PROJECT DEVELOPED BY: Miguel de Cervantes European University

FOR: DGT (Directorate-General for Traffic)

File: 3DGT6A000194

REPORT TITLE: Project report on the evaluation of neuro-psychological tests to determine profiles relating to the use of various psychoactive substances in driving contexts

Published by: Directorate-General for Traffic
44, Josefa Valcárcel Street MADRID 28027

Author: National Road Safety Observatory

Catalogue of publications of the General State Administration: https://cpage.mpr.gob.es

O.P.I.N.: (on line ed.): 128-26-068-X

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Suggested citation:

Roncero, C., & González Sánchez, A. (2025). Informe sobre proyecto de evaluación de pruebas neuropsicológicas para la determinación de perfiles relacionados con el consumo de distintas sustancias psicoactivas en la conducción [Unpublished report, File: 3DGT6A000194]. Miguel de Cervantes European University; Directorate-General for Traffic.

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Summary

This report analyses the relationship between the use of psychoactive substances and neuro-psychological performance in driving contexts. The consumption of alcohol, cannabis and cocaine increases the risk of road accidents and affects cognitive functioning, emotional regulation capability and driving behaviour, although the discriminative capacity of the tests with population with substance use disorders (SUD) is not known. In order to determine the quality of the SUD tests currently performed at Medical Assessment Centres for Drivers (CRs), this prospective and comparative study was conducted with individuals with SUD and healthy controls. All the study subjects had held a driving licence for over 10 years. Psychometric tests were conducted using the LNDeter multiple reaction time testing device along with structured interviews to obtain clinical and socio-demographic data, driving history and information on road rage, expression of anger and co-morbidities. The results were analysed using non-parametric statistical tests to study the reliability, validity and discriminative capacity of various approved neuro-psychological tools. The final sample consisted of 78 subjects: 48 with SUD and 30 controls. The cases presented more physical and mental health problems, a poorer socio-economic situation, lower income and further indebtedness. They also had a driving profile presenting higher risk, greater removal of points from the driving licence and serious sanctions. The cognitive tests showed that the cases suffered greater overall impairment, with lower scores on the MoCA test. The response time and reaction time tests were reliable for both groups, while the attention and decision-making tasks proved less consistent. The drivers with SUD exhibited higher levels of aggression and lower emotional regulation, with a tendency to attribute road risks to external factors. There were clear differences depending on the substance consumed: cocaine was associated with greater psychological vulnerability, alcohol with higher cognitive impairment, and cannabis primarily with greater agitation.

It is concluded that there is an impaired neuro-psychological profile with higher risk in drivers with SUD, who exhibit greater emotional risk, poorer cognitive function and more unsafe behaviours while driving. The current tests are of

sufficient quality to effectively identify individuals with SUD. Emphasis is placed on the need to effectively apply the updated grading scales in medical fitness assessments to optimise classification, thereby reducing accident rate and improving road safety.

Introduction

Psychoactive substances are chemical substances – whether psychotropic or other drugs - of synthetic or natural origin that affect the functions of the central nervous system (CNS), that is, the brain and spinal cord. Their effects include pain inhibition, mood changes and altered perception. Some of these substances are used for therapeutic and medicinal purposes, while others are used for recreational purposes.

Psychoactive substances can alter a person's reasoning and judgement, resulting in possible health risks, such as addiction. Driving under the influence of such substances increases the risk of accidents (Wilson et al., 2014). Numerous studies (Biecheler et al., 2008; Elvik, 2013; Wilson et al., 2014) have shown that individuals who drive with Tetrahydrocannabinol (THC) in their bloodstream are almost twice as likely to cause a fatal accident or to be killed in a road crash, compared to those who have not consumed psychoactive substances or alcohol.

The use of psychoactive substances in Spanish society has increased or is on an upward trend compared to previous years in the use of prescription and over-the-counter hypnotics, opioid analgesics, cannabis, ecstasy, amphetamines, and powdered cocaine and cocaine base (Spanish Observatory on Drugs and Addiction, 2024).

Along with distracted driving and inappropriate speed, alcohol remains a significant contributing factor in fatal accidents on interurban and urban roads (National Road Safety Observatory, 2023). Neuro-psychological evaluation activities are undertaken at Medical Assessment Centres for Drivers (CRs) using psychometric instruments to determine the fitness of individuals to perform potentially dangerous activities, including driving vehicles (González-Sánchez, 2021b). The reduction in fatal accidents due solely to the correction of visual

impairments has been quantified at 12.2% (Shipp, 1998). If a physical and psychological assessment is performed, this percentage reduction in the accident rate is necessarily higher. However, the possibility of improving assessments of individuals to request restrictions and/or adaptations, where appropriate, has become a matter of utmost importance to conduct more accurate assessments and consequently reduce accidents.

For psychological examinations, psychometric tests must currently be performed with material for clinical and personality diagnosis, tests free from cultural bias to assess general and practical intelligence and motion estimation, visual-motor coordination and multiple reaction time using approved equipment (Royal Decree 170/2010, 2010).

Patients with substance use disorders often drive and it can be hypothesised that they have a higher risk of accidents (Roncero et al., 2013). In line with the Sustainable Development Goal set for 2030, which seeks to reduce deaths from road traffic accidents, and given that the number of accidents linked to substance use has not fallen significantly, the objectives of this study are as follows:

- To ascertain the reliability and validity of the tests with equipment approved under Royal Decree 170/2010 in a population of individuals with substance use disorders as regards scores for alcohol, cocaine and cannabis.
- To determine the neuro-psychological profile of individuals with substance use disorder due to alcohol, cocaine and cannabis using the psychological examination tools described in Royal Decree 170/2010.
- To ascertain the grading scales for individuals with substance use disorder due to alcohol, cocaine and cannabis using the approved equipment described in Royal Decree 170/2010.

Methodology

This is a prospective comparative cohort study involving individuals with SUD (Substance Use Disorder) and healthy controls without SUD. Measurements were taken on two occasions one month apart.

Procedure

A research project was designed under the supervision of the bioethics committee of the Salamanca Biomedical Research Institute (IBSAL) with the code: CEIm: PI.2024.01.1487.

Two measurements, a minimum of one month apart, were taken to study the stability of the tests. This meant that whilst samples were being collected for the first measurement, some of the first subjects in the second measurement overlapped with the last subjects in the second measurement. As such, data were collected from 18 February 2025 to 22 October 2025.

Participants

The study focused initially on the participation of subjects who had held a driving licence for at least ten years. These subjects were divided into two groups.

The first group was the control group, made up of individuals who had not had a previous diagnosis of substance-related disorders and who had voluntarily consented to their participation in the study.

The inclusion criteria for patients without SUD are: A) They must not have previously been diagnosed with alcohol- or substance-related disorders. B) They must have given their voluntary consent to take part in the study. C) They must have obtained a driving licence in Spain at some point.

The second group was the case group. This was made up of patients who attended collaborating centres in the field of addictions. These were the Red Cross Drug Addiction Support Centre (CAD) and the Proyecto Hombre institution in Valladolid. As inclusion criteria, these patients had to meet one of the following DSM-5-TR criteria for SUD. As regards alcohol: dependence (F10.2x) or use disorder (F10.1); with regard to disorders related to other substances, individuals who met criteria for either cannabis dependence (F12.2x) or cannabis abuse (F12.1) were included; and with regard to cocaine, both cocaine dependence (F14.2x) and cocaine use disorder (F14.1) were included.

The following exclusion criteria were applied to all participants:

- subjects who refuse to undergo psychometric assessments;
- patients with cognitive impairment who are unable to understand and cooperate in the assessments;
- patients with a language barrier;
- patients who are unable to complete the evaluation process due to change of location, imprisonment or other reasons.

Instruments

The psychometric tests were performed using the LnDeter-100 multiple reaction time testing device, corresponding to: motion estimation, visual motor coordination and multiple reaction time. The following was also assessed:

- Substance use: level of substance use or abuse and type of substances. This information was obtained either from the patient's medical history or from the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-II).
- The subject's cognitive capability. This information was obtained either from the patient's medical history or from the Montreal Cognitive Assessment (MoCA).
- Driving history: prior accidents, aggressive driving, types of licences and use thereof. In addition, the subject's record of complaints and restrictions was obtained from information provided by the Directorate-General for Traffic.
- Socio-demographic variables: DNI [National ID Document]/NIE [Foreign Resident ID Number], sex, gender, age, marital status, employment status, educational attainment level, primary and secondary drugs of abuse or dependence, age of onset of primary and secondary drug use, years of dependence or abuse and other information of interest.
- Aggressive driving test, the Brief Anger Expression Inventory for Drivers
- (DAX) and the multidimensional traffic locus of control scale (T-LOC). The Multidimensional Scale of Locus of Control in Traffic was developed to measure how drivers attribute the causes of accidents to various factors.

- Co-morbidities: information on other diseases present in the cases was collected using a self-generated interview.

Information on lost points from the driving licence and types of licence was checked against the database of the Directorate-General for Traffic to improve the quality of information. To this end, DGT was sent a list of the DNI/NIE numbers of the study participants who had given their authorisation, requesting data on driving licence points (penalty points record), types of driving licence and the restriction or observation code associated with those driving licences.

Assessment team

The assessment team consisted of five psychologists, two of them with previous experience at Medical Assessment Centres for Drivers; in addition, we received support from two psychology students on work placement from the Health Sciences Faculty at Miguel de Cervantes European University in Valladolid (UEMC). All of them have received proper training in conducting interviews, providing instructions and collecting data.

Statistical analysis

The non-parametric Mann-Whitney U and Chi-square tests were applied to determine the differences between the groups. Differences with a p-value of less than 0.05 were considered significant.

For this report, the DAX and T-LOC aggressive driving tests were analysed in their initial assessments.

The considerations of the medical and psychological examination protocol were considered to determine the cut-off points for the multiple reaction time tests: “The minimum acceptable cut-off point is the 20th percentile (50th percentile minus the dispersion measure, the interquartile range) or an error of less than 20%” (Mirabet et al., 2022). This applies to the calibration tables set out in the LNDeter polygraph manual.

Table 1. Grading scales according to LNDeter manual.

NORMS		TEST-1		TEST-2		TEST-3	TEST-4		NORMS	
E	PC	T.R.	N.E.	T.R.	N.E.	V.A.	T.E.	N.E.	PC	E
9	96	30	0	67	0	8	2319	62	96	9
8	89	33	0	74	0	10	2955	73	89	8
7	77	38	0	83	2	15	3738	86	77	7
6	60	43	1	93	2	20	4677	97	60	6
5	40	53	2	106	4	27	5811	106	40	5
4	23	62	3	122	6	36	7016	115	23	4
3	11	74	5	147	9	46	8190	122	11	3
2	4	91	8	167	11	55	9227	131	4	2
1	1	117	11	180	13	71	10052	140	1	1

Note: E: Stanines; PC Percentiles; T.R.: Reaction time; N.E.: Number of errors; V.A.: Speed of anticipation; T.E.: Time spent in error (total errors in test).

The percentile refers to the percentage above the reference sample. This means that it outperforms the other participants, who scored lower. Given that the scale is inverted, for interpretation purposes, the cut-off point shall be those individuals whose errors exceed 80%, not 20%.

To determine the reliability and validity of the tests, 25 points on the MoCA test was established as the cut-off point with detection of cognitive impairment. The analysis was carried out using the ROC curve and new cut-off points determined using the Youden method (Youden, 1950) and the nearest point on the left. The results in the areas under the ROC curve make it possible to assess the discriminative capacity of each test to differentiate between clinical situations or features of interest. The values of the areas under the curve (AUC) are reported. They indicate that scores of 0.5 indicate a discriminatory ability equivalent to chance, whereas the closer the score is to one, the greater the discriminatory ability. Generally speaking, AUC with values of 0.7-0.8 are considered acceptable (Armesto, 2011; Del Valle Benavides, 2017). Values below 0.5 indicate that the test discriminates worse than chance (it classifies the subjects ineffectively).

The scoring key provided in the manual was used to mark the M7p personality test.

Table 2. Equivalence of raw scores and percentile scores. The lines represent the cut-off points. A score higher than the cut-off point would indicate the presence of the trait.

Raw Score	Neuroticism	Paranoia	Agitation	Instability	Psychasthenia	Hypochondriasis	Suicidality
0	12	47	6	17	13	30	51
1	28	66	21	42	28	58	67
2	47	72	48	55	52	69	74
3	59	86	62	68	65	73	82
4	77	91	76	76	73	77	85
5	79	92	87	80	79	86	86
6	84	93	90	84	85	87	90
7	88	96	92	89	91	90	92
8	94	98	93	92	95	94	92
9	96	98	99	97	97	97	94
10	100	100	100	100	100	100	100

As might be expected, personality test 6 is not related to factors associated with dementia so the DAX was used as a reference, with a score of less than 80% for the non-pathological population (corresponding to a score of 25 or higher being classified as pathological).

The same method was used to calculate the standardisation scores for the first five tests as for the reliability and validity analyses, as the MoCA test was used as the gold standard, whereas the DAX was used for the sixth test. The cut-off points were obtained following the Youden index techniques (Youden, 1950) and Closest top-left (Hanley & McNeil, 1982).

Results

Sample

The sample of cases was collected from the Red Cross Drug Addiction Support Centre (CAD), and also from the Proyecto Hombre Therapeutic Unit, both in

Valladolid. The control sample was recruited using a snowball sampling method using the assessors' contacts.

The initial interviews were conducted from 21 January 2025 to 10 June 2025. A preliminary analysis was performed to determine the ages and sex of the cases in order to include controls with characteristics that were as similar as possible. As such, the initial information from the controls was collected between 20 January 2025 and 22 August 2025. The second interviews were conducted at least one month after the first interview.

