Predicting Alcohol Intoxication Using Eye-Tracking Metrics When Reading Instructions

Raimondas Zemblys
Smart Eye AB
Gothenburg, Sweden
raimondas.zemblys@smarteye.se

Christer Ahlström
Swedish National Road and Transport Research Institute (VTI)
Linköping, Sweden
Department of Biomedical Engineering
Linköping University
Linköping, Sweden
christer.ahlstrom@vti.se

Abstract

Reading is a complex process that can be affected by alcohol consumption. In this paper, we investigate whether eye-tracking measures can be utilised to recognise the state of alcohol intoxication in readers. We analysed natural reading data in which sober and intoxicated participants read instructions in Swedish prior to performing experimental tasks. Our analysis revealed that fixation and saccade duration, fixation and saccade rate, saccade amplitude, and saccade peak velocity were all significantly affected by alcohol. Furthermore, a logistic regression classifier was able to correctly detect the intoxication state with 87% accuracy.

CCS Concepts

• **Human-centered computing**; • **Social and professional topics → User characteristics**;

Keywords

Alcohol intoxication, Eye movements, Reading

ACM Reference Format:
Raimondas Zemblys and Christer Ahlström. 2025. Predicting Alcohol Intoxication Using Eye-Tracking Metrics When Reading Instructions. In *2025 Symposium on Eye Tracking Research and Applications (ETRA '25), May 26–29, 2025, Tokyo, Japan.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3715669.3726842

1 Introduction

Reading is a complex cognitive task that involves the coordination of several visual and linguistic processes. Eye-tracking technology is a valuable tool in psycholinguistic research, offering insights into the visual and cognitive mechanisms underlying reading. By measuring eye movements such as fixations and saccades, it is possible to infer how readers process text, recognise words, and comprehend sentences [Mézière et al. 2023]. Studies have demonstrated that eye movements during reading are influenced by both the lexical and syntactic properties of the text and the reader's cognitive state [Rayner 1998, 2009; Schotter and Dillon 2025]. For example, longer fixation durations and more frequent regressions (saccades to the opposite direction than that of reading) are typically associated with increased cognitive load or difficulties in processing the text [Schotter and Dillon 2025].

Alcohol consumption has been demonstrated to impair various cognitive functions, including those involved in reading [Watten and Lie 1997]. Research indicates that alcohol can slow information processing and impair higher-order cognitive abilities [Fillmore 2007]. However, the relationship is complex, as the degree of impairment varies across different cognitive processes and alcohol dosage levels [Dry et al. 2012]. Regarding eye movements, alcohol intoxication generally results in a global visuo-motor impairment, attributable to reduced cerebellar functioning, alongside diminished memory and inhibitory control [Maurage et al. 2020].

In this paper, we investigate whether eye-tracking measures can be employed to recognise alcohol intoxication in readers. The data for this study were obtained from an experiment in which participants completed eye movement tasks in the laboratory and subsequently drove a vehicle on a test track under both – sober condition and varying levels of intoxication. Here, we focus exclusively on the laboratory data, specifically the eye-tracking recordings captured while participants read the instructions for the experimental tasks. Collecting reading data was not the main goal of the experiment, however it gave us opportunity to study the effects of alcohol intoxication on eye movements in natural reading.

2 Method

The study was conducted in accordance with the Declaration of Helsinki, and informed consent was obtained from all participants. The study protocol was approved by the Swedish Ethical Review Authority (Dnr 2024-04822-01). An exemption from Swedish law was provided by the Ministry of Rural Affairs and Infrastructure, permitting tests with intoxicated drivers (Regeringsbeslut LI2024/01496).

2.1 Experimental design

Upon arrival at the test site, the participants received an oral recapitulation of the procedures and signed an informed consent form. Their blood alcohol concentration (BAC) level was measured to ensure that all participants were completely sober. They were then shown a demonstration of the eye-tracking tasks and a short test drive was taken to familiarise themselves with the test vehicle.

ETRA '25, Tokyo, Japan

ACM ISBN 979-8-4007-1487-0/25/05
https://doi.org/10.1145/3715669.3726842

Table 1: Eye movement task instructions in Swedish. Each instruction was followed by the text "Tryck MELLANSLAG för att fortsätta..." separated by an empty line. Text was presented in white letters on gray background, centred vertically and horizontally. The exact text layout is depicted in the "Text" column.

