, 2019). This is due to the lack of a validated *on-road* assessment test for use in Spain. Therefore, a possible limitation of this study is the undesired variability in the results of this professional judgment. Secondly, some of the chosen tests have not been validated in the population of stroke survivors, thus it is unknown whether these tests are the most suitable for evaluating these aspects in relation to driving. However, it is essential to measure the constructs assessed by these tests, as they have been shown to be crucial for explaining safe driving in other populations. It is equally fair to point out that the sample may be small, but our goal was to prioritize a thorough and complete evaluation, which involved many hours of testing. Future studies could expand the sample, also including analyses by groups according to the lateralization of the injury.

Additionally, although the ratio of participants to predictor variables met the minimum threshold recommended by Austin and Steyerberg (2015) and all regression assumptions were satisfied, the relatively small sample size may limit the statistical power to detect individual effects of moderate magnitude. Regarding potential overfitting, the adjusted R^2 of 0.560 compared to an unadjusted R^2 of 0.718 suggests that some degree of overfitting cannot be ruled out, although the pattern of results — with only two of nine predictors reaching individual significance — is inconsistent with severe overfitting. Replication in larger independent samples would be necessary to confirm the generalisability of these findings.

4.2. Practice implications

This study aims to offer a set of off-road assessment tools, both cognitive and behavioral, to guide healthcare professionals (occupational therapists, neuropsychologists, psychologists and neurologists) in assessing the potential abilities of stroke patients and it could be generalised to other drivers with Mild Cognitive Impairment (MCI) or elderly drivers, after its correct validation. The results also provide a proposed sequence for administering tests, which would reduce assessment times.

Research and assessment tools that better understand the behavior of driver's post-stroke are essential for designing and evaluating interventions targeted at this population. Such tools can identify strengths and weaknesses in these drivers and guide the development of tailored interventions to promote safe driving. This knowledge is important not only for the Spanish government but also for other governments as an assessment method useful for licensing and crash prevention. This project was conducted in Spain, although its procedure, as well as the selection of tests, could be extrapolated to other countries, such as in the EU, which is supportive of consensus and standardization in these measures.

CRediT authorship contribution statement

L. Laffarga: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft. **A.C. Szot:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – review and editing. **C. Castro:** Conceptualization, Funding acquisition, Resources, Supervision, Writing – review and editing. **M. Espinoza García:** Conceptualization. **M.J. Funes:** Conceptualization. **M. Rodríguez Bailón:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing.

Ethics statement

The study was approved by the Andalusian Committee on Biomedical Research (Comité Andaluz de Investigación Biomédica; Ethical Portal code: 1607-M1-22) and was conducted in accordance with the ethical principles of the Declaration of Helsinki for research involving human participants. Prior to participation, all individuals received detailed written and verbal information about the study and were informed that participation was voluntary, anonymous, and that all data would be treated confidentially. Written informed consent was obtained from all participants before the initiation of study procedures. All participants received detailed information about the study and voluntarily provided written informed consent prior to participation.

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Declaration of competing interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2026.103643.

Data availability

Data will be made available on request.

References

Akinwuntan, A. E., Backus, D., Grayson, J., & Devos, H. (2018). Validation of a short cognitive battery to screen for fitness-to-drive of people with multiple sclerosis. *European Journal of Neurology, 25*(10), 1250–1254. https://doi.org/10.1111/ene.13690

Akinwuntan, A. E., Devos, H., Stepleman, L., Casillas, R., Rahn, R., Smith, S., & Williams, M. J. (2013). Predictors of driving in individuals with relapsing-remitting multiple sclerosis. *Multiple Sclerosis Journal, 19*(3), 344–350. https://doi.org/10.1177/1352458512451944

Akinwuntan, A. E., Wachtel, J., & Rosen, P. N. (2012). Driving simulation for evaluation and rehabilitation of driving after stroke. *Journal of Stroke and Cerebrovascular Diseases: The Official Journal of National Stroke Association, 21*(6), 478–486. https://doi.org/10.1016/j.jstrokecerebrovasdis.2010.12.001

