Watch out! Integrating Theory and Practice in Studies of Collision Perception

Patricia R. DeLucia
Psychological Sciences
Rice University

[Click here to start video](https://www.youtube.com/watch?v=IDeSYEeywNk)

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https://www.youtube.com/shorts/KcFUlGokEkQ?feature=share

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https://www.reddit.com/r/IdiotsInCars/comments/9nu62n/terrifying_near_miss_headon_collision_captured_by/

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https://www.youtube.com/watch?v=SujIf7WWilU

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From Benjamin Wolfe's Road Hazard Stimuli #167 osf.io/mkqys

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From Benjamin Wolfe’s Road Hazard Stimuli #142 osf.io/mkqys

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https://www.youtube.com/watch?v=yKvu63qXSp8

Creating and Avoiding Collisions

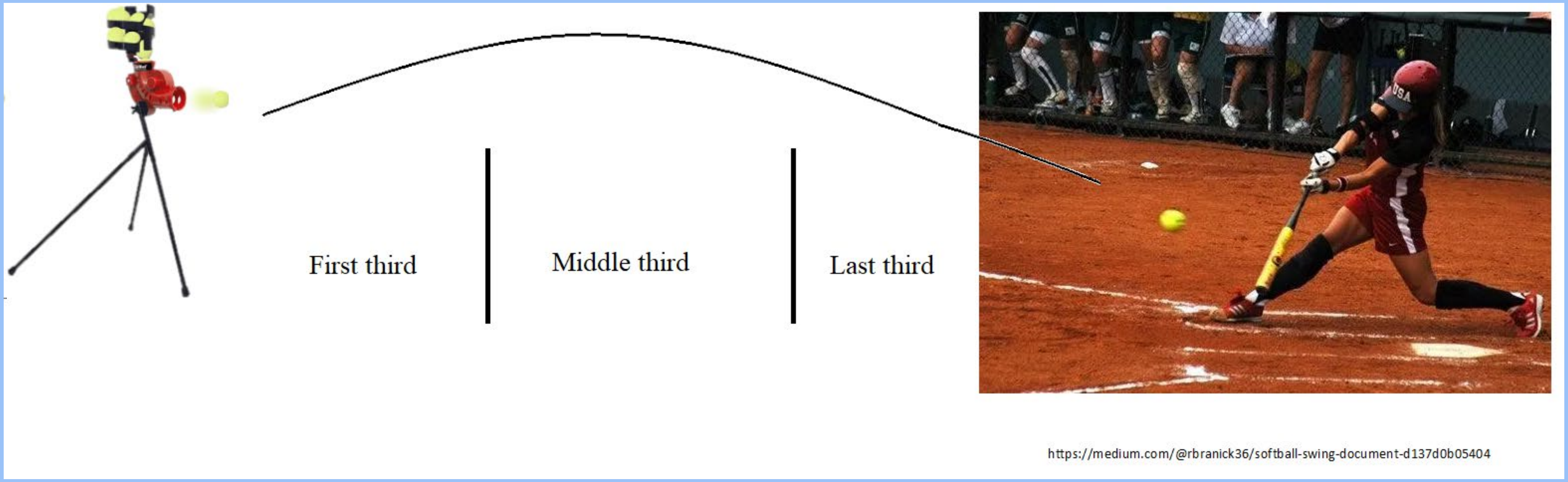
- How are these actions achieved?
  - Collision detection
  - Time-to-collision estimation
  - Action
- Perception of depth and time-to-collision
  - How do people perceive depth and collision?
  - What practical implications does this have for collision avoidance in the real world?

Keep your eye on the ball!

- How fast can the eyes move?
- Can batters track a ball moving at 95 mph?
  - Do they?
  - Maybe this is not necessary?

(DeLucia & Cochran, 1985)

Batting with Occluded Views



(DeLucia & Cochran, 1985)

Batting with Occluded Views

Blocked Portion	Mean % Hits
Baseline 1	79
First third	69
Middle third	57
Last third	65
Baseline 2	77

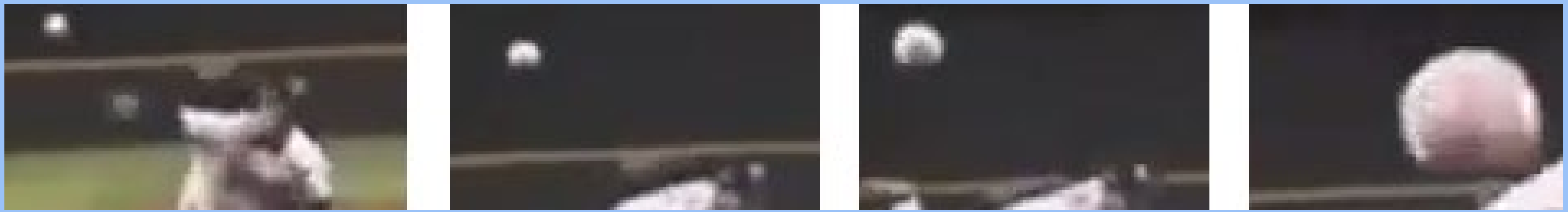
What information were batters getting?

