

Human-centered solutions to advance roadway safety

Mitigating Risk in Work Zones: Informing Drivers Using In-Vehicle Technology

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In-Vehicle Technology?

- Industry continues toward implementing native infotainment systems
- Average passenger vehicle age: 12 years (USDOT, 2016 data)
- **Smartphones as the *bridging* technology**
 - Increasingly ubiquitous, financially obtainable
 - More equitable across socio-economic continuum




2016 Ford Fusion


Can smartphones convey work zone information as well as or better than conventional signage?



Literature Review

- Environmental Risks in Work Zone crashes
 - 78% of MN WZ crashes occur during day & clear conditions
 - Rural and local roads with a high speed limit
 - Perceived safety elicits riskier driving
 - Static signs are often ignored (especially low speed limits)
 - 40-57% of crashes occur in activity areas, rear-end and side-swipe crashes in advance and transition areas
 - Driver Behavior in Work Zone crashes
 - Varies by work zone type
 - Teens and older drivers pose the most risk as a group
 - Men riskier than women overall
 - Older vehicles and trucks
 - Alcohol and impairment, inattention, speeding
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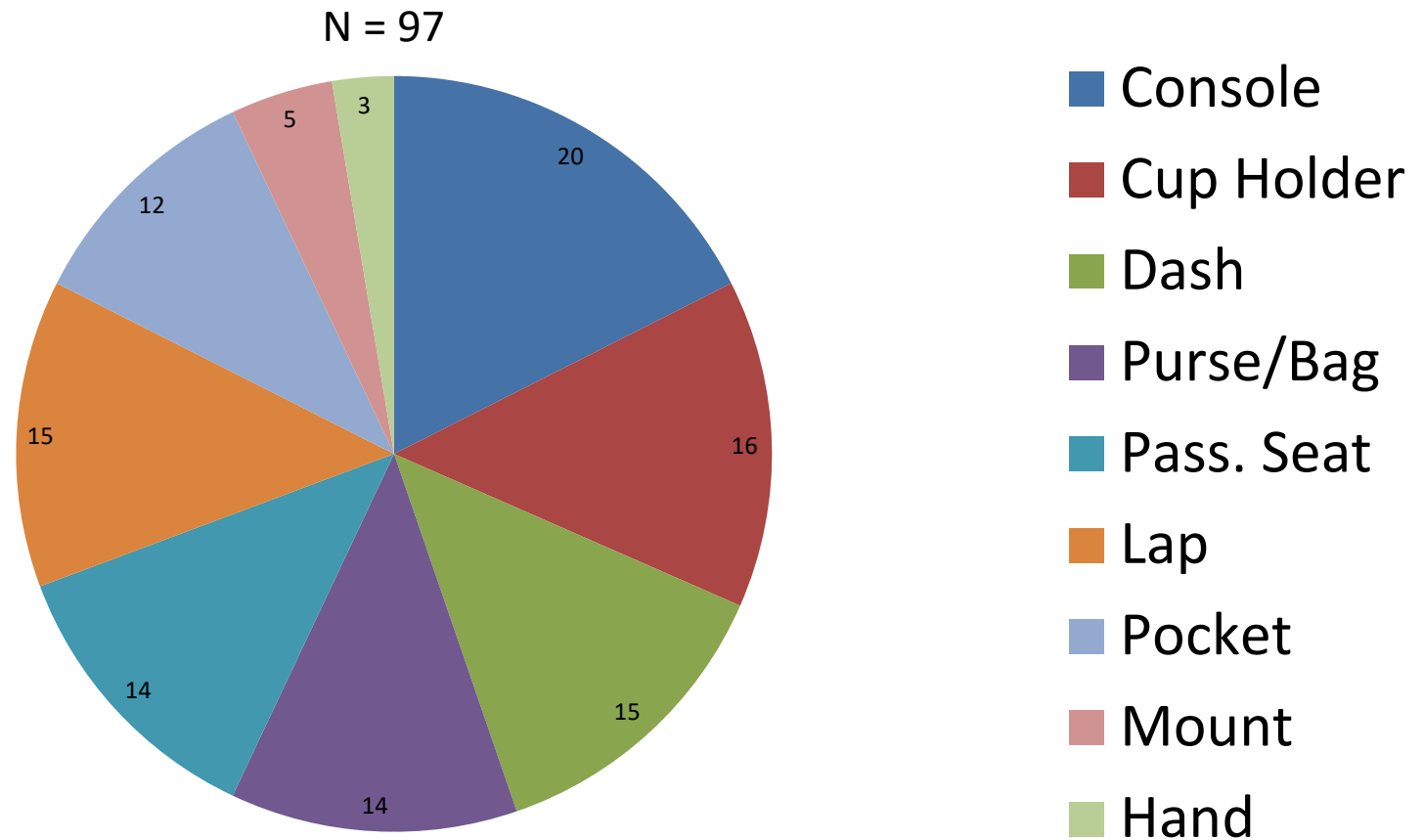
Safety Culture Survey

