In-Vehicle Work Zone Messages

Presented by

Curtis M. Craig & Jacob Achtemeier

Introduction

- Work Zones
  - Heightened risk to drivers and crew

- Questions
  - General issues in work zones
  - Driver attitudes toward work zones
    - And cell phone use
  - Will in-vehicle messages help?

Outline

- Literature Review of Work Zone Behavior
- Safety Culture Survey
- Design of In-Vehicle Messages
- Driving Simulation Study
- Take-Away Message

Literature Review

- Environmental Risks in Work Zone crashes
  - 78% of work zone crashes in Minnesota occur during daytime and clear weather conditions
  - Rural and local roads with a high speed limit
  - Perceived safety elicits riskier driving
    - “It’s safe, so I don’t have to be careful”
    - Safer roads, conspicuous work zones and barriers
  - Variable speed limit signs better than static signs

Literature Review

- Driver Behavior in Work Zone crashes
  - Teens and older drivers pose the most risk as a group, men riskier than women overall
    - Varies by work zone type
  - Older vehicles and trucks
  - Alcohol and impairment, inattention, speeding
  - 40-57% of crashes occur in activity area, rear-end and side-swipe crashes in advance and transition
  - Drivers tend not to obey artificially low speed limits

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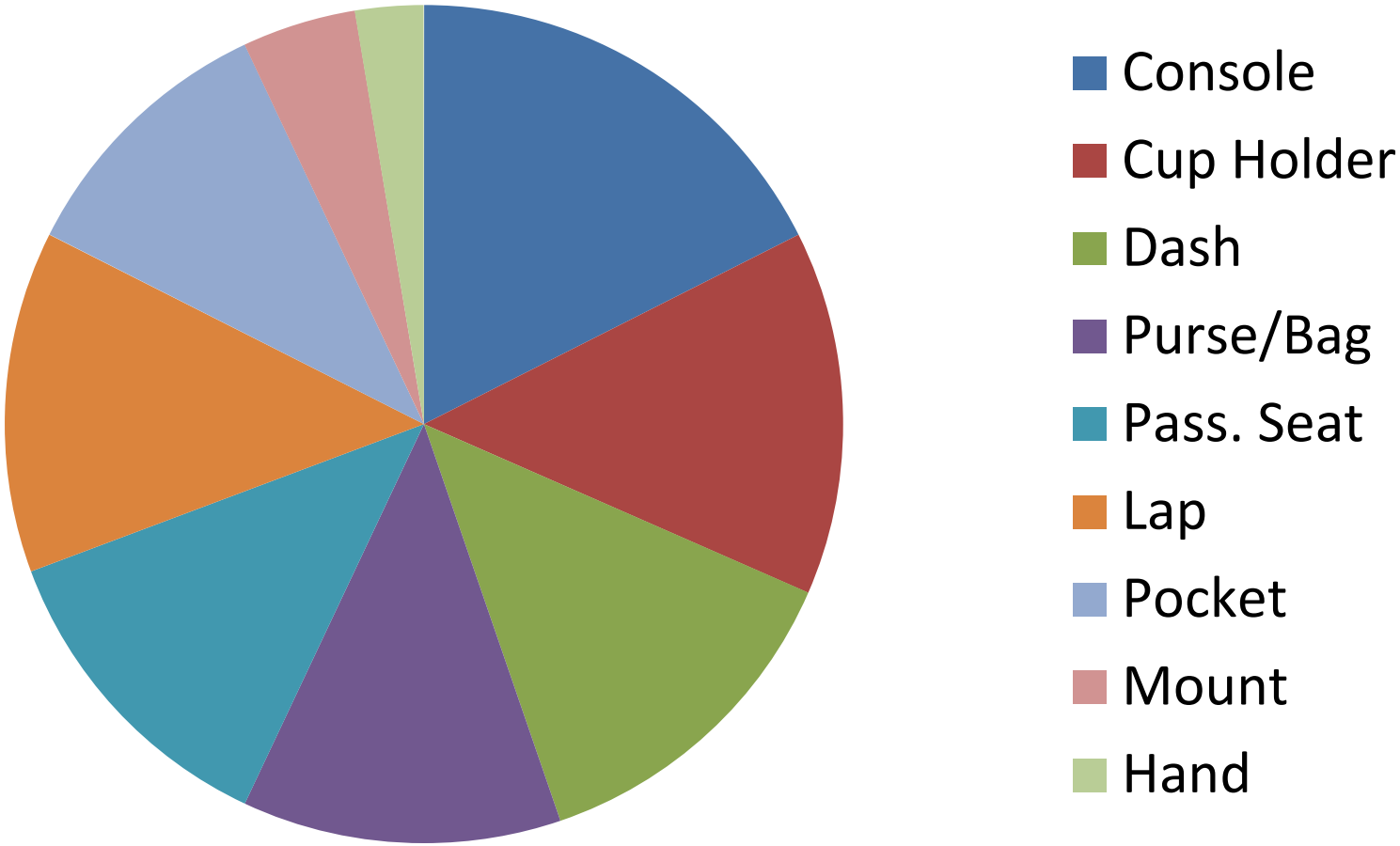
Safety Culture Survey

