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FEATURES OF THE INFLUENCE OF LOW LEVELS OF ALCOHOL INTOXICATION ON THE FUNCTIONS OF THE HUMAN BRAIN

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Abstract

Aim. To investigate the influence of subclinical levels of alcohol intoxication on human cognitive functions, in particular attention, and to develop forensic criteria for their assessment. This study is motivated by the need to improve existing standards, especially given the varying legal limits for intoxication around the world and the cognitive risks that occur even at low blood alcohol concentration levels.
Materials and methods. A sample of 42 healthy volunteers (men and women aged 21-63 years) participated in the assessment of attention by the «arrangement of numbers» method. In this test, participants had to arrange randomly placed numbers in a grid of 25 cells within two minutes. The study-controlled alcohol consumption with a maximum blood alcohol concentration of 0.5‰ measured by the AlcoControl 9.0 PRO MEDICA+ Breathalyzer. Statistical analysis was performed using McNemar's test with Yates correction and two-sample t-test using software packages including EZR, MedStat, and GNU Octave. A significance level of p=0.05 was applied.
Results. The results showed that at blood alcohol concentration levels between 0.31 and 0.5‰, there was a statistically significant decrease in attention ($p<0.05$), which was manifested in slower performance of the test and a higher rate of errors. Gender and age differences emerged, with women and those over 40 showing more pronounced declines in attention compared to men and younger participants. Levels of alcohol concentration in the blood of 0.1-0.3‰ did not show significant changes compared to the sober initial level.
Conclusions. Alcohol at subclinical levels, particularly between 0.31 and 0.5‰, negatively affects cognitive performance in attention-based tasks, with increased effects seen in women and the elderly. Given that blood alcohol concentrations as low as 0.3‰ indicated minimal cognitive impairment, this study suggests revising current forensic standards to reflect these findings, potentially adjusting the legal threshold of intoxication for drivers.

Keywords: **cognitive functions, alcohol-induced disorders, forensic toxicology, psychomotor performance, attention, subclinical alcohol intoxication**

INTRODUCTION

For the first time in Ukraine, the official procedure for determining drivers' alcohol intoxication based on the quantitative alcohol content in blood was approved in 2009. This was regulated by the «Instruction on the Procedure for Detecting Signs of Alcohol, Drug, or Other Intoxication or Influence of Medicinal Products That Reduce Attention and Reaction Speed in Vehicle Drivers,» which was updated in 2015 [1]. According to this instruction, police officers use special technical devices for testing, and alcohol intoxication is considered proven if the level exceeds 0,2‰. In global practice, specifically under the U. S. Federal Aviation Regulations (CFR) 91,17, legal limits for driving in most states are set at 0,8 or 1,0‰, whereas operating an aircraft is prohibited with a blood alcohol content of 0,4‰ or more [2].

The effects of alcohol on human cognitive abilities have been widely studied by many researchers. For example, Weafer J. examined inhibitory control mechanisms after three doses of alcohol: 0,65 g/kg, 0,45 g/kg, and 0,0 g/kg (placebo) and found that it impairs behavior and suppresses attention in both men and women, with gender differences that may impact disinhibition in men and women [3]. Alistair J. expanded knowledge on the concept of alcohol myopia, finding that alcohol reduces the amount of peripheral information processed during visual scenes [4]. Ben D., in his study on the effects of 0,45 g/kg and 0,65 g/kg of alcohol, found that alcohol reduced intentional

inhibitory control over selective attention but did not affect automatic inhibitory influences [5]. Harvey A. J., studying the effects of intoxication on cognitive or perceptual ability, established that alcohol decreases only cognitive abilities [6]. Roberto U Cofresí, in an experiment with 231 young adults consuming 0,80 g/kg (males), 0,72 g/kg (females), and active placebo (0,04 g/kg), found that acute alcohol-induced impairment of working memory updating may be limited, but alcohol-induced weakening of practical effects may interfere with performing new tasks [7].

AIM

The aim was to investigate the effects of subclinical levels of alcohol intoxication on human cognitive functions (attention) and to develop forensic criteria for their evaluation.