The first data collection included 78 participants: 48 cases and 30 controls; one patient had to be excluded and 29 reassessments of cases and 30 of controls are studied. The sample size for each question or test may vary and conclusions are described and drawn from the available data. The reasons for these variations are that 48 cases were presented, but two did not complete the first assessment and one was excluded from the study for not meeting the criterion of having held a driving licence for at least ten years.

Comorbidities

Information regarding the cases is shown below (table 3)

Table 3. Comorbidities of the cases.

Group of pathologies	Pathology	Does not present (n)	Does not present (%)	Presents (n)	Presents (%)
Infectious	HIV/AIDS	30	96.8	1	3.2
	Hepatitis B	30	96.8	1	3.2
	Hepatitis C	27	87.1	4	12.9
	Tuberculosis	31	100	0	0
	STD (Syphilis, Gonorrhoea, HPV, etc.)	30	96.8	1	3.2
Liver	Hepatic steatosis (fatty liver)	28	90.3	3	9.7
	Alcoholic hepatitis	30	96.8	1	3.2
	Cirrhosis	29	93.5	2	6.5
Cardiovascular	High blood pressure	30	96.8	1	3.2
	Ischaemic heart disease (heart attack, angina)	31	100	0	0
	Arrhythmia	27	87.1	4	12.9
Respiratory	Chronic bronchitis/COPD	24	77.4	7	22.6
	Recurrent pneumonia	29	93.5	2	6.5
Gastrointestinal	Gastritis	28	90.3	3	9.7

	Peptic ulcers	29	93.5	2	6.5
	Pancreatitis	30	100	0	0
Nutritional/Metabolic	Malnutrition/Vitamin deficiencies	29	93.5	2	6.5
	Metabolic syndrome	31	100	0	0
Others	Skin problems (skin infections, etc.)	26	83.9	5	16.1
	Neurological (epileptic seizures, etc.)	27	87.1	4	12.9
	Musculoskeletal disorders	28	90.3	3	9.7
	Endocrine dysfunctions (thyroid, etc.)	30	96.8	1	3.2

Among the cases, there is a wide range of associated conditions, with a prevalence of respiratory and infectious diseases.

Substance use

As one of the inclusion criteria was that the control group should not have UAS, they have no history of substance use; therefore, the analysis of substance use focuses on the cases.

The use of other substances shows a much lower prevalence compared to alcohol. For example, cannabis presented lifetime use in 12 participants (28.6%) and current use in 5 participants (11.9 %). Cocaine exhibited past use in 11 participants (26.2%) and current use in 5 participants (11.9 %). The use of opiates and sedatives was limited, with past use in 9 (21.4%) and 8 participants (19.0%), respectively, and current use was virtually non-existent. The remaining substances (hallucinogens, stimulants, inhalants and other substances) registered use and dependence percentages of less than 12%, in both lifetime and current use.

Thus, when considering only the cases, a pattern emerges in which historical alcohol consumption is relatively high, with lifetime abuse reported by 32 of the participants (76.2 %) and past dependence by 18 participants (42.9 %), whilst problematic use of other substances is less common. This suggests that alcohol is the most prevalent substance in the case group, while other forms of consumption are marginal or occasional.

Socio-demographic

None of the participants identified with a gender other than their biological sex.

The cases were older than the controls (p=0.041), as the controls showed a mean age of 43.63 years and a standard deviation of 8.99. Meanwhile, the control groups presented a mean of 54.2 and a standard deviation of 7.66.

As regards debts, no statistically significant difference was found (p=0.077).

Table 4. Socio-demographic variables of the sample.

Variable	Category	Cases (n)	Cases (%)	Controls (n)	Controls (%)
Sex	Male:	38	84.4	17	56.7
	Female	7	15.6	13	43.3
Marital status	Single	23	50	13	43.3
	Married	6	13	13	43.3
	In a relationship	7	15.2	3	10
	Divorced	7	15.2	1	3.3
	Separated	1	2.2	–	–
	Widowed	1	2.2	–	–
Nationality	Spanish (including naturalised citizens)	44	97.8	30	100
	Colombian	1	2.2	–	–
Current work status	In employment	16	35.6	27	90
	Unemployed (active)	12	26.7	–	–
	Inactive	8	17.8	–	–
	Others	9	20	3	10
Type of employment	Employee	18	40	20	66.7
	Self-employed	4	8.9	–	–
	Contract	7	15.6	5	16.7
	Others (including civil servants)	16	35.6	5	16.7
Employment pattern (last 3 years)	Full time	31	68.9	22	73.3
	Part-time (irregular/temporary)	5	11.1	1	3.3
	Part-time (regular)	–	–	6	20
	Retired/invalidity	5	11.1	–	–
	Unemployed/homemaker	3	6.7	1	3.3
	Protected environment	1	2.2	–	–
Disability or chronic illness	No	29	64.4	26	86.7
	Yes (permanent total disability)	1	2.2	–	–
	Yes (permanent occupational disability)	2	4.4	–	–

	Yes (non-permanent disability)	2	4.4	1	3.3
	Yes (chronic disabling occupational disease)	5	11.1	–	–
	Yes (non-disabling chronic disease)	6	13.3	3	10
Educational attainment level	Reading and writing only	1	2.2	–	–
	Incomplete primary education	2	4.4	–	–
	Completed primary education	3	6.7	–	–
	Incomplete secondary education	6	13.3	1	3.3
	Secondary education (ESO [compulsory secondary education], Bach. [upper secondary education], CFGM [middle-level vocational training])	29	64.4	4	13.3
	Under graduate [3-year degree course]/CFGS [higher level vocational training]	4	8.9	9	30
	Graduate [5-year degree course]/Doctorate	–	–	16	53.3
Gross monthly income	< €600	10	22.2	1	3.3
	€601-1000	7	15.6	4	13.3
	€1000-1500	17	37.8	6	20
	€1500-2000	7	15.6	7	23.3
	€2000-2500	3	6.7	5	16.7
	< €2500	1	2.2	7	23.3
Source of money in last month	None	2	4.4	–	–
	Employment	17	37.8	26	86.7
	Unemployment benefit	3	6.7	–	–
	Social assistance	5	11.1	–	–
	Pension/social security	11	24.4	3	10
	Family/friends	3	6.7	1	3.3
	Other sources	4	8.9	–	–
Source of additional money	Unemployment benefit	2	4.4	–	–
	Social assistance	2	4.4	–	–
	Pension/social security	3	6.7	1	3.3
	Family/friends	1	2.2	–	–
	Illegal sources	1	2.2	–	–
	Other sources	1	2.2	–	–
Debts	No	14	31.1	23	76.7
	Yes	31	68.9	7	23.3
General health	Poor/unwell	6	13.3	–	–

Fair (minor ailments)	14	31.1	3	10
Good or very good	25	55.6	27	90

Note: 43.3% of the cases are naturalised Spanish citizens.

As regards educational attainment level, a significant relationship was found between the educational attainment level and the subject group ($\chi^2 = 45.24$, $p < 0.001$), indicating that the cases have considerably lower levels of education: most have only completed secondary education or less, whereas university education is the norm among the control group.

Significant differences were observed in terms of income level ($\chi^2 = 16.09$, $p = 0.007$), indicating greater financial insecurity in the case group. In addition, almost half of the cases report an income of less than €1,000, compared to a more balanced distribution in the controls, who more frequently present an income of over €2,000.

There are significant differences in terms of source of income ($\chi^2 = 19.22$, $p = 0.004$). In the control group, the main source of income is paid employment, while in the case group there is a greater reliance on pensions, social security benefits or support from third parties, reflecting greater instability in terms of employment and finances.

Although there were cases who mentioned informal or illegal sources, the differences between groups did not reach statistical significance ($\chi^2 = 1.93$, $p = 0.859$), possibly due to the low number of valid observations ($n = 11$).

There is a marked difference in debt levels ($\chi^2 = 14.95$, $p < 0.001$). More than two-thirds of the participants with TUS have debts, compared with less than a quarter of the control group.

Driving history

Kilometres driven

There were no significant differences between the groups in terms of the number of kilometres driven over a lifetime ($U = 458{,}000$; $p = 0.077$), with a mean of 539,345 km (SD = 572.71) in the case group and 342,241 km (SD = 381.37) in

the control group, nor in the number of kilometres driven in the last month (U = 818,500; p = 0.063), with means of 2,394 km (SD = 4.93) for cases and 1,464 km (SD = 1.85) for controls.

Fines

There are two ways to find out about fines: the information provided by the driver themselves and the information from DGT records.

Information from interview

As regards record data, no differences were found in the number of fines in driving contexts (U = 656,000; p = 0.773), with means of 0.81 (SD = 0.40) for cases and 0.86 (SD = 0.58) for controls. The subjects were asked about the reason for the fines, which revealed that the control group received highly varied types of fines, including in relation to alcohol, drugs, speeding, parking, traffic lights, driving in the opposite direction and excessive safety distance. In particular, there are several cases of sanctions relating to substance use and reckless driving, while most fines in the case group are for speeding and parking offences, with a few exceptions involving accidents or minor infringements.

However, differences were observed in variables relating to more serious sanctions: the number of points removed from the licence was higher in the case group (U = 412,500; p < 0.001), with means of 0.52 (SD = 0.51) compared to 0.17 (SD = 0.38) in the controls; driving licence withdrawal was also more frequent in the case group (U = 457,500; p = 0.001), with means of 0.33 (SD = 0.48) compared to 0.03 (SD = 0.19) in the controls; and the number of times they were stopped by traffic police in the last year was higher in the case group (U = 542,000; p = 0.044), with means of 0.74 (SD = 1.55) compared to 0.17 (SD = 0.60) in the controls. Among the reasons for these sanctions, some individuals even report losing points for transferring them (when asked to identify the driver due to a traffic infringement) or for work-related reasons (one individual had their licence removed for testing positive for THC whilst serving in the army). Only one instance of a driving licence being removed on legal grounds was recorded in the group of cases. By contrast, point deduction is much less frequent in the control group and it is generally limited to minor infringements (speeding, parking, seat belt). It is only on control groups that driving licences are withdrawn due to

alcohol, drugs or exceptional circumstances (for instance those relating to military service or to judicial reasons); in addition, in control groups, only one case of a licence being withdrawn for administrative reasons was observed, which was due to speeding offences.

Information from DGT

The information provided from official records revealed differences between the groups in the number of traffic offenses (U = 370,500; p = 0.010). The case group had a mean of 7.10 offenses (SD = 8.81; median = 4), while the control group had a mean of 2.14 offenses (SD = 2.64; median = 1), indicating that the cases received more and a greater variety of traffic offenses than the controls.

In the case group, most participants have no driving restrictions. 58.3% have no limitations, a single case (2.1%) has a restriction relating to alcohol, while others have restrictions in relation to the date of first issue or exchange of a foreign driving licence (12.5% each). In addition, as regards restrictions on group 2 vehicles (professional vehicles), 93.8% of cases have no limitations, while three cases (2.1% each) have restrictions relating to the date of first issue, exchange of foreign driving licence or day time journeys.

The control group presents a greater range of restrictions. Only 43.3% of participants have no limitations, while another 43.3% have restrictions relating to exchange of foreign driving licences and another 13.3% in relation to the date of first issue. As for subjects with various restrictions, these are related to exchange of foreign driving licences (3.3%) or driving within a specific radius (6.7%), day time journeys (3.3%) or automatic transmission (6.7%). With regard to restrictions for the professional driving group (group 2), the majority (93.3%) do not present any limitations, while one of the controls (3.3%) has restrictions relating to exchange of a foreign driving licence and another one (3.3%) in relation to day time journeys.

Basic use of the vehicle

In the case group, most individuals use their vehicle for work (test drivers, delivery drivers, lorry drivers, builders), while others do not identify a specific work use. The control group shows a much more consistent pattern of use, primarily for everyday journeys (work, leisure, tractor maintenance). This is consistent with the

fact that the participants have a greater variety of roles and purposes for which they use the vehicle.

Accidents

As regards the total lifetime number of traffic accidents, the cases present a mean of 2.44 (SD = 1.85), while the controls have a mean of 1.67 (SD = 1.61). The difference between groups does not reach statistical significance (U = 502, Z = -1.908, p = 0.056), indicating that both groups report a similar number of accidents overall.

A specific analysis of the accidents caused by the study subjects reveals that the cases have a mean of 1.24 (SD = 1.54) while the controls have a much lower mean of 0.23 (SD = 0.43). This difference is statistically significant (U = 329, Z = -4,100, p < 0.001), showing that the case group are the ones who have caused the most accidents.

In accidents not caused by the study subjects, however, the mean for the cases is 1.20 (SD = 1.36) and for the controls 1.40 (SD = 1.57), with no significant differences observed between groups (U = 714.5, Z = 0.446, p = 0.655), which indicates that the variation in accidents between groups is concentrated mainly on accidents caused by the participants themselves.

Consequences of accidents

With regard to the most serious consequence arising from accidents, the case group mainly presents bodily injuries (41.7%) and material damage (31.3%), while the controls have suffered more material damage (46.7%) and a considerable proportion without any consequences from the accident (36.7 %). These differences are statistically significant (χ^2 = 8.151, df = 3, p = 0.043), suggesting that the case group experiences more serious accidents more frequently than the controls.

With respect to personal consequences from traffic accidents, the cases present physical consequences (33.3%) and psychological consequences (10.4%), while the majority of the controls do not report consequences (86.7 %). The differences between groups are significant according to Pearson's chi-square (χ^2 = 10.626, df = 3, p = 0.014) and a significant linear association is also observed (χ^2 = 9.523,

df = 1, p = 0.002), indicating that the cases are more likely to suffer long-term effects following an accident.