- Goals
  - Identify driver use, outlook on driving with phones
  - Examine safety culture within Minnesota
- Procedure and Method
  - 46 questions on safety culture and technology use
  - Eligible participants (97 drivers)
    - 18 years of age or older
    - lived in Minnesota
    - held a valid driver's license

Safety Culture Survey

- Summary of Results
  - Drivers open to a work zone smartphone app
    - 20% had no reservations
    - 42% open but wanted issues with distraction ironed out
  - Drivers with less patience with work zones
    - Distrust road signs and rely on other drivers for cues
    - More open to a smartphone app
  - Drivers that care more about work zone safety
    - Attend to sign information and less on other drivers
  - Drivers more anxious or uncomfortable in work zones
    - Less confident in signage, but more open to smartphone app

Phone Placement Location



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In-Vehicle Message Design

- Auditory Guidelines
  - Minimize annoyance
  - Choose appropriate timing and word choice
  - Urgency (e.g., female voices)

- Visual Guidelines
  - Redundant color coding
  - No distractions

In-Vehicle Message Design

- In-Vehicle Messages (United Nations, 2010)
  - Distinguishable from all other stimuli
  - Avoid a startling response
  - Coupling warning tones and speech is not advised
  - Synthetic speech is recommended
  - 15-25 dB above cabin noise

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Driving Simulation Study

- Directly test whether in-vehicle messages can promote safer driving behavior in work zones
  - Compared to PCMS, road side signs

- Driving simulation with 2 work zone types
  - Mock-up in-vehicle smartphone messages
  - Consider
    - Driving performance, gaze/eye-tracking, mental demand and user friendliness, driver preference

Design and Method

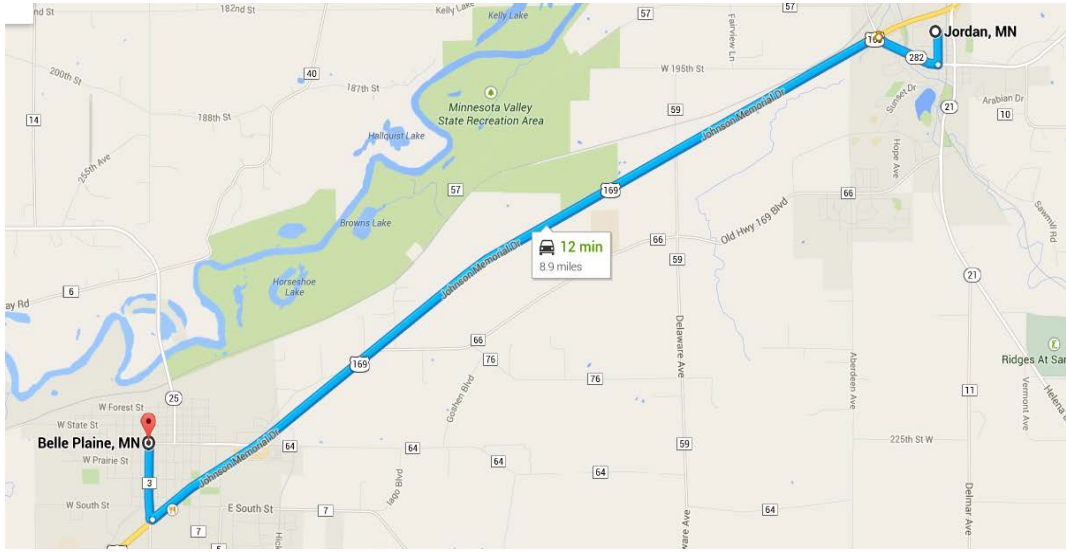
- Work Zone Messaging
  - Roadside messages
    - Portable Changeable Message Signs (**PCMS**)
  - In-vehicle messages
    - **Audio-Visual & Audio-Only** conditions
    - 7-inch LCD display, placed on either **Dashboard** or **Passenger Seat**
      - With visual icon in **Audio-Visual** condition
      - Blank with audio for **Audio-Only** condition