(DeLucia & Cochran, 1985)

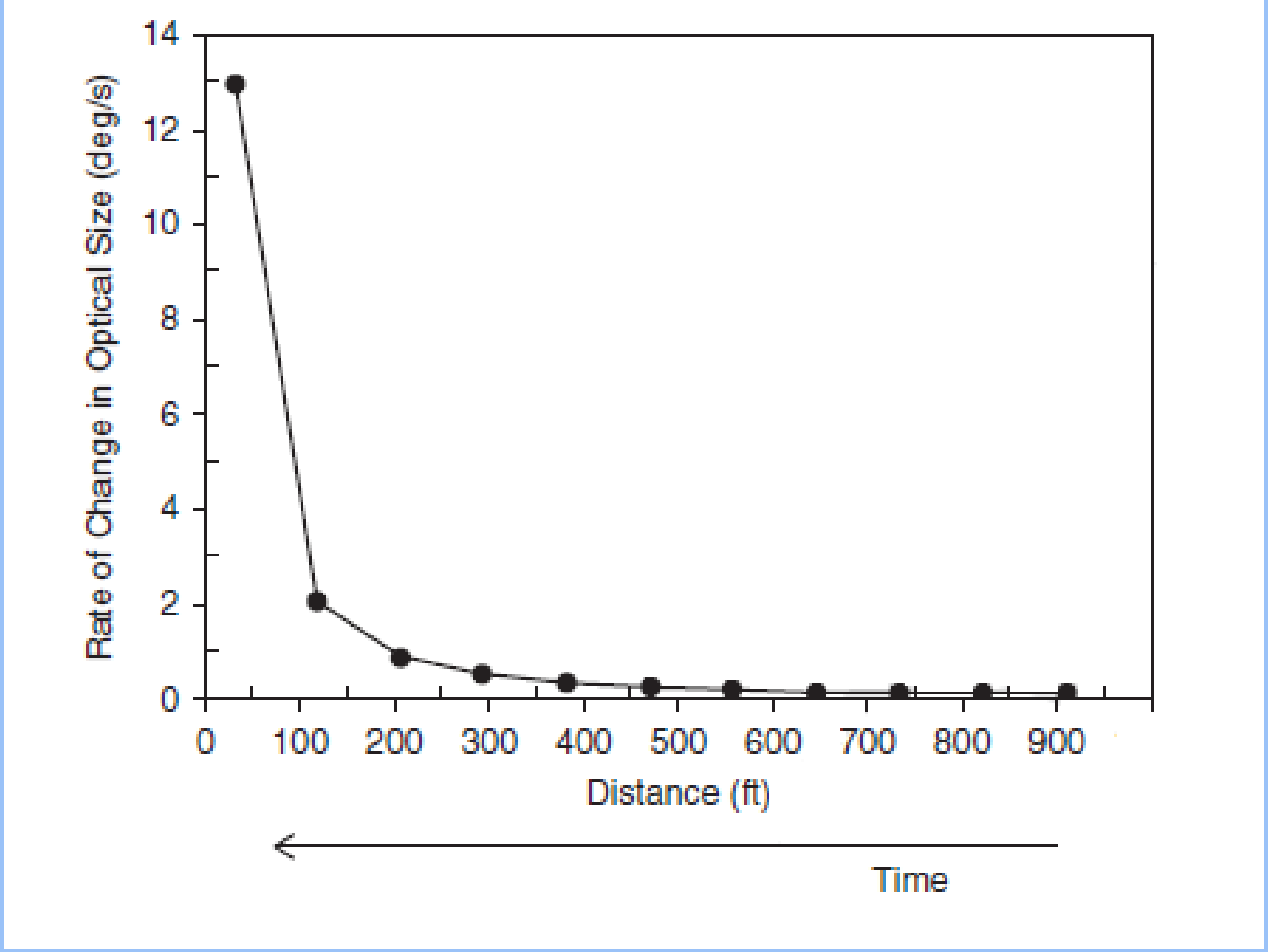
Click here to start video

https://www.youtube.com/watch?v=0Ss0bHdE1Lk

Ball's Optical Expansion



Optical Expansion or Looming Curve



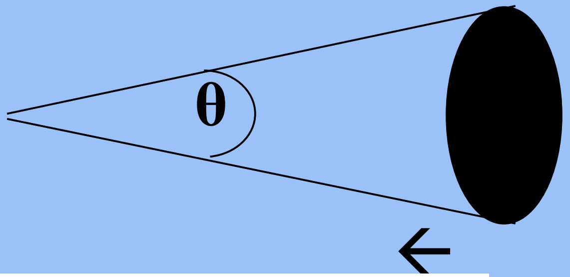
C:\cdpsdemos\cdpsloom\winjul5.exe loom.ord

