Increased Dependence on Saccades for Ocular Tracking with Low-dose Alcohol

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Previous studies have shown that certain features of oculomotor performance are impaired at or slightly below the legal limit for driving in most U.S. States (0.08% Blood Alcohol Concentration or BAC). Specifically, alcohol impairs 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 (Liston & Stone, 2014) to examine the effect of ultra-low levels of alcohol (down to 0.01% BAC) on steady-state tracking. Our high-uncertainty tracking task reveals that the smooth pursuit system is highly sensitive to BAC, with impairment extrapolating back to BAC levels at or below 0.01%. BAC generates a dose-dependent increase in reliance on the saccadic system that fully maintains overall steady-state tracking effectiveness at least up to 0.08% BAC, albeit with a significant decrease in smoothness.

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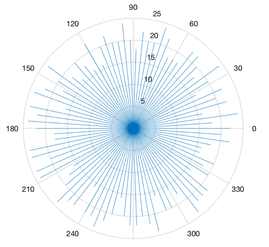
Introduction

Previous studies have shown that certain features of oculomotor performance are impaired at or slightly below the legal limit for driving in most U.S. States (i.e., 0.08% BAC). Specifically, alcohol impairs 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 (Liston & Stone, 2014) to examine the effect of ultra-low levels of alcohol (down to 0.003% BAC) on steady-state tracking.

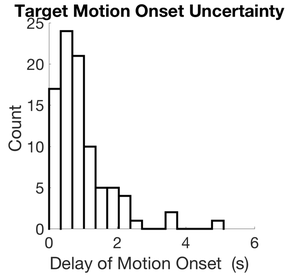
Methods

- 16 healthy participants (8 females, mean age ± SD = 25.6 ± 3.1 years) with normal or corrected-to-normal visual acuity.
- 2-day study where, on a given day, subjects consumed one of two possible doses of ethanol (40% ABV Vodka mixed with juice; targeting either 0.06% or 0.02% peak BAC), with 3 pre-dose and 6-9 post-dose ocular tracking tests using a 5 minute Rashbass-like task (Krukowski & Stone, 2005).

Speed & Directional Uncertainty

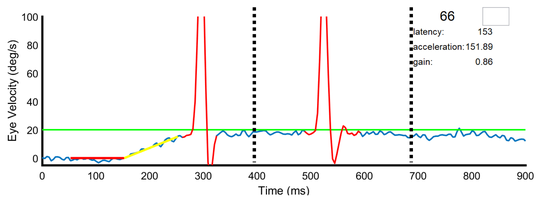


Target Motion Onset Uncertainty



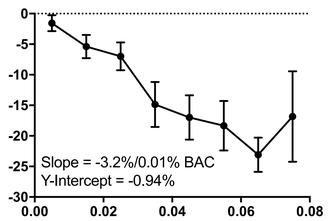
- We then computed 6 largely independent measures of pursuit and saccadic performance in a steady-state analysis interval, 400-700 ms after target motion onset (Liston & Stone, 2014).

Example Trial

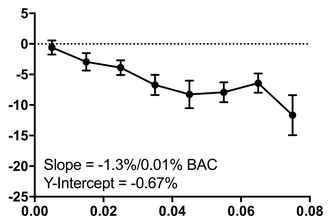


Pursuit Behavior

Steady-State Gain



Proportion Smooth



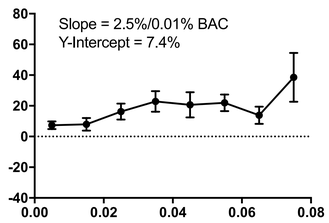
%Δ from Baseline

Blood Alcohol Concentration (%)

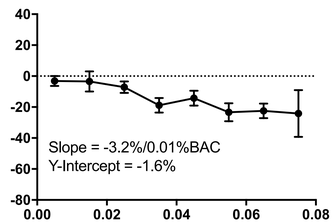
- Steady-state gain and proportion smooth was compromised above 0.01% BAC (linear regression: both $p < 0.0001$, and x-intercepts: 0.003% BAC and 0.002% BAC).
- Gain loss causes ~1.1 deg of "lost ground" in steady-state for the 0.065% BAC bin.