Messaging Example

Message Placement	Audio-Only Message	Audio-Visual Message (Icon displayed)	PCMS
Mile Marker 1.25 **Introductory Drive (Before Transition Zone)**	"Work Zone Ahead" "Half Mile" "Reduce Speed"		

Design and Method

- Simulated work zone routes
  - 9.2 miles based off of segment of MN US Hwy 169
  - 2 drive layouts
    - **Northbound** shoulder work, **southbound** lane closure



Design and Method

- Participants
  - 48 drivers, 25 men, 23 women, average age 25.3
  - 2 groups, **dashboard** or **passenger seat** placement

- Method
  - Drivers drove the 2 routes, 6 times
    - **Northbound** shoulder work & **Southbound** lane closure
  - Each drive they would experience one of the three work zone event message conditions
    - **PCMS, Audio-Visual, Audio-Only**

Work Zone Events

- Northbound
  - Slow Traffic Ahead
  - Debris in Lane
  - Trucks Entering Roadway
  - Heavy Machinery Ahead
  - Crash Ahead
- Southbound
  - Work Zone Ahead
  - Lane Closure
  - Active Work Zone Ahead
  - Workers Ahead
  - Stopped Traffic Ahead

Measurements

- Driving Performance
  - Average speed, speed deviation, lane deviation
- Subjective Measures
  - Situational Awareness Inventory
  - Rating Scale Mental Effort
  - System Usability Scale
- Visual Attention
  - Four camera eye tracking system (Smart Eye AB)

Driving Performance Results

- Average Speed
  - Southbound (lane closure) **slower** than northbound (shoulder work)
    - Overall
    - During work zone event messages
  - Southbound route may be more challenging for participants