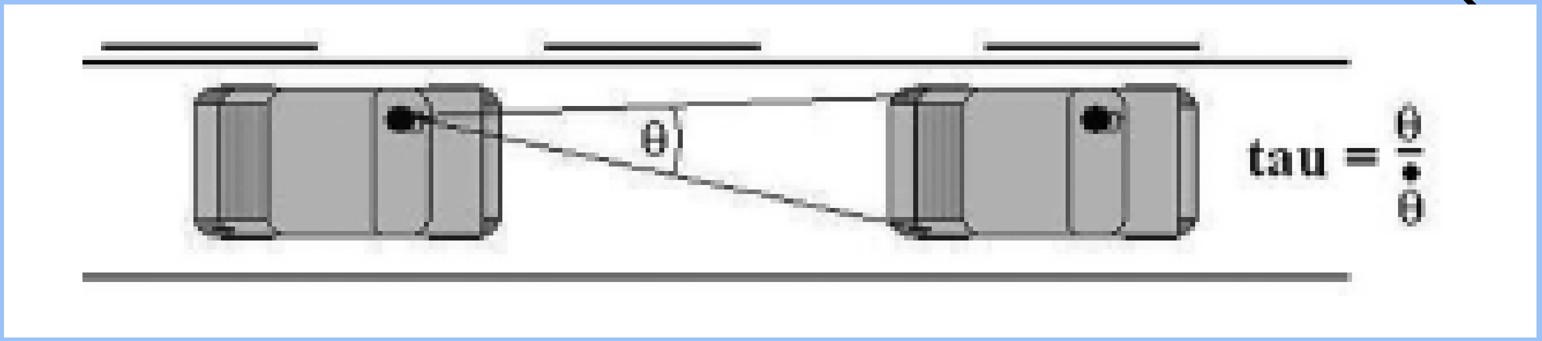
Time-to-collision (TTC), Tau

- In 3D space: TTC= Distance/Velocity
- Tau does not require perceptual estimates of distance or velocity
  - Sample optical size at two points in time

- Tau = $\frac{\theta}{\dot{\theta}} = \frac{\text{optical size}}{\text{rate of expansion}}$

Eye





Lee (1974, 1980)

What information is USED?

- Is tau used?
  - What if other information also is available?
  - What if they contradict each other?

Pictorial Depth Cues

- Patterns in retinal image associated with objects' 3D locations
  - Example: Relative Size Cue: closer objects result in larger retinal images than farther objects of the same 3D size
- Can be considered heuristics
- Less reliably accurate than tau

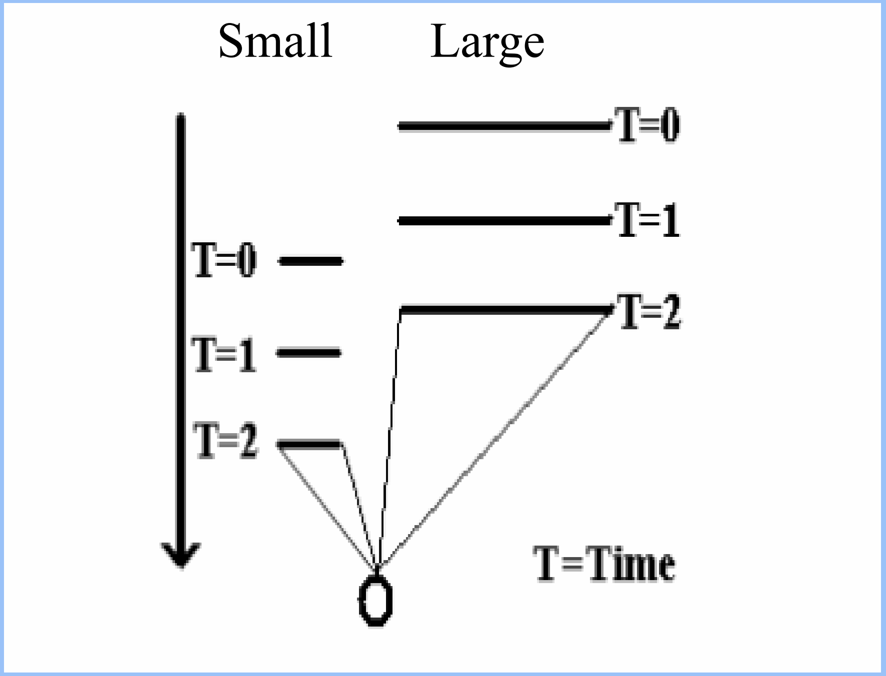
Invariants

- Higher order properties (e.g., ratio of tau)
- Provide accurate information more reliably than depth cues

- Two identical cylinders occlude same number of ground texture elements
- Provides correct information that they are the same 3D size
- Even though the farther one has a smaller image

The "Size-Arrival Effect" (SAE)