Conversely, no significant differences were found between groups in the consequences of the accident (χ^2 = 0.589, df = 3, p = 0.899) nor in the incapacity for work resulting from the accident (χ^2 = 1.360, df = 2, p = 0.507). This indicates that although the cases experience more serious accidents and more personal consequences, the need for medical assistance or hospitalisation, damage to third parties or incapacity for work do not differ significantly from the values observed in the controls.

Road rage test

The results of the comparisons between groups in relation to aggressive behaviours and experiences as road victim show significant differences in several variables.

As regards incidents of verbal or gestural aggression, no significant differences were found as victims: both cases and controls reported being shouted, insulted or were made obscene gestures to a similar extent (cases 86.7%, controls 80%; χ^2 = 0.595, p = 0.440). However, analysed as aggressors, the cases are significantly more likely to have insulted or made obscene gestures to other drivers (cases 60%, controls 30 %; χ^2 = 6,490, p = 0,011), indicating a greater tendency towards active aggression in this group.

With regard to threats of aggression or damage to the vehicle, the cases also stand out as more aggressive: while no controls reported having threatened to damage a vehicle, 26.7% of the cases did, with significant differences (χ^2 = 9.524, p = 0.002). In addition, the cases are more likely to be victims of threats of aggression or damage to the vehicle than the controls (42.2% versus 16.7 %; χ^2 = 5.402, p = 0.020).

With respect to physical damage or attempt to cause harm to others or to the vehicle, the differences between groups were not statistically significant in most variables, although trends were observed: the cases reported more aggressions and intentional damage, but the number of incidents was small and some tests

approach significance (e.g. damage or attempt to damage the vehicle, $\chi^2 = 3.571$, $p = 0.059$).

DAX anger expression test

The results of the Driving Anger Expression Inventory - Short Form (DAX) show relevant differences between the case and control groups in several factors in the questionnaire. In verbal anger expression, the cases have a mean of 1.01 (SD = 0.76) compared to 0.67 (SD = 0.51) in the controls; however, this difference does not reach statistical significance ($p = 0.076$), so the null hypothesis of equality between groups is maintained. By contrast, personal physical anger expression does show a significant difference ($p < 0.001$), with a notably higher mean in the cases (0.48; SD = 0.56) compared to the controls (0.10; SD = 0.20), indicating a higher tendency to externalise anger through physical or aggressive behaviours in the case group.

Significant differences were also observed in displaced aggression, in which the cases obtained a mean of 0.39 (SD = 0.40) versus 0.15 (SD = 0.17) in the controls ($p = 0.011$). This suggests that the cases tend to redirect their anger more frequently towards third parties or contexts other than those that originally caused it. As regards anger control, the results also differ significantly ($p = 0.013$), with the controls scoring higher (3.22; SD = 0.84) than the cases (2.69; SD = 1.01), reflecting better emotional management and greater self-regulation capacity in the group without disorders.

The results showed that there are no statistically significant differences in the variable Vehicle-related anger expression between cases and controls ($U = 512.00$; $p = 0,062$). By contrast, a significant difference was observed in Adaptive Anger Expression (PRE) ($U = 884.50$; $p = 0.022$), with higher scores in the control group. These results suggest that the individuals with no such history in the case group exhibit greater adaptive strategies in situations that cause anger in driving contexts.

At a descriptive level, the cases obtained a mean of 0.49 (SD = 0.61) in Vehicle, compared to 0.20 (SD = 0.28) in the controls. With regard to Adaptive Anger Expression, the cases presented a mean of 2.71 (SD = 1.05), while the controls stood at 3.21 (SD = 0.91). These values reflect a greater tendency towards the

direct expression of anger in driving contexts in the case group, accompanied by a lower use of cognitive strategies for emotional regulation compared to the control group.

Lastly, the total DAX-22 score shows a marginal difference, with means of 24.58 (SD = 7.81) in the cases and 21.60 (SD = 5.47) in the controls, albeit without reaching statistical significance (p = 0.071). Taken together, these results indicate that although verbal expression and total anger do not differ significantly, the cases show higher levels of physical expression and displaced aggression, along with less emotional control, evidencing a pattern of greater impulsivity and less anger management in driving contexts.

T-LOC test

Comparisons between groups were carried out using the Mann-Whitney U test for the four factors of the T-LOC.

In the “Other Drivers” factor, a significant difference was found between cases (M = 14.71, SD = 3.90) and controls (M = 12.70, SD = 4.32), U = 481, p = 0.035, indicating that the cases perceive greater risks attributable to the behaviour of others.

By contrast, no significant differences were observed for the "Self" factor (cases: M = 12.18, SD = 2.60; controls: M = 11.77, SD = 2.75; U = 630, p = 0.623), suggesting similar perceptions regarding self-related risks.

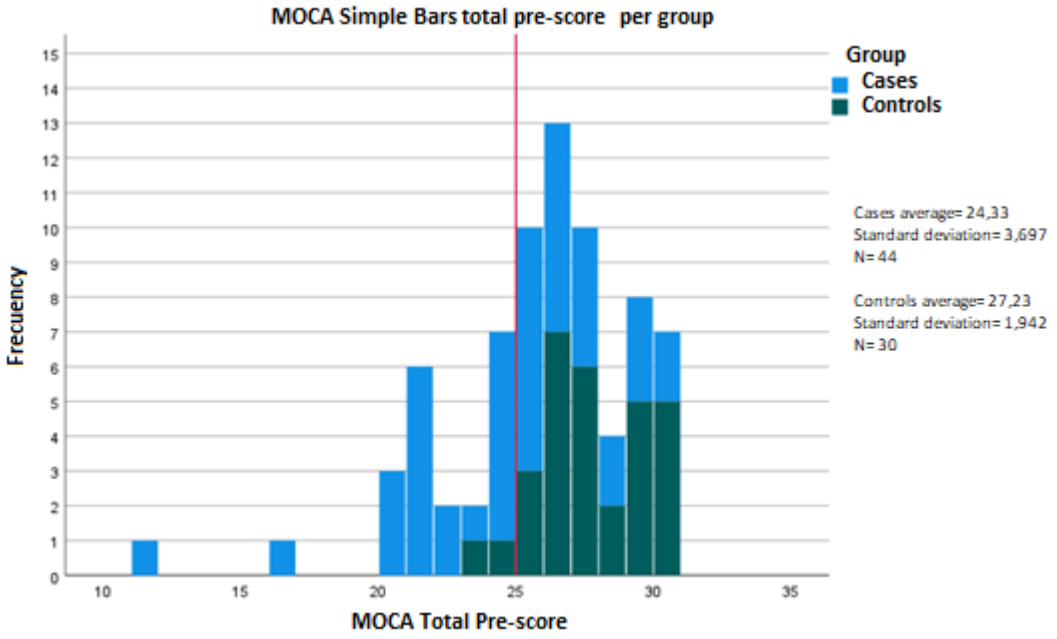
With respect to the “Vehicle and Environment” factor, the controls scored significantly higher (M = 9.13, SD = 1.85) than the cases (M = 7.69, SD = 2.57), U = 903, p = 0.012, reflecting a greater perception of risks associated with the environment and the vehicle in this group.

Lastly, in the “Fate” factor, no significant differences were detected between groups (cases: M = 6.38, SD = 1.75; controls: M = 6.80, DE = 1.24; U = 738, p = 0.476). These results suggest that, while the cases tend to attribute risks to other drivers, the controls are more aware of risks related to the environment and the vehicle.

MoCA

A non-parametric contrast test (Mann-Whitney U) was performed to compare the initial total MoCA score between the case group and the control group, given that the data did not follow a normal distribution in the case group (Shapiro-Wilk, p = 0.005). The effective sample size was 44 for cases and 30 for controls. The results showed significant differences between groups (U = 1014.5; Z = 3.93; p < 0.001), indicating that the cases obtained lower scores (Mean = 24.23, SD = 3.70) than the controls (Mean = 27.23, SD = 1.94). The median for the cases was 25, compared to 27 in the controls, and the interquartile range was higher in the case group (6 versus 3), suggesting greater variability in their cognitive performance.

Figure 1. Bar chart of the initial interview in the MoCA test, differentiated by groups.



Note: number 25 was marked with a red vertical line, corresponding to the cut-off point that differentiates the pathological population with detection of cognitive impairment.

As regards the MoCA test scores, it is observed that in the case group most participants have scores below 25, with a total of 25 individuals (59.5% of the group), while 20 participants (47.6%) obtained scores of at least 25, considering the available data and excluding the cases lost by the system (n = 4). Besides,

most of the subjects in the control group scored at least 25, with 25 participants (83.3%) in this category, compared to only 5 individuals (16.6%) with scores equal to or below 25. The final sample size included 42 valid cases and 30 valid controls.

Reliability and validity of the LNDeter tests

Table 5. Areas under the ROC curve for the various tests

Test No.	Test measure	Cases	Controls	Full sample
1	Mean response time	0.737	0.583	0.687
	Stimulus-response confusion	0.625	0.471	0.615
2	Mean response time	0.709	0.588	0.673
	Stimulus-response confusion	0.725	0.604	0.727
3	Mean absolute deviation	0.411	0.529	0.469
4	Errors	0.678	0.483	0.644
	Error time	0.704	0.558	0.644
5	Number of attempts (NI)	0.414	0.317	0.426
	Number of correct answers (NA)	0.375	0.583	0.454
	Proportion of correct answers (PA)	0.451	0.700	0.503
	Risk-taking (AR)	0.481	0.246	0.436
	Reaction time (TR)	0.676	0.579	0.582
6	Neuroticism	0.721	0.574	0.700
	Paranoia	0.520	0.636	0.626
	Agitation	0.740	0.594	0.733
	Power of the self	0.669	0.480	0.657
	Psychasthenia	0.661	0.648	0.692
	Hypochondriasis	0.704	0.517	0.698
	Suicidality	0.516	0.494	0.568

Note: The first five tests were evaluated using the MoCA test at scores ≤25. The sixth test was evaluated using the DAX at scores ≥25.

In the full sample, several tests show good predictive capacity, especially those related to mean response time (0.687), agitation (0.733) and neuroticism (0.700), indicating that these variables have reasonable sensitivity and specificity for identifying relevant differences in the studied population. When the groups are analysed separately, the substance use cases generally show higher areas under the curve than the controls, most notably in mean response time, agitation and neuroticism, suggesting that the tests are more sensitive and consistent in individuals with a history of substance use. Meanwhile, some indicators in the controls, such as the proportion of correct answers or paranoia, show better AUC

than in the case group, indicating that certain measures may be more informative in a population without substance use.

Grading scale

The following table provides a summary of each test, showing its AUC with its optimal cut-off points for the SUD population and its associated sensitivity and specificity values.

Table 6. Optimal cut-off points for each test in the SUD population.

Test/Variable	Optimal cut-off point	Sensitivity	Specificity	AUC
Test 1. Mean response time	49.5	0.852	0.471	0.737
Test 1. Errors (Stimulus-response confusion)	0.5	0.519	0.765	0.625
Test 2. Mean response time	62	1.0	0.056	0.709
Test 2. Errors (Stimulus-response confusion)	0.5	0.889	0.278	0.719
Test 3. Mean absolute deviation	30.5	0.333	0.667	0.409
Test 4. Total error time	2212	0.667	0.778	0.718
Test 4. Number of errors	77.5	0.556	0.889	0.693
Test 5. Number of attempts	22.5	0.185	0.889	0.432
Test 5. Number of correct answers	14.5	0.963	0.056	0.386
Test 5. Proportion of correct answers	71.5	1.0	0.056	0.442
Test 5. Risk-taking	59.5	0.741	0.333	0.507
Test 5. Reaction time	60.5	0.926	0.278	0.675
Test 6. Neuroticism	2.5	0.792	0.65	0.721
Test 6. Paranoia	0.5	0.875	0.2	0.520
Test 6. Agitation	2.5	0.917	0.6	0.740
Test 6. Power of the self	3.5	0.5	0.9	0.669
Test 6. Psychasthenia	1.5	0.875	0.35	0.661
Test 6. Hypochondriasis	0.5	0.958	0.3	0.704
Test 6. Suicidality	0.5	0.542	0.5	0.516

Test 1

In the case group, an area under the curve of 0.737 was obtained for the mean response time. And 0.625 for errors. Figure 2.

Figure 2. ROC curve for test 1 for the case group.

