Impairment of Human Ocular Tracking with Low-Dose Alcohol

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Previous studies have documented adverse effects of alcohol on oculomotor performance. For example, moderate-dose alcohol (yielding a Blood Alcohol Concentration or BAC of 0.04-0.1%) has been shown to decrease steady-state pursuit gain (Fransson et al., 2010, Clin Neurophysiol, 121(12): 2134; Moser et al., 1998, J Neurol, 245(8): 542; Roche & King, 2010, Psychopharmacology, 212(1): 33), to increase saccade latency (Moser et al., 1998, J Neurol, 245(8): 542; Roche & King, 2010, Psychopharmacology, 212(1): 33), to decrease peak saccadic velocity (Fransson et al., 2010, Clin Neurophysiol, 121(12): 2134; Roche & King, 2010, Psychopharmacology, 212(1): 33), and to increase the frequency of catch-up saccades (Moser et al., 1998, J Neurol, 245(8): 542). Here, we administered two doses of ethanol on different days, yielding moderate (0.06%) and low (0.02%) levels of initial BAC, to examine the effects on human ocular tracking over BACs ranging from 0.00 to 0.07%. Twelve subjects (8 females) participated in a 5-day study. Three days of at-home measurements of daily activity and sleep were monitored, followed by two laboratory days where, ~5 hours after awakening, we administered one of the two possible single doses of alcohol. Using a previously published paradigm (Liston & Stone, 2014, J Vis, 14(14): 12), we measured oculomotor performance multiple times throughout the day with three pre-dosing baseline runs and bi-hourly post-dosing test runs until the subject recorded a BAC of 0.00% for two hours. BAC was measured before each run using an Alco-Sensor IV breathalyzer (Intoximeters, Inc., St. Louis, MO). For each of the oculometric measures, for each subject, we computed the within-subject % deviation for each test run from their baseline averaged across their three pre-dosing runs. We then averaged the data across subjects in 0.01% BAC bins. Finally, we used linear regression to compute the slope and x-intercept (threshold) of the mean binned % deviation as a function of BAC. We found that pursuit initiation was impaired at very low BAC levels, with significant ($p < 0.002$) linear trends in latency (+1.3%/0.01%BAC) and initial acceleration (-4.6%/0.01%BAC) with extrapolated absolute thresholds at or below 0.01% BAC. We also found that steady-state tracking was impaired showing significant ($p < 0.002$) linear trends in gain (-3.8%/0.01%BAC) and catch-up saccade amplitude (+9.1%/0.01%BAC), again with extrapolated absolute thresholds around 0.01% BAC. We also found a significant ($p < 0.02$) increase in pursuit direction noise (+9.8%/0.01%BAC) with

an extrapolated absolute threshold below 0.01% BAC. Many aspects of ocular tracking are impaired in a dose-dependent manner beginning at a BAC level around 0.01%, with significant effects at levels lower than previously reported and up to 8-times lower than the legal limit for driving in most states.

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INTRODUCTION

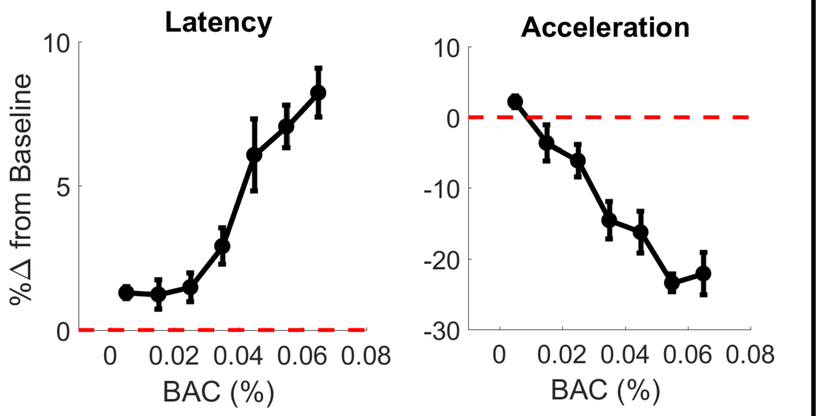
Previous studies have shown that some features of oculomotor performance are impaired at or slightly below the driving legal limit of most U.S. States (0.08% BAC). Specifically, alcohol impairs saccade latency (Moser et al., 1998; Roche & King, 2010), saccadic velocity (Fransson et al., 2010; Roche & King, 2010), and steady-state tracking (Fransson et al., 2010; Moser et al., 1998; Roche & King, 2010) at levels between 0.04% and 0.1% BAC. Here we used a suite of standardized oculometric measures (see Liston & Stone, 2014) to examine the effect of low levels of alcohol (down to 0.01% BAC) to assess the impact on dynamic visual processing and oculomotor control (Stone & Krauzlis, 2003; Krukowski & Stone, 2005; Stone et al., 2009). We found that very low levels of alcohol generate significant impairment in visual motion processing and pursuit.