- Goals
 - Identify driver use, outlook on driving with phones
 - Examine driving 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
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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 more concerned 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


Drivers' Phone Placement Location





In-Vehicle Message Design

- Auditory Guidelines
 - Minimize annoyance
 - Choose appropriate timing and word choice
 - Urgency (e.g., female voices)
 - Visual Guidelines
 - Redundant color coding
 - Limit distractions
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Design and Method

- Work Zone Messaging
 - Roadside: Portable Changeable Message Signs (**PCMS**)
 - 2 In-vehicle messages
 - **Audio-Visual & Audio-Only** conditions
 - Message Placement
 - **Dash & Passenger Seat**
 - Driving simulation with 2 work zone types
 - Lane Closure & Shoulder Work
 - Metrics
 - Driving performance, eye-tracking, mental workload
 - Usability, user friendliness, driver preference
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Work Zone Messaging Example


Message Placement	Audio-Only Message	Audio-Visual Message (Icon displayed)	Portable Changeable Message Sign (PCMS)
<p>Mile Marker 1.25</p> <p>Introductory Drive (Before Transition Zone)</p>	<p>“Work Zone Ahead”</p> <p>“Half Mile”</p> <p>“Reduce Speed”</p>		

*Exposure time consistent for PCMS, in-vehicle messages

Design and Method

- Participants
 - 48 drivers, 25 men, 23 women, average age 25.3
 - 2 groups, **dashboard** or **passenger seat** placement
 - Dashboard per best practices, passenger seat to reflect drivers' phone placement locations
- Method
 - Participants drove the 2 routes, 6 times
 - Shoulder work & Lane closure
 - Each drive they would experience one of the three work zone event message conditions
 - **PCMS, Audio-Visual, Audio-Only**

Work Zone Events

- Shoulder Work
 - Slow Traffic Ahead
 - Debris in Lane
 - Trucks Entering Roadway
 - Heavy Machinery Ahead
 - Crash Ahead
 - Lane Closure
 - Work Zone Ahead
 - Lane Closure
 - Active Work Zone Ahead
 - Workers Ahead
 - Stopped Traffic Ahead
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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)
 - Glances, or fixations, to road events and message source

