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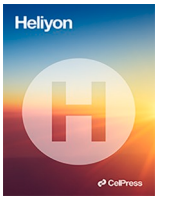

Research article

Driving impairment due to psychoactive substances and attention deficit disorder: A pilot study

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ABSTRACT

Objective: Attention disorder and substance use disorder are linked to driving impairment and increased road crash involvement. This study explores attention deficits in a population of drivers found driving under the influence (DUI) of psychoactive substances.

Methods: A case-control study was conducted comparing subjects with a previous DUI episode (cases) to subjects who were negative for DUI offenses (controls). Personal, socio-demographic, and DUI data were collected for both groups. All subjects were administered the Continuous Performance Test–third edition (CPT-3), which measures dimensions of attention, including inattentiveness, impulsivity, sustained attention, and vigilance. Possible associations with a previous DUI episode, the use of illicit substances or excessive alcohol use, and road crash involvement were analyzed statistically.

Results: Overall, the study included 147 subjects (100 cases, 47 controls). The parameter distributions of detectability, probability of ADHD, and inattentiveness indicated statistical differences between the two groups. No attention deficits predicted substance use disorder or excessive alcohol consumption. Inattentiveness was an independent risk factor for previous road collision involvement.

Conclusions: The results suggest that alterations exist in some attention dimensions in a population of DUI subjects who were users of alcohol or other psychoactive substances and involved in road traffic crashes. The CPT-3 had successfully distinguished between the two study groups, and after validation, it could be useful in the process of reinstating a driver's license. Future research should expand the study sample to better understand the relevance of the proposed methodological approach in terms of prevention, rehabilitation, and the monitoring of subjects evaluated for driving eligibility requirements.

1. Introduction

Driving under the influence (DUI) of psychoactive substances, whether legal or illegal, is a risk factor for public safety and is associated with morbidity and mortality [1]. In 2020, crashes involving subjects found driving under the influence of alcohol claimed the lives of 11,654 individuals, and every day in the United States, crashes involving intoxicated drivers result in the deaths of 32

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people on average [2].

In 2018, alcohol-impaired driving was responsible for 25 % of all road fatalities in the European Union [3]. In Italy during 2019, 4 % of total traffic crashes were caused by an alcohol-impaired driver, while 1.4 % were associated with drug-related DUI offenses [4]. Alcohol consumption, both acute and chronic, causes impairments in driving ability due to alterations in cognitive function, executive function, motor coordination, or visual function [5]. The clinical manifestations of acute intoxication are mainly correlated with blood alcohol concentration but also with individual tolerance and age [6].

The use of psychoactive substances other than alcohol is important from an epidemiological point of view and certainly affects driving ability. However, the existing literature on multiple substances, differences in pharmacodynamics and pharmacokinetics, and frequent polydrug use does not provide accurate epidemiological data on the relationship between psychoactive substance use and road collisions [7,8].

In addition to the use of psychoactive substances, another factor possibly affecting the risk of road crashes is attention deficit hyperactivity disorder (ADHD). The essential features of ADHD are a persistent pattern of attention deficit, hyperactivity, and/or impulsivity that interferes with functioning [9]. The prevalence of ADHD in the adult population is estimated to be 2.5 % [10]. According to DSM-5 [11], inattention manifests itself on the behavioral level, with avoidance of and lack of persistence in a task, difficulty in organizing tasks and activities, and distraction by extraneous stimuli [11]. Hyperactivity includes excessive agitation or excessive talkativeness; impulsivity refers to sudden actions that occur in moments that may harm individuals, as well as impulsive decision-making [11].

Drivers with ADHD are involved in traffic crashes and traffic violations more frequently than average [12–14] and experience higher rates of mortality [15,16]. Analysis of risk factors for road collisions suggests that individuals with ADHD are less likely, over time, to maintain attention to cues relevant to driving [17]. Higher rates of distraction, stress, and overconfidence have been described as factors increasing the prevalence of ADHD in accident victims [18].

Comorbid disorders, including substance use disorder (SUD), are also frequently described in individuals with ADHD [15,19]. In their meta-analysis, Rohner et al. incorporated data from 31 studies and determined that the prevalence of ADHD among individuals with SUD was estimated at 21 % [20]. In line with this, adolescents with SUD have a higher risk of being affected by ADHD [21]; indeed, a prevalence of 23–40 % of ADHD in subjects affected by SUD and seeking treatment has been previously observed [22,23].

Even if the reasons for the association between SUD and ADHD remain unclear, the latter comorbidity could increase the risk of road accident involvement [18]. The hazardous driving behaviors observed in motorcyclists with an association between alcohol or narcotics intake and ADHD scores support the hypothesis of an increased risk when ADHD and SUD are both present [24]. Alcohol-related crashes reported among young drivers with ADHD are consistent with the tendency of ADHD individuals to engage in risk-taking behaviors, including substance abuse, traffic violations, and risky sexual behaviors [25,26].