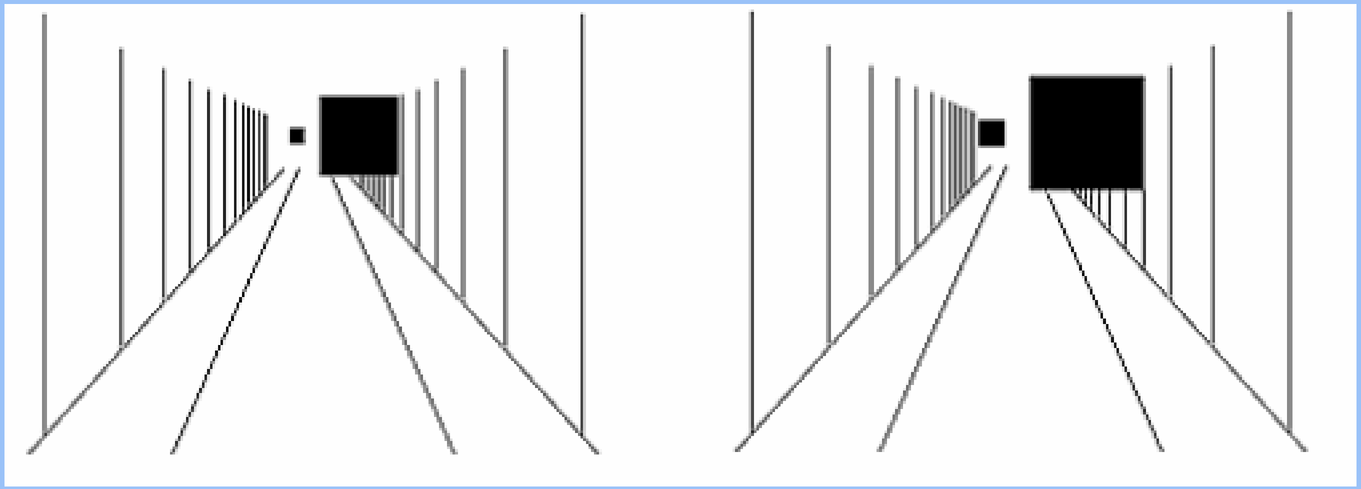
- DeLucia (1991, 2004)
  - Large, small object approach eye
  - Small object is always closer
  - Small object always projects smaller image
  - Relative size depth cue: Large would arrive first
  - Tau: Small object would arrive first



Task

Which object would "hit" you first? (left or right)

First Frame   Last Frame



EXAMPLE

C:\cdpsdemos\cdpssa1\winjul5.exe demoslow.ord

Results

- All participants selected large object
- Consistent with relative size cue, not tau
- “Size-arrival effect”

Practical Implications: Motorcycle Crashes

- Motorcycle crashes (Horswill et al., 2005)
  - Typically due to violation of motorcycle's right of way
  - Proposed that misperception of motorcycle speed and distance is a factor due to small size
  - Hypothesized that size-arrival effect contributes to crashes
  - Supported with empirical data

http://jafrum.files.wordpress.com/2008/08/screenhunter_08-aug-08-0154.jpg

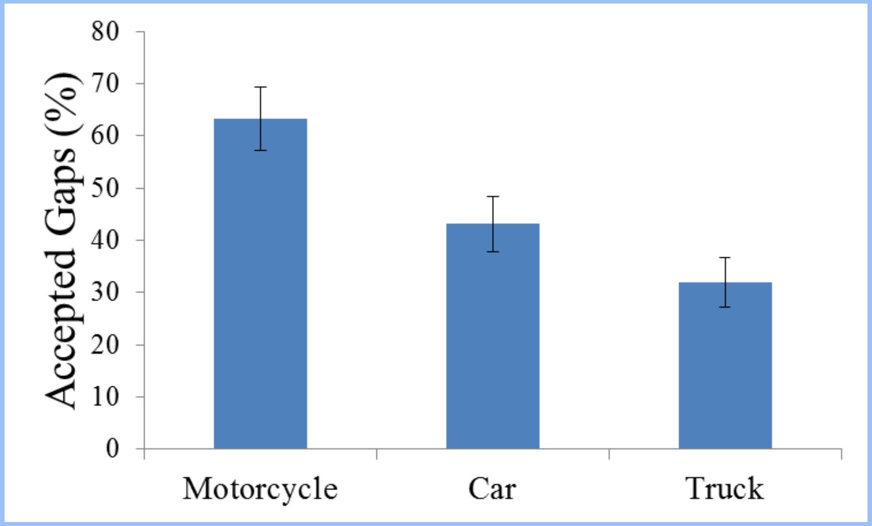
Practical Implications: Overtaking

- Overtaking (Levulis, DeLucia, & Jupe 2015)
  - Does oncoming vehicle size affect overtaking judgments?
  - 24 licensed drivers, STI-SIM driving simulator; car-following scenario
  - Task: Report whether it is safe to overtake lead car, when prompted
  - Varied: Oncoming vehicle size: motorcycle, car, truck

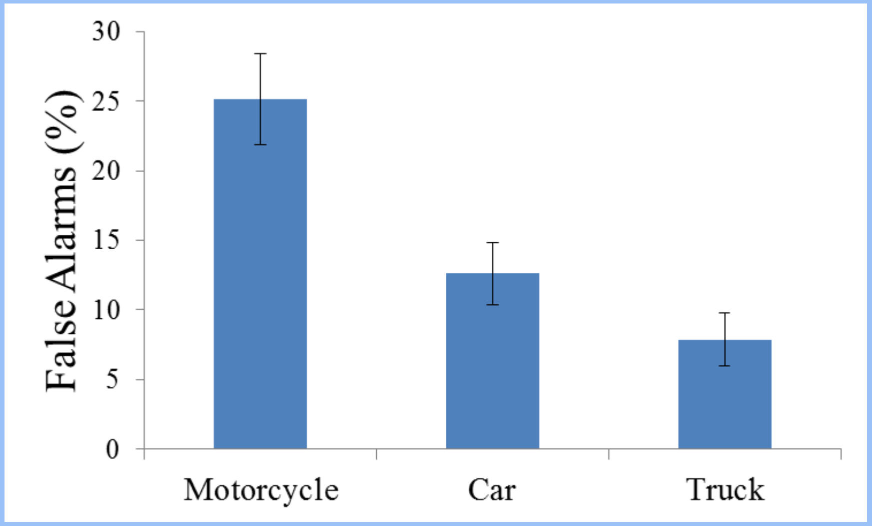
Overtaking: Results

- More accepted gaps and more false alarms for oncoming motorcycle compared to a car or truck