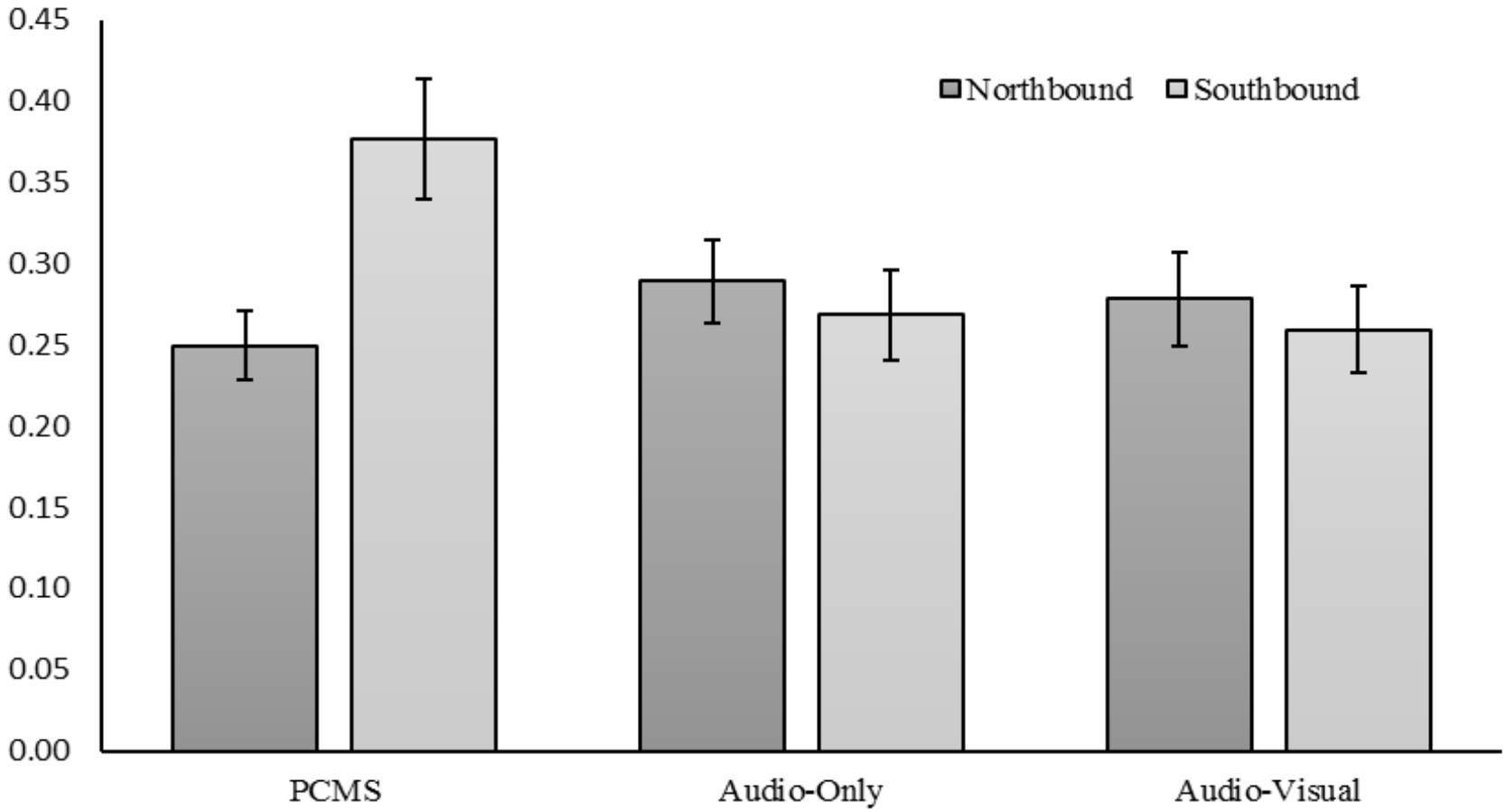
Driving Performance

- Speed Deviation
  - Southbound route had *greater* speed deviation than northbound *overall*, but less speed deviation during event messages
    - Suggests higher mental workload for southbound route
  - During event messages, **PCMS** had ***less*** speed deviation than the **Audio-Visual** and **Audio-Only**
    - Suggests less likely to change speed during PCMS

Driving Performance Results

- Lane Deviation
  - Greater lane deviation ***overall*** for Southbound
    - Drivers must change lanes in Southbound (lane closure)
    - Southbound route may be more mentally demanding
  - During work zone event messages, there was a notable effect on lane deviation