Aksan, N., Anderson, S. W., Dawson, J., Uc, E., & Rizzo, M. (2015). Cognitive functioning differentially predicts different dimensions of older drivers' on-road safety. *Accident; Analysis and Prevention, 75*, 236–244. https://doi.org/10.1016/j.aap.2014.12.007

Alhashmi, D., Lalor, A., & Fossey, E. (2022). Methods to evaluate driving competence for people with acquired brain injury (ABI): A systematic review. *Frontiers in Rehabilitation Sciences, 3*, Article 1020420. https://doi.org/10.3389/fresc.2022.1020420

Anstey, K. J., Eramudugolla, R., Huque, M. H., Horswill, M., Kiely, K., Black, A., & Wood, J. (2020). Validation of brief screening tools to identify impaired driving among older adults in Australia. *JAMA Network Open, 3*(6), Article e208263. https://doi.org/10.1001/jamanetworkopen.2020.8263

Asimakopulos, J., Boychuck, Z., Sondergaard, D., Poulin, V., Ménard, I., & Korner-Bitensky, N. (2012). Assessing executive function in relation to fitness to drive: A review of tools and their ability to predict safe driving. *Australian Occupational Therapy Journal, 59*(6), 402–427. https://doi.org/10.1111/j.1440-1630.2011.00963.x

Austin, P. C., & Steyerberg, E. W. (2015). The number of subjects per variable required in linear regression analyses. *Journal of Clinical Epidemiology, 68*(6), 627–636. https://doi.org/10.1016/j.jclinepi.2014.12.014

Azzam, D., & Ronquillo, Y. (2023). Snellen Chart. In *StatPearls*. StatPearls Publishing.

Badenes Guía, D., Casas Hernanz, L., & Aguilar Barberá, M. (2007). Discriminación de la valoración de la capacidad de conducción de vehículos en personas con diagnóstico de deterioro cognitivo ligero y demencia en los exámenes de conducción normalizados. *Mapfre Medicina, 18*(2), 98–107.

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology & Visual Science, 34*(11), 3110–3123 (PMID: 8407219).

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, 50*(1–3), 7–15. https://doi.org/10.1016/0010-0277(94)90018-3 (PMID: 8039375).

Bédard, M., Maxwell, H., Dubois, S., Schurr, S., Swoluk, C., Colosimo, A., … Stinchcombe, A. (2025). Serial trichotomization to determine fitness to drive: Results from a cohort of clients referred to a neurology program. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association, 79*(3). https://doi.org/10.5014/ajot.2025.050670, 7903205030.

Bellagamba, D., Margot-Cattin, I., & Vaucher, P. (2020). Standardized on-road tests assessing fitness- to-drive in people with cognitive impairments: A systematic review. *PLoS One, 15*. https://doi.org/10.1371/journal.pone.0233125

Bennett, J., Chekaluk, E., & Batchelor, J. (2016). Cognitive tests and determining fitness to drive in dementia: A systematic review. *Journal of the American Geriatrics Society, 64*(9), 1904–1917. https://doi.org/10.1111/jgs.14180

Braga, M. M., Nickel, R., Lange, M., & Piovesan, É. J. (2018). Driving and visual deficits in stroke patients. *Arquivos de Neuro-Psiquiatria, 76*, 85–88. https://doi.org/10.1590/0004-282X20170184

Broadbent, D. P., D'Innocenzo, G., Ellmers, T. J., Parsler, J., Szameitat, A. J., & Bishop, D. T. (2023). Cognitive load, working memory capacity and driving performance: A preliminary fNIRS and eye tracking study. *Transportation Research Part F: Traffic Psychology and Behaviour, 92*, 121–132. https://doi.org/10.1016/j.trf.2022.11.013

Canadian Association of Occupational Therapists. (2017). *CAOT position statement: Occupational therapy and driver rehabilitation and community mobility*. Canadian Association of Occupational Therapists.