Percentage of Accepted Gaps



Percentage of False Alarms

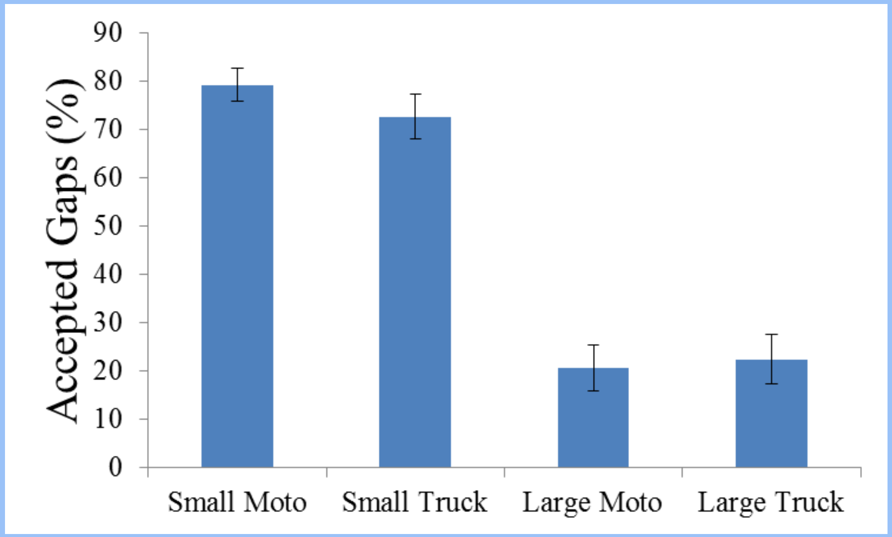


Control Study

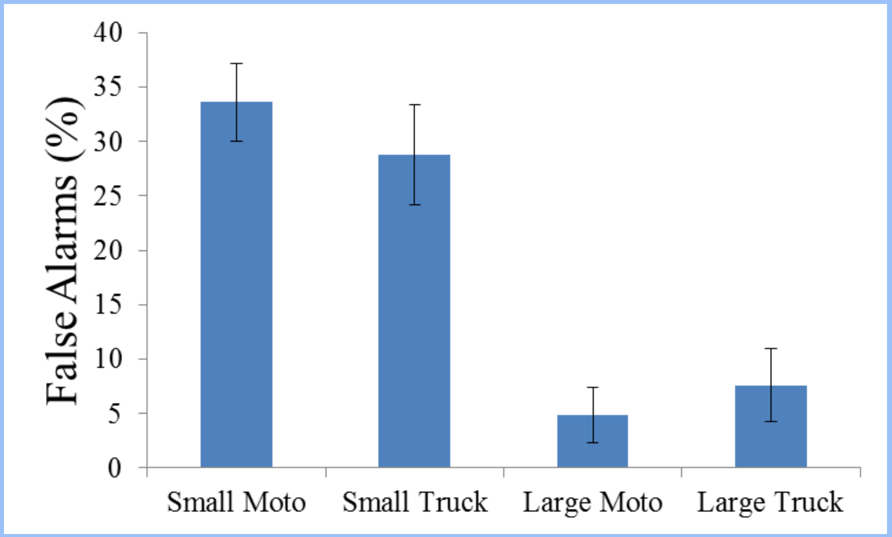
- Tease apart vehicle size and vehicle type (e.g., perceived harm)
- Tested with control scenes (same-sized truck and motorcycle)

Control Study: Results

Percentage of Accepted Gaps

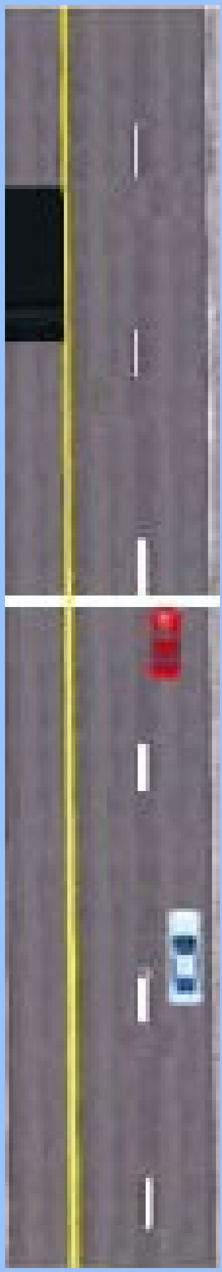


Percentage of False Alarms



❖ Effects of size were not due to vehicle type

Follow up Study



Levulis, S. J., DeLucia, P. R., Yang, J., & Nelson, V. (2018).