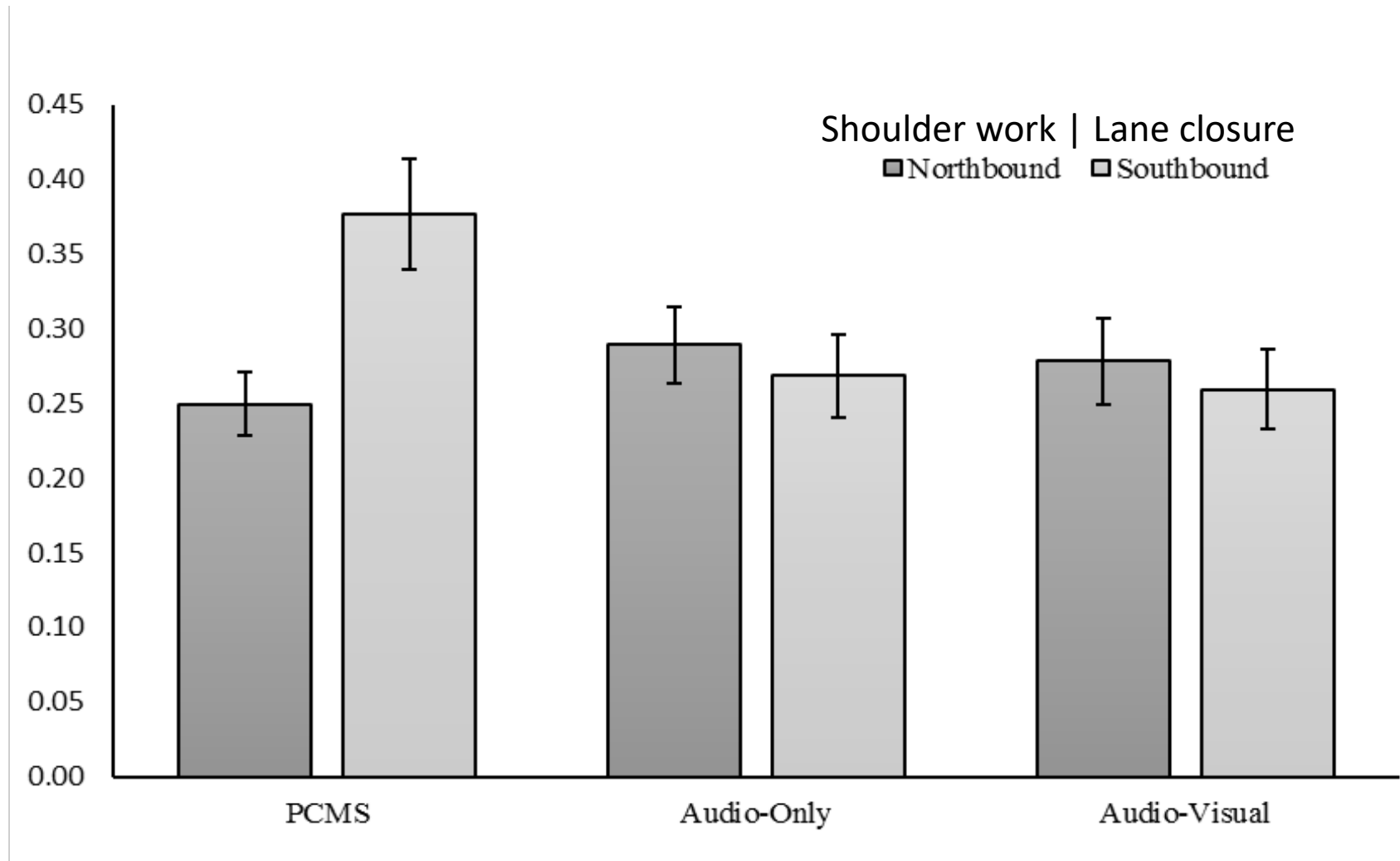
Driving Performance Results

- Average Speed
 - Lane closure **slower** than shoulder work
 - Overall
 - During work zone event messages
 - Lane closure route may be more challenging for participants