To contribute to the analysis of the relationship between SUD, ADHD, and driving impairment, it could be of interest to analyze these factors jointly in a population considered as at-risk drivers. The study of such a population could help clarify the following hypotheses: 1) individuals driving under the influence of alcohol and/or other psychoactive substances may exhibit alterations in some dimensions of attention due to the comorbidity of SUD and ADHD, and 2) in road crashes involving individuals under the influence of alcohol or drugs, the presence of attention impairments could play an additive or multiplicative role.

Based on the premises described above, the first purpose of the study was to investigate the presence of alterations in attention dimensions in a population of subjects with a previous DUI who were being examined for driver's license reinstatement. Second, the study aimed to explore alterations in attention dimensions related to excessive alcohol consumption and/or the use of an illicit substance in our population. The third aim was to analyze potential alterations in attention dimensions associated with road crashes involving individuals with a history of DUI.

Any identification of attentional alterations in our population could be useful in clinical and medicolegal settings for preventive, therapeutic, and rehabilitative purposes.

2. Materials and methods

2.1. Population studied

The study was structured as a case-control study performed on subjects with a previous DUI episode (cases, Group 1) compared with subjects with a negative history of DUI episodes (controls, Group 2). DUI of alcohol and DUI of psychoactive substances other than alcohol, according to Italian legislation, are respectively demonstrated when the subject is found driving with a blood alcohol concentration above 0.5 g/L or a positive blood test for illicit psychoactive substances.

Inclusion criteria for all participants were informed consent to participate in the study and being between 18 and 65 years old. All participants provided written informed consent and volunteered to participate, without any form of financial compensation. For Group 1 cases, a previous DUI episode according to Italian legislation was also required; all cases had been previously convicted for being found driving under the influence of alcohol and/or psychoactive substances during a routine stop check or after a road traffic collision. For members of the control group, the absence of DUI episodes or road crash involvement was requisite; the absence of DUI episodes or road crash involvement in the control group was assessed by a physician collecting the history of the subjects. Exclusion criteria were refusal to participate in the study, a diagnosis of substance use disorder (SUD), psychiatric or neurological disorders, visual impairment, sleep disorders, or psychopharmacological treatment. The exclusion criteria encompassed factors similar to SUD that unequivocally could impact performance on the Continuous Performance Test, third edition (CPT-3), due to the well-established relationship between SUD and attention disorders [27]. Subjects were recruited during the period 09/2022–02/2023. Cases were

enrolled at the Complex Unit of Legal Medicine and Toxicology, University Hospital of Padua, during procedures for driver's license reinstatement after a DUI episode. According to Italian law, drivers must undergo evaluation at a specialized facility after a DUI episode to determine if they have a SUD or use an illicit substance. The DUI episode could have occurred at any point in the past, although the majority of cases involved individuals who had a DUI episode within the last year. The mandatory examination typically occurs within six months following the DUI episode.

Controls were recruited from the general population at a general practitioner's office and matched by gender and age with cases to enable exploration of potential differences in the other variables collected. In some instances, after presenting the project, some subjects in the case and the control groups declined to participate in the study. This data, a possible source of bias, was considered in the limitations of the study.

The study (code 5543/AO/22, ID study 21052) was approved on September 8, 2022 by the Ethics Committee for Clinical Experimentation of the Province of Padua.

2.2. Methodological assessment protocol

The study involved the following phases.

(1) Informed consent collection.
(2) Collection of personal and sociodemographic data, and for the cases, data related to their DUI episode. These data were collected through medical history interviews or official documents. The examinations were conducted by physicians specializing in legal medicine for cases at the Unit of Legal Medicine and Toxicology, University Hospital of Padua, and for controls at a general practitioner's office. Subsequently, the data were entered into a database, with each subject being assigned an alphanumeric code for identification. Personal and sociodemographic data were collected by a physician for all participants, and included the following: date of birth, sex, type of driver's license, family history of alcohol or substance use disorders, education, marital status, occupation, and smoking habits. Some of these variables, such as driver's license type and family history of alcohol or SUD, were dichotomous, while others, including education level, marital status, occupation, and smoking habits, were nominal. For the cases only, the following data were collected: date of DUI, DUI recidivism, type of DUI (alcohol and/or drugs), blood alcohol levels, substances involved in DUI, and road crash involvement related to the DUI episode. The data pertaining to the DUI episode were obtained from official documents provided by the police. Drivers undergoing evaluation were required to present these documents at the time of their assessment.
(3) Administration of the CPT-3 test [27] for cases and controls.
(4) For the cases, the collection of biological materials for toxicological analysis. After forensic examination, hair and urine were collected and analyzed. Toxicological analysis aimed at discovering psychoactive substances was performed on proximal head hair segments with a length of 3–6 cm. To assess alcohol consumption, ethyl glucuronide (EtG) quantification in hair was also performed. The examined subjects were assessed as either fit or unfit to drive, based on the integrated evaluation of the results of this methodological approach. Specifically, excessive alcohol intake according to the Society of Hair Testing (SOHT) consensus document (EtG >30 pg/mg) [28] was considered a cause for a determination of unfitness to drive, as was the discovery of illicit psychoactive substances in hair samples [1]. Excessive alcohol consumption or the use of illicit substances were considered when assessing an individual's fitness or unfitness to drive, but they were not automatically associated with a clinical diagnosis of a SUD. The diagnosis, when it was confirmed to be present, was supported by an integrated evaluation of clinical and toxicological data, following the criteria outlined in DSM-5 for SUD [11].