METHODS

- 13 healthy participants (8 females, mean age ± SD = 25.2 ± 2.1 years) with normal or corrected-to-normal acuity.
- 3-day at-home pre-study schedule including 8.5 hours in bed at night with regular timing verified by actigraphy, call ins, and sleep logs.
- 2-day laboratory study where subjects consumed a single low-dose of ethanol (40% ABV Vodka mixed with juice), with three pre-dose and 6-9 post-dose oculomotor testing sessions using a 5-minute Rashbass-like ocular tracking task (Krukowski & Stone, 2005).
- Subjects were asked to track radial step-ramp motion of a small spot in a random direction (90 trials sampling directions around the full circle every 4°) with randomized fixation duration (i.e., target motion onset) thus generating large spatial, directional, and temporal uncertainty in the stimulus trajectory.
- We computed 21 largely independent measures of oculomotor performance, plotted mean±SEM across subjects, and used linear regression to quantify the slope and threshold of any deviation from baseline.

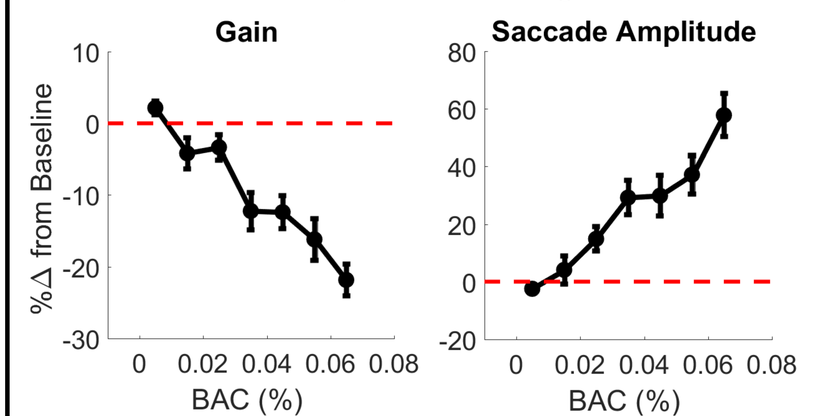
RESULTS

Pursuit Initiation



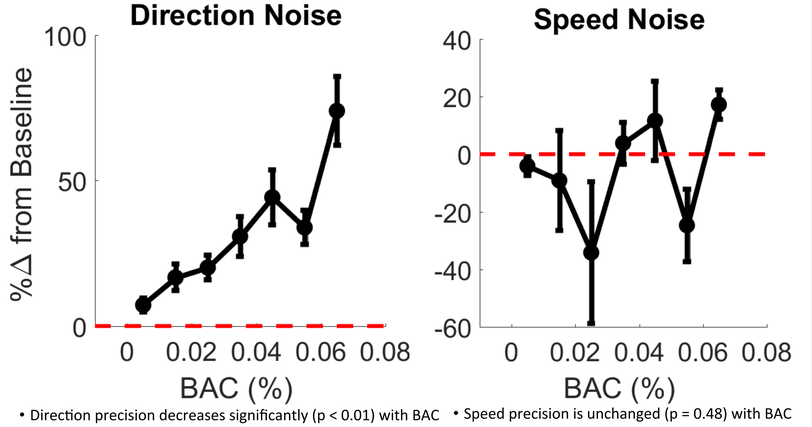
- Pursuit latency increases significantly with BAC ($p < 0.001$)
- Slope = 1.32%/0.01% BAC and threshold = 0.016% BAC
- Initial acceleration decreases significantly ($p < 0.001$)
- Slope = -4.38%/0.01% BAC and threshold = 0.005% BAC