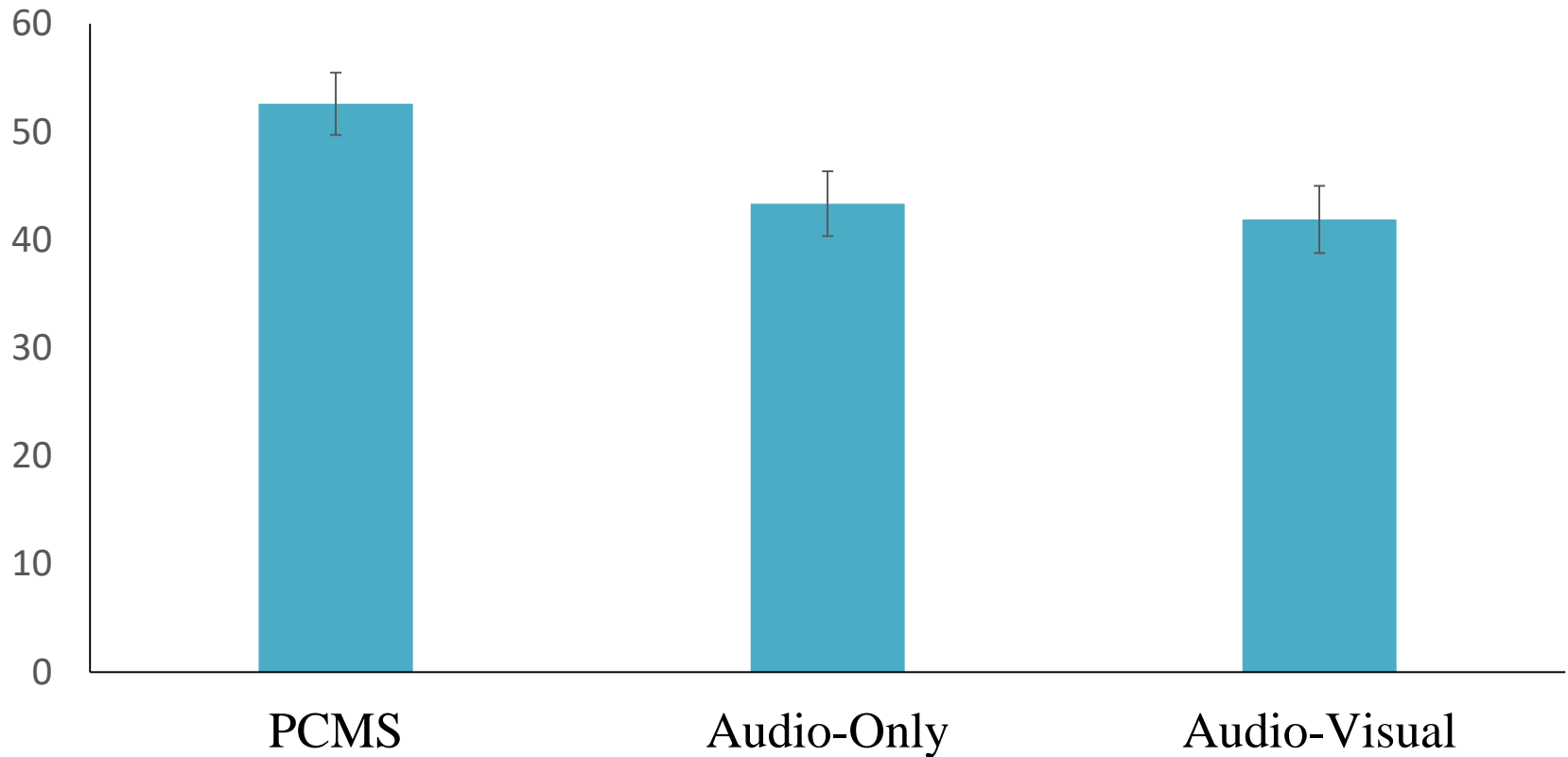
Driving Performance

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

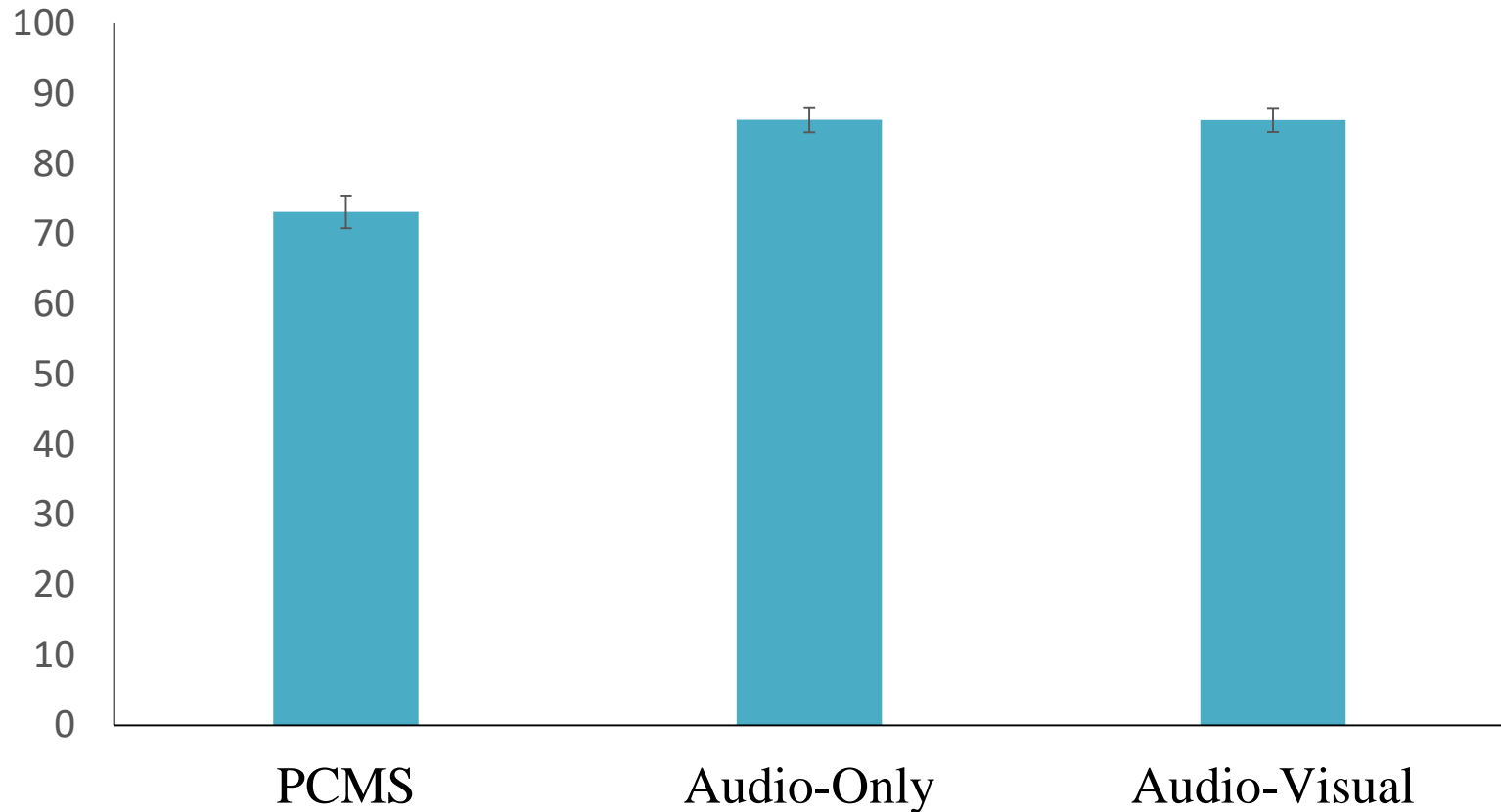
Lane Deviation During Messages



Rating Scale Mental Effort



System Usability Scale

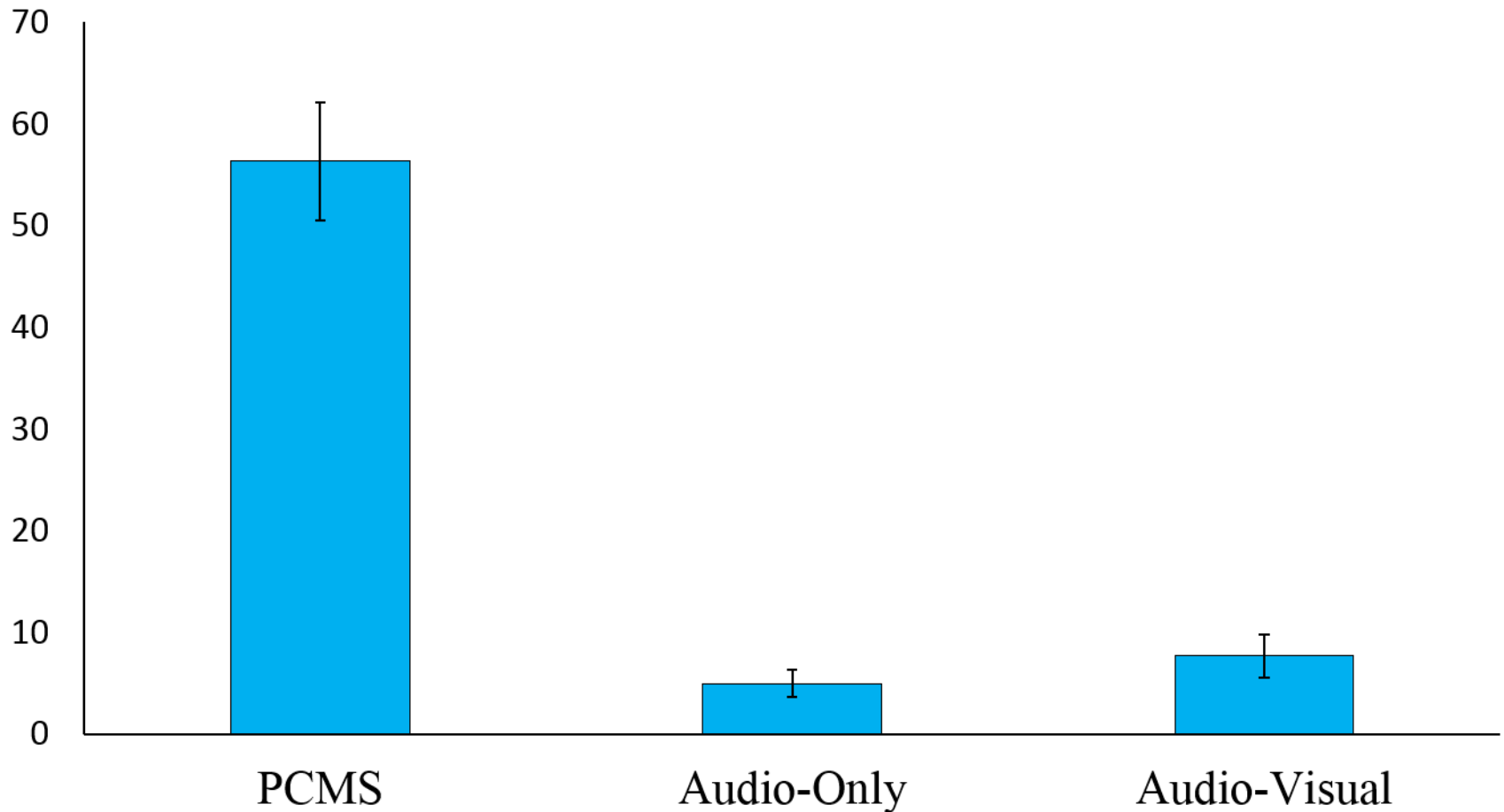


Number of Participants who Preferred System		