2.2.1. CPT-3 test

Continuous performance tests are used in standard neuropsychological practice to evaluate attention, particularly among specific clinical populations, such as individuals with ADHD [29] and mild traumatic brain injuries [30]. Conners' Continuous Performance Test (CPT) is considered the most widely used continuous performance test. Its current version, the third edition (CPT-3) [27], measures several aspects of sustained attention. In addition to these uses, embedded validity indicators have been derived from CPT indices with the aim of identifying invalid neuropsychological test performances.

The sensitivity and specificity of CPT in evaluating ADHD are still debated, varying by up to 88 % and 100 %, respectively [31].

The test is administered through a computer and requires the examinee to be seated in front of a monitor and to press the left mouse button as quickly as possible every time a letter appears on the monitor. The action of pressing the mouse button must be interrupted whenever the letter X appears.

During the 14-min administration period, the software measures multiple parameters as described in the following [32]: "C-style" is the style of responding; "detectability" is the ability to discriminate targets (letters other than X) from non-targets (X); "omissions" is the rate of missed targets, while "commissions" represents the rate of incorrect responses (100 msec or more) to non-targets; "perseverations" is the rate of anticipatory, repetitive, or random responses (under 100 msec); "hit reaction time" (HRT) is the average response speed; "hit reaction time standard deviation" (HRT-SD) is the response speed consistency; "variability" indicates the variability of response speed consistency; "hit reaction time block change" is the change in HRT across blocks; and "hit reaction time interstimulus interval (ISI) change" is the change in HRT across ISIs. Based on these parameters, response styles and four dimensions of attention—inattention, impulsivity, sustained attention, and vigilance—are evaluated.

The above parameters are compared to the reference already present in the program with the return of numerical values

(accompanied by a confidence interval) above or below the mean. A value of 50 for the variable indicates a situation corresponding to the mean; generally (but not for all variables), the higher the score, the worse the performance.

The software finally returns the results in terms of the probability of ADHD or other neuropsychiatric problems that affect attention. The probability of a disorder is provided as very high, high, moderate, minimal, or the lack of any indication. In terms of the four dimensions of attention listed earlier, they are expressions of the parameters previously described. Inattention is suggested by a poor ability to discriminate targets, a low response speed to stimuli, and high levels of inconsistency in response. Impulsivity is suggested by a high response speed and a higher rate of omissions/commissions. Sustained attention is defined as the examinee's ability to maintain response consistency during the test. Vigilance is the examinee's ability to maintain performance level. At the end of the test, the software provides an assessment in which it indicates, for each of the dimensions mentioned, the absence of indications, some indication, or a strong indication of a problem related to that dimension.

2.3. Statistical analysis

The personal, sociodemographic, and clinical data, as well as those derived from the administration of the CPT-3 at the end of the recruitment phase, were anonymously entered into an Excel spreadsheet, and a descriptive analysis of the subjects included in the two groups was conducted. Possible associations of the condition of subjects with a previous DUI were analyzed using the chi-square test for dichotomous variables, the *t*-test, and the Mann–Whitney test for parametric and non-parametric variables, with a significance level of $p = .05$. The same analyses were conducted for the CPT-3 subscales. The variables that differed significantly between the two groups ($p < .05$) in the preliminary analysis were then included in a multivariate binary logistic regression model with significance set at 0.05 to explore possible predictors of belonging to the case group. Subsequently, some variables related to DUI (blood alcohol level above 1.5 g/L, involvement in a traffic accident, recidivism) were analyzed within the case group in relation to the parameters measured by the CPT-3. The cut-off of 1.5 g/L was chosen because this level is associated with more severe consequences from clinical and legal perspectives. A blood alcohol concentration above 1.5 g/L indicates severe impairment and a higher risk of being involved in a road crash compared to sober subjects. Under Italian law, driving under the influence of alcohol with a BAC above 1.5 g/L results in stiffer penalties, including confiscation of the vehicle and longer revocation of the driver's license. Finally, possible predictors of traffic accidents were investigated by means of a multivariate binary logistic regression model. Variables relevant in relation to driving license regranting with a $p < .2$ were also included in the model. All analyses were performed using IBM SPSS Statistics for Windows, version 28.0 [32].