Other factors that affect collision judgments

Height in field

http://psychsciencenotes.blogspot.com/2015/06/the-perturbation-experiment-as-way-to.html

- Other depth cues DeLucia et al. (2003)
  - Height in field (near objects fall lower in the visual field than far objects)
  - Occlusion (near objects hide farther objects)
  - Motion parallax (close objects move faster in the visual field than far objects)

Occlusion

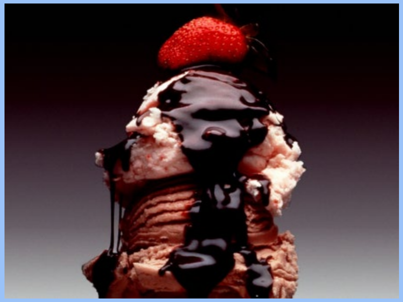
http://www.losangeleshotairballoons.com/

Affective Content

❖ **Task:** Press button when approaching picture would reach you

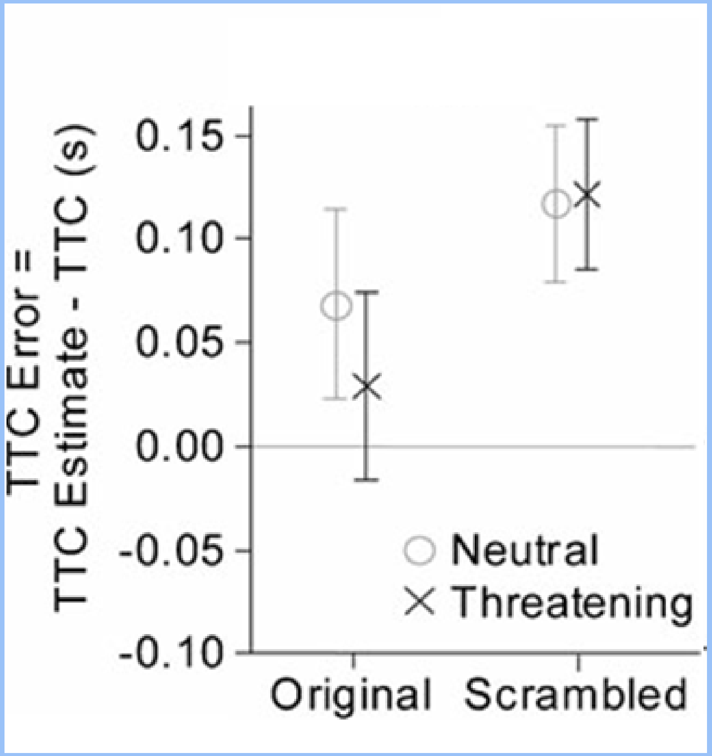
Threatening

“Neutral”