2	38	8

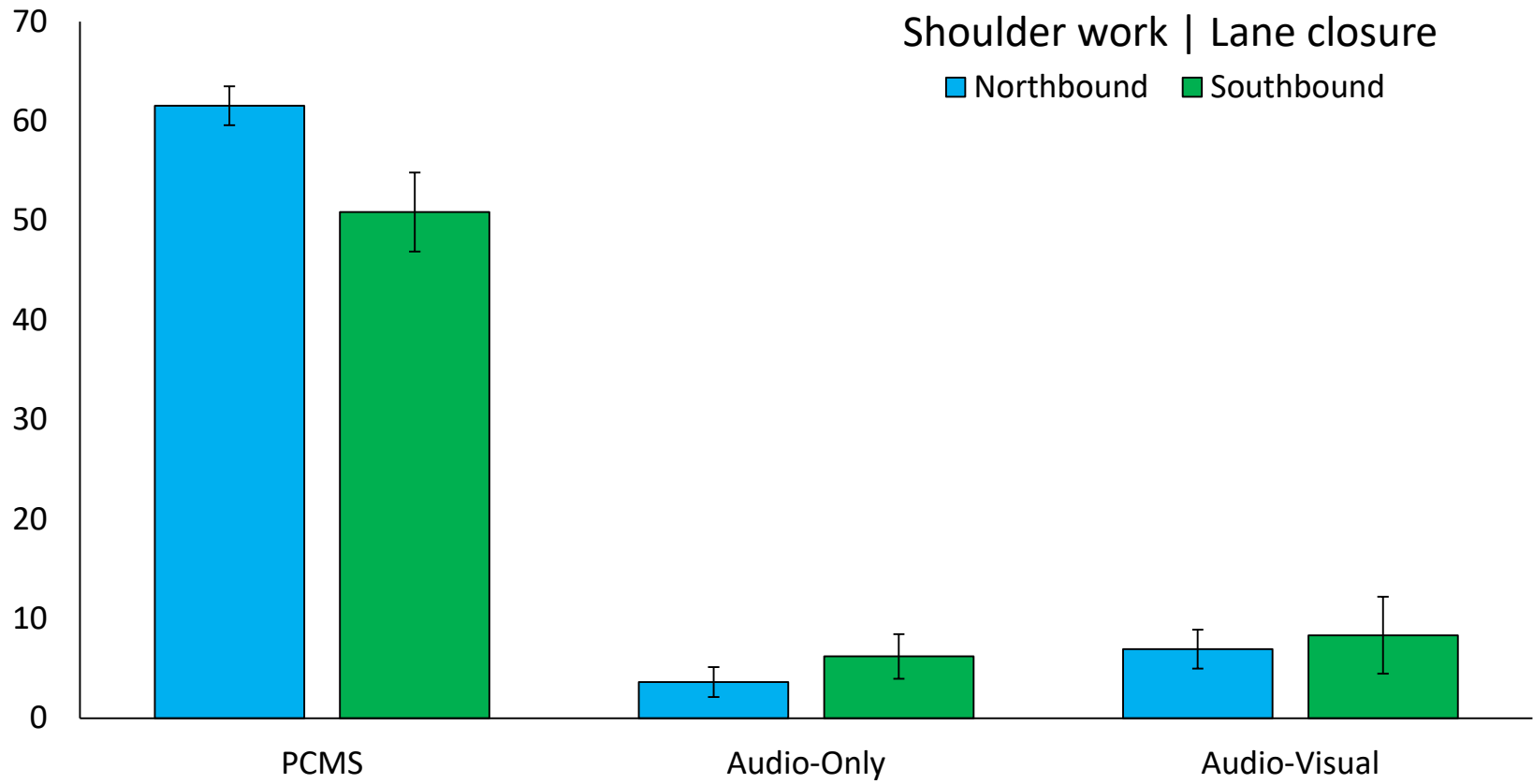
Situational Awareness Inventory

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


Overall Average Fixations on Interface



Interface Fixation (Route / Modality)



Driving Simulation Summary

- Driving Performance
 - Better driving performance for in-vehicle messages, worse for PCMS and lane closure 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

- Safety survey indicates that drivers
 - Are open to in-vehicle messages, especially if distrustful or uncomfortable around work zones
 - Simulation results suggest **in-vehicle** message systems may be useful for work zone safety
 - Not found to be distracting if in-vehicle messages are related to driving task
 - Placement does not appear to matter much
 - Non-dashboard placement could even be beneficial
 - The more difficult driving scenario, the more effective the in-vehicle messages
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