3. Results

3.1. Personal data and socioeconomic factors

The study included 147 subjects (120 males [81.6 %], 27 females [18.4 %]). The number of cases in Group 1 was 100 (68.0 % of the total), and the number of controls in Group 2 was 47 (32.0 % of the total). Personal data and socioeconomic factors, both overall and

Table 1
Personal data and socio-economic factors, in cases and controls.

Variable	Total $n = 147$ (100 %)	Cases $n = 100$ (100 %)	Controls $n = 47$ (100 %)	P-value*
PERSONAL DATA				
Age at examination, years, mean (Standard deviation)	38.65 (12.97)	38.91 (12.69)	38.11 (13.68)	0.32
Tobacco use**				
No use	71 (48.3)	35 (35.0)	36 (76.59)	**< 0.001**
Less than 20 cigarettes per day	69 (46.9)	58 (58.0)	11 (23.4)	
More than 20 cigarettes per day	6 (4.1)	6 (6.0)	0 (0.0)	
SOCIO-ECONOMIC FACTORS				
Education**				
8 years	24 (16.3)	22 (22.0)	2 (4.3)	**< 0.001**
13 years–high school degree	72 (49.0)	60 (60.0)	12 (25.5)	
Bachelor's degree	50 (34.0)	17 (17.0)	33 (70.2)	
Employment Situation**				
Dependent	95 (64.6)	63 (63.0)	32 (68.1)	**0.029**
Freelance	31 (21.1)	26 (26.0)	5 (10.6)	
Unemployed	7 (4.8)	5 (5.0)	2 (4.3)	
Student	12 (8.2)	4 (1.0)	8 (17.0)	
Retired	1 (0.7)	1 (1.0)	–	
Marital status**				
Single	89 (60.5)	59 (59.0)	30 (63.8)	0.468
Married	49 (33.3)	33 (33.0)	16 (3.0)	
Divorced	8 (5.4)	7 (7.0)	1 (2.1)	

Note. * *P*-values refer to chi-square test for dichotomous variables and to Mann-Whitney test for continuous data with non-parametric distribution; ** Data may be incomplete for some subjects. The sum of the numbers and the percentages with reference to the variable considered may not correspond to the total or to 100 %.

according to cases versus controls, are provided in Table 1. DUI variables, toxicological analyses, and judgment of fitness/unfitness to drive for the cases are provided in Table 2. Tobacco use ($\chi^2 = 22.34$, $p < .001$), education ($\chi 2 = 40.39$, $p < .001$), and employment situation ($\chi 2 = 10.81$, $p = .029$) exhibited significant differences between the two groups, while age and marital status showed no significant differences between them. Post-hoc pairwise comparisons were conducted to examine differences within the categories of tobacco use, education, and employment situation. After adjusting for multiple comparisons using Bonferroni correction, all three levels of both tobacco use and education significantly differed between the groups. Regarding employment situation, cases, and controls showed significant differences in the "student" category ($p = .0094$), while it is worth noting that there were no retired subjects in the control group.

Most of the subjects included in the case group were found to be driving under the influence of alcohol (79.0 %). Furthermore, 34 % of the subjects had a blood alcohol concentration exceeding 1.5 g/L at the time of the DUI. In addition, 28 % of the sample were involved in a road crash. Notably, 10 subjects from the sample were found to have driven under the influence on two or more occasions. 26.0 % of the cases resulted in a judgment of being unfit to drive after medicolegal toxicological assessment (11 % for excessive alcohol consumption, 1 % for excessive alcohol consumption associated with illicit substance use, and 14 % for illicit substance use).

The results of the chi-square test for dichotomous variables, the *t*-test, and the Mann–Whitney test for parametric and non-parametric variables are reported in Table 3.

3.2. Comparison of attention dimensions in cases and controls

The distribution of the parameters "detectability," ($\chi 2 = 22.34$, $p = .026$), "probability of ADHD," ($\chi 2 = 6.36$, $p = .012$), and "inattentiveness" ($\chi^2 = 4.39$, $p = .036$) differed between the two groups, while the other variables did not exhibit significant differences between the two groups. In a model including the independent variables of education, smoking habits, employment situation, and inattentiveness, higher educational levels (bachelor's degree; $p < .001$, OR = 0.052; CI [0.010–0.258]) provided protection against belonging to Group 1, whereas having a smoking habit was identified as an independent risk factor for Group 1 membership ($p < .001$, OR = 4.737, CI [1.948–11.518]) (Table 4).