Cardoso, C.d. O., Branco, L. D., Cotrena, C., Kristensen, C. H., Schneider Bakos, D. D. G., & Fonseca, R. P. (2014). The impact of frontal and cerebellar lesions on decision making: Evidence from the Iowa gambling task. *Frontiers in Neuroscience, 8*. https://doi.org/10.3389/fnins.2014.00061

Castro, C., Padilla, J.-L., Doncel, P., Garcia-Fernandez, P., Ventsislavova, P., Eisman, E., & Crundall, D. (2019). How are distractibility and hazard prediction in driving related? Role of driving experience as moderating factor. *Applied Ergonomics, 81*, Article 102886. https://doi.org/10.1016/j.apergo.2019.102886

Castro, C., Padilla, J. L., Roca, J., Benítez, I., García-Fernández, P., Estévez, B., … Crundall, D. (2014). Development and validation of the Spanish hazard perception test. *Traffic Injury Prevention, 15*(8), 817–826. https://doi.org/10.1080/15389588.2013.879125

Castro, C., Ventsislavova, P., Garcia-Fernandez, P., & Crundall, D. (2021). Risky decision-making and hazard prediction are negatively related and could be assessed independently using driving footage. *Psychology Research and Behavior Management, 14*, 857–876. https://doi.org/10.2147/PRBM.S305979 (PMID: 34211301).

Castro Ramírez, C., Durán Segura, M., & Cantón Cortés, D. (2006). La conducción vista por los psicólogos cognitivos. *Boletín de psicología, 87*, 35–60.

Clark, L., Bechara, A., Damasio, H., Aitken, M. R. F., Sahakian, B. J., & Robbins, T. W. (2008). Differential effects of insular and ventromedial prefrontal cortex lesions on risky decision-making. *Brain, 131*(5), 1311–1322. https://doi.org/10.1093/brain/awn066

Crundall, D., Chapman, P., Trawley, S., Collins, L., van Loon, E., Andrews, B., & Underwood, G. (2012). Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. *Accident Analysis & Prevention, 45*, 600–609. https://doi.org/10.1016/j.aap.2011.09.049

Devos, H., Akinwuntan, A. E., Nieuwboer, A., Truijen, S., Tant, M., & De Weerdt, W. (2011). Screening for fitness to drive after stroke: A systematic review and meta-analysis. *Neurology, 76*(8), 747–756. https://doi.org/10.1212/WNL.0b013e31820d6300

Devos, H., Hawley, C., Conn, A., Marshall, S., & Akinwuntan, A. (2021). *Driving after stroke* (pp. 243–260). https://doi.org/10.1007/978-3-030-58505-1_13

Devos, H., Tant, M., & Akinwuntan, A. E. (2014). On-road driving impairments and associated cognitive deficits after stroke. *Cerebrovascular Diseases, 38*(3), 226–232. https://doi.org/10.1159/000368219

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(64), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Duque, P., Ibáñez-Alfonso, J., Barco, A., Sepulcre, J., Ramon, E., & Fernández, O. (2012). Normalisation and validation of the brief neuropsychological battery as the reference neuropsychological test in multiple sclerosis. *Revista de Neurologia, 54*, 263–270.

Edwards, J. D., Vance, D. E., Wadley, V. G., Cissell, G. M., Roenker, D. L., & Ball, K. K. (2005). Reliability and validity of useful field of view test scores as administered by personal computer. *Journal of Clinical and Experimental Neuropsychology, 27*(5), 529–543. https://doi.org/10.1080/13803390490515432 (PMID: 16019630).