Task	Letter size (px)	Number of words	Text
Fixate-Saccade	54	9	Följ prickarna med blicken
Pro-Saccade	27	21	Titta på den svarta pricken och flytta blicken till de röda prickarna när de dyker upp
Anti-Saccade	27	30	Titta på den svarta pricken och flytta blicken I motsatt riktning från de röda prickarna när de dyker upp d.v.s. spegla den röda prickens position
Smooth-Pursuit	54	9	Följ prickarna med blicken
Vestibulo-ocular reflex	54	18	Titta på pricken och vrid huvudet så att näsan följer den röda pricken
Pupil Response	54	37	Titta på skärmens mittpunkt och fortsätt hålla blicken där. Håll huvudet stilla. VARNING! Titta bort eller blunda om du är känslig för blinkande ljus. Testledaren kommer berätta när du kan titta igen.
Random Dot Kinematogram	54	17	Titta på skärmens mittpunkt och fortsätt hålla blicken där. Håll huvudet stilla.

The study employed a mixed design with participants assigned to either *day* (group A – 8:00–17:00 and group B – 11:00–18:00) or *night* (group C – 17:00–04:00 and group D – 18:00–03:00) shifts. Groups A and D first performed the eye-tracking tasks and driving while sober, then consumed alcohol to reach BAC levels of approximately 0.5, 0.8, and 1.2‰. Group A remained for two additional trials to sober up to target BAC levels of 0.9 and 0.6‰. Groups B and C commenced with a BAC level of around 1.2‰ and performed tasks while sobering up to target BAC levels of 0.9 and 0.6; group C continued for two more sobering-up trials targeting BAC levels of 0.3 and 0.0‰. Alcohol dosage was based on the Hume–Weyers formula [Hume and Weyers 1971]. Participants were offered vodka, rum, and gin, which could be mixed with a soft drink of choice.

To control for learning effects [Ahlström et al. 2023; Zemblys et al. 2024], 25% of the participants were invited to participate twice, once in an *alcohol* condition following the procedure described above and once in a *sober* condition following the same procedure, but without alcohol consumption. The order of the *alcohol* and *sober* conditions was balanced.

The experimental trials comprised laboratory-based eye-tracking tasks followed by driving a real vehicle on a test track. The laboratory component included seven tasks: Fixate-Saccade, Pro- and Anti-Saccade, Smooth Pursuit, Vestibulo-ocular Reflex, Pupil Response, and Random Dot Kinematogram. This portion was designed to be completed in approximately 5 minutes. The order of tasks was fixed, except for the Pro- and Anti-Saccade tasks, whose order was randomly determined. The test leader selected the preferred language (Swedish or English) and provided a remote keyboard so that the participant could control the pace of the experiment. Before each task, instructions detailing how to complete the task were displayed on the screen. Participants could take as much time as needed to read the instructions, ask questions, or rest their eyes. The experiment could be terminated at any time by either the participant or the test leader. The eye-tracking tasks were performed in an enclosed space away from the alcohol consumption area, after which participants proceeded outside to the vehicle and drove on the test track.

2.2 Participants

Participant recruitment was conducted via social media advertisements, an information webpage, and a recruitment questionnaire hosted by VTI. Potential candidates were selected based on predefined inclusion and exclusion criteria: driving experience and frequency, regular alcohol consumption without any drinking problems (as assessed by the AUDIT score [Saunders et al. 1993]), not being pregnant, etc., ensuring a balanced distribution of gender and age.

A total of 76 subjects (36 females, aged 22–63 years, mean 40.7 years) participated in the study. Fifty-four subjects participated once in the *alcohol* condition, 20 participants took part in both the *sober* and *alcohol* conditions, and the remaining 2 participants only completed the *sober* condition and did not return. Participants received 2000 SEK (about €175 at the time of the experiment, before tax) for each visit as compensation for their time, effort, and travel costs.

2.3 Data

Participants' BAC was measured after completing the eye-tracking tasks in the laboratory and again after the driving session using one of two newly calibrated Dräger Alcotest 5820 breathalysers. In this paper, we use the measurement obtained in the laboratory.

Eye-tracking data in the laboratory were recorded as videos using Smart Eye Pro 13.0.0 with two Basler daA1920-160um cameras running at 120 Hz, mounted on the table below the monitor. Psychopy version 2024.3.0 [Peirce et al. 2019] was used to control the stimuli, which were displayed on a 50-inch monitor (110 x 63 cm, resolution 1920 x 1080 px). Participants were seated approximately 1 meter from the monitor on a non-rotating, rigid chair. Gaze heading and pitch (using the calibration-free gaze signal [Smart Eye AB 2024]) were obtained by processing the recorded videos offline with Smart Eye Pro 13.0.0, while fixations and saccades were detected using a customised version of the I-RF event detector [Zemblys et al. 2024, 2018]. For a description of the vehicle setup, see Ahlström et al. [2025].