3.3. Associations between attention dimensions and substance use

To explore the potential use of the CPT-3 to predict excessive alcohol consumption or the use of illicit psychoactive substances among cases, subjects assessed as unfit to drive were compared to subjects judged as fit to drive. The two groups were not different in relation to CPT-3 parameters, whereas DUI recidivism ($\chi^2 = 23.33$, $p < .001$) and a lower level of education ($\chi^2 = 6.67$, $p = .036$) were

Table 2
DUI variables and judgement of fitness/unfitness to drive in cases.

Variable	Total *N* = 100 (100 %)
DRIVING UNDER THE INFLUENCE VARIABLES	
Age at DUI, years, mean (Standard deviation)	35.20 (12.53)
Type of DUI	
DUI – Alcohol only	79 (79.0)
DUI - Alcohol plus psychoactive substances	8 (8.0)
DUI - psychoactive substances other than alcohol	10 (10.0)
BAC at DUI*	
0.5–0.8 g/L	19 (19.0)
0.8–1.5 g/L	31 (31.0)
1.5–2.5 g/L	27 (27.0)
>2.5 g/L	7 (7.0)
Refusal of alcohol determination	2 (2.0)
Road crash at DUI*	28 (28.0)
No road crash	72 (72.0)
DUI recidivism	10 (10.0)
First DUI episode	90 (90.0)
Toxicological analysis	
EtG values < 5 pg/mg	29 (29.0)
EtG values 6–29 pg/mg	28 (28.0)
EtG values ≥ 30 pg/mg	12 (12.0)
FITNESS OR UNFITNESS TO DRIVE	
Fit to drive	73 (73.0)
Unfitness - excessive alcohol consumption	11 (11.0)
Unfitness - excessive alcohol consumption and illicit substance use	1 (1.0)
Unfitness - Illicit substance use	14 (14.0)

Note: BAC = Blood alcohol concentration; DUI = driving under the influence; EtG = ethyl glucuronide. * Data may be incomplete for some subjects. The sum of the numbers and of the percentages with reference to the variable considered may not correspond to the total or to 100 %.

Table 3
Parameters measured by the CPT-3 (Conners CK, 2014).

Variable	Cases value (mean)	Controls value (mean)	P-value*
C-style	52.40 (15.95)	52.21 (13.51)	0.941
Detectability	56.37 (10.53)	52.38 (9.65)	**0.026**
Omissions	58.46 (16.95)	54 (12.84)	0.188
Commissions	53.88 (11.20)	50.68 (9.68)	0.141
Perseverations	48.58 (6.96)	49.40 (9.68)	0.782
HRT (hit reaction time)	48.86 (8.57)	48.17 (7.08)	0.609
HRT SD (HRT standard deviation)	49.05 (7.70)	47.51 (9.27)	0.108
Variability	48.61 (7.12)	47.68 (8.10)	0.505
HRT block change	49.42 (9.6)	49.94 (9.85)	0.768
HRT ISI change	48.04 (7.77)	47.19 (7.90)	0.543
	Cases	**Controls**	
	N (%)	N (%)	
Probability ADHD**	47 (48)	33 (70.2)	**0.012**
	51 (52)	14 (29.8)	
Inattentiveness***	39 (39)	27 (57.4)	**0.036**
	61 (61)	20 (42.6)	
Impulsivity***	81 (81)	40 (85.1)	0.543
	19 (19)	7 (14.9)	
Sustained attention***	63 (63)	32 (68.1)	0.548
	37 (37)	15 (31.9)	
Vigilance***	77 (77)	34 (72.3)	0.540
	23 (23)	13 (27.7)	

Note. * *P*-values refer to chi-square test for dichotomous variables, T-test for continuous data with non-parametric distribution, and to Mann-Whitney test for continuous data with non-parametric distribution; ** The probability of ADHD provided by the CPT-3 as very high, high, moderate, minimal, or absent was converted into two categories, where very high, high, and moderate correspond to the first category and minimal and absent to the second category; *** The three levels of the dimension (absent, minimal, and strong indication) have been converted into two levels: no indication vs minimal or strong indication of a problem related to that dimension.

Table 4
P-Value, Odds ratio and Confidence interval of the variables associated to Cases using multiple logistic regression model.