Fields, S. M., & Unsworth, C. A. (2017). Revision of the competency standards for occupational therapy driver assessors: An overview of the evidence for the inclusion of cognitive and perceptual assessments within fitness-to-drive evaluations. *Australian Occupational Therapy Journal, 64*(4), 328–339. https://doi.org/10.1111/1440-1630.12379

Fisk, G. D., & Mennemeier, M. (2006). Common neuropsychological deficits associated with stroke survivors impaired performance on a useful field of view test. *Perceptual and Motor Skills, 102*(2), 387–394. https://doi.org/10.2466/pms.102.2.387-394

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Friedman, N. P., & Miyake, A. (2017). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex; A Journal Devoted to the Study of the Nervous System and Behavior, 86*, 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

García-Fortea, P., Estebaranz-García, F. J., Heredia-Civantos, M. D., Bermúdez-Virgós, A., & Rodríguez-Ortega, J. (2016). Son efectivos nuestros centros de reconocimiento médico valorando la aptitud psicofísica para permisos de conducción y licencias de armas. *Revista de Calidad Asistencial, 31*(1), 34–41. https://doi.org/10.1016/j.cali.2015.09.005

Gasne, C., Ranchet, M., Evennou, M., Delebecque, M.-C., Hoang, I., Luaute, J., Coignard, P., & Paire-Ficout, L. (2024). Two profiles of post-stroke drivers based on their driving perception. *Transportation Research Part F: Traffic Psychology and Behaviour, 107*, 17–28. https://doi.org/10.1016/j.trf.2024.08.029

Gentle, J., Brady, D., Woodger, N., Croston, S., & Leonard, H. C. (2021). Driving skills of individuals with and without developmental coordination disorder (DCD/dyspraxia). *Frontiers in Human Neuroscience, 15*. https://doi.org/10.3389/fnhum.2021.635649

George, S., & Crotty, M. (2010). Establishing criterion validity of the useful field of view assessment and stroke drivers screening assessment: Comparison to the result of on-road assessment. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association, 64*(1), 114–122. https://doi.org/10.5014/ajot.64.1.114

Gibbons, C., Smith, N., Middleton, R., Clack, J., Weaver, B., Dubois, S., & Bédard, M. (2017). Using serial trichotomization with common cognitive tests to screen for fitness to drive. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association, 71*(2). https://doi.org/10.5014/ajot.2017.019695, 7102260010p1-7102260010p8.

Gillen, G., & Rubio, K. B. (2016). Treatment of cognitive-perceptual deficits: A function-based approach. In *En stroke rehabilitation* (pp. 612–646). Mosby. https://doi.org/10.1016/B978-0-323-17281-3.00027-7.

Gloth, F. M., Magaziner, J., & Wetle, T. F. (2001). The functional pain scale: Reliability, validity, and responsiveness in an elderly population. *Journal of the American Geriatrics Society, 49*(5), 594–598. https://doi.org/10.1046/j.1532-5415.2001.49113.x

Gombao-Ferrándiz, J. C., & Muñoz-Menéndez, A. (2011). Guía de utilización para la exploración de las Dimensiones Psicológicas recogidas en los apartados X, XII Y XII del Real Decreto 772/97 y en el apartado XIV del anexo al R.D. 2487/98 con equipos de LN-Deter. Modulo de conducción. http://www.lndeter.com/.

Goodglass, H., Kaplan, E., García Albea, J. E., & Sánchez Bernardos, M. L. (1986). *Evaluación de la afasia y de trastornos relacionados*. Editorial Médica Panamericana. https://dialnet.unirioja.es/servlet/libro?codigo=915970.

Gronwall, D. M. (1977). Paced auditory serial-addition task: A measure of recovery from concussion. *Perceptual and Motor Skills, 44*(2), 367–373. https://doi.org/10.2466/pms.1977.44.2.367. PMID: 866038.