MATERIALS AND METHODS

The study focused on examining human attention by testing 42 physically healthy volunteers of both sexes aged 21 to 63, using the «number placement» method to assess attention at subclinical levels of alcohol intoxication not exceeding 0,5‰. In the «number placement» method, the respondent, according to testing rules, had to place numbers located randomly in 25 cells of a stimulus material square in ascending order within empty cells on a fill-in form within 2 minutes.

The level of alcohol intoxication was determined using the AlcoControl 9,0 PRO MEDICA+ electrochemical breathalyzer (Japan), with a measurement range of 0,00-4,00‰ and a sensor sensitivity of 0,001%. Alcohol intoxication was measured at the beginning and end of testing.

Since the measured indicators of attention under alcohol intoxication are characterized by the frequency of qualitative feature occurrence (results «better/worse» in the same subjects), McNemar's test with continuity correction (Yates correction) was used to test the null hypothesis. Statistical processing of results was carried out using two statistical packages: Statistical software EZR v. 1,54 (graphical user interface for R statistical software, version 4,0,3, R Foundation for Statistical Computing, Vienna, Austria) and the MedStat statistical analysis package. Statistical processing was also performed in OpenOffice (Base, Calc, Writer, Draw, Math), and GNU Octave, with source documents saved in *.doc, *.xls formats. This software is open-source and regulated by the GPL (GNU General Public License). If normal distribution was confirmed, data were described using the mean (M) and standard error (m). To assess the significance of differences, a two-sample t-test with unequal variances was used. The chosen confidence level P corresponded to 95%, and the accepted statistical significance level was 0,05 (p=0,05). The difference was considered significant at a significance level of $p<0,05$.

RESULTS

According to the results of the study involving 42 respondents (both men and women), their attention was assessed before and after alcohol consumption (with a concentration not exceeding 0.5‰). Before alcohol consumption, most respondents showed no errors or lapses, and their attention remained stable, indicating a high level of concentration. For instance, respondents displayed no change (value «0»), which indicates normal task performance.

After consuming alcohol, minor lapses appeared in the results of a few respondents; however, overall changes were minimal. Some participants made errors (value «1»), indicating a slight decline in attention after alcohol consumption. Nonetheless, attention remained at the previous level or changed only slightly for many respondents. Overall, the results suggest that a low level of alcohol intoxication may cause a slight decrease in attention in some respondents, but not all. The tendency for errors became more noticeable after alcohol consumption, yet these changes were minimal and did not occur in all respondents, indicating individual differences in the response to alcohol.

The results of the analysis on whether test completion speed differed among the study group, conducted using the EZR package (with a significance level set at 0.05), are presented in Figure 1.

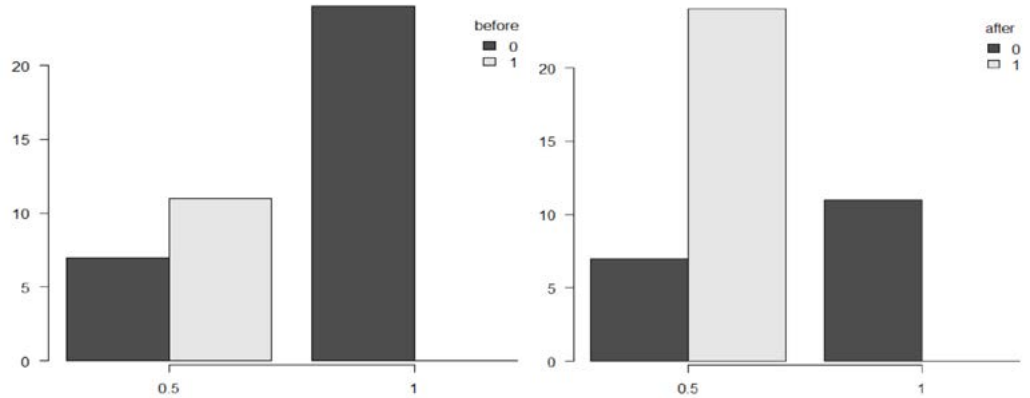

Figure 1. Solution Result.

In analyzing the results of the attention test using the proposed method, it was found that before alcohol consumption, 57,14%±7,64% (24 subjects) showed better results, while after alcohol intake, 26,19%±6,78% (11 subjects) performed better on the test. Thus, a statistically significant decrease in attention (p=0,0425) was observed in the subjects after alcohol consumption.