Variable	P-value	OR*	95 % CI**
Education (8 years) ***	<0.001		
Education – (13 years)	0.271	0.404	0.080–2.032
Education – (degree)	<0.001	0.052	0.010–0.258
Tobacco use**	<0.001	4.737	1.948–11.518

Variables in the model: education, tobacco use, employment situation, inattentiveness. Employment situation and inattentiveness were found to be not significant in the first and second steps of the regression analysis, and therefore, are not reported in the table.
Note. *OR=Odds ratio; ** CI= Confidence interval; *** Reference category: 8 years; **** Reference category: no tobacco use.

associated to belonging to the group of subjects unfit to drive.

Subsequently, some variables that are potentially explainable by attention alterations and, therefore, might motivate suboptimal performance on the CPT-3 were investigated in depth. To this end, with exclusive reference to cases, subjects with a blood alcohol level exceeding 1.5 g/L, DUI recidivists, and subjects involved in a road crash were further examined. A blood alcohol concentration at the time of DUI of >1.5 g/L was not associated with alterations in the CPT-3. Recidivism was associated with an alteration of the HRT ISI change parameter (p = .010) playing a protective role against recidivism (OR = 0.862; CI [0.77, 0.965]).

3.4. Associations between attention dimensions and road crashes

For subjects involved in a road collision, higher scores were observed in the probability of the vigilance ($\chi^2 = 7.96$, $p = .019$) and inattentiveness dimensions ($\chi^2 = 9.41$, $p = .009$). The parameter of the probability of ADHD was consequently different ($\chi^2 = 8.57$, p = .036).

To further explore the variables associated with road crash involvement, the distribution of personal data and socioeconomic factors, as well as CPT-3 variables, were also analyzed. Age at DUI (Mann–Whitney = 701, Z = −2.026, $p = .043$), and detectability (Mann–Whitney = 748.5, Z = - 1.994, $p = .046$) differed between the two groups (i.e., cases with road crash involvement vs. cases negative for road crash involvement). The variables that differed between the two groups (not including detectability) were then included in a multivariate binary logistic regression model with significance set at 0.05 to explore possible predictors of road crash involvement. Due to its potential significance in the regranting of driving licenses, we included blood alcohol concentration in the model, despite this variable not showing a significant difference between the two groups (Mann-Whitney = 518.5, Z = −1.574, $p = .116$). In a model that included the independent variables of age at DUI, blood alcohol concentration at DUI, vigilance, and inattentiveness, inattentiveness was found to be an independent risk factor for previous road crash involvement (p = .020, OR = 5.158, CI

[1.292–20.586]) (Table 5).

4. Discussion

4.1. Alterations in attention dimensions in DUI-subjects

The methodological approach included medicolegal, toxicological, and neuropsychological analyses aiming at determining possible alterations in attention parameters in a population of DUI subjects. The choice to use the CPT-3 is innovative compared to other studies and allowed the analysis of specific aspects of attention linked to SUD and driving impairment [18,23] in a population of subjects examined for driver's license reinstatement. The integrated methodological approach allowed us to objectively assess the current use of psychoactive substances in this context [33]. The population studied was unusual compared to other populations reported in the literature because of its peculiar characteristics. Subjects found driving under the influence of alcohol are heterogeneous in relation to different variables [6] and do not correspond to subjects with a prior diagnosis of SUD.

After a descriptive analysis, the distribution of parameters of detectability, probability of ADHD, and inattentiveness were found to be statistically different between the two groups. After binary logistic regression, a higher educational level was found to protect against belonging to Group 1. A smoking habit was also identified as an independent risk factor for Group 1 membership.

The lack of a specific alteration related to a possible diagnosis of ADHD in the case versus control groups does not contradict the premises of our study [18,23] in relation to the association between SUD and ADHD [34]. The study confirms that our sample is heterogeneous in relation to a DUI episode. In fact, our population includes subjects found driving under the influence of alcohol, illicit drugs, and both alcohol and illicit drugs; nevertheless, the subjects included in the study had not previously been diagnosed as affected by SUD, according to the DSM-5 criteria [11]. Another factor that could explain the lack of CPT-3 alterations is the relatively low number of subjects in our sample.

Among socioeconomic factors, more subjects with a low educational level were observed in the group of DUI subjects than in the comparison group. This finding is in line with previous research [6,35], although it is important to note that an epidemiological study cannot determine a cause-and-effect relationship between education level and DUI. However, previous studies [33,36] have suggested a connection between low educational achievement and DUI or excessive alcohol consumption, similar to the relationship between low education levels and deviant behavior.