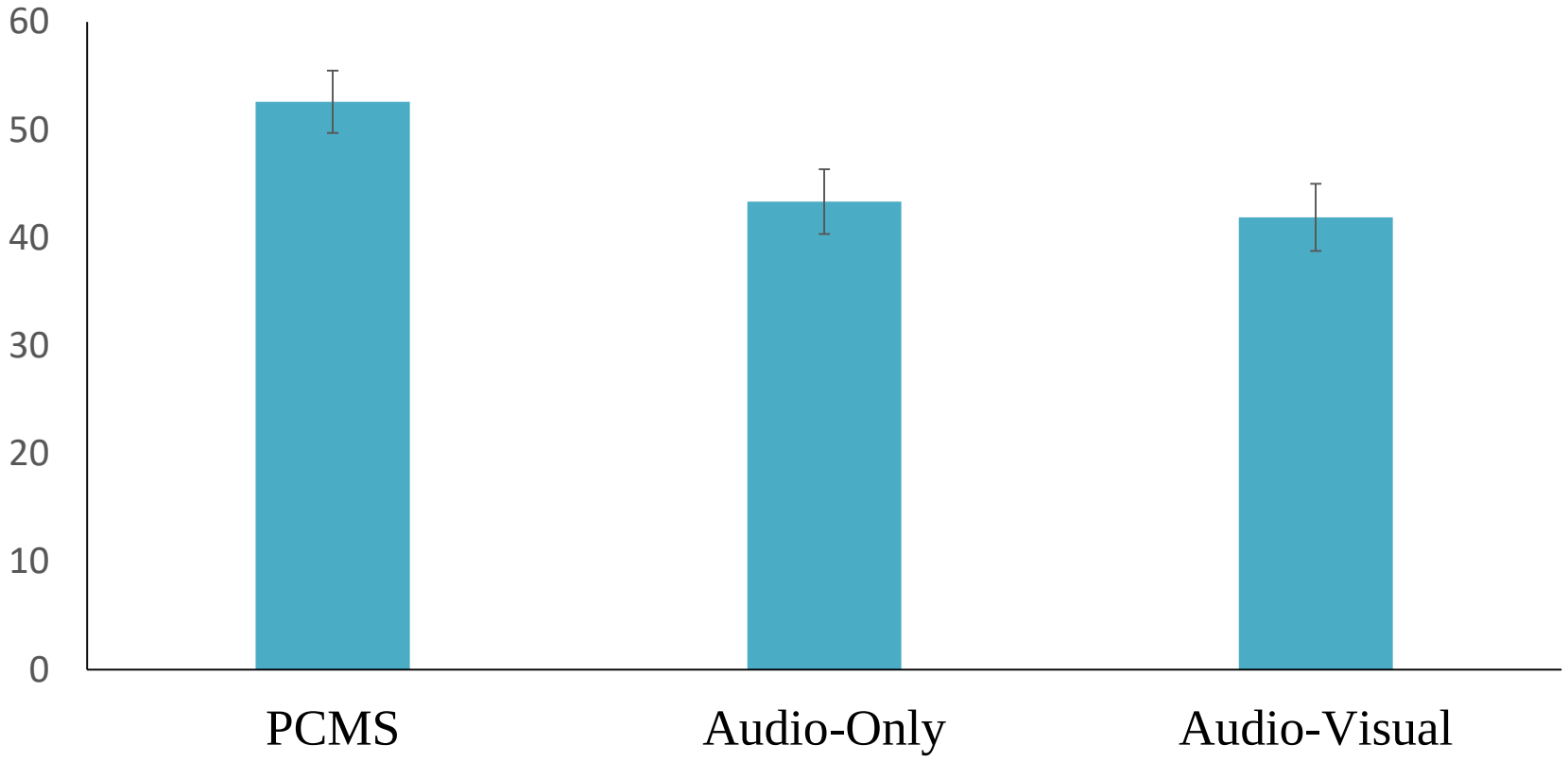
Lane Deviation During Messages



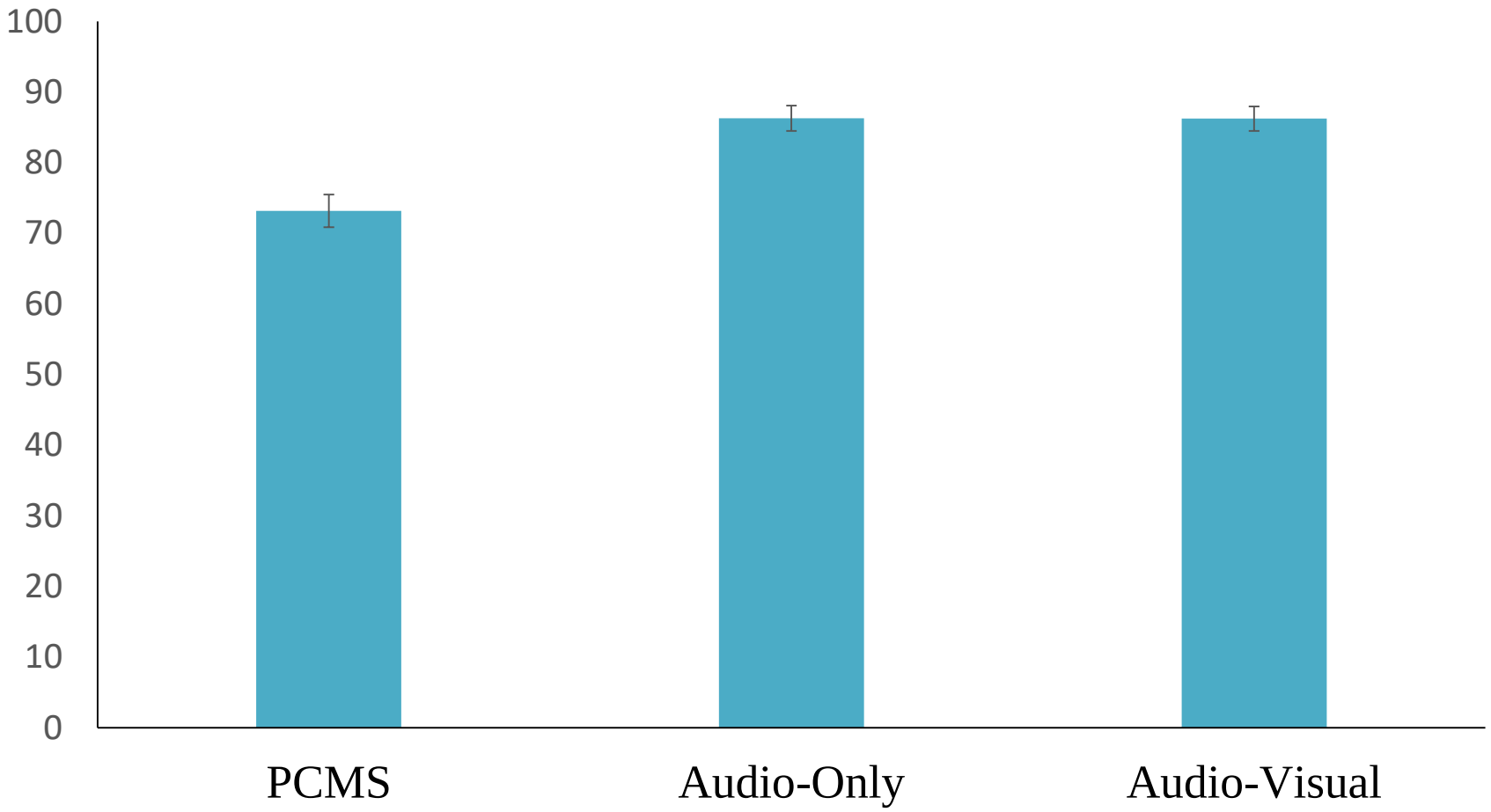
Subjective Measurements Results

- Driver Preference
  - 38 preferred Audio-Only
  - 8 preferred Audio-Visual
  - 2 preferred PCMS