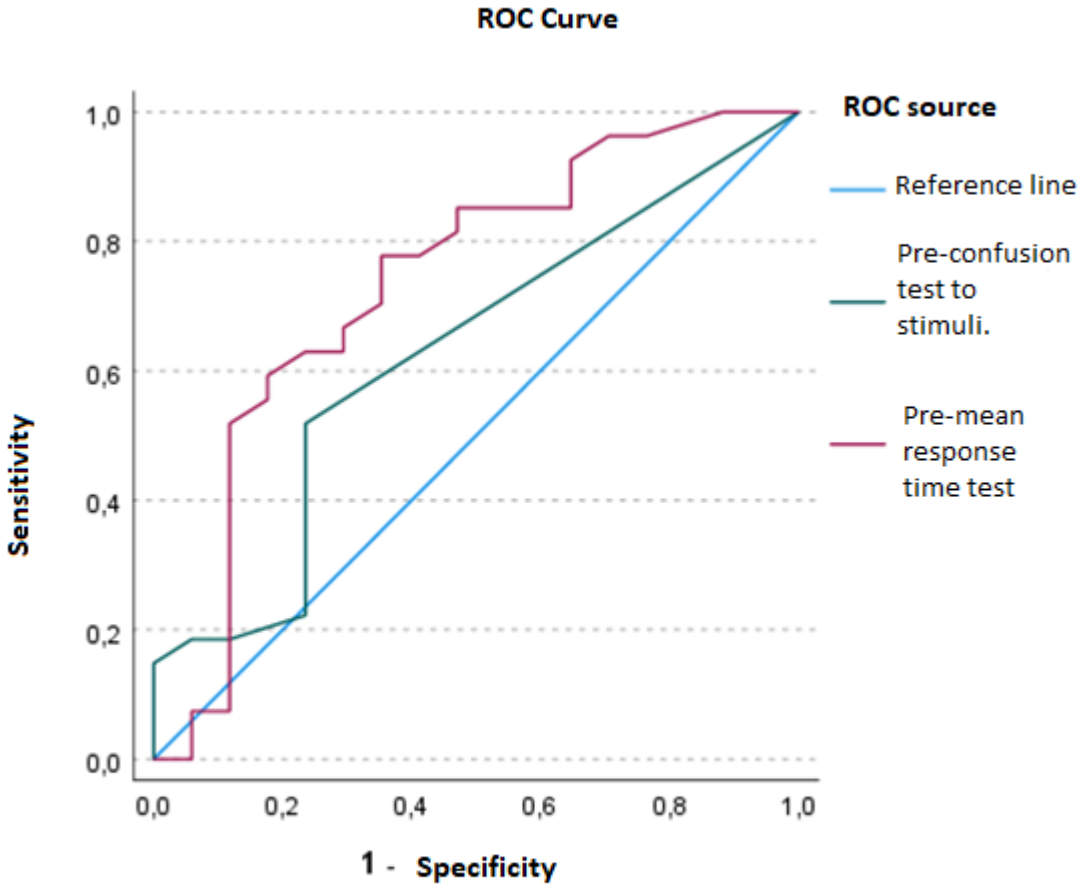


Table 7. Test 1 coordinates for sensitivity and specificity in case group. The Youden index and closest top left correction were applied to determine the optimal cut-off point.

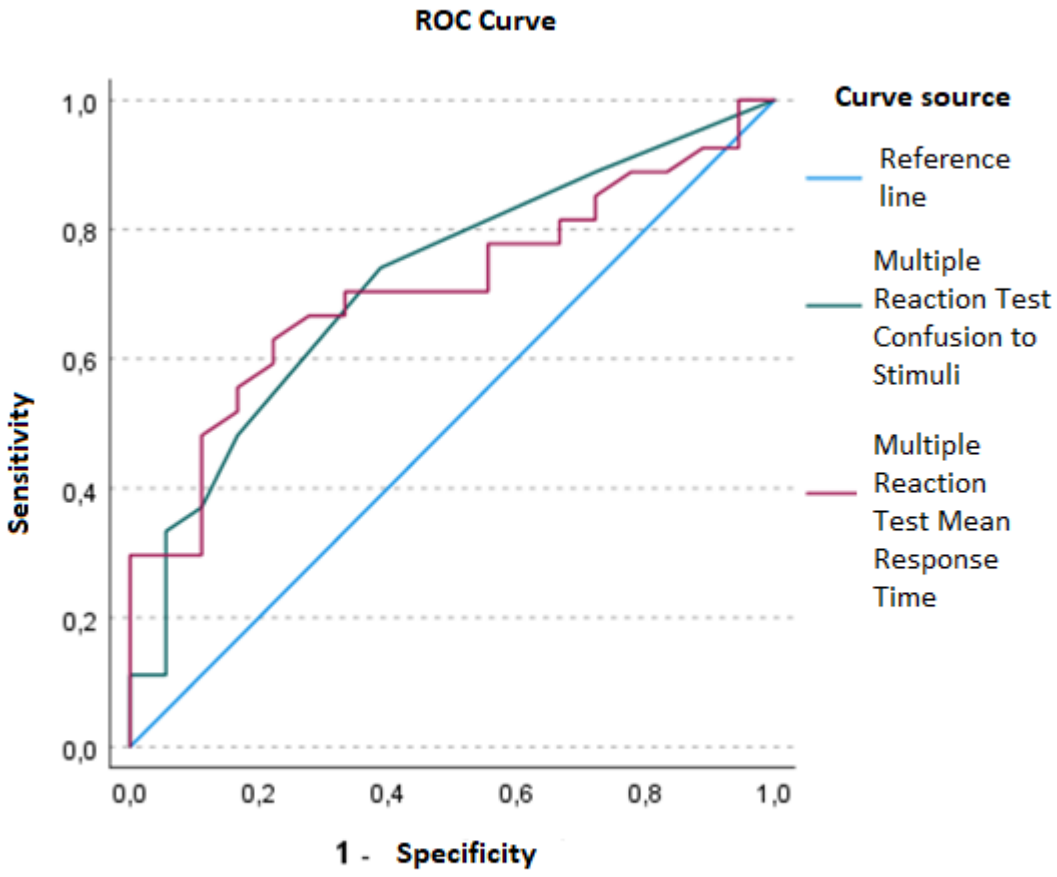
	Cut-off point	Sensitivity	1-specificity	Youden	Closest top left
1. Mean response time	29	1	1	0	1
	33.5	1	0.941	0.059	0.941
	38	1	0.882	0.118	0.882
	40.5	0.963	0.765	0.198	0.76589425
	42.5	0.963	0.706	0.257	0.70696888
	44.5	0.926	0.647	0.279	0.65121809
	47	0.852	0.647	0.205	0.66371153
	49.5	0.852	0.529	0.323	0.54931321
	51.5	0.852	0.471	0.381	0.49370538

	52.5	0.815	0.471	0.344	0.50602964
	54.5	0.778	0.412	0.366	0.46800427
	57.5	0.778	0.353	**0.425**	**0.4170048**
	61	0.741	0.353	0.388	0.43782417
	64	0.704	0.353	0.351	0.46067885
	66.5	0.667	0.294	0.373	0.44421279
	68.5	0.63	0.294	0.336	0.47258438
	69.5	0.63	0.235	0.395	0.43832066
	71.5	0.593	0.176	0.417	0.44342418
	74	0.556	0.176	0.38	0.47761072
	75.5	0.519	0.118	0.401	0.49526256
	77	0.444	0.118	0.326	0.56838367
	79	0.407	0.118	0.289	0.60462633
	81.5	0.37	0.118	0.252	0.64095554
	83.5	0.333	0.118	0.215	0.67735737
	84.5	0.296	0.118	0.178	0.71382071
	85.5	0.222	0.118	0.104	0.78689771
	87.5	0.185	0.118	0.067	0.82349803
	90.5	0.148	0.118	0.03	0.86013255
	92.5	0.111	0.118	-0.007	0.89679708
	94	0.074	0.118	-0.044	0.93348808
	96	0.074	0.059	0.015	0.92787769
	107.5	0.037	0.059	-0.022	0.96480568
	119	0	0.059	-0.059	1.00173899
	121	0	0	0	1
1. Stimulus-response confusion	-1	1	1	0	1
	0.5	0.519	0.235	**0.284**	**0.53533728**
	1.5	0.222	0.235	-0.013	0.81271705
	2.5	0.185	0.118	0.067	0.82349803
	3.5	0.185	0.059	0.126	0.81713279
	4.5	0.148	0	0.148	0.852
	6	0.074	0	0.074	0.926
	14	0.037	0	0.037	0.963
	22	0	0	0	1

Note: The optimum cut-off point is highlighted in green.

Test 2

Figure 3. ROC curve for test 2 for the case group.



With an area under the curve of 0.709 for MRT and 0.719 for errors.

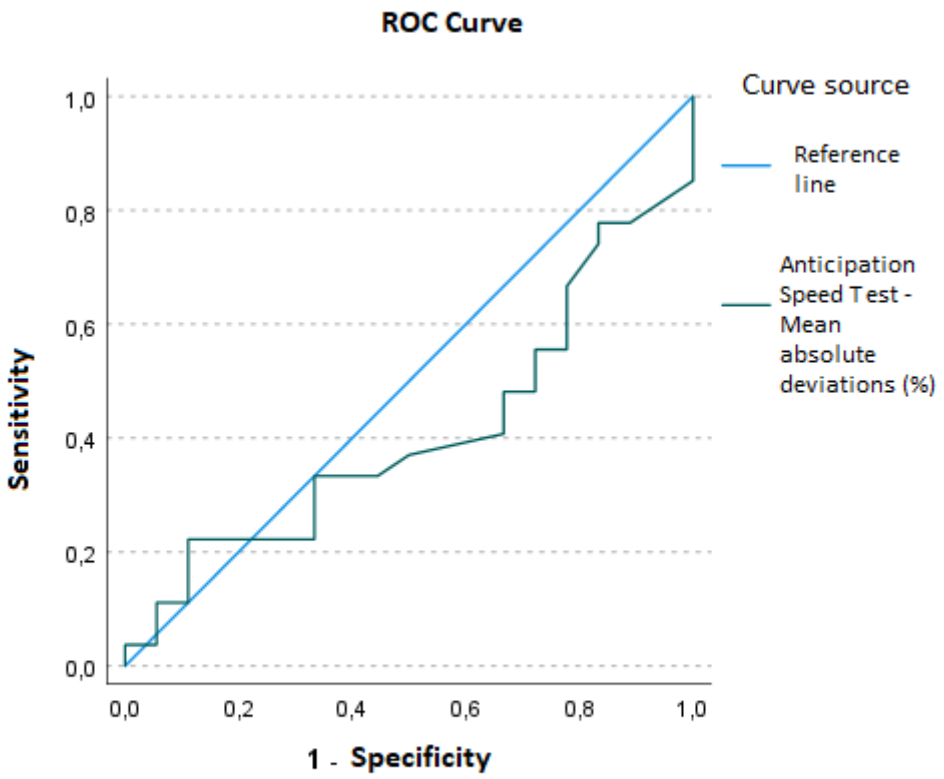
Table 8. Test 2 coordinates for sensitivity and specificity in case group.

	Cut-off point	Sensitivity	1-specificity	Youden	Closest top left
	56	1	1	0	1
	62	1	0.944	0.056	0.944
	69.5	0.963	0.944	0.019	0.94472483
	72.5	0.926	0.944	-0.018	0.94689598
	73.5	0.926	0.889	0.037	0.89207455
	76.5	0.889	0.833	0.056	0.84036302
	79.5	0.889	0.778	0.111	0.78587849
	82.5	0.852	0.722	0.13	0.73701289
	87.5	0.815	0.722	0.093	0.74532476
	91	0.815	0.667	0.148	0.69218061
	92.5	0.778	0.667	0.111	0.70297439
	96	0.778	0.556	0.222	0.59868189
	99.5	0.741	0.556	0.185	0.61336531
	100.5	0.704	0.556	0.148	0.62988253
	101.5	0.704	0.389	0.315	0.48881182
	103	0.704	0.333	0.371	0.445539
	105	0.667	0.333	0.334	0.47093312
2. Multiple response	107	0.667	0.278	0.389	0.43378912
test - Mean response	**108.5**	**0.63**	**0.222**	**0.408**	**0.43149044**
time	114.5	0.593	0.222	0.371	0.46360867
	120.5	0.556	0.167	0.389	0.474368
	122.5	0.519	0.167	0.352	0.50916598
	124.5	0.481	0.111	0.37	0.53073722
	127	0.444	0.111	0.333	0.56697178
	131	0.37	0.111	0.259	0.63970384
	138.5	0.333	0.111	0.222	0.67617305
	145	0.296	0.111	0.185	0.71269699
	146.5	0.296	0.056	0.24	0.70622376
	147.5	0.296	0	0.296	0.704
	150.5	0.259	0	0.259	0.741
	155	0.222	0	0.222	0.778
	161	0.185	0	0.185	0.815
	169.5	0.148	0	0.148	0.852
	176	0.111	0	0.111	0.889
	188.5	0.074	0	0.074	0.926
	690	0.037	0	0.037	0.963
	1182	0	0	0	1
2. Multiple response	-1	1	1	0	1
test - Stimulus-	0.5	0.889	0.722	0.167	0.73048272
response confusion	**1.5**	**0.741**	**0.389**	**0.352**	**0.467335**

2.5	0.481	0.167	0.314	0.54520638
3.5	0.37	0.111	0.259	0.63970384
4.5	0.333	0.056	0.277	0.6693467
5.5	0.259	0.056	0.203	0.74311305
7	0.222	0.056	0.166	0.78001282
8.5	0.148	0.056	0.092	0.85383839
9.5	0.111	0.056	0.055	0.89076203
11	0.111	0	0.111	0.889
12.5	0.074	0	0.074	0.926
14	0	0	0	1

Test 3

Figure 4. ROC curve for test 3 for the case group.



Area under the curve 0.409.

Table 9. Test 3 coordinates for sensitivity and specificity in case group.

	Cut-off point	Sensitivity	1-specificity	Youden	Closest top left
	4	1	1	0	1
	6.5	0.963	1	-0.037	1.000684266
	8.5	0.926	1	-0.074	1.002734262
	9.5	0.889	1	-0.111	1.00614164
	10.5	0.852	1	-0.148	1.010892675
	11.5	0.815	0.944	-0.129	0.96195686
	12.5	0.778	0.889	-0.111	0.916299623
	13.5	0.778	0.833	-0.055	0.862074823
	14.5	0.741	0.833	-0.092	0.872335944
	16	0.667	0.778	-0.111	0.846270051
	17.5	0.63	0.778	-0.148	0.861501016
	18.5	0.556	0.778	-0.222	0.895778991
	19.5	0.556	0.722	-0.166	0.847596602
	21	0.481	0.722	-0.241	0.889182209
	23	0.481	0.667	-0.186	0.845133126
Test 3. Mean absolute	25	0.444	0.667	-0.223	0.868346129
deviation	27	0.407	0.667	-0.26	0.892489776
	28.5	0.37	0.5	-0.13	0.804300939
	29.5	0.333	0.444	-0.111	0.801264625
	30.5	0.333	0.333	0	0.745505198
	32	0.296	0.333	-0.037	0.778784309
	36	0.259	0.333	-0.074	0.812385377
	39.5	0.222	0.333	-0.111	0.846270051
	40.5	0.222	0.278	-0.056	0.826176737
	41.5	0.222	0.167	0.055	0.795721685
	42.5	**0.222**	**0.111**	**0.111**	**0.785878489**
	45	0.148	0.111	0.037	0.859200209
	53.5	0.111	0.111	0	0.895902897
	61	0.111	0.056	0.055	0.890762033
	75	0.074	0.056	0.018	0.927691759
	91	0.037	0.056	-0.019	0.964626871
	102.5	0.037	0	0.037	0.963

Test 4

Figure 5. ROC curve for test 4 for the case group.