The study showed that the speed of test completion varied among respondents depending on the level of alcohol intoxication, age, and gender. For men, the test completion time without alcohol ranged from 13 to 25 seconds, whereas at subclinical levels of alcohol intoxication, it ranged from 16 to 23 seconds. In general, men showed some slowing in test performance after alcohol consumption. For women, the speed without alcohol ranged from 12 to 25 seconds, and with alcohol intoxication, from 11 to 24 seconds. Results for women were less straightforward: in some cases, there was even an improvement in results with alcohol intoxication, although an overall trend toward slower performance was noted.

Regarding the effect of alcohol intoxication on attention by age, younger respondents (under 40 years) had a testing speed without alcohol between 13 and 25 seconds, and under the influence of alcohol, between 13 and 23 seconds. In this group, alcohol also led to a slight decrease in speed; however, in some cases, the results remained nearly unchanged. For older respondents (40 years and older), the speed without alcohol ranged from 14 to 25 seconds, and with alcohol intoxication, from 13 to 24 seconds. A more pronounced impact of alcohol was noted in older respondents, especially in cases where test speed decreased. Overall, alcohol intoxication tended to slow down test performance, with a slightly stronger effect observed in men and older individuals.

The study also showed that the influence of alcohol on test completion speed varied depending on gender and age. In a sober state, 12 respondents performed better compared to their performance under alcohol intoxication, while under intoxication, only 8 men showed better results. In a sober state, 15 women performed better, while under the influence of alcohol, this number decreased to 4, indicating a more pronounced negative impact of alcohol on task completion speed in women.

Age group under 40: 12 respondents performed better in a sober state, while under alcohol intoxication, this figure was 7 respondents. Age group over 40: 15 respondents performed better in a sober state, while under alcohol intoxication, only 5 showed better test completion speed. Overall, alcohol negatively affected test completion speed, which was particularly noticeable among women and older individuals.

An analysis of the frequency of better responses across different age and gender groups yielded the following results. Under 40 years: among 20 men, 12 showed better responses, amounting to 60% (95% confidence interval: 36,8-81,0%). Among 19 women, 15 showed better results, which corresponds to 78,9% (95% confidence interval: 56,8-94,5%). Over 40 years: among 19 men, 12 demonstrated better responses, amounting to 63,2% (95% confidence interval: 39,3-84,0%). Among 20 women, 15 showed better results, corresponding to 75% (95% confidence interval: 52,8-91,8%).

Thus, the frequency of better responses was slightly higher among women in both age groups, with the frequency of better responses after alcohol intoxication decreasing less in the older groups than in the younger groups for both men and women.

Figure 2 displays the frequency of better responses before alcohol consumption in the two study groups.

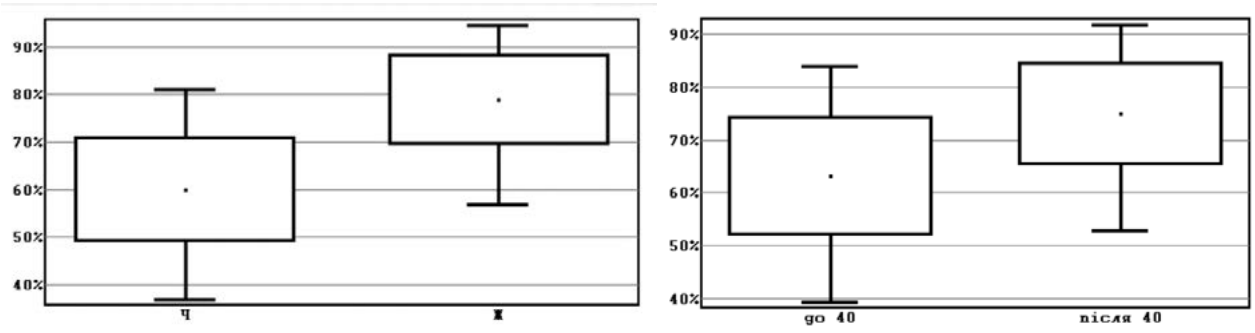

Figure 2. Frequency of Better Responses Before Alcohol Consumption (Left) and Alcohol Consumption Among Men and Women Under and Over 40 Years of Age (Right).