Hayashi, Y., Foreman, A. M., Friedel, J. E., & Wirth, O. (2018). Executive function and dangerous driving behaviors in young drivers. *Transportation Research Part F: Traffic Psychology and Behaviour, 52*, 51–61. https://doi.org/10.1016/j.trf.2017.11.007

Hines, A., & Bundy, A. C. (2014). Predicting driving ability using DriveSafe and DriveAware in people with cognitive impairments: A replication study. *Australian Occupational Therapy Journal, 61*(4), 224–229. https://doi.org/10.1111/1440-1630.12112

Hird, M. A., Vetivelu, A., Saposnik, G., & Schweizer, T. A. (2014). Cognitive, on-road, and simulator-based driving assessment after stroke. *Journal of Stroke and Cerebrovascular Diseases, 23*(10), 2654–2670. https://doi.org/10.1016/j.jstrokecerebrovasdis.2014.06.010

Hwang, S., & Song, C.-S. (2023). Driving rehabilitation for stroke patients: A systematic review with meta-analysis. *Healthcare, 11*(11), 1637. https://doi.org/10.3390/healthcare11111637

Kay, L. G., Bundy, A. C., Clemson, L., Cheal, B., & Glendenning, T. (2012). Contribution of off-road tests to predicting on-road performance: A critical review of tests. *Australian Occupational Therapy Journal, 59*(1), 89–97. https://doi.org/10.1111/j.1440-1630.2011.00989.x

Kim, H., Kim, H.-K., Kim, N., & Nam, C. S. (2021). Dual task effects on speed and accuracy during cognitive and upper limb motor tasks in adults with stroke hemiparesis. *Frontiers in Human Neuroscience, 15*. https://doi.org/10.3389/fnhum.2021.671541

Kleinbaum, D. G., Kupper, L. L., & Muller, K. E. (1988). *Variable Reduction and Factor Analysis. Applied Regression Analysis and Other Multivariable Methods* (pp. 595–640). Boston: PWS Kent Publishing Co.

Krasniuk, S., & Crizzle, A. M. (2024). Using serial trichotomization to determine fitness to drive in medically at-risk drivers. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association, 78*(1), 7801205020. https://doi.org/10.5014/ajot.2024.050134

Laffarga, L., Szot, A. C., Castro, C., Salazar-Frías, D., Clavijo-Ruiz, J., & Rodríguez-Bailón, M. (2026). The planning strategies for driving on a map test (COMAP): Initial validation in stroke patients. *Clinical Rehabilitation*. https://doi.org/10.1177/02692155251410487, 2692155251410487.

Lodha, N., Patel, P., Shad, J. M., Casamento-Moran, A., & Christou, E. A. (2021). Cognitive and motor deficits contribute to longer braking time in stroke. *Journal of Neuroengineering and Rehabilitation, 18*, 7. https://doi.org/10.1186/s12984-020-00802-2

Louie, J. F., & Mouloua, M. (2019). Predicting distracted driving: The role of individual differences in working memory. *Applied Ergonomics, 74*, 154–161. https://doi.org/10.1016/j.apergo.2018.07.004

Lovakov, A., & Agadullina, E. R. (2021). Empirically derived guidelines for effect size interpretation in social psychology. *European Journal of Social Psychology, 51*(3), 485–504. https://doi.org/10.1002/ejsp.2752

Luria, A. R. (1976). *The working brain: An introduction to neuropsychology*.

Marshall, S. C., Molnar, F., Man-Son-Hing, M., Blair, R., Brosseau, L., Finestone, H. M., … Wilson, K. G. (2007). Predictors of driving ability following stroke: A systematic review. *Topics in Stroke Rehabilitation, 14*(1), 98–114. https://doi.org/10.1310/tsr1401-98

Mazer, B. L., Korner-Bitensky, N. A., & Sofer, S. (1998). Predicting ability to drive after stroke. *Archives of Physical Medicine and Rehabilitation, 79*(7), 743–750.