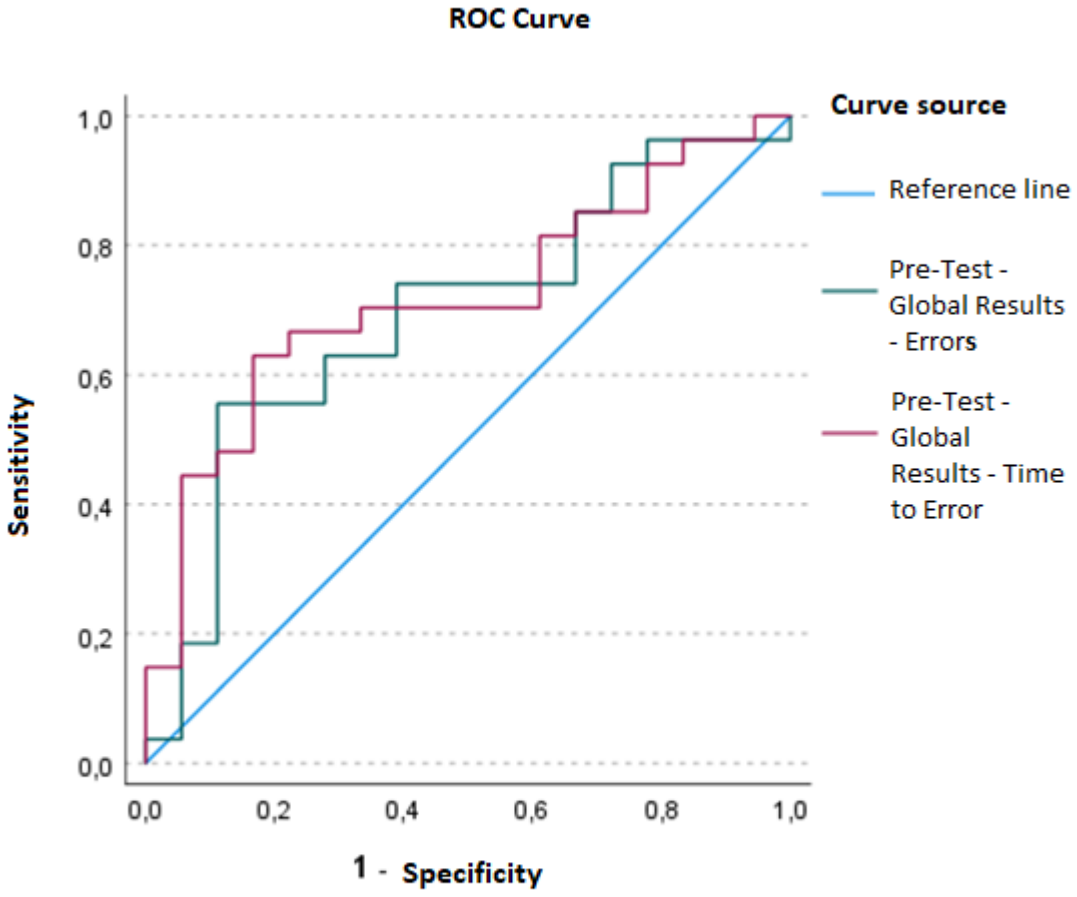


Table 10. Test 4 coordinates for sensitivity and specificity in case group.

	Cut-off point	Sensitivity	1-specificity	Youden	Closest top left
4. Test - Overall results - Error time	73	1	1	0.000	1.000
	123	1	0.944	0.056	0.944
	287	0.963	0.944	0.019	0.945
	407	0.963	0.833	0.130	0.834
	463	0.926	0.833	0.093	0.836
	525	0.926	0.778	0.148	0.782
	562	0.889	0.778	0.111	0.786
	615	0.852	0.778	0.074	0.792
	649	0.852	0.722	0.130	0.737
	719	0.852	0.667	0.185	0.683
	840	0.815	0.667	0.148	0.692
	916	0.815	0.611	0.204	0.638
	970	0.778	0.611	0.167	0.650
	1017	0.741	0.611	0.130	0.664
	1054	0.704	0.611	0.093	0.679
	1204	0.704	0.556	0.148	0.630
	1397	0.704	0.5	0.204	0.581
	1497	0.704	0.444	0.260	0.534
	1675	0.704	0.389	0.315	0.489
	1835	0.704	0.333	0.371	0.446
	1909	0.667	0.333	0.334	0.471
	2058	0.667	0.278	0.389	0.434
	2212	0.667	0.222	0.445	0.400
	2367	**0.63**	**0.222**	**0.408**	**0.431**
	2546	0.63	0.167	0.463	0.406
	2654	0.593	0.167	0.426	0.440
	2710	0.556	0.167	0.389	0.474
	2815	0.519	0.167	0.352	0.509
	2935	0.481	0.167	0.314	0.545
	3192	0.481	0.111	0.370	0.531
	3429	0.444	0.111	0.333	0.567
	3544	0.444	0.056	0.388	0.559
	3643	0.407	0.056	0.351	0.596
	3669	0.37	0.056	0.314	0.632
	3726	0.333	0.056	0.277	0.669

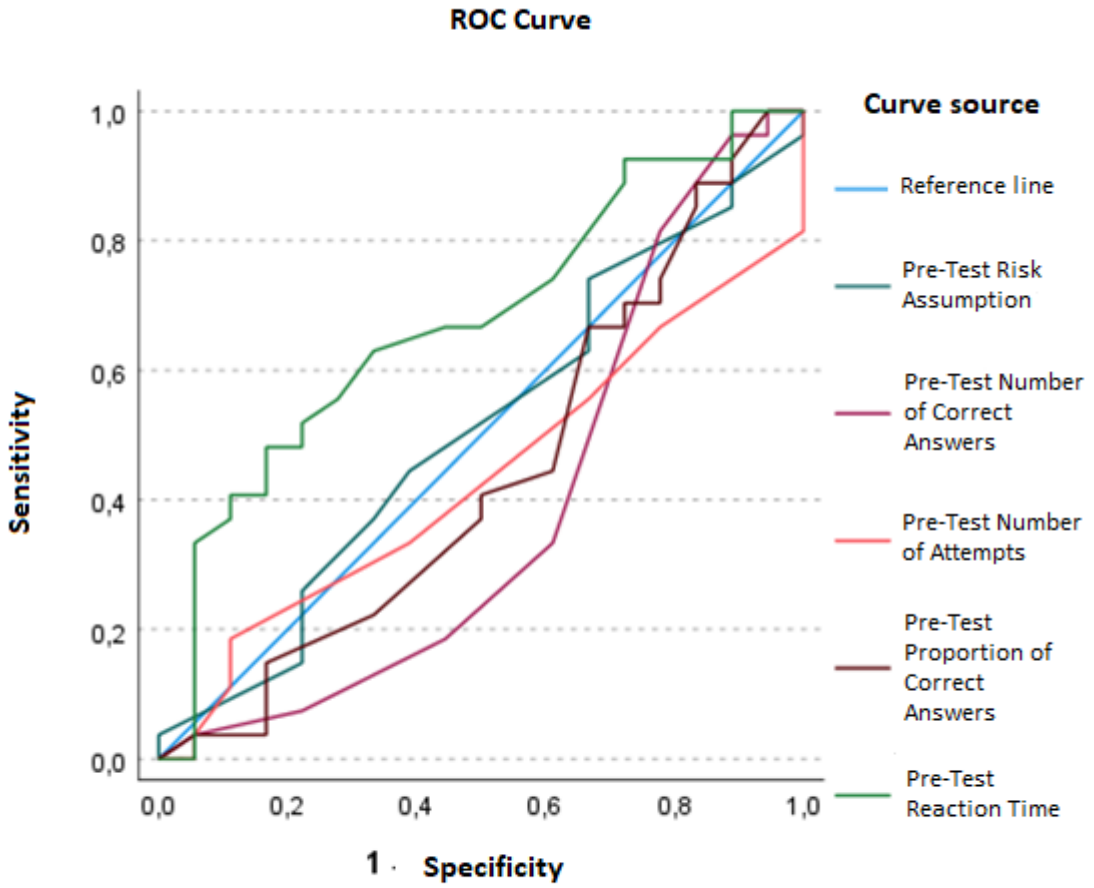
	3821	0.296	0.056	0.240	0.706
	3902	0.259	0.056	0.203	0.743
4. Test - Overall results - Errors	5	1	1	0.000	1.000
	7	0.963	1	-0.037	1.001
	12.5	0.963	0.944	0.019	0.945
	18	0.963	0.889	0.074	0.890
	19.5	0.963	0.833	0.130	0.834
	21.5	0.963	0.778	0.185	0.779
	25.5	0.926	0.778	0.148	0.782
	28.5	0.926	0.722	0.204	0.726
	30	0.889	0.722	0.167	0.730
	31.5	0.852	0.722	0.130	0.737
	32.5	0.852	0.667	0.185	0.683
	34	0.815	0.667	0.148	0.692
	35.5	0.778	0.667	0.111	0.703
	38	0.741	0.667	0.074	0.716
	40.5	0.741	0.611	0.130	0.664
	42.5	0.741	0.556	0.185	0.613
	46.5	0.741	0.5	0.241	0.563
	49.5	0.741	0.444	0.297	0.514
	52.5	0.741	0.389	0.352	0.467
	55.5	0.704	0.389	0.315	0.489
	61	0.667	0.389	0.278	0.512
	67	0.63	0.389	0.241	0.537
	69	0.63	0.333	0.297	0.498
	71.5	0.63	0.278	0.352	0.463
	73.5	0.593	0.278	0.315	0.493
	74.5	0.556	0.278	0.278	0.524
	75.5	0.556	0.222	0.334	0.496
	76.5	0.556	0.167	0.389	0.474
	77.5	**0.556**	**0.111**	**0.445**	**0.458**
	78.5	0.444	0.111	0.333	0.567
	79.5	0.407	0.111	0.296	0.603
	80.5	0.37	0.111	0.259	0.640
	82.5	0.333	0.111	0.222	0.676
	84.5	0.259	0.111	0.148	0.749
	86	0.222	0.111	0.111	0.786
	89	0.185	0.111	0.074	0.823
	91.5	0.185	0.056	0.129	0.817
	93.5	0.148	0.056	0.092	0.854

97	0.074	0.056	0.018	0.928
99.5	0.037	0.056	-0.019	0.965
102	0.037	0	0.037	0.963
105	0	0	0.000	1.000

Area under the curve of Total error time 0.718 and for number of errors: 0.693.

Test 5

Figure 6. ROC curve for test 5 for the case group.



In test 5, most variables have values lower than 0.50, indicating a low discriminatory capacity among the case and control groups. Specifically, the number of attempts (AUC = 0.432), the number of correct answers (AUC = 0.386) and the proportion of correct answers (AUC = 0.442) show limited discrimination power. The risk-taking variable presents a value close to chance (AUC = 0.507), while reaction time achieves the highest value (AUC = 0.675), suggesting a moderate capacity to differentiate between the two groups.

Table 11. Test 5 coordinates for sensitivity and specificity in case group.