Brendel et al., 2012

❖ Earlier responses for threatening pictures

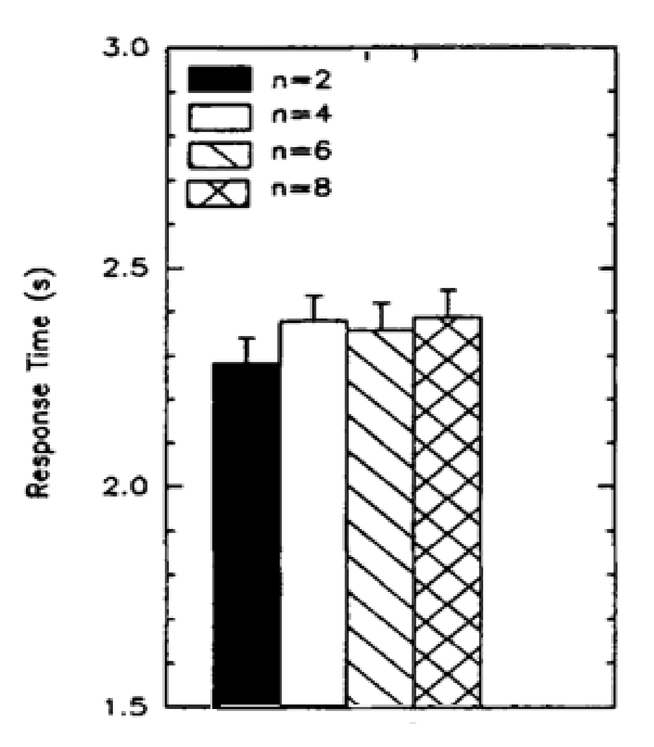


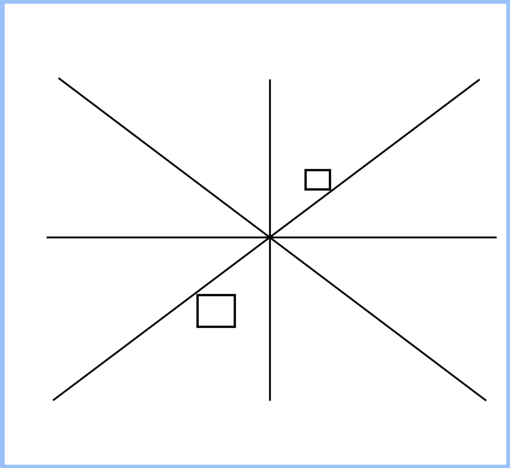
Threatening Scene

C:\cdpsdemos\cdpset9\winaug28.exe demo.ord

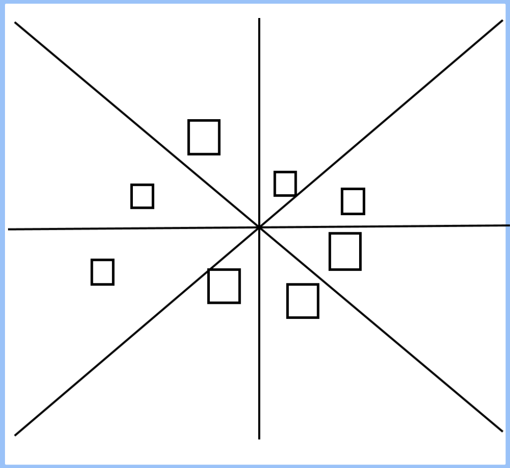
Limits in Cognitive Processes

- **DeLucia & Novak (1997)**
  - 2, 4, 6, or 8 approaching objects
  - Which object would reach you first?





2-object scene



8-object scene

- Mean RT greater with 8 objects than 2 objects
- Consistent with limited capacity processing

Relevance

- Collision judgments are influenced by multiple factors
  - Tau, depth cues
  - Affective content
  - Cognitive processes
- Crashes are not due solely to visual factors
- Vehicles may be seen but not perceived correctly

Rear-end Collisions

- 30% of crashes
  - 70% of these are with a stopped vehicle far ahead
  - Less frequent but more fatal
  - What do drivers need to avoid ?

https://youtu.be/aW39PaYYsuk

Example

Responses to a Stopped Vehicle: Explanations

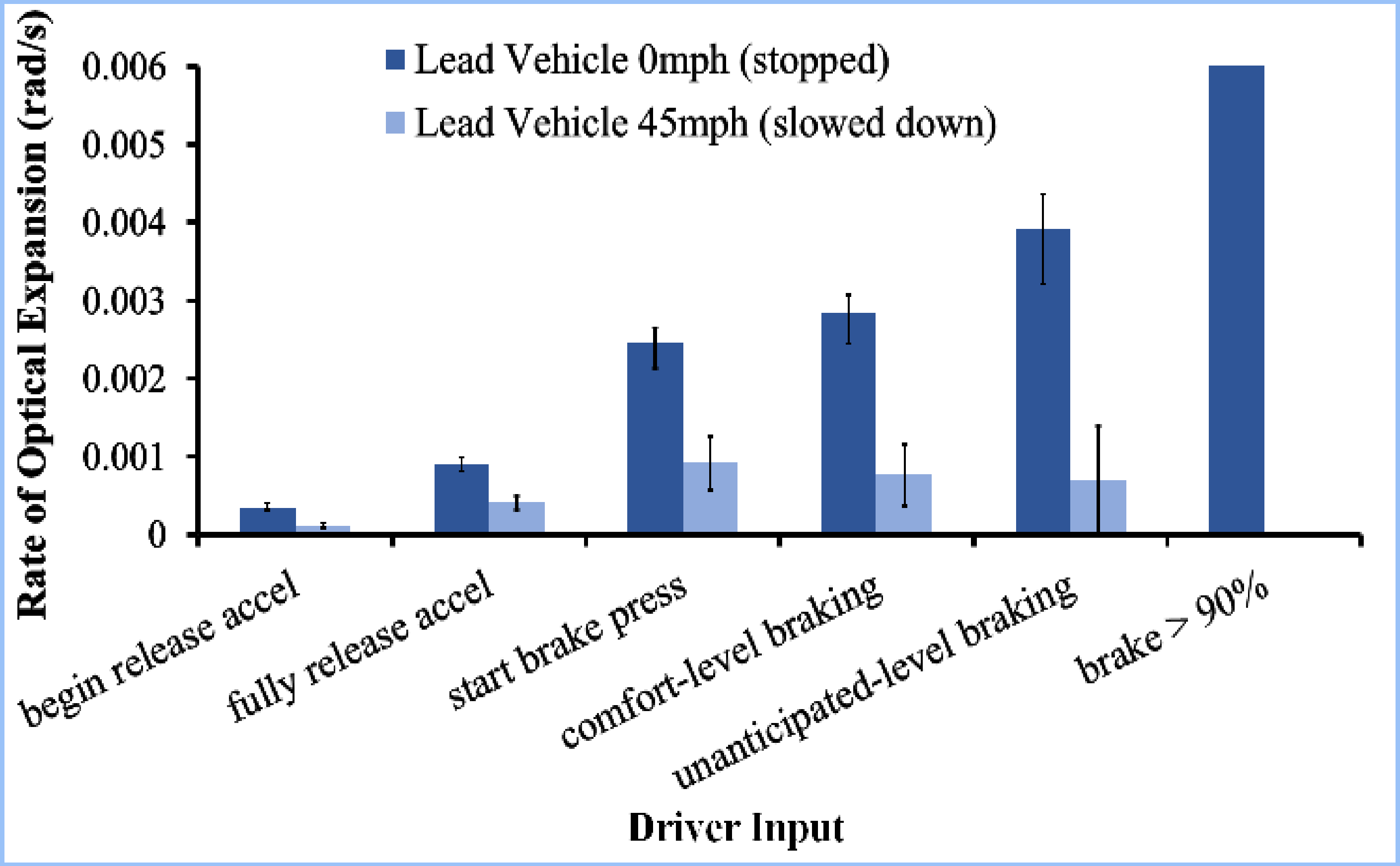
- Lead vehicle's optical expansion
- Critical value
  - Perception of closing when rate reaches .003 rad/s (Olson, Dewar, Farber, 2010)
  - Perception of immediate hazard when optical expansion rate reaches .006 rad/s (Muttart, 2005)
- Evidence accumulation (Markkula, 2014)
  - Response occur in stages as evidence accumulates over time
  - Not a response to a threshold expansion rate