In this paper, we only use data from the laboratory tasks, and more specifically, only the data recorded during the periods when the instruction text was displayed on the screen (hereafter referred to as *reading routines*; see Table 1). We included data from the very first laboratory trial, as subsequent trials might have been affected by participants' familiarity with the tasks, leading them to merely skim through the instructions, leaving data where the participants were either sober or at their highest intoxication level.

2.4 Measures

We calculated six eye-tracking measures commonly used in reading research: fixation duration, fixation rate, saccade duration, saccade rate, saccade amplitude, and saccade peak velocity. These *global* measures primarily indicate overall reading behaviour and differences in text processing [Mézière et al. 2023]. Previous research found that reading under the influence of alcohol leads to increased fixation durations and a higher number of fixations [Watten and Lie 1997]. In contrast, effects on *local* measures – such as regressions and the number of words read, were not observed. Detailed word-level analyses require well-calibrated eye-tracking data and often manual adjustments [Schotter and Dillon 2025], which were not feasible in our study. Consequently, we focused exclusively on these six global measures.

Since the reading routines in our experiments represented natural reading with potential interruptions, we undertook the following steps to ensure that primarily reading data were analysed. For each reading routine, we excluded data exceeding the duration outlier threshold, as determined using Tukey's fence method [Tukey 1977]. Then, for each participant and for each reading routine, we computed a *robust mean* (the mean with the outliers removed, where outliers are detected using Tukey's fence method) for each eye-tracking measure and averaged these values across the routines.

2.5 Analyses

Data were analysed using a three-step approach. First, a one-way multivariate analysis of variance (MANOVA) was performed to assess the overall effect of alcohol intoxication on the six dependent features. This analysis tested the null hypothesis that there were no differences in the combined features between intoxicated and non-intoxicated groups. Next, separate one-way analyses of variance (ANOVAs) were conducted for each feature to determine the specific impact of alcohol intoxication on individual variables. Finally, to evaluate the discriminatory power of the features, a logistic regression model was fitted to the Z-score normalised data. The performance of the logistic regression model was assessed using 10-fold cross-validation at the subject level.

3 Results

Data from 70 out of 76 participants were available for analysis. The remaining participants were excluded due to not completing all tasks, prioritising driving sessions over laboratory testing, or other reasons. In one case, a participant opted to receive the instructions in English rather than Swedish and was therefore excluded from this analysis. Among the analysed participants, 38 were sober and 32 were intoxicated, with an average BAC of 1.03±0.17 ‰ (as measured after completing eye-tracking tasks).

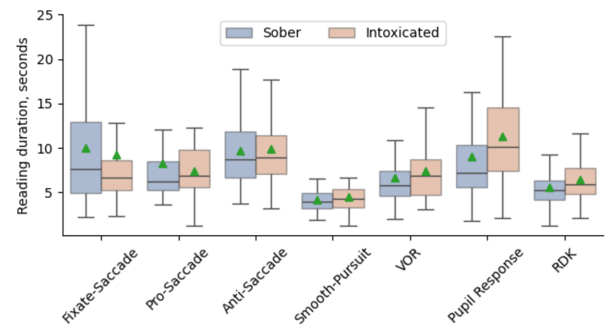

Figure 1: Distribution of time spent reading task instructions and proceeding to perform the eye-tracking task. Green triangles indicate averages; outliers are not shown.

Figure 1 displays the distribution of time taken by participants to read the instructions and proceed to the task. Notably, the initial instruction for the Fixate-Saccade task took considerably longer to process, despite being identical in content to the Smooth-Pursuit task instruction (see Table 1). Inspection of the gaze scanpaths revealed that, prior to the first eye-tracking task, participants not only read the instructions but also looked around, primarily at the keyboard and the test leader handing the keyboard to them. Consequently, the instruction reading data also captured elements of visual search and face-to-face interaction. Other cases included non-reading data as well, but to a lesser extent.

3.1 Feature analysis

A one-way MANOVA was conducted to examine the effect of alcohol on the six dependent features. The multivariate effect was statistically significant, Wilks' $\Lambda = 0.42$, $F(1,69) = 14.4$, $p < .001$, indicating that the groups differed on the combined dependent measures.

Separate one-way ANOVAs revealed a significant increase in fixation duration in the alcohol condition compared to the sober condition, with a large effect size (Table 2). In contrast, fixation rate, saccade duration, saccade rate, saccade amplitude, and saccade peak velocity were all significantly reduced in the intoxicated state. The effect sizes ranged from moderate to large, indicating that alcohol intoxication had a substantial impact on eye movement behaviour.