Rating Scale Mental Effort



System Usability Scale



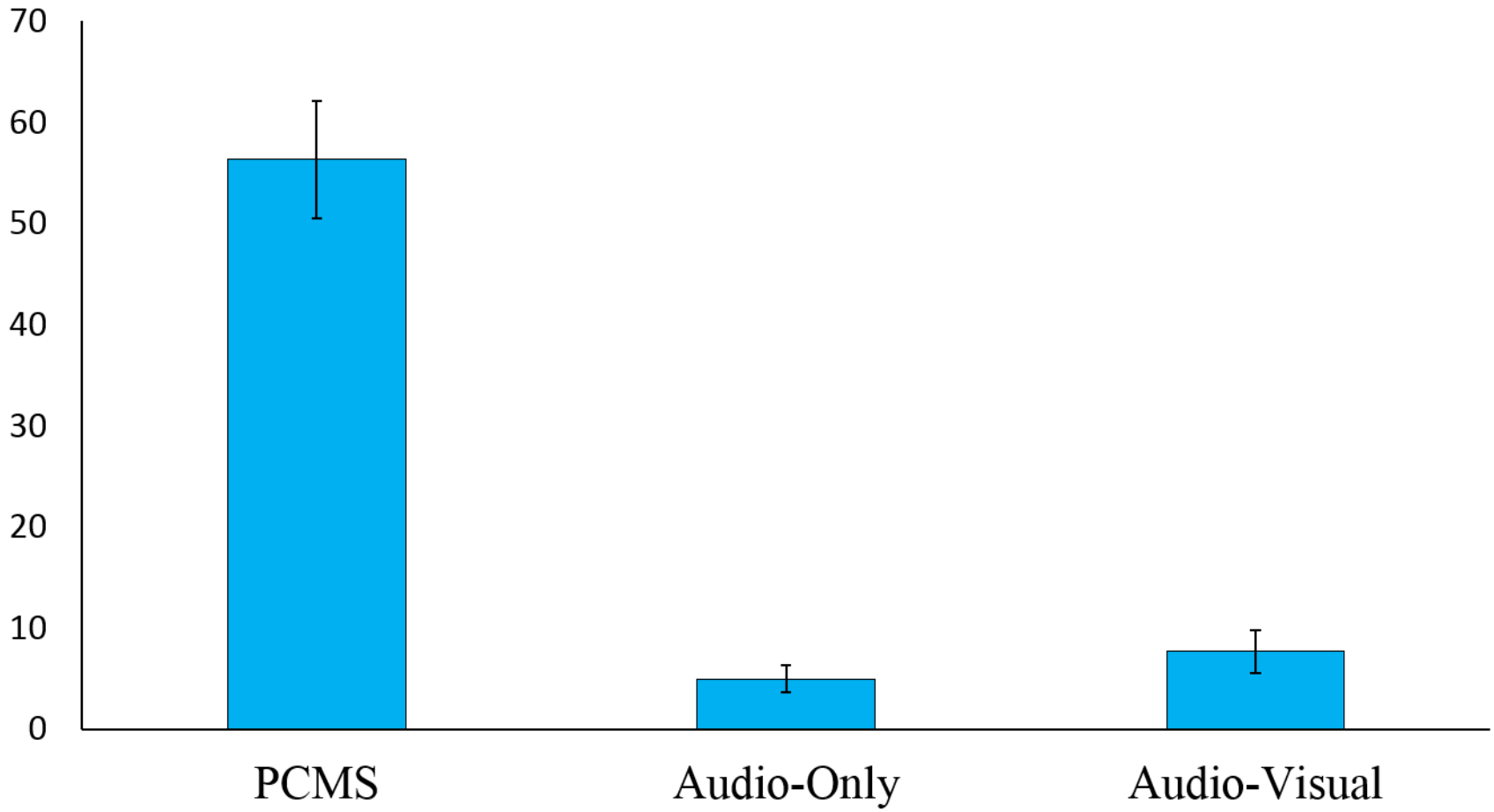
Situational Awareness Inventory

- Recall scores
  - Overall
    - PCMS (.407) **<** Audio-Only (.509)
  - For **passenger seat** placement of in-vehicle interface, on the **southbound** route
    - PCMS (.348) **<** Audio-Only (.530) & Audio-Visual (.522)
    - Task demand and placement as possible explanation