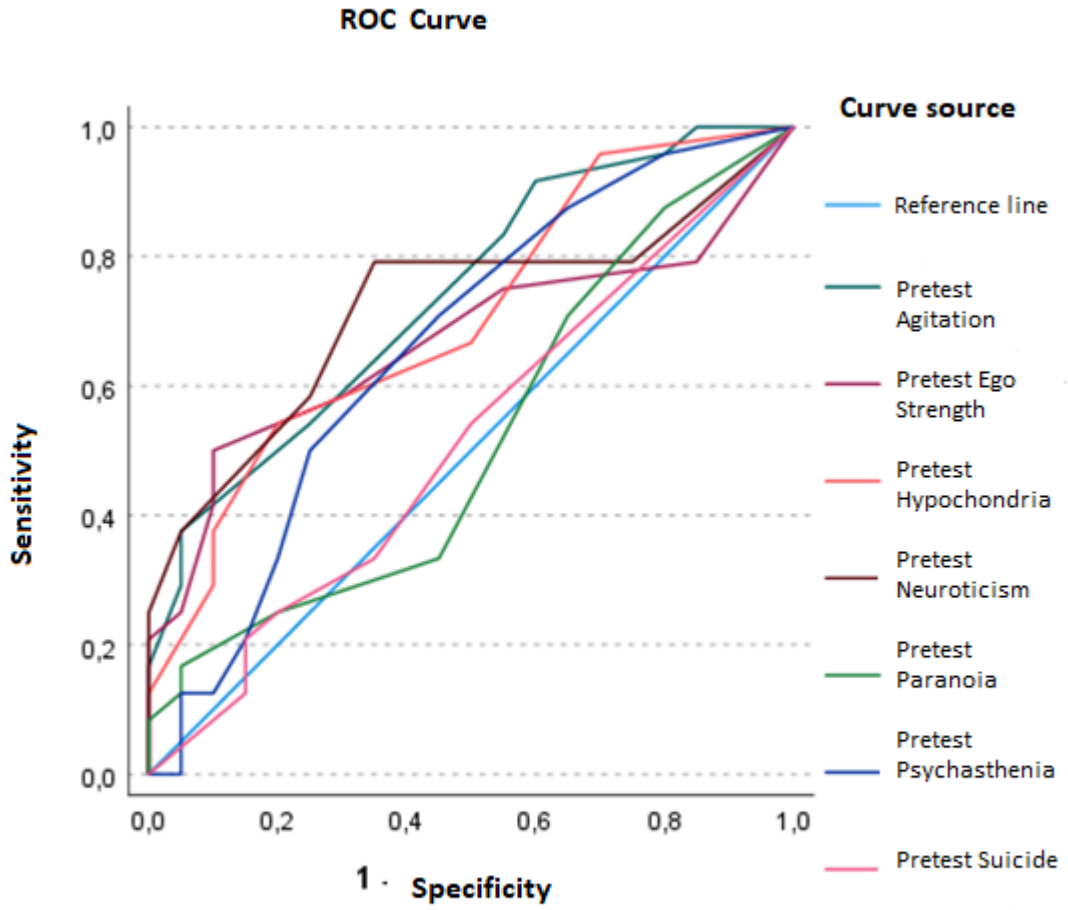
	Cut-off point	Sensitivity	1-specificity	Youden	Closest top left
5. Pre-test - Number of attempts (NI) - Practice trial	16	1	1	0	1
	17.5	0.889	1	-0.111	1.00614164
	18.5	0.815	1	-0.185	1.01696853
	19.5	0.667	0.778	-0.111	0.84627005
	20.5	0.556	0.667	-0.111	0.80126463
	21.5	**0.333**	**0.389**	**-0.056**	**0.77214636**
	22.5	**0.185**	**0.111**	**0.074**	**0.82252416**
	23.5	0.111	0.111	0	0.8959029
	24.5	0.037	0.056	-0.019	0.96462687
	25.5	0	0.056	-0.056	1.00156677
	27	0	0	0	1
5. Pre-test - Number of correct answers (NA) - Practice trial	10	1	1	0	1
	12.5	1	0.944	0.056	0.944
	14.5	0.963	0.944	0.019	0.94472483
	15.5	**0.963**	**0.889**	**0.074**	**0.88976963**
	16.5	**0.815**	**0.778**	**0.037**	**0.79969307**
	17.5	0.333	0.611	-0.278	0.90454961
	18.5	0.185	0.444	-0.259	0.92809536
	19.5	0.074	0.222	-0.148	0.95223947
	21	0.037	0.056	-0.019	0.96462687
	23	0	0	0	1
5. Pre-test - Proportion of correct answers (PA) - Practice trial	70	1	1	0	1
	71.5	1	0.944	**0.056**	0.944
	72.5	0.926	0.889	0.037	0.89207455

	74	0.889	0.889	0	0.8959029
	75.5	0.889	0.833	**0.056**	0.84036302
	76.5	0.852	0.833	0.019	0.84604551
	78	0.741	0.778	-0.037	0.81997866
	79.5	0.704	0.778	-0.074	0.83240615
	81	0.704	0.722	-0.018	0.78032045
	83	0.667	0.722	-0.055	0.79509308
	84.5	0.667	0.667	0	**0.7455052**
	85.5	0.444	0.611	-0.167	0.82610956
	87	0.407	0.5	-0.093	0.77566036
	88.5	0.37	0.5	-0.13	0.80430094
	89.5	0.222	0.333	-0.111	0.84627005
	90.5	0.148	0.167	-0.019	0.86821253
	92.5	0.111	0.167	-0.056	0.90454961
	94.5	0.037	0.167	-0.13	0.97737301
	97.5	0.037	0.056	-0.019	0.96462687
	101	0	0	0	1
5. Pre-test - Risk-taking (AR) - Practice trial	52	1	1	0	1
	54	0.963	1	-0.037	1.00068427
	55.5	0.926	0.944	-0.018	0.94689598
	57	0.889	0.889	0	0.8959029
	58.5	0.852	0.889	-0.037	0.90123526
	59.5	0.741	0.667	**0.074**	0.71552079
	60.5	0.63	0.667	-0.037	0.76275094
	61.5	0.519	0.5	0.019	0.69380184
	62.5	0.444	0.389	0.055	**0.67856982**
	63.5	0.37	0.333	0.037	0.71259315
	64.5	0.259	0.222	0.037	0.77354056
	65.5	0.222	0.222	0	0.80905377
	67	0.148	0.222	-0.074	0.88044761
	68.5	0.037	0	0.037	0.963
	70	0	0	0	1
5. Pre-test - Reaction time (TR) - Practice trial	47	1	1	0	1
	51	1	0.944	0.056	0.944
	54.5	1	0.889	0.111	0.889
	56	0.963	0.889	0.074	0.88976963
	58	0.926	0.889	0.037	0.89207455
	59.5	0.926	0.833	0.093	0.83628046

	60.5	0.926	0.722	0.204	0.72578234
	62	0.889	0.722	0.167	0.73048272
	63.5	0.815	0.667	0.148	0.69218061
	64.5	0.741	0.611	0.13	0.66362791
	66	0.667	0.5	0.167	0.60074038
	68.5	0.667	0.444	0.223	0.555
	70.5	0.63	0.333	0.297	**0.49778409**
	71.5	0.556	0.278	0.278	0.52385112
	73	0.519	0.222	0.297	0.52975938
	74.5	0.481	0.222	0.259	0.56448649
	75.5	0.481	0.167	**0.314**	0.54520638
	76.5	0.444	0.167	0.277	0.58053854
	78	0.407	0.167	0.24	0.61606655
	79.5	0.407	0.111	0.296	0.60329926
	80.5	0.37	0.111	0.259	0.63970384
	82	0.333	0.056	0.277	0.6693467
	85	0.296	0.056	0.24	0.70622376
	88	0.259	0.056	0.203	0.74311305
	90.5	0.222	0.056	0.166	0.78001282
	93.5	0.185	0.056	0.129	0.81692166
	96.5	0.148	0.056	0.092	0.85383839
	99.5	0.074	0.056	0.018	0.92769176
	101.5	0.037	0.056	-0.019	0.96462687
	114	0	0.056	-0.056	1.00156677
	127	0	0	0	1

Test 6

Figure 7. ROC curve for test 6 for the case group.



In the AUC analysis corresponding to the previous test, a moderate variation is observed in the discriminative capacity of the various personality dimensions between the case and control groups. The variables with the greatest discrimination power were Agitation (AUC = 0.740), Neuroticism (AUC = 0.721) and Hypochondriasis (AUC = 0.704), all with values indicating a satisfactory capacity to differentiate between the groups. At a slightly lower level are Power of the self (AUC = 0.669) and Psychasthenia (AUC = 0.661), which show moderate discrimination. Conversely, the variables Paranoia (AUC = 0.520) and Suicidality (AUC = 0.516) present values close to chance, reflecting a low classification capacity.

Table 12. Test 6 coordinates for sensitivity and specificity in case group.

Test outcome variables	Cut-off point	Sensitivity	1-Specificity	Youden	Closest top left
6. Pre-test - Neuroticism	-1	1	1	0	1
	0.5	0.958	0.95	0.008	0.95092797
	1.5	0.792	0.75	0.042	0.77830842
	2.5	0.792	0.35	**0.442**	**0.40714125**
	3.5	0.583	0.25	0.333	0.48619852
	4.5	0.375	0.05	0.325	0.62699681
	5.5	0.25	0	0.25	0.75
	6.5	0.125	0	0.125	0.875
	8	0.083	0	0.083	0.917
	10	0	0	0	1
6. Pre-test - Paranoia	-1	1	1	0	1
	0.5	0.875	0.8	0.075	0.80970674
	1.5	0.708	0.65	0.058	**0.71257561**
	2.5	0.333	0.45	-0.117	0.80460487
	3.5	0.25	0.2	0.05	0.77620873
	4.5	0.167	0.05	**0.117**	0.83449925
	5.5	0.125	0.05	0.075	0.87642741
	6.5	0.083	0	0.083	0.917
	8	0	0	0	1
6. Pre-test - Agitation	-1	1	1	0	1
	0.5	1	0.85	0.15	0.85
	1.5	0.958	0.8	0.158	0.80110174
	2.5	0.917	0.6	0.317	0.60571363
	3.5	0.833	0.55	0.283	0.57479475
	4.5	0.542	0.25	0.292	**0.52178923**
	5.5	0.417	0.1	0.317	0.59151416
	6.5	0.375	0.05	**0.325**	0.62699681
	7.5	0.292	0.05	0.242	0.70976334
	8.5	0.167	0	0.167	0.833
	9.5	0.125	0	0.125	0.875
	11	0	0	0	1
6. Pre-test – Power of the self	-1	1	1	0	1
	0.5	0.792	0.85	-0.058	0.87507942
	1.5	0.75	0.55	0.2	0.6041523
	2.5	0.583	0.3	0.283	0.51370128
	3.5	0.5	0.1	**0.4**	**0.50990195**
	4.5	0.417	0.1	0.317	0.59151416
	5.5	0.25	0.05	0.2	0.75166482

	6.5	0.208	0	0.208	0.792
	7.5	0.125	0	0.125	0.875
	8.5	0.042	0	0.042	0.958
	10	0	0		
6. Pre-test - Psychasthenia	-1	1	1	0	1
	0.5	0.958	0.8	0.158	0.80110174
	1.5	0.875	0.65	0.225	0.66191011
	2.5	0.708	0.45	**0.258**	**0.53643639**
	3.5	0.5	0.25	0.25	0.55901699
	4.5	0.333	0.2	0.133	0.69633972
	5.5	0.208	0.15	0.058	0.8060794
	6.5	0.125	0.1	0.025	0.88069575
	7.5	0.125	0.05	0.075	0.87642741
	8.5	0	0.05	-0.05	1.00124922
	10	0	0	0	1
6. Pre-test - Hypochondriasis	-1	1	1	0	1
	0.5	0.958	0.7	0.258	0.70125887
	1.5	0.667	0.5	0.167	0.60074038
	2.5	0.542	0.2	**0.342**	**0.49976394**
	3.5	0.375	0.1	0.275	0.63294945
	4.5	0.292	0.1	0.192	0.71502727
	5.5	0.208	0.05	0.158	0.79357671
	7	0.125	0	0.125	0.875
	8.5	0.083	0	0.083	0.917
	9.5	0.042	0	0.042	0.958
	11	0	0	0	1
6. Pre-test - Suicidality	-1	1	1	0	1
	0.5	0.542	0.5	0.042	**0.67805899**
	1.5	0.333	0.35	-0.017	0.75325228
	2.5	0.25	0.2	0.05	0.77620873
	3.5	0.208	0.15	**0.058**	0.8060794
	4.5	0.125	0.15	-0.025	0.88776405
	5.5	0.083	0.1	-0.017	0.92243645
	6.5	0.042	0.05	-0.008	0.95930391
	8	0	0	0	1

Test-reliability - retesting

Full sample

Test-retest reliability was studied after a one-month interval taking the full sample (both cases and controls) into account (Table 12).

Table 13. Test-retest reliability after a one-month interval. Spearman's R test. Full sample.

Test No.	Variable	Rho	p-value	n (Pre)	n (Post)
1	Mean response time	0.639	<0.001**	74	54
	Stimulus-response confusion	0.177	0.201	74	54
2	Mean response time	0.751	<0.001**	73	53
	Stimulus-response confusion	0.544	<0.001**	74	53
3	Mean absolute deviation	0.395	0.003**	75	54
4	Errors	0.801	<0.001**	75	54
	Error time	0.793	<0.001**	75	54
5	Number of attempts (NI)	0.183	0.186	75	54
	Number of correct answers (NA)	0.193	0.162	75	54
	Proportion of correct answers (PA)	0.243	0.077	75	54
	Risk-taking (AR)	0.080	0.565	75	54
	Reaction time (TR)	0.715	<0.001**	75	54
6	Neuroticism	0.463	<0.001**	74	54
	Paranoia	0.787	<0.001**	74	54
	Agitation	0.681	<0.001**	74	54
	Power of the self	0.693	<0.001**	74	54
	Psychasthenia	0.505	<0.001**	74	54
	Hypochondriasis	0.541	<0.001**	74	54
	Suicidality	0.689	<0.001**	74	54

*p<0.05. **p<0.001.

Spearman correlation analyses between pre- and post-scores (one month apart) show moderate to high stability in most of the medical fitness tests performed. In the reaction time tasks (Tests 1 and 2), the coefficients were high (Rho = 0.639 and Rho = 0.751; $p < 0.001$), indicating good consistency in the response time of the participants, while stimulus-response confusion only showed a significant relationship in Test 2 (Rho = 0.544; $p < 0.001$). Attentional accuracy (Test 3) showed a moderate correlation (Rho = 0.395; $p = 0.003$) and performance measures in recognition (Test 4) showed high stability (Rho = 0.801 and Rho =

0.793; p < 0.001). By contrast, the variables of the decision-making task (Test 5) showed low and non-significant correlations in most indicators, except for reaction time, which showed high consistency (Rho = 0.715; p < 0.001), suggesting greater stability in speed processes than in strategy or risk processes. Lastly, the personality dimensions assessed (Test 6) showed significant correlations in all cases, with values ranging from Rho = 0.463 to Rho = 0.787 (p < 0.001), indicating good temporal reliability for the emotional and personality characteristics measured.

Sample by group

An intra-group analysis - considering solely the controls and, separately, only the cases - was performed to study test-retest reliability after a one-month interval (Table 13)

Table 14. Test-retest reliability after a one-month interval. Spearman's R test. Sample by group.

