A Novel Paradigm for Identifying Eye-Tracking Metrics Associated with Cognitive Control During Driving Through MEG Neuroimaging

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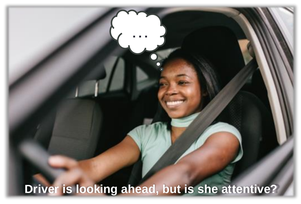
Introduction

- *Inattention* a leading cause of crashes for young drivers.
  (Curry et al., 2011; Lestina & Miller, 1994; McKnight & McKnight, 2003; Seacrist et al., 2021)
  - Attributable to limited frontal-lobe cognitive abilities that are *still developing* throughout adolescence (Satterthwaite et al., 2013)
- External distractions are easier to detect with driver monitoring
- Cognitive inattention more difficult
  - *"Look but do not see"*



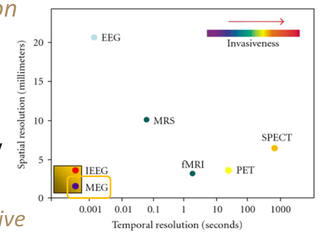
- **Need to identify metrics that indicate top-down cognitive control during driving**
  - Identify *absence* of cognitive control during safety critical events

Objectives

- Demonstrate the utility of MEG neuroimaging to identify eye-tracking metrics that proxy periods of increased cognitive control during driving

Magnetoencephalography (MEG)

- Magnetoencephalography (MEG) is *non-invasive* and exhibits *high spatial* and *temporal resolution*
  - Identify frequency-specific and precise location of brain activity
- Use to identify periods of elevated *frontal midline theta* (FMT) activity (3-9 Hz) during driving
  - FMT an established *marker of cognitive control* over behavior (Callaghan et al. 2017)



MEG + Eye-Tracking + Driving

- Participants seated in a CTF-Omega 275 Channel MEG (600 Hz)
  - Included MEG-compatible eye-tracker (SR Research EyeLink 1000; 1000 Hz) and driving hardware (Current Designs, Inc.)

Methods

POPULATION

- Typically developing adolescents (12-17 yrs) were recruited.

Population Demographics

	n	Age	Sex
Participants	11	15.1 ± 1.5 yrs	4 Female 7 Male

SIMULATED DRIVE

- Participants drove a *Basic Braking Task*, designed to elicit increased FMT activity when actively braking for the red light.
  - Repeated for 20 trials

Drive begins with a 9 sec *Rest* period.

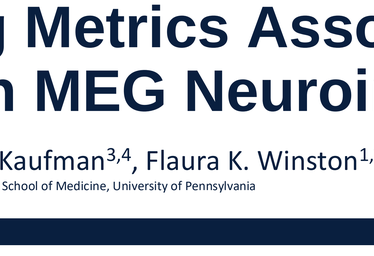
Begins at red light, awaiting green light.

Proceed straight to next intersection.

Come to a stop at next red light.

DATA ANALYSIS

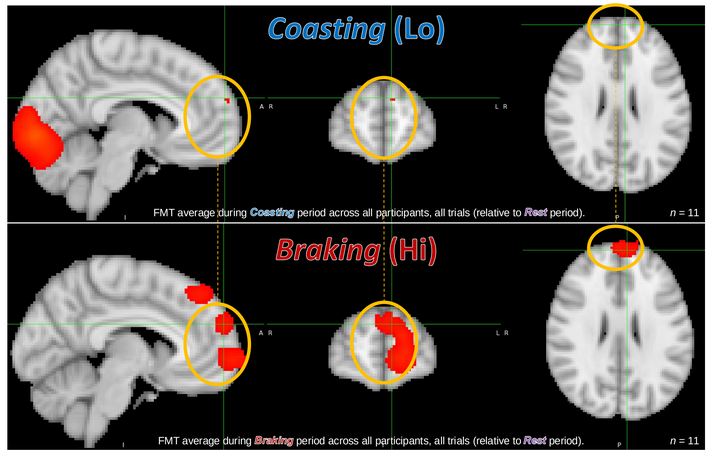
- FMT and eye-tracking metrics compared between:
  - ***Coasting*** – 4 sec of steady-state driving, requiring minimal (Lo) top-down cognitive control
  - ***Braking*** – 4 sec of active braking at red light, requiring elevated (Hi) top-down cognitive control
- Eye-tracking metrics compared between *Coasting* (Lo) and *Braking* (Hi) using paired t-tests



Walshe et al. (2023) *Human Brain Mapping*

Results – Neuroimaging

Frontal Midline Theta (FMT) Activity During *Coasting* and *Braking*



- Increased FMT was observed during *Braking* (Hi), relative to *Coasting* (Lo)

Results – Eye-Tracking

Mean (±SD) Eye-Tracking Metrics Between *Coasting* and *Braking*

Metric	Unit	*Coasting* (Lo)	*Braking* (Hi)	*p*-value
Fixation Count	#	12 ± 3	10 ± 4	0.02
Fixation Duration	ms	339 ± 125	429 ± 146	0.06
Mean Gaze (Horizontal)	pxls	839 ± 55	932 ± 72	0.00
Mean Gaze (Vertical)	pxls	738 ± 58	652 ± 100	0.00
Spread of Search (Horizontal)	pxls	160 ± 33	147 ± 59	0.46
Spread of Search (Vertical)	pxls	174 ± 24	147 ± 38	0.04

- Drivers exhibited *narrower* vertical spread of search during *Braking* (Hi)
  - Indicative of narrower, more focused scanning
- Higher vertical *mean gaze* and lower *fixation count* during *Braking* (Hi)
  - Focused on traffic signals and intersection ahead; less on speedometer

Exemplar Scan Paths During *Coasting* (Lo) and *Braking* (Hi)

- Exemplar scan path from a single driver, single trial during *Coasting* (Lo) (left) and *Braking* (Hi) (right)
  - Circles represent fixations; diameter proportional to duration

Conclusions

- Findings suggest that *eye-tracking metrics may be a useful proxy for periods of cognitive control* during driving.
- Data will help OEMs optimize driver monitoring to *detect absence of top-down cognitive control* in real-time.

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