To develop forensic criteria for the effect of alcohol on human attention using the «number placement» method, we studied the indicators based on quantitative alcohol content, dividing the respondents into three groups (0,1-0,2‰, 0,21-0,3‰, 0,31-0,5‰) and comparing them with the overall content (0,1-0,5‰) as well as with sober individuals, as shown in Table 1.

Table 1

Impact of Different Alcohol Content Levels on the Speed of «Number Placement» Task Performance

Alcohol content ‰		Number of numbers		t		t tab.	p
		n	M ± m				
1	0	45	21,93±0,36	(t1- t2)	0, 5	2,08	p>0,05
2	0,1-0,2	15	22,4±0,84	(t1- t3)	1,03	1,99	p>0,05
3	0,21-0,3	37	21,31±0,46	(t1- t4)	4,05	1,99	p<0,05
4	0,31-0,5	41	19,96±0,35	(t3- t4)	2,48	1,99	p<0,05
5	0,1-0,5	93	20,91±0,29	(t1- t5)	2,15	1,98	p<0,05

The analysis of the study results showed that, when comparing attention between the group of individuals who did not consume alcohol and those with blood alcohol levels of 0,1-0,2 and 0,21-0,3‰, no diagnostically significant difference was found (p>0,05). However, a significant difference (p<0,05) was observed with the group of individuals with levels of 0,31-0,5‰, as well as between the groups with levels of 0,21-0,3 and 0,31-0,5‰. When comparing the group of individuals who did not consume alcohol with the averaged group that included all individuals with levels from 0,1 to 0,5‰, a diagnostically significant difference was also found (p<0,05). This indicates that alcohol overall affects human attention. The statistical distribution is visually represented in a box-and-whisker diagram in Fig. 3.

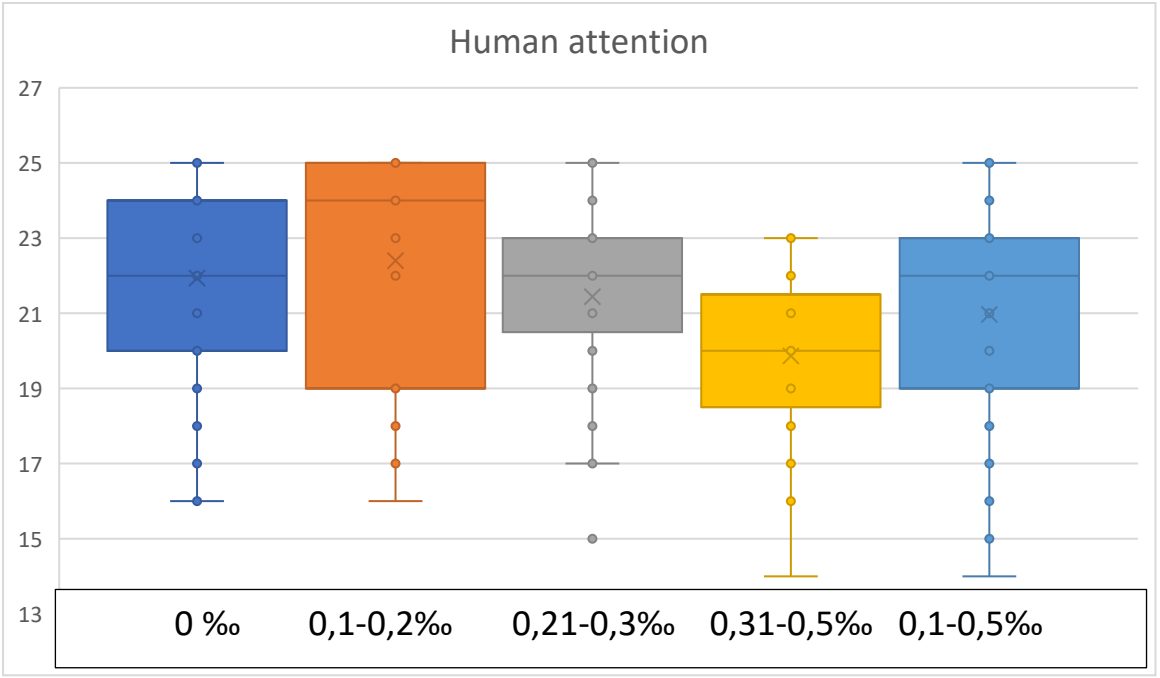

Figure 3. The Effect of Intoxication on Human Attention.