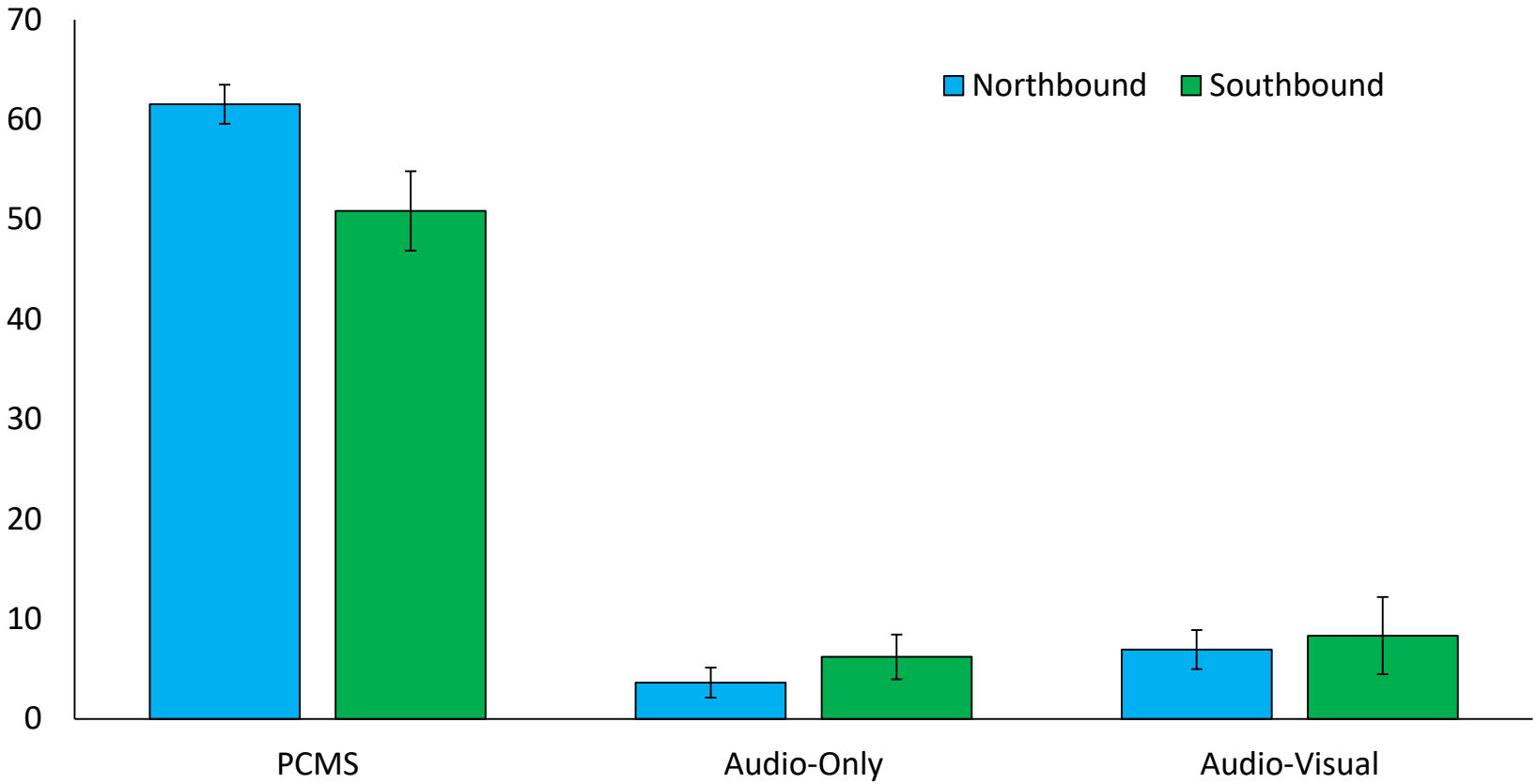
Visual Attention Results

- Primary analysis
  - *Number of fixations on messaging interfaces*
- Potential issues
  - Some data sets excluded or lost from analysis due to technical errors or equipment failure