The literature [37] suggests that tobacco use could lead to impaired and risky decision making, which is consistent with the cases reporting a higher rate of tobacco use. Additionally, tobacco use may reduce the subjective effects of alcohol, potentially leading to increased alcohol consumption [38]. In this regard, other scholars [39,40] have also linked smoking while driving to an increased risk of road crashes. This behavior, although not perceived as distracting by most drivers, is recognized as leading to distractions and, thus, as a risk factor for traffic collisions [40]. Previous studies by the authors [6,33] have already shown a significant correlation between smoking and DUI recidivism or excessive alcohol consumption. Once again, our results confirm the well-established association between tobacco use (especially heavy smoking) and DUI variables. For this reason, it might be beneficial to focus the initiatives aimed at increasing road safety on encouraging people to stop smoking cigarettes, especially while driving.

4.2. Association Between Alterations in Attention Dimensions and Excessive Alcohol Consumption and/or Consumption of Illicit Substances

To explore the potential use of the CPT-3 to predict excessive alcohol consumption or the use of illicit psychoactive substances among the cases, subjects assessed as unfit to drive (EtG $\geq$30 pg/g and/or presence of illicit substances in hair samples) were compared to subjects judged as fit to drive. No differences in CPT-3 performance were identified, whereas DUI recidivism and lower education were associated with belonging to the group judged as unfit to drive.

4.3. Association between alterations in attention dimensions and road crashes in DUI-subjects

The most relevant finding of our study was the presence of worse performance on the CPT-3 in cases previously involved in a road crash compared to the other cases. This result is consistent with the possible contribution of altered attention to road crash involvement, which is consistent with the findings of other authors [12–14] and suggests that alteration in the dimensions of attention

Table 5
P-Value, Odds ratio and Confidence interval of the variables associated to previous road crash involvement.

Variable	P-value	OR*	95 % CI**
Age at DUI	0.027	1.050	1.006–1.096
Inattentivenss***	0.067	–	–
Inattentiveness 1	0.170	2.617	0.662–10.346
Inattentivenss 2	0.020	5.158	1.292–20.586

Variables in the model: age at DUI, blood alcohol concentration, vigilance and inattentiveness. Blood alcohol concentration and vigilance were not found to be significant in the first and second steps of the regression analysis, and thus, are not reported in the table.
Note. *OR=Odds ratio; ** CI= Confidence interval; *** Reference category, no signs of vigilance.

plays a role in increasing the risk of road crash involvement. Our results indeed suggest that inattention (captured by the parameter "inattentiveness") rather than impulsivity could play a role in road crash involvement. In this regard, attention regulation has previously been linked to considerable differences in subjects' driving performance, such as conversing over phones or talking when attempting to locate a street address [41]. Inattention has also been studied as a contributing factor related to more severe crashes [42], thus leading to a greater number of fatal road collisions. In this regard, Sundfør et al. [43] observed that the main forms of inattention possibly contributing to a greater risk of fatal crashes are failure to check behind sight obstructions and distraction by the use of phones. Road crashes due to inattention are most frequently multiple-vehicle crashes and usually occur as turn/angle or rear-end collisions [44]. Thus, considering the abovementioned data widely reported in the literature, the results of our study reiterate the significant correlation between inattention and road traffic crashes; nonetheless, our different methodological approach, based on the employment of the CPT-3 in DUI subjects, suggests the possibility of implementing specific psychopathological tests (such as the CPT-3) in driver's license issuance/reinstatement processes as a screening method to identify individuals at higher risk of causing collisions. A thorough examination of an individual's history, conducted by a trained physician specializing in psychiatry and/or DUI offenses, may prompt the need for these tests. Implementing preventative measures based on a more precise assessment of drivers with a higher inherent risk of causing car accidents could significantly improve road safety. This approach has the potential to enhance road safety, reduce the incidence of crash-related injuries and fatalities, and proactively identify and monitor individuals displaying potential hazardous driving behaviors at an early stage.

Moreover, considering the well-established correlation between SUD and attention deficits, it is advisable to adopt a multidisciplinary approach involving both psychiatrists and toxicologists when determining the eligibility of individuals for driver's license reinstatement, particularly for those at higher risk. In cases where individuals with a history of DUI offenses are seeking reinstatement of their driving privileges, a personalized approach, including tailored assessments and ongoing monitoring, may be necessary.