McInerney, K., & Suhr, J. (2016). Neuropsychological correlates of hazard perception in older adults. *Journal of the International Neuropsychological Society, 22*(3), 332–340. https://doi.org/10.1017/S1355617715001253

Ministerio del Interior, Dirección General de Tráfico, & Ministerio de Sanidad. (2022). *Protocolo de exploración médico-psicológica para Centros de Reconocimiento de Conductores (CRC). Actualización 2022*.

Moore, S., Naragon-Gainey, K., Pestell, C. F., Becerra, R., Buelow, M. T., Fynn, D. M., & Weinborn, M. (2025). The level and nature of impairment on the Iowa gambling task following acquired brain injury: A meta-analysis. *Neuropsychology Review*. https://doi.org/10.1007/s11065-025-09668-4

Motta, K., Lee, H., & Falkmer, T. (2014). Post-stroke driving: Examining the effect of executive dysfunction. *Journal of Safety Research, 49*, 33–38. https://doi.org/10.1016/j.jsr.2014.02.005

Muela, I., Chica, A. B., Garcia-Fernandez, P., & Castro, C. (2021). Visual attention in realistic driving situations: Attentional capture and hazard prediction. *Applied Ergonomics, 90*, Article 103235. https://doi.org/10.1016/j.apergo.2020.103235 (PMID: 32871352).

National Health Service. (2022). *Driving after a stroke or TIA*. NHS. https://www.nhs.uk/conditions/stroke/driving-after-a-stroke-or-tia/.

Nouri, F. M., & Lincoln, N. B. (1992). Validation of a cognitive assessment: Predicting driving performance after stroke. *Clinical Rehabilitation, 6*(4), 275–281. https://doi.org/10.1177/026921559200600402

Padilla, J.-L., Castro, C., Doncel, P., & Taubman - Ben-Ari, O. (2020). Adaptation of the multidimensional driving styles inventory for Spanish drivers: Convergent and predictive validity evidence for detecting safe and unsafe driving styles. *Accident Analysis & Prevention, 136*, Article 105413. https://doi.org/10.1016/j.aap.2019.105413

Pergantis, P., Bamicha, V., Chaidi, I., & Drigas, A. (2024). Driving under cognitive control: The impact of executive functions in driving. *World Electric Vehicle Journal, 15*(10), 474. https://doi.org/10.3390/wevj15100474

Rabadi, M. H., Akinwuntan, A., & Gorelick, P. (2010). The safety of driving a commercial motor vehicle after a stroke. *Stroke, 41*(12), 2991–2996. https://doi.org/10.1161/STROKEAHA.110.587196

Real Decreto 818/2009. (2009). de 8 de mayo, por el que se aprueba el Reglamento General de Conductores, Pub. L. No. Real Decreto 818/2009, BOE-A-2009-9481 48068. https://www.boe.es/eli/es/rd/2009/05/08/818.

Reitan, R., & Wolfson, D. (1985). *The Halstead-Reitan neuropsychological test battery: Theory and clinical interpretation*. Neuropsychological Laboratory.

Roca, J., Castro, C., López-Ramón, M. F., & Lupiáñez, J. (2011). Measuring vigilance while assessing the functioning of the three attentional networks: The ANTI-vigilance task. *Journal of Neuroscience Methods, 198*(2), 312–324. https://doi.org/10.1016/j.jneumeth.2011.04.014

Rosvold, H. E., Mirsky, A. F., Sarason, I., Bransome, E. D., & Beck, L. H. (1956). A continuous performance-test of brain damage. *Journal of Consulting Psychology, 20*(5), 343–350. https://doi.org/10.1037/h0043220 (PMID: 13367264).