Steady-State Tracking



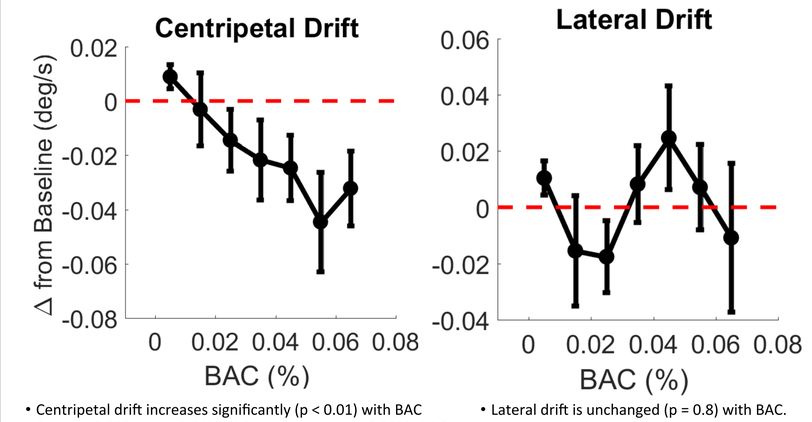
- Pursuit gain decreases significantly ($p < 0.001$) with BAC
- Slope = -3.75%/0.01% BAC and threshold = 0.013% BAC
- Saccades get significantly ($p < 0.001$) bigger with BAC
- Slope = 9.35%/0.01% BAC and threshold = 0.009% BAC

Motion Processing



- Direction precision decreases significantly ($p < 0.01$) with BAC
- Slope = 9.24%/0.01% BAC and threshold = 0.008% BAC
- Speed precision is unchanged ($p = 0.48$) with BAC

Fixational Stability



- Centripetal drift increases significantly ($p < 0.01$) with BAC
- Slope = -0.008 deg/s/0.01% BAC and threshold = -0.002% BAC
- Lateral drift is unchanged ($p = 0.8$) with BAC.

CONCLUSIONS

- Visuomotor performance is significantly impaired in a dose-dependent manner at BAC levels starting as low as 0.01%, which is 8-times lower than the legal limit for operating a motor vehicle in most States.
- For most metrics of pursuit, saccades, fixation, and visual motion processing, performance deficits increase quasi-linearly by between 1.3% and 9.4% for each 0.01% increase in BAC.

REFERENCES

1. Fransson, P.A., Modig, F., Patel, M., Gomez, S., & Magnusson, M. (2010). Oculomotor deficits caused by 0.06% and 0.10% blood alcohol concentration and relationship to subjective perception of drunkenness. *Clinical Neurophysiology, 121*(12), 2134-2142.
2. Krukowski, A.E., & Stone, L.S. (2005). Expansion of direction space around the cardinal axes revealed by smooth pursuit eye movements. *Neuron, 45*(2), 315-323.
3. Liston, D.B., & Stone, L.S. (2014). Oculometric assessment of dynamic visual processing. *Journal of Vision, 14*(14), 12.
4. Moser, A., Heide, W., & Kompf, D. (1998). The effect of oral ethanol consumption on eye movements in healthy volunteers. *Journal of Neurology, 245*(8), 542-550.
5. Roche, D.J., & King, A.C. (2010). Alcohol impairment of saccadic and smooth pursuit eye movements: impact of risk factors for alcohol dependence. *Psychopharmacology, 212*(1), 33-44.
6. Stone, L.S., Beutter, B.R., Eckstein, M.P., & Liston, D.B. (2009). Perception and Eye Movements. *In Squire LR (ed.) Encyclopedia of Neuroscience, volume 7, pp. 503-511. Oxford: Academic Press.*
7. Stone, L.S., & Krauzlis, R.J. (2003). Shared motion signals for human perceptual decisions and oculomotor actions. *Journal of Vision, 3*(11), 725-736.

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