Table 2: ANOVA results, including mean ± standard deviation for the sober and alcohol conditions, and F-values, p-values and effect sizes for the six features.

Feature name	Sober	Intoxicated	F, p, η^2
Fixation duration	0.20 ± 0.03	0.27 ± 0.04	$F(1,69)=72.2$, $p<0.001$, $\eta^2=0.51$
Fixation rate	2.55 ± 0.44	2.17 ± 0.37	$F(1,69)=14.7$, $p<0.001$, $\eta^2=0.18$
Saccade duration	0.049 ± 0.003	0.047 ± 0.003	$F(1,69)=6.3$, $p=0.01$, $\eta^2=0.09$
Saccade rate	2.66 ± 0.43	2.25 ± 0.37	$F(1,69)=18.1$, $p<0.001$, $\eta^2=0.21$
Saccade amplitude	4.59 ± 0.76	3.98 ± 0.70	$F(1,69)=12.3$, $p<0.001$, $\eta^2=0.15$
Saccade peak velocity	213.6 ± 21.7	187.8 ± 20.3	$F(1,69)=25.9$, $p<0.001$, $\eta^2=0.28$

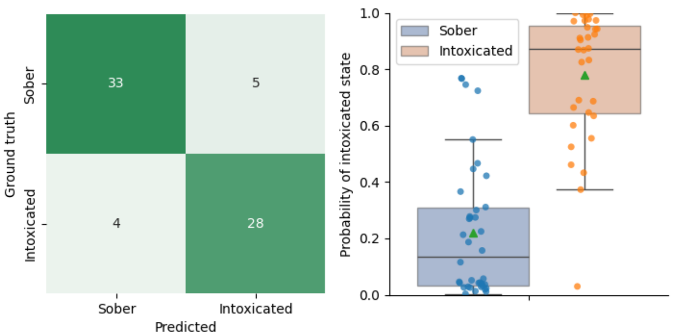

Figure 2: Confusion matrix (left) and boxplot of raw probability scores (right) from the logistic regression analysis distinguishing between intoxicated and sober individuals using eye-tracking features.

3.2 Classification of intoxicated state

Next, we explored the practical utility of these effects for recognising the state of the reader. A logistic regression model, evaluated using subject-level 10-fold cross-validation, achieved an accuracy of 87.1% (precision: 84.85%, recall: 87.50%, F1-score: 86.15%) using the default probability threshold of 0.5. The confusion matrix is shown in Figure 2 (left), while the distribution of raw probability scores (Figure 2, right) demonstrates clear separability between sober and intoxicated states. The average probability scores of 0.22 (sober) and 0.78 (intoxicated) suggest that the operating point of the classifier can be adjusted to suit specific application needs, for example, to minimise false positives or maximise true positives.

4 Conclusion

This study investigated whether eye-tracking measures can be employed to detect alcohol intoxication during reading. Our findings indicate that all six our global eye-tracking measures are significantly affected by alcohol. Specifically, under the influence of alcohol (average BAC $\approx$ 1‰), participants exhibited longer fixation durations, reduced fixation and saccade rates, and saccades that were shorter in duration, smaller in amplitude, and slower in peak velocity. These changes suggest that alcohol impairs visual processing and reading efficiency, in line with previous research [Watten and Lie 1997].

Although our experimental design utilised uncalibrated eye-tracking data – limiting our ability to examine local measures such as regression rate or word-level metrics, the robust differences observed in global measures demonstrate the potential of this approach. Future work should incorporate calibrated eye-tracking systems and more controlled reading tasks to isolate pure reading behaviour. It might also be beneficial to use an eye-tracker with higher than 120 Hz sampling rate for more reliable estimation of saccade characteristics. Additionally, investigating the effects of alcohol on reading in different languages may yield further insights into the cognitive mechanisms underlying alcohol-induced impairment. We have also not separately analysed if daytime (participant groups A and B) and night-time (groups C and D) have any effect on reading patterns and whether that affects the features we used. The text we used was stylistically highly specific, as it consisted solely of instructions on how to perform the tasks in the experiment; however, we see this as an advantage as the participants had to focus on the content to be able to perform the next step. This is likely different from just reading a random text and could be investigated further.