Salazar-Frías, D., Funes, M. J., Merchán-Baeza, J. A., Ricchetti, G., Torralba-Muñoz, J. M., & Rodríguez-Bailón, M. (2023). Translation, cross-cultural adaptation and validation of the 10-item weekly calendar planning activity in Spanish-speaking ABI patients: A multicenter study. *Frontiers in Psychology, 14*, Article 1018055. https://doi.org/10.3389/fpsyg.2023.1018055

Salvadori, E., Cova, I., Mele, F., Pomati, S., & Pantoni, L. (2022). Prediction of post-stroke cognitive impairment by Montreal cognitive assessment (MoCA) performances in acute stroke: Comparison of three normative datasets. *Aging Clinical and Experimental Research, 34*(8), 1855–1863. https://doi.org/10.1007/s40520-022-02133-9

Samuelsson, K., Lundqvist, A., Selander, H., & Wressle, E. (2021). Fitness to drive after acquired brain injury: Results from patient cognitive screening and on-road assessment compared to age-adjusted norm values. *Scandinavian Journal of Psychology, 63*. https://doi.org/10.1111/sjop.12774

Samuelsson, K., Lundqvist, A., Selander, H., & Wressle, E. (2022). Fitness to drive after acquired brain injury: Results from patient cognitive screening and on-road assessment compared to age-adjusted norm values. *Scandinavian Journal of Psychology, 63*(1), 55–63. https://doi.org/10.1111/sjop.12774

Sasaki, T., Nogawa, T., Yamada, K., Kojima, T., & Kanaya, K. (2019). Hazard perception of stroke drivers in a video-based Japanese hazard perception task. *Traffic Injury Prevention, 20*(3), 264–269. https://doi.org/10.1080/15389588.2019.1579906

Sawada, T., Tomori, K., Hamana, H., Ohno, K., Seike, Y., Igari, Y., & Fujita, Y. (2019). Reliability and validity of on-road driving tests in vulnerable adults: A systematic review. *International Journal of Rehabilitation Research. Internationale Zeitschrift Fur Rehabilitationsforschung. Revue Internationale De Recherches De Readaptation, 42*(4), 289–299. https://doi.org/10.1097/MRR.0000000000000374

Schultheis, M. T., & Whipple, E. K. (2014). Driving after traumatic brain injury: Evaluation and rehabilitation interventions. *Current Physical Medicine and Rehabilitation Reports, 2*(3), 176–183. https://doi.org/10.1007/s40141-014-0055-0

Scottish Stroke Allied Health Professionals Forum. (2023). *Driving after stroke: Guidance for allied health professionals in Scotland. Scottish stroke AHP forum*.

Sedo, M. (2004). Test de las cinco cifras: Una alternativa multilingue y no lectora al test de stroop. *Revista Espanola de Neurologia, 38*(9), 824–828.

Selander, H., Wressle, E., & Samuelsson, K. (2020). Cognitive prerequisites for fitness to drive: Norm values for the TMT, UFOV and NorSDSA tests. *Scandinavian Journal of Occupational Therapy, 27*(3), 231–239. https://doi.org/10.1080/11038128.2019.1614214

Steen, L. (2023). State of research regarding cognitive assessments in predicting driving safety for persons with cognitive impairments. *The American Journal of Occupational Therapy, 77*. https://doi.org/10.5014/ajot.2023.77S2-PO44, 7711500044p1-7711500044p1.

Stroke Foundation. (2021). *Clinical guidelines for stroke management*. Stroke Foundation. https://informme.org.au.

Subdirección Adjunta de Formación Vial, Dirección General de Tráfico. (2019). *Criterios de calificación de la prueba de control de aptitudes y comportamientos en circuito abierto*. Ministerio del Interior. https://sede.dgt.gob.es/sede-estaticos/Galerias/permisos-de-conducir/notas-de-examen/CRITERIOS-DE-CALIFICACION-VIAS-ABIERTAS-SEPTIEMBRE-2019.pdf.

Sundström, A. (2008). Self-assessment of driving skill – A review from a measurement perspective. *Transportation Research Part F: Traffic Psychology and Behaviour, 11*(1), 1–9. https://doi.org/10.1016/j.trf.2007.05.002

Taubman-Ben-Ari, O., Mikulincer, M., & Gillath, O. (2004). The multidimensional driving style inventory—Scale construct and validation. *Accident; Analysis and Prevention, 36*(3), 323–332. https://doi.org/10.1016/S0001-4575(03)00010-1

Toglia, J. (2015). *Weekly Calendar Planning Activity (WCPA): A performance test of executive function*. AOTA Press.