Saccade Behavior

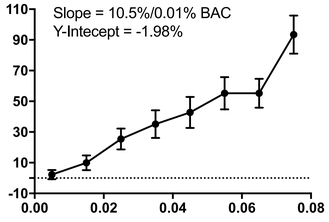
Rate



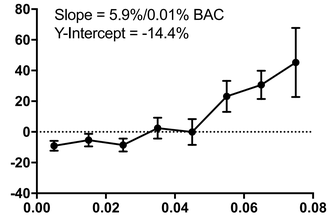
Peak Velocity - Slope



Amplitude



Peak Velocity - Intercept



%Δ from Baseline

Blood Alcohol Concentration (%)

- Saccades became larger and more frequent (linear regression: $p < 0.0001$ and $p < 0.003$).
- Saccades gained back, on average, 0.9 deg (~80%) of the lost ground.

- Main sequence was disrupted with peak velocity increasingly less sensitive to changes in amplitude with increasing BAC (linear regression: $p < 0.0002$ and $p < 0.0001$).

Conclusions

- A high-uncertainty tracking task revealed that the smooth pursuit system is highly sensitive to BAC, with impairment extrapolating back to BAC levels at or below 0.01%.
- This cannot be explained by subjective, non-BAC effects of alcohol consumption.
- The results suggest that ethanol consumption generates a dose-dependent increase in reliance on the saccadic system, which compensates for up to 80% of the lost ground at ~0.065% BAC, albeit with a significant decrease in smoothness.

References

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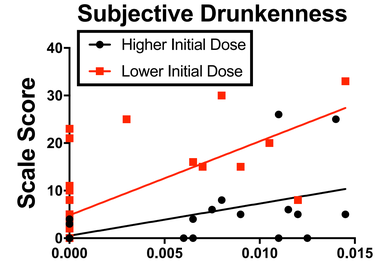
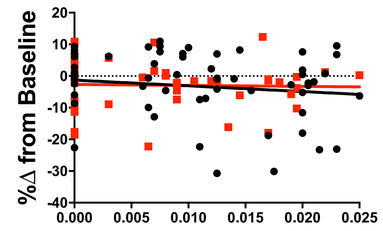
Controls

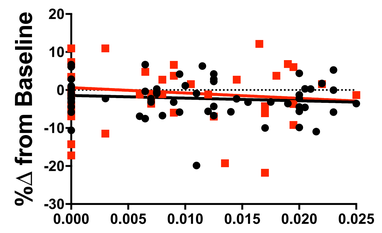
Subjective Drunkenness



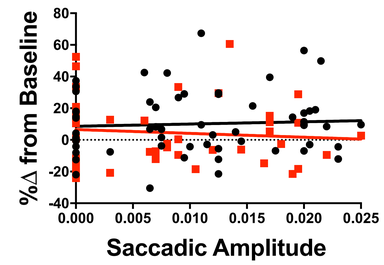
Steady-State Gain



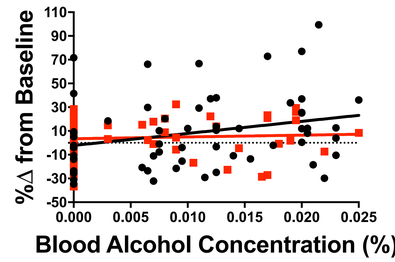
Proportion Smooth



Saccadic Rate



Saccadic Amplitude



Blood Alcohol Concentration (%)

There was a significant non-BAC effect of initial dose size on subjective drunkenness (different slopes, $p < 0.03$), but non-BAC effects on slope and intercept did not reach significance for any of the 6 objective performance measures ($p > 0.17$). Data from peak velocity metrics not shown.