The practical applicability of these findings is significant. For instance, the development of non-invasive screening tools based on eye-tracking could be beneficial in various settings, such as roadside sobriety tests or workplace safety checks. These tools could provide a quick and reliable indication of intoxication, prompting further confirmatory testing when necessary. Moreover, our results contribute to the broader understanding of how alcohol affects cognitive functions, supporting the need for public health interventions aimed at reducing alcohol-related impairments.

Overall, this study contributes to our understanding of how alcohol affects reading and highlights the potential for developing non-invasive screening tools to detect intoxication. By building on these findings, future research can further refine and validate eye-tracking measures as reliable indicators of alcohol intoxication.

5 Privacy and ethics statement

Our findings suggest that eye-tracking measures can provide a non-invasive indication of alcohol intoxication, however, they are not intended to replace traditional screening methods such as breathalysers or blood tests. Rather, these methods could serve as supplementary tools to alert individuals or authorities to potential intoxication, prompting further confirmatory testing.

The collection and analysis of eye-tracking data raise important privacy considerations. All participants provided informed consent, and every effort was made to ensure the confidentiality and security of the data. The research protocol was reviewed and approved by the Swedish Ethical Review Authority, in line with the Declaration of Helsinki and applicable legal requirements.

References

Christer Ahlström, Raimondas Zemblys, Svitlana Finér, and Anna Anund. 2025. The Combined Effect of Alcohol and Sleepiness on Eye Tracking Features: Implications for Driver Monitoring Systems. In *47th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. 1–5.

Christer Ahlström, Raimondas Zemblys, Svitlana Finér, and Katja Kircher. 2023. Alcohol impairs driver attention and prevents compensatory strategies. *Accident Analysis & Prevention* 184 (2023), 107010.

Matthew J Dry, Nicholas R Burns, Ted Nettelbeck, Aaron L Farquharson, and Jason M White. 2012. Dose-related effects of alcohol on cognitive functioning. *PloS one* 7, 11 (2012), e50977.

Mark T Fillmore. 2007. Acute alcohol-induced impairment of cognitive functions: Past and present findings. *International Journal on Disability and Human Development* 6, 2 (2007), 115–126.

R Hume and Elspeth Weyers. 1971. Relationship between total body water and surface area in normal and obese subjects. *Journal of Clinical Pathology* 24, 3 (1971), 234–238.

Pierre Maurage, Nicolas Masson, Zoé Bollen, and Fabien D'Hondt. 2020. Eye tracking correlates of acute alcohol consumption: A systematic and critical review. *Neuroscience & Biobehavioral Reviews* 108 (2020), 400–422.

Diane C Mézière, Lili Yu, Erik D Reichle, Titus Von Der Malsburg, and Genevieve McArthur. 2023. Using eye-tracking measures to predict reading comprehension. *Reading Research Quarterly* 58, 3 (2023), 425–449.

Jonathan Peirce, Jeremy R Gray, Sol Simpson, Michael MacAskill, Richard Höchenberger, Hiroyuki Sogo, Erik Kastman, and Jonas Kristoffer Lindeløv. 2019. PsychoPy2: Experiments in behavior made easy. *Behavior research methods* 51 (2019), 195–203.

Keith Rayner. 1998. Eye movements in reading and information processing: 20 years of research. *Psychological bulletin* 124, 3 (1998), 372.

Keith Rayner. 2009. Eye movements and attention in reading, scene perception, and visual search. *Quarterly journal of experimental psychology* 62, 8 (2009), 1457–1506.

John B Saunders, Olaf G Aasland, Thomas F Babor, Juan R De la Fuente, and Marcus Grant. 1993. Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption-II. *Addiction* 88, 6 (1993), 791–804.

Elizabeth R. Schotter and Brian Dillon. 2025. A beginner's guide to eye tracking for psycholinguistic studies of reading. *Behavior Research Methods* (2025). doi:10.3758/s13428-024-02572-4

Smart Eye AB. 2024. *Smart Eye Pro Manual, Revision 13.0*.

John W Tukey. 1977. *Exploratory data analysis*. Vol. 2. Reading, MA.

Reidulf G Watten and Ivr Lie. 1997. The effects of alcohol on eye movements during reading. *Alcohol and alcoholism* 32, 3 (1997), 275–280.

Raimondas Zemblys, Christer Ahlström, Katja Kircher, and Svitlana Finér. 2024. Practical aspects of measuring camera-based indicators of alcohol intoxication in manual and automated driving. *IET Intelligent Transport Systems* (2024).

Raimondas Zemblys, Diederick C Niehorster, Oleg Komogortsev, and Kenneth Holmqvist. 2018. Using machine learning to detect events in eye-tracking data. *Behavior research methods* 50 (2018), 160–181.