Test no.	Variable	Cases				Controls			
		Rho	p	n pre	n post	Rho	p	n pre	n post
1	Mean response time	0.702	<0.001**	44	24	0.553	0.002**	30	30
	Stimulus-response confusion	0.048	0.825	44	24	0.231	0.22	30	30
2	Multiple reaction test	0.782	<0.001**	45	24	0.667	<0.001**	29	30
	Multiple reaction test	0.434	0.034*	45	24	0.576	0.001**	29	30
3	Speed of anticipation	0.503	0.012*	45	24	0.302	0.105	30	30
4	Errors	0.87	<0.001**	45	24	0.773	<0.001**	30	30
	Error time	0.919	<0.001**	45	24	0.684	<0.001**	30	30
5	Number of attempts (NI)	0.088	0.682	45	24	0.301	0.106	30	30
	Number of correct answers (NA)	0.188	0.38	45	24	0.216	0.252	30	30
	Proportion of correct answers (PA)	0.133	0.537	45	24	0.326	0.079	30	30
	Risk-taking (AR)	-0.097	0.65	45	24	0.241	0.199	30	30
	Reaction time (TR)	0.706	<0.001**	45	24	0.715	<0.001**	30	30
6	Neuroticism	0.59	0.002**	44	24	0.283	0.129	30	30
	Paranoia	0.745	<0.001**	44	24	0.605	<0.001**	30	30
	Agitation	0.601	0.002**	44	24	0.604	<0.001**	30	30
	Power of the self	0.602	<0.001**	44	24	0.442	0.014*	30	30
	Psychasthenia	0.519	0.009**	44	24	0.389	0.034*	30	30
	Hypochondriasis	0.566	0.004**	44	24	0.412	0.024*	30	30
	Suicidality	0.709	<0.001**	44	24	0.422	0.02*	30	30

The temporal reliability results differentiated by group show that, in general, both substance users (Cases) and participants with no substance use (Controls) present significant correlations in most of the tests, albeit with some differences in magnitude and significance.

In the response and reaction time tasks, the cases showed higher correlations than the controls, especially in mean response time (Rho = 0.702 vs 0.553) and in reaction time (Rho = 0.706 vs 0.715, both groups significant $p < 0.001$). Stimulus-response confusion did not show stability in the cases (Rho = 0.048, $p = 0.825$) and was also low in controls (Rho = 0.231, $p = 0.22$).

In multiple reaction tasks, the cases showed moderate to high correlations (Rho = 0.782 and 0.434), while the controls showed consistent and significant values (Rho = 0.667 and 0.576, $p < 0.01$), demonstrating good temporal reliability. Anticipatory speed showed a significant correlation in the cases (Rho = 0.503, $p = 0.012$) and a non-significant correlation in the controls (Rho = 0.302, $p = 0.105$).

As regards the error and error time measures, both groups showed very high correlations, highlighting the stability of these measures over time (cases: Rho = 0.87–0.919; controls: Rho = 0.684–0.773; $p <0.001$).

The number of attempts, correct answers, proportion of correct answers and risk-taking tasks showed low temporal consistency in both groups, except for reaction time, which maintained high and significant correlations (cases Rho = 0.706, controls Rho = 0.715, $p < 0.001$).

With respect to personality traits and psychopathological factors, the cases showed higher and more consistent correlations than the controls in neuroticism, paranoia, agitation, power of the self, psychasthenia, hypochondriasis and suicidality (Rho between 0.519 and 0.745, $p < 0.01$). The controls also showed significant correlations in all traits, but not in neuroticism (Rho = 0.283, $p = 0.129$).

Neuro-psychological profile using LNDeter tests

Test 1. For mean response time, no significant differences are observed between cases and controls ($U = 596.5$; $p = 0.484$), although the cases show a slightly higher mean (67.14 hundredths of a second versus 64.28 hundredths of a second), indicating a somewhat slower, but not statistically relevant, response pattern. With regard to stimulus-response confusion, the difference is marginally significant ($U = 514.5$; $p = 0.056$), with the cases presenting more confusion (mean 1.43 vs 0.28), suggesting a tendency towards greater difficulty in stimulus discrimination.

2. Multiple reaction test: The mean response time shows no significant differences between groups (U = 568.5; p = 0.352), although the cases present higher mean values (137.8 hundredths of a second versus 106.45 hundredths of a second), with high dispersion. However, errors in response to stimuli do show a significant difference (U = 439.5; p = 0.016), with the cases in question being more prone to errors (mean 3.16 versus 1.48), indicating a deficit in selective attention or impulse control during the task.

3. Anticipation speed test: No significant differences were observed between cases and controls (U = 621.5; p = 0.563), with relatively similar means (30.7% versus 28.93%), although both groups showed high variability, suggesting that the ability to anticipate is not significantly impaired in the cases.

4. Bimanual coordination test: None of the variables show significant differences (Errors: U = 594.5, p = 0.384; Error time: U = 627.0, p = 0.604). The cases tend to show slightly more errors and longer error time, but the differences are small and not statistically relevant, indicating that overall performance on the test is comparable between groups.

5. Decision test (NI, NA, PA, AR, TR): None of these variables show significant differences between cases and controls (p-values between 0.156 and 0.947). It is observed that the cases show slightly higher means in number of attempts and reaction time, and a very similar pattern in number and proportion of correct answers and risk-taking, indicating that the measures of effectiveness and strategy in the task do not differ significantly between groups.

6. Personality test (Neuroticism, Paranoia, Agitation, Power of the self, Psychasthenia, Hypochondriasis, Suicidality): All variables show significant and consistent differences between cases and controls ($p < 0.01$ in all cases). The cases show higher scores in neuroticism, paranoia, agitation, psychasthenia, hypochondriasis and suicidality, and lower scores in power of the self, reflecting a pattern of clearly greater psychological vulnerability in the cases compared to the controls.

Neuro-psychological profile based on dependence or abuse of various substances

When comparing individuals diagnosed with abuse or dependence on each of the main substances under study (alcohol, cocaine and cannabis), both currently and over their lifetime, the following results were obtained.

Table 15. Neuro-psychological profile by subtest according to diagnosis of alcohol, cocaine or cannabis abuse or dependence.

Test No.	Test measure	Alcohol		Cocaine		Cannabis	
		U	p-value	U	p-value	U	p-value
1	Mean response time	735	0.492	676	0.965	667	0.715
	Stimulus-response confusion	770.5	0.200	748.5	0.375	717.5	0.266
2	Mean response time	701	0.790	637	0.622	637	0.938
	Stimulus-response confusion	745.5	0.443	813	0.149	694.5	0.565
3	Mean absolute deviation	683	0.915	820.5	0.200	641	0.852
4	Errors	731.5	0.681	592	0.251	538.5	0.190
	Error time	695.5	0.979	592	0.251	512.5	0.111
5	Number of attempts (NI)	666	0.769	742	0.650	630.5	0.759
	Number of correct answers (NA)	809.5	0.198	814.5	0.208	825	0.058
	Proportion of correct answers (PA)	814.5	0.193	678.5	0.819	786	0.159
	Risk-taking (AR)	610	0.374	702	0.983	538.5	0.189
	Reaction time (TR)	615	0.405	482.5	0.021*	612	0.614
6	Neuroticism	814	0.115	883.5	0.025*	711	0.382
	Paranoia	914	0.007**	1009	<0.001**	777	0.101
	Agitation	822	0.096	831.5	0.095	810.5	0.044*
	Power of the self	934.5	0.003**	1064	<0.001**	773.5	0.106
	Psychasthenia	816	0.111	916.5	0.009**	735	0.253
	Hypochondriasis	888.5	0.015*	1010	<0.001**	716.5	0.342
	Suicidality	797	0.113	930	0.002**	703	0.371

*p<0.05. **p<0.001.

Conclusions

The collection of patient data proved to be more extensive and complex than anticipated. The control group underwent the initial and final assessments without any unforeseen issues. In contrast, patients with substance use disorder had a high experimental mortality rate due to idiosyncrasy, despite the reward for completing the assessment, which is consistent with other research, (Roncero et al., 2025). However, the role of the reward did not result in a clear change in assessment attendance patterns, as attendance at assessments tends to be more a matter of ability than of attitude.

The variation in the associated medical conditions among these cases may be due to the fact that these individuals are in an advanced state of decline characterised by substance dependence or abuse, which has significant implications for their health.

As regards the socio-economic profile of the cases, they present greater financial instability, with a lower educational attainment level, lower income level, the existence of illegal sources of income or greater debts. Given the rise in health problems and the deterioration in financial security, the differences between the groups are becoming apparent, with the group in question standing out as the most socially vulnerable.

The cases have more driving-related jobs: test drivers, delivery drivers, lorry drivers. They also exhibit more extreme driving behaviour and a higher risk of accidents, with greater diversity in vehicle use, a higher incidence of serious offences and more penalty points or licence suspension. The controls present a more homogeneous and safer pattern, with minor infringements and fewer serious consequences Although there is no difference between the groups in terms of the amount of driving or minor fines, there are significant differences when it comes to more serious offences and penalties. This suggests that the case group has a driving profile that involves greater exposure to legal and road safety risks compared with the control group.

Accidents in the case group tend to have a greater impact on the physical and mental well-being of those involved, but this does not necessarily translate into differences in the practical or occupational consequences of the accidents.

Regarding the aggressive driving test. The cases tend to behave as aggressors more frequently than the controls, and are also victims of threats more often, while incidents of direct physical aggression are rare and show no significant differences between groups.

DAX anger expression. The cases show a greater tendency to manifest anger in a physical and displaced way, suggesting less emotional regulation and greater impulsivity in driving situations. By contrast, the control group stands out for greater adaptive expression and better anger management, reflecting more effective coping strategies. Although not all the differences reach statistical significance, the general pattern points to a greater emotional and behavioural risk associated with anger in driving contexts within the case group.

L-LOC test. The cases tend to attribute greater risk to the behaviour of other drivers, while the controls perceive the risks associated with the vehicle and the environment more intensely. No significant differences were found in the perception of personal risks or those associated with the destination. Taken as a whole, this suggests that attribution of responsibility for risks in driving contexts varies by group, notably with a more external pattern in the cases and a more environment-focused one in the controls. Drivers who attribute risks to external factors may be less likely to modify their own behaviour as they believe that accidents are determined by others or the environment. This can influence their motivation to change behaviours as they do not see themselves as primarily responsible for driving risks. Finding no differences in the "self" factor suggests that both groups perceive themselves similarly as regards their own responsibility or personal influence on risks. The lack of differences in the "destination" factor indicates that beliefs about luck or fatalism do not differentiate the groups in terms of risk attribution.

Case group grading scales were provided for each of the LNDeter battery tests and optimal cut-off points were reported for the SUD population.

Reliability of LNDeter tests. With regard to the full sample. The results show good temporal stability in most of the tests, suggesting that the measurements are reliable and consistent over time. The strongest correlations were observed in reaction time, recognition and personality trait tasks, while tests related to decision-making showed less consistency, possibly due to the influence of situational or motivational factors. Overall, and for the full sample, the findings support the temporal validity of the set of medical fitness tests used in the study.

With regard to the sample differentiated by group (cases and controls). Firstly, tests of response speed, reaction time and errors show a high degree of consistency between measurements taken one month apart, in both substance users and control subjects, suggesting that these measures are stable and reliable for assessing basic cognitive function. In contrast, tasks related to selective attention and decision-making—such as confusion in response to stimuli, number of attempts, accuracy rates, or risk-taking—show lower reliability, particularly in the group of consumers, suggesting that these skills may be more variable or sensitive to external factors. Secondly, the personality traits and psychopathological factors assessed, such as neuroticism, paranoia, agitation, power of the self, psychasthenia, hypochondriasis and suicidal tendencies, generally show higher temporal correlations in the user group than in the controls, which could reflect greater stability of these traits in this population or greater consistency in the response to the tests.

These findings support the validity of the psychometric tests used to measure cognitive functions and personality traits, although they indicate that some measures of attention and risk are less stable and should be interpreted with caution. In addition, the results suggest subtle differences in the temporal consistency of the measures between users and non-users, implying that substance users exhibit higher and more significant correlations between pre- and post-measures, especially in variables related to emotional control, impulsivity and certain psychopathological traits, indicating that these factors have greater temporal stability. By contrast, the controls show less consistency in some cognitive and attention tests, suggesting that these skills may fluctuate more in the absence of substance use. The significance of these differences makes it possible to identify which measures are most reliable for assessing

changes over time, guiding specific interventions, and gaining a better understanding of how substance use may be linked to persistent personality traits and executive function, and consequently how these should be measured.

Neuro-psychological profile

In In general terms, and when considering the case group, performance on psychometric tests shows no significant differences in the basic measures of attention and processing speed (mean reaction time, errors, absolute deviations) when comparing substance users with the control group. However, relevant differences are observed in personality variables and psychological functioning. For example, cocaine users score higher in neuroticism, paranoia, power of the self, psychasthenia, hypochondriasis and suicidality, indicating a more vulnerable and symptomatic profile. In the case of alcohol, significant differences are detected in paranoia, power of the self and hypochondriasis, while in cannabis users a significant difference is only observed in agitation ($p < 0.05$). These differences suggest that substance use, particularly cocaine and alcohol, is associated with a more pronounced personality profile and psychological vulnerability, whilst the basic cognitive functions assessed by the psychometric subtests appear to be relatively well preserved.

Reliability and validity of the tests

Areas under the ROC curve. Analysis of the areas under the ROC curve suggests that some psychological tests are effective at distinguishing between individuals who do and do not use substances, particularly in tests of agitation, neuroticism and mean reaction time. The tests tend to be more sensitive and consistent in the user group, indicating that the effects of substance use are more clearly reflected in these measures. In addition, the decision-making or paranoia tests show better performance in controls, indicating that some variables can also provide useful information in populations without substance use.