Furthermore, in relation to the other factors studied, no differences among the cases were identified for the other variables related to alcohol or substance use. Blood alcohol concentration, recidivism, a smoking habit, the presence of excessive alcohol consumption, or the presence of illicit substances in hair were not statistically different between the sub-groups, suggesting the prominent role of attention deficits in our sample. This result does not support the hypothesis of a cumulative effect of psychoactive substances and ADHD on the risk of road crash involvement [24] and, in some ways, stands in contrast to the study of Barkley et al. [45], where, in an experimental context, the use of alcohol had the same deleterious effects on the driving ability of subjects affected by ADHD and the controls, but the effects were not differentially greater in the ADHD group. The lack of a cumulative effect of attention deficits and substance use could again be related to a sample characterized by different intakes of psychoactive substances. Thus, other variables should be investigated to exclude confounding factors, such as the driving experience of the subjects [25]. Moreover, as suggested by previous researchers [46,47], the CPT, known for its sensitivity to attention deficits, may lack the necessary specificity in distinguishing between ADHD, SUD, and cases where these two conditions co-occur. This lack of specificity could be attributed to the shared neurobiological and behavioral traits between ADHD and SUD. Additionally, the early onset of substance use in many individuals poses a significant challenge in isolating the independent effects of ADHD and SUD [46,47].

4.4. Limitations of the study and future perspectives

A significant limitation of this study lies in the size of the population under investigation, particularly the relatively small number of subjects in the control group. On the one hand, the number of subjects involved may limit the relevance of some parameters that could possibly be appreciated when examining a greater population; on the other hand, it could suggest associations that need to be validated by expanding the case series. Another limitation of this study is the lack of chemical-toxicological tests performed on controls. The exclusion of the pathological consumption of psychoactive substances (legal or illegal) based solely on anamnestic data in this group could also result in improper enrollment of subjects as controls. Self-report data may also be a limitation of the study when considering road crash involvement in controls. Furthermore, it is worth acknowledging that potential biases could have arisen from the method of population selection, as some individuals may have declined participation in the study. Additionally, the recruitment settings for cases and controls were substantially different, with cases being selected from the medicolegal office for driving license regranting and controls from a general practitioner's office. In this context, it is essential to recognize that the refusal rate was not evaluated as part of this study. From a methodological point of view, the study could be implemented by focusing on specific types of subjects with behaviors that could be favored by an attention disorder (such as alcohol DUI recidivists) or conditions that could undermine test performance (subjects with a previous diagnosis of an alcohol use disorder). In this regard, in future studies, cases and controls could be matched not only for age and gender but also for additional variables (e.g., education) to reduce the influence of confounding factors. Furthermore, when selecting subjects, consideration should be given to the type of work or video gaming activities in which they engage. Individuals who regularly use a computer mouse for work or leisure may develop a more efficient grip for clicking speed compared to those who are not accustomed to using such a device. Additionally, individuals with a gaming habit tend to be more reactive, exhibiting reduced reaction times without compromising accuracy [48,49]. Finally, our study did not explore the mechanism through which ADHD symptoms could contribute to an increased risk of road crashes.

4.5. Possible treatment and intervention outcomes

Determining a broad case series with replicability of altered test performance data could have clinical and medicolegal implications. On a clinical level, other studies propose a therapeutic approach after a diagnostic assessment based on a test or suggest monitoring the course of therapy by readministering the test. On a medicolegal level, identifying a neuropsychological risk marker for

driving could motivate the implementation of protocols in the context of granting or reviewing a driver's license. For example, as discussed above, a test could be conducted during the evaluation of the requirements for driving eligibility. Additionally, during a review, specific categories of subjects at higher risk could be identified, and differentiated periods of monitoring of these subjects over time could be required.

5. Conclusion

This paper suggests the existence of alterations in some attention dimensions in a population of subjects who drove under the influence of alcohol or psychoactive substances and were involved in road crashes. Based on the results of our study, the CPT-3, which has already been validated as a diagnostic tool for the diagnosis of ADHD, proved to be a useful test for the assessment of attention in the driving setting, despite the drivers' consumption of licit or illicit psychoactive substances. This result confirms that, independently of the context, the identification of elements suggesting an attention problem should be considered in driver's license reinstatement or issuance with the possibility of an increased risk in road crash involvement, consistent with the indications of the literature. For example, the additive role of alcohol or drug intoxication, not supported in our sample, should be an object of further study and cannot be excluded.

No alterations in the attention parameters were associated with excessive alcohol use or the use of illicit substances. An expansion of the sample in future studies is necessary to understand the relevance of the proposed methodological approach in terms of prevention, rehabilitation, and the monitoring of subjects who are evaluated for driving eligibility requirements.

Data availability statement

The data will be available on request.

CRediT authorship contribution statement

Claudio Terranova Ap: Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Francesco Pozzebon:** Writing – original draft, Methodology, Data curation. **Alessandro Cinquetti:** Writing – review & editing, Writing – original draft, Methodology, Data curation. **Matteo Perilli:** Writing – review & editing, Data curation. **Stefano Palumbi:** Methodology, Data curation. **Donata Favretto Ap:** Writing – review & editing. **Guido Viel Ap:** Writing – review & editing. **Anna Aprile Ap:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24083.

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