Torrubia, R., Avila, C., Moltó, J., & Caseras, X. (2001). The sensitivity to punishment and sensitivity to reward questionnaire (SPSRQ) as a measure of grays anxiety and impulsivity dimensions. *Personality and Individual Differences, 31*, 837–862. https://doi.org/10.1016/S0191-8869(00)00183-5

Unsworth, C. A., Baker, A., Lannin, N., Harries, P., Strahan, J., & Browne, M. (2019). Predicting fitness-to-drive following stroke using the occupational therapy – Driver off road assessment battery. *Disability and Rehabilitation, 41*(15), 1797–1802. https://doi.org/10.1080/09638288.2018.1445784

Walshe, E. A., Ward McIntosh, C., Romer, D., & Winston, F. K. (2017). Executive function capacities, negative driving behavior and crashes in young drivers. *International Journal of Environmental Research and Public Health, 14*(11), 1314. https://doi.org/10.3390/ijerph14111314

Warrington, E. K., & James, M. (1991). *The visual object and space perception battery*. Thames Valley Test Company.

Weaver, B., Walter, S. D., & Bédard, M. (2014). How to report and interpret screening test properties: Guidelines for driving researchers. *Traffic Injury Prevention, 15*(3), 252–261. https://doi.org/10.1080/15389588.2013.816692

Weber, E. U., Blais, A. R., & Betz, N. E. (2002). A domain-specific risk-attitude scale: Measuring risk perceptions and risk behaviors. *Journal of Behavioral Decision Making, 15*(4), 263–290. https://doi.org/10.1002/bdm.414

Wells, P., Tong, S., Sexton, B., Grayson, G., & Jones, E. (2008). Cohort II: A study of learner and new drivers: volume 1: main report (Número 81). https://trid.trb.org/View/1153843.

Wolfe, P. L., & Lehockey, K. A. (2016). Neuropsychological assessment of driving capacity. *Archives of Clinical Neuropsychology, 31*(6), 517–529. https://doi.org/10.1093/arclin/acw050

Wood, G., Hartley, G., Furley, P. A., & Wilson, M. R. (2016). Working memory capacity, visual attention and hazard perception in driving. *Journal of Applied Research in Memory and Cognition, 5*(4), 454–462. https://doi.org/10.1016/j.jarmac.2016.04.009

Yamin, S., Ranger, V., Stinchcombe, A., Knoefel, F., Gagnon, S., & Bédard, M. (2024). Using serial trichotomization with neuropsychological measures to inform clinical decisions on fitness-to-drive among older adults with cognitive impairment. *Occupational Therapy in Health Care, 38*(1), 5–25. https://doi.org/10.1080/07380577.2020.1843750

Zhang, H., Guo, Y., Yuan, W., & Li, K. (2023). On the importance of working memory in the driving safety field: A systematic review. *Accident Analysis & Prevention, 187*, Article 107071. https://doi.org/10.1016/j.aap.2023.107071

Zhang, H., He, K., Zhao, Y., Peng, Y., Feng, D., Wang, J., & Gao, Q. (2025). FNIRS biomarkers for stratifying poststroke cognitive impairment: Evidence from frontal and temporal cortex activation. *Stroke, 56*(11), 3245–3256. https://doi.org/10.1161/STROKEAHA.124.050269

Zhou, Z., Wang, Y., Liu, R., Wei, C., Du, H., & Yin, C. (2022). Short-term lateral behavior reasoning for target vehicles considering driver preview characteristic. *IEEE Transactions on Intelligent Transportation Systems, 23*(8), 11801–11810. https://doi.org/10.1109/TITS.2021.3107310