DISCUSSION

We established that alcohol, even at a subclinical level (up to 0,5‰), can cause a slight decrease in attention among certain respondents, especially among women and older individuals. Similar conclusions were supported in the study by Weafer and Fillmore (2012), who found that alcohol disrupts behavioral and attentional mechanisms, particularly response inhibition, which aligns with our results indicating an increase in errors at alcohol concentrations of 0,31-0,5‰ [3]. However, unlike their findings of a significant decrease in attention post-alcohol consumption, our data indicate more individualized differences in responses to alcohol, especially among men, where the negative impact on cognitive functions was less pronounced.

Harvey, Kneller, and Campbell (2013) studied the effects of alcohol on memory and attention in visual scene perception and confirmed that alcohol reduces the effectiveness of memory and attention [4]. Our findings on the reduced test speed and increased errors among the older age group (after 40 years) coincide with their conclusions regarding the impact of alcohol on cognitive functions, particularly at concentrations of 0,31-0,5‰, where significant performance deterioration was observed.

The study by Abroms, Gottlob, and Fillmore (2006) confirmed that alcohol affects inhibitory control of attention, including both automatic and intentional mechanisms, which also matches our observations of decreased test performance with increased alcohol

concentration [5]. Their conclusions supplement and clarify our data, which indicates an increase in errors in respondents with an alcohol concentration of 0,31-0,5‰.

Harvey and Seedhouse (2021) noted that cognitive abilities in number-related tasks also decline under the influence of alcohol [6], which correlates with our findings on decreased test speed in women and older respondents. At the same time, our data showed that alcohol did not always lead to significant changes in the younger age group, suggesting a certain cognitive resilience to low alcohol concentrations (up to 0,3‰) among younger respondents.

Cofresí and colleagues (2021) found that alcohol affects working memory, particularly when updating information [7]. This partially aligns with our findings, where alcohol slowed cognitive processes; however, slight improvements were noted in some respondents, especially women, indicating individual differences in alcohol responses that were not as evident in their study.

Lees and others (2020) confirmed that alcohol particularly negatively impacts the adolescent brain, especially in behavior and cognitive functions [8]. Our results among younger respondents showed a lesser effect of alcohol on their attention, suggesting that such negative consequences may manifest more in the long term or at higher alcohol concentrations.

Topiwala and others (2022) highlight a link between moderate alcohol consumption and the accumulation of iron in the brain and reduced cognitive functions [9]. While our study did not examine the long-term impact of alcohol on the brain, the significant decrease in attention at alcohol concentrations of 0,31-0,5‰ indicates potential cognitive risks even at moderate doses.

Egervari and colleagues (2021) emphasized the genetic and neural mechanisms of alcohol's impact on the brain [10]. This can be related to our findings on individual differences in responses to alcohol, as certain respondents demonstrated resistance to alcohol's effects, which may be linked to their genetic traits.

Mavromatis and colleagues (2022) also indicate a connection between alcohol consumption and structural changes in the brain [11], which supports our conclusions regarding cognitive function deterioration in respondents with alcohol concentrations of 0,31-0,5‰.

Finally, Shields and Gremel (2020) point to impaired functioning of the orbitofrontal cortex in cases of alcohol dependence, affecting cognitive processes [12]. Although our study focused only on subclinical levels of alcohol intoxication, the decreased test speed and increased error rate at a concentration of 0,31-0,5‰ may be an early sign of such impairments.

Overall, our results are consistent with most existing studies, which confirm the negative impact of alcohol on cognitive functions, particularly attention, with individual differences based on age and gender.

CONCLUSIONS

1. The study showed that alcohol consumption, even at a subclinical level (up to 0,5‰), negatively impacts the speed and accuracy of attention-related tasks. Specifically, with a blood alcohol concentration of 0,31-0,5‰, a significant decrease in test speed and an increase in errors were observed, confirming alcohol's detrimental effect on cognitive functions.

2. Alcohol had a varying impact on respondents depending on their gender and age differences. Women and older individuals (over 40 years) showed a more pronounced decrease in attention after alcohol consumption compared to men and younger respondents, indicating individual differences in response to alcohol based on gender and age.