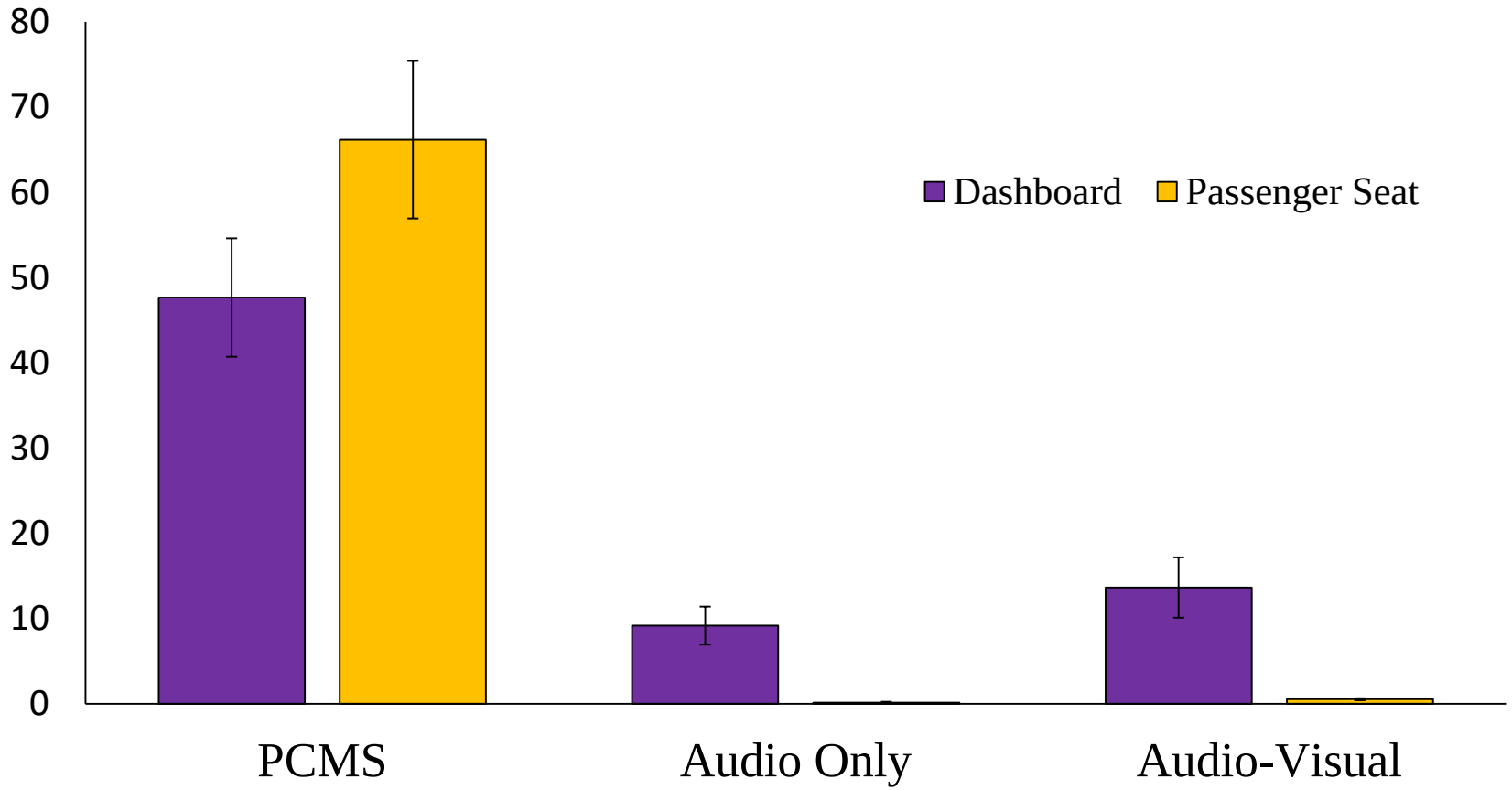
Overall Average Fixations on Interface



Interface Fixation (Route / Modality)



Interface Fixation (Place / Modality)



Driving Simulation Summary

- Driving Performance
  - Better driving performance for in-vehicle messages, worse for PCMS and southbound route
- Subjective Measures
  - Prefer in-vehicle messages (esp. Audio-Only)
  - Less mental workload, better usability and situation awareness for in-vehicle conditions relative to PCMS
- Visual Attention
  - Drivers with PCMS fixate more on signs and take gaze off of road

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Take-Away Message

- Significant **environmental** and **driver behavior** risks in work zones, elevating risk of crash

- Safety survey indicates that drivers
  - Are open to in-vehicle messages, especially if distrustful or uncomfortable around work zones
  - Already carry smartphones in vehicle and have a wide range of placement options

Take-Away Message

- Simulation results suggest **in-vehicle** message systems may be useful for work zone safety
  - Not necessarily distracting if in-vehicle messages are related to driving task
  - Placement does not appear to matter much
    - Non-dashboard placement could even be beneficial
  - In-vehicle messaging advantage may be affected by difficulty of driving task
    - Southbound vs. Northbound

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