At the time of writing this report, there are regulations in force that inconsistently require compliance with their various provisions, thereby creating legal uncertainty (Armando González Sánchez et al., 2023). Specifically, Royal Decree 170/2010 of 19 February, which approves the Regulations on medical

examination centres responsible for assessing the physical and mental fitness of drivers (Royal Decree 170/2010, 2010), sets out a model medical history form in Annex III; whilst Article 6.3 of the same Royal Decree advocates following the medical-psychological examination protocol, which sets out a different medical history form. Given that institutions currently only suggest, rather than mandate, the use of one medical history form or another, and given the possibility of using either of the two interchangeably, private companies, faced with this dilemma and seeking to safeguard their continuity and economic interests, are faced with the choice of conducting more accurate assessments with a better protocol or faster and cheaper ones. These companies tend to adopt the shortest, most economical and least time-consuming medical history form. This problem reinforces the stagnation of the medical and psychological professions, worsens their working conditions, whilst also resulting in a poorer service to society and, consequently, a poorer perception of this type of service by society.

Another possible cause may be the lack of clarity regarding the mandatory nature of testing at medical examination centres, as some researchers state that four tests should be carried out using the polygraph (de Las Cuevas Castresana & Sanz Alvarez, 2009), whilst the ABEPSICO project states that three should be carried out (Alonso et al., 2012) or other researchers state that all four are required (Álava et al., 2011); although Royal Decree 170/2010 (2010) contains no indication regarding their mandatory nature, there is inconsistency across the different versions of the protocol, as the 2007 edition (Jubal et al., 2007) within the same document there are inconsistent indications regarding its mandatory nature (page 38 vs. page 110), alternatively stating that the multiple reaction time test is not indicated in all cases; or in the 2022 version (Mirabet et al., 2022) (p. 35) where it is stated that “Drivers in both licence groups 1 and 2 must undergo the same basic examination” of reaction time and bimanual visomotor coordination, adding the Multiple Reaction Time test for group 2 and a screening test for Mild Cognitive Impairment for those over 70 years of age. However, given the lax approach to both training and monitoring of correct implementation, in reality and generally speaking, these tests are not usually carried out at licence renewal centres (Álava et al., 2011; González-Sánchez, 2025).

Most medical examination centres use payment processing software, as the additional features it offers are superior to those of the software provided by the DGT (González-Sánchez, 2021a). Among these features is the ability to save the photograph. This makes it possible to carry out the examination without the patient being physically present. Whilst this feature offers flexibility, it compromises compliance with the regulations.

One explanation could be that, given that 73.8% of psychology professionals working in CR soften their assessments due to pressure or outside influences (González-Sánchez, 2025), notably the reputation the centre might acquire for being very restrictive and/or the employer or payer.

Another possibility lies in the difficulty of interpreting the scales; indeed, in a survey of psychologists in CR (González-Sánchez, 2025), over 50% reported having severe difficulties when interpreting the scales. This in turn may be influenced by one of the following reasons or a combination of them: the results from a multiple reaction time testing device may be corrected using the scales for a different brand (González-Sánchez, 2025); the scales may be in reverse order in some of the tests (Armando González Sánchez et al., 2023), causing them to be rounded off incorrectly; the centre may be applying outdated scales (González-Sánchez, 2025), even though the discrepancies in them have been brought to light, or unvalidated scales that are currently used through processing software. In these circumstances, a score of 67 on the Discriminative Multiple Reactions test for the LN Deter polygraph corresponds to a reaction time in hundredths of a second that falls within the 99th percentile according to the scale provided by the ABEPSICO project (Alonso et al., 2012) and the 20th percentile according to the manual's scoring system, which is followed by 71.7% of the psychology professionals surveyed (González-Sánchez, 2025).

Limitations

The sample size and representativeness were small (78 subjects, with 48 cases and 30 controls), which limits the statistical power and the possibility of generalising the findings to the entire population of drivers with SUD in Spain. In addition, the selection of the cases at specific centres in Valladolid may have

introduced geographical and socio-economic biases. Data collection also posed a challenge, particularly among the participants, who had a high dropout rate despite the incentive offered. Added to this is the presence of comorbidities and adverse socio-economic conditions, which may have affected comparability between the groups. Moreover, the distinctive characteristics of the population with SUD, such as the high proportion of professional drivers, may limit the generalisability of the results.

Recommendations

In only one of the 48 cases was the restriction on drinking and driving (restriction 68) identified, which would suggest shortcomings in detection at the CRs.

The personality test included in the LNDeter battery is based on DSM-II criteria, including terms such as psychasthenia, which is no longer used under current criteria and whose use has been discouraged since 1980 (the year the DSM-III was published). It is recommended that the guidelines advising its use be updated.

Given that there are clear differences between people with substance use disorders and those without and given that the former group constitutes a sufficiently large proportion of the Spanish population, it is considered that this population and its characteristics should be studied specifically.

In addition, the population with SUD has specific attributes such as the fact that a large proportion work as professional drivers, underscoring the need to study them in greater depth.

Although there are updated and norm-referenced scales based on sex, age or essential variables in this field such as the specific vehicle group, there is a need to apply these scales to clinical practice by implementing them as part of care work and not relegating them to unused files.

The following initiatives are proposed as improvements: Quality inspections. Inspections are currently performed to check that medical professionals are present, but the tests that are applied, who applies them and how they are applied are overlooked. There are autonomous regions where it is mandatory to identify

the medical professional, but this does not prevent professionals from performing assessments outside their scope of practice (intrusiveness or unethical practice) or evaluations of insufficient quality. With proper inspections, whether carried out by the relevant authorities or by subcontractors, malpractice will be minimised.

Modifying legislation to ensure that all professionals involved in the process are appropriately trained and supervised by professional association divisions or branches, for example, in psychology, the Traffic and Safety Division of the General Council of Psychology.

Finally, it may be advisable to standardise the number of tests, setting a minimum number to be administered, so that patients are adequately assessed prior to psychometric testing.

It is worth highlighting the following points in this paper:

1. Higher risk driving profile in the cases. Drivers in the case group exhibit more extreme and dangerous behaviour, with greater diversity in vehicle use, serious offences and severe sanctions. In contrast, the controls present a more homogeneous and safer pattern.

2. Physical and psychological impact of accidents. Although accidents have a greater impact on the physical and mental integrity of the cases, no significant differences were observed in work-related or practical consequences between the groups.

3. Higher level of aggression in the cases. The cases tend to act as aggressors more frequently and are also victims of threats more often. However, incidents of direct physical aggression are rare, with a similar frequency for both cases and controls.

4. Anger expression and emotional regulation. The cases show a greater tendency to express anger in a physical and displaced way, indicating less emotional regulation. The controls, however, use more adaptive and effective strategies to manage anger.

5. Attribution of risks in driving contexts. The cases attribute risks primarily to other drivers, while the controls perceive them more in the environment and the vehicle. This difference can influence their motivation to change risk behaviours.

6. Reliability of the medical fitness tests. The response speed and reaction time tests are highly consistent and reliable. Attention and decision-making tasks show lower reliability, especially in substance users.

7. Stability of personality traits in substance users. Psychopathological traits such as neuroticism, paranoia and agitation are more stable in the cases, suggesting greater consistency in their psychological profile. This is especially evident in substance users.

8. Differences according to the type of substance consumed. Cocaine users exhibit a more vulnerable psychological profile, with higher scores in several negative traits. Alcohol also demonstrates an impact, while cannabis is primarily associated with agitation.

9. Discriminatory capacity of the tests. Some medical fitness tests, such as those relating to personality, agitation and neuroticism, discriminate well between substance users and non-users. Decision-making tests work better in controls and provide value in both groups.

10. Lower overall cognitive functioning in the cases. These cases show greater cognitive impairment, which supports the idea that substance use leads to a more impaired neuropsychological profile.

References

Álava, C., Huerta, I., & Noval, M. (2011). Revisión bibliográfica exploratoria sobre los criterios de aptitud en conductores profesionales con enfermedad psiquiátrica. *Medicina y Seguridad Del Trabajo*, *57*(222), 41–62.

Alonso, F., Tortosa, G., Esteban, C., Calatayud, C., Ozcoidi, M., Sanchis, M. V., & Asencio, F. (2012). *ABEPSICO: actualización de los baremos de la evaluación de variables psicomotoras reguladas en el Anexo IV del Reglamento General de Conductores*. https://www.dgt.es/Galerias/la-dgt/centro-de-documentacion/estudios-e-informes/2012/0100dgt21353_ABEPSICO_INFORME_PARA_WEB.pdf

Armesto, D. (2011). Pruebas diagnósticas: curvas ROC. *Rev Electron Biomed / Electron J Biomed*, *1*, 77–82.

Biecheler, M.-B., Peytavin, J.-F., the SAM Group, Facy, F., & Martineau, H. (2008). SAM Survey on "Drugs and Fatal Accidents": Search of Substances Consumed and Comparison between Drivers Involved under the Influence of Alcohol or Cannabis. *Traffic Injury Prevention*, *9*(1), 11–21. https://doi.org/10.1080/15389580701737561

de Las Cuevas Castresana, C., & Sanz Alvarez, E. (2009). Mental illness and road safety. *Actas Espanolas de Psiquiatria*, *37*(2), 75–81. http://www.ncbi.nlm.nih.gov/pubmed/19401855

del Valle Benavides, A. R. (2017). *Curvas ROC (Receiver-Operating-Characteristic) y sus aplicaciones*. Universidad de Sevilla.

Elvik, R. (2013). Risk of road accident associated with the use of drugs: A systematic review and meta-analysis of evidence from epidemiological studies. *Accident Analysis & Prevention*, *60*, 254–267. https://doi.org/10.1016/j.aap.2012.06.017

González-Sánchez, A. (2021a). Encuesta sobre psicólogos en Centros de Reconocimiento de Conductores. Edición 2020. In *Prolepsis*. Colegio Oficial de Psicología de Castilla y León. https://www.copcyl.es/wp-content/uploads/2021/01/Resultados-encuesta-CRC-1.pdf

González-Sánchez, A. (2021b). *Manual de los Centros de Reconocimiento de Conductores de España. Enfocado a los Psicólogos.* (2nd ed.). Bubok.

González Sánchez A, Roncero, C., Álvarez, A., M.A., G. de P., Remón-Gallo, D., Vicente-Hernández, B., López-Alfayate, M., Aguilar, L., & Pérez-Madruga, A. (2023). La obligatoriedad e interpretación de las pruebas psicométricas en el nuevo protocolo. *I Congreso Nacional de Profesionales En Centros de Reconocimiento de Conductores*.

González-Sánchez, A. (2025). *Encuesta sobre psicólogos en Centros de Reconocimiento de Conductores. Edición 2021. [Under preparation]*.

Hanley, J. A., & McNeil, B. J. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology*, *143*(1), 29–36. https://doi.org/10.1148/radiology.143.1.7063747

Jubal, J. S., Luque, J. C. G., & González, F. J. Á. (2007). Protocolo de exploración médico-psicológica para centros de reconocimiento de conductores. Guía para la historia clínica. In *Ministerio de Sanidad y Consumo*.

Mirabet, E., Ozcoidi, M., Sanz, R., Patricia, P., Valdés, E., Gil, S., & Justo, S. (2022). *Protocolo de exploración médico-psicológica para Centros de Reconocimiento de Conductores. Actualización 2022.* (E. Valdés Rodríguez, S. Justo Gil, & S. G. Tarragato, Eds.; 3ª Edición). Ministerio del Interior & Ministerio de Sanidad. https://www.sanidad.gob.es/en/profesionales/saludPublica/prevPromocion/Prevencion/SeguridadVial/docs/Centros_reconocimiento_conductores.pdf

Observatorio Español de las Drogas las Adicciones. (2024). *Encuesta sobre alcohol y otras drogas en España (EDADES)*. Delegación del Gobierno para el Plan Nacional sobre Drogas (DGPNSD). https://pnsd.sanidad.gob.es/profesionales/sistemasInformacion/sistemaInformacion/pdf/2024_Informe_EDADES.pdf

Observatorio Nacional de Seguridad Vial. (2023). *Avance de las cifras de siniestralidad vial 2022*.

Real Decreto 170/2010, Pub. L. No. 54, Boletín Oficial del Estado [Official state gazette] 20695 (2010). https://www.boe.es/eli/es/rd/2010/02/19/170

Roncero C, Álvarez FJ, Barral C, Gómez-Baeza S, Gonzalvo B, Rodríguez-Cintas L, Brugal MT, Jacas C, Romaguera A, Casas M (2013), PROTEUS study investigators. Driving and legal status of Spanish opioid-dependent patients. Subst Abuse Treat Prev Policy. Jun 3;8:19. https://doi.org/10.1186/1747-597X-8-19

Roncero, C., Remón-Gallo, D., García-Ullán, Ll., Vicente-Hernández, B., Buch-Vicente, B., Palma-Álvarez, R. F., Grau-López, L., González-Bolaños, K. R., Álvarez-Navares, A., Pérez, J., & Aguilar, L. (2025). Gender differences in ADHD and impulsivity among alcohol or alcohol and cocaine-dependent

patients. *Frontiers in Psychiatry*, *16*. https://doi.org/10.3389/fpsyt.2025.1446970

Shipp, M. D. (1998). Potential Human and Economic Cost-Savings Attributable to Vision Testing Policies for Driver License Renewal, 1989???1991. *Optometry and Vision Science*, *75*(2), 103–118. https://doi.org/10.1097/00006324-199802000-00014

Wilson, F. A., Stimpson, J. P., & Pagán, J. A. (2014). Fatal Crashes from Drivers Testing Positive for Drugs in the U.S., 1993–2010. *Public Health Reports*, *129*(4), 342–350. https://doi.org/10.1177/003335491412900409

Youden, W. J. (1950). Index for rating diagnostic tests. *Cancer*, *3*(1), 32–35. https://doi.org/10.1002/1097-0142(1950)3:1<32::AID-CNCR2820030106>3.0.CO;2-3