3. Statistical analysis showed that a blood alcohol content of 0,31 to 0,5‰ has a significant impact on attention, causing diagnostically significant deterioration in test results. In contrast, lower concentrations (0,1-0,3‰) did not show a significant difference in task performance compared to a sober state. The study of subclinical levels of alcohol intoxication's effect on human cognitive functions indicated that levels up to 0,3‰ do not statistically significantly affect attention. Therefore, the «Instruction on the Procedure for Detecting Signs of Alcohol, Drug, or Other Intoxication in Vehicle Drivers» requires revision.

Perspectives for further research. Further research may focus on expanding the sample size and investigating the impact of various blood alcohol concentrations on specific cognitive functions, such as short-term memory, reaction time, and more complex executive functions. Additionally, examining gender and age differences in alcohol's effects on cognitive processes, as well as studying the long-term consequences of alcohol consumption on brain activity, would be promising directions for future research.

COMPLIANCE WITH ETHICAL REQUIREMENTS

All study procedures were conducted in accordance with the ethical standards set by the Declaration of Helsinki and were approved by the local ethics committee. Each participant was informed about the study's objectives and provided voluntary informed consent for participation.

The study is part of a comprehensive research work «Forensic assessment of the influence of subclinical degrees of alcohol intoxication on human cognitive functions» (state registration number: 0122U000635, term: 2022-2024) and was carried out on the basis of the Department of Forensic Medicine and Medical Law of Bogomolets National Medical University.

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The authors declare no conflicts of interest that could have influenced the objectivity or outcomes of this study.

AUTHOR CONTRIBUTIONS

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Резюме

ОСОБЛИВОСТІ ВПЛИВУ НИЗЬКИХ РІВНІВ АЛКОГОЛЬНОГО СП'ЯНІННЯ НА ФУНКЦІЇ ЛЮДСЬКОГО МОЗКУ

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Мета. Дослідити вплив субклінічних ступенів алкогольного сп'яніння на когнітивні функції людини, зокрема увагу, та розробити криміналістичні критерії їх оцінки. Це дослідження мотивовано необхідністю вдосконалити існуючі стандарти, особливо з огляду на різні законодавчі обмеження для сп'яніння в усьому світі та когнітивні ризики, які виникають навіть при низьких рівнях алкоголю в крові.

Матеріали та методи. Вибірка з 42 здорових добровольців (чоловіків і жінок віком 21-63 роки) брала участь в оцінці уваги методом «розташування чисел». У цьому тесті учасники повинні були розташувати випадково розміщені числа в сітці з 25 клітинок протягом двох хвилин. Дослідження контролювало вживання алкоголю з максимальною концентрацією алкоголю в крові 0,5‰, виміряною алкотестером AlcoControl 9.0 PRO MEDICA+. Статистичний аналіз проводили за допомогою тесту Мак-Немара з поправкою Єйтса та двовибіркового t-критерію з використанням програмних пакетів, включаючи EZR, MedStat і GNU Octave. Було застосовано рівень значущості p=0,05.

Результати. Результати показали, що при рівнях концентрації алкоголю в крові від 0,31 до 0,5‰ спостерігалося статистично значуще зниження уваги ($p<0,05$), що проявлялося у повільнішому виконанні тесту та вищому рівні помилок. З'явилися гендерні та вікові відмінності, при цьому жінки та ті, хто старше 40 років, демонстрували більш виражене зниження уваги порівняно з чоловіками та молодшими учасниками. Рівні концентрації алкоголю в крові 0,1-0,3‰ не зазнали істотних змін порівняно з тверезим вихідним рівнем.

Висновки. Алкоголь на субклінічних рівнях, особливо між 0,31 і 0,5‰, негативно впливає на когнітивні показники при виконанні завдань, пов'язаних із концентрацією уваги, причому посилений ефект спостерігається у жінок і людей похилого віку. Враховуючи, що концентрація алкоголю в крові лише 0,3‰ вказує на мінімальні когнітивні порушення, це дослідження пропонує переглянути поточні стандарти судово-медичної експертизи, щоб відобразити ці висновки, потенційно скоригувавши законний поріг сп'яніння для водіїв.

Ключові слова: **когнітивні функції, алкогольні розлади, судово-медична токсикологія, психомоторика, увага, субклінічне алкогольне сп'яніння**

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