Responses to a Stopped Vehicle- Study

Weaver, B., DeLucia, P. R., Jupe, J. (2019); Weaver, B. W., DeLucia, P. R., & Jupe, J. (2023);
Oliver, M., DeLucia, P. R., Jupe, J., Dudley, L., & Weaver, B. W. (in press)

Example Scene

Responses to a Stopped Vehicle: Results



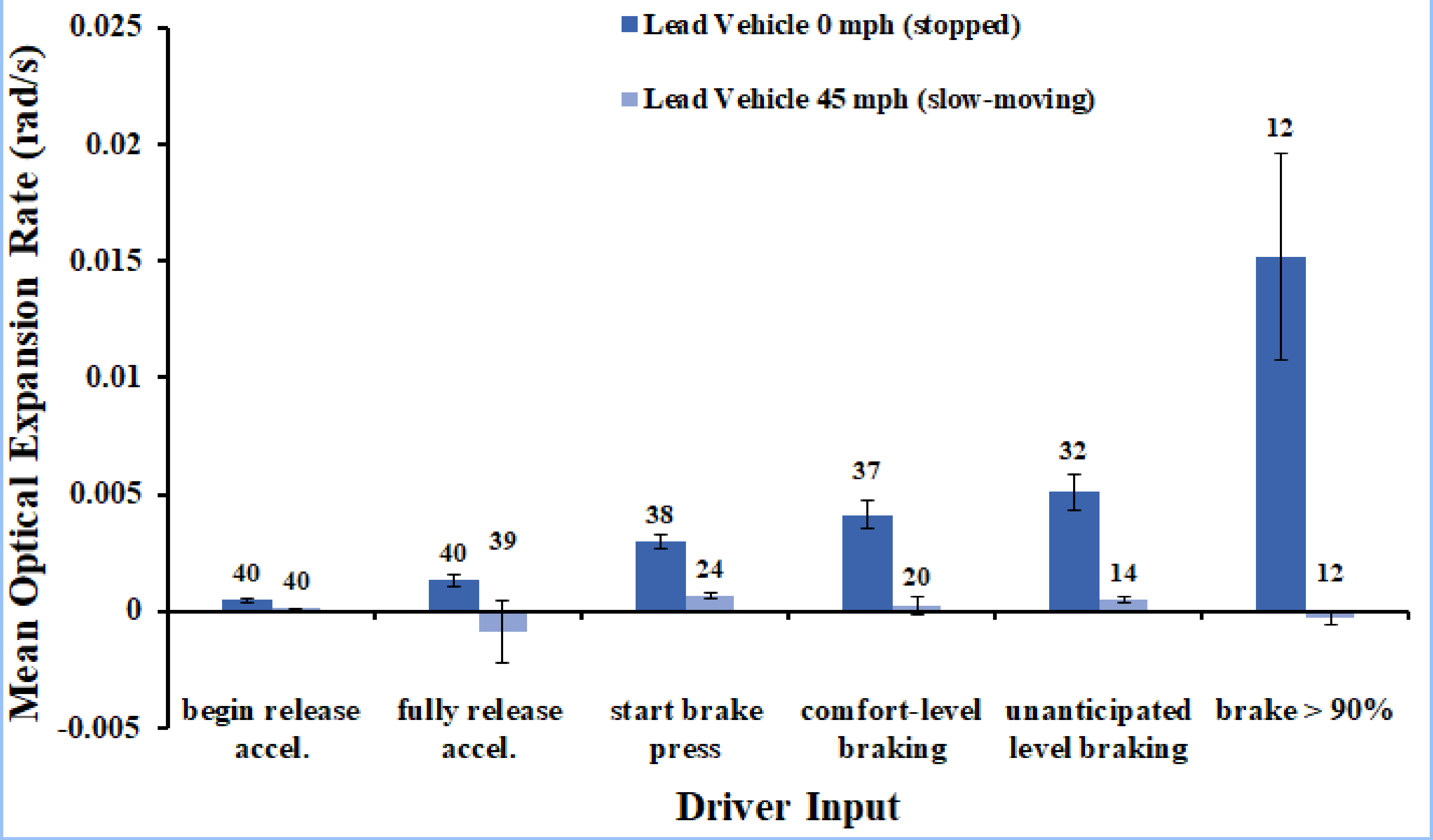
Weaver, B. W., DeLucia, P. R., & Jupe, J. (2023)

Nighttime Study

❖Oliver, M., DeLucia, P. R., Jupe, J., Dudley, L., & Weaver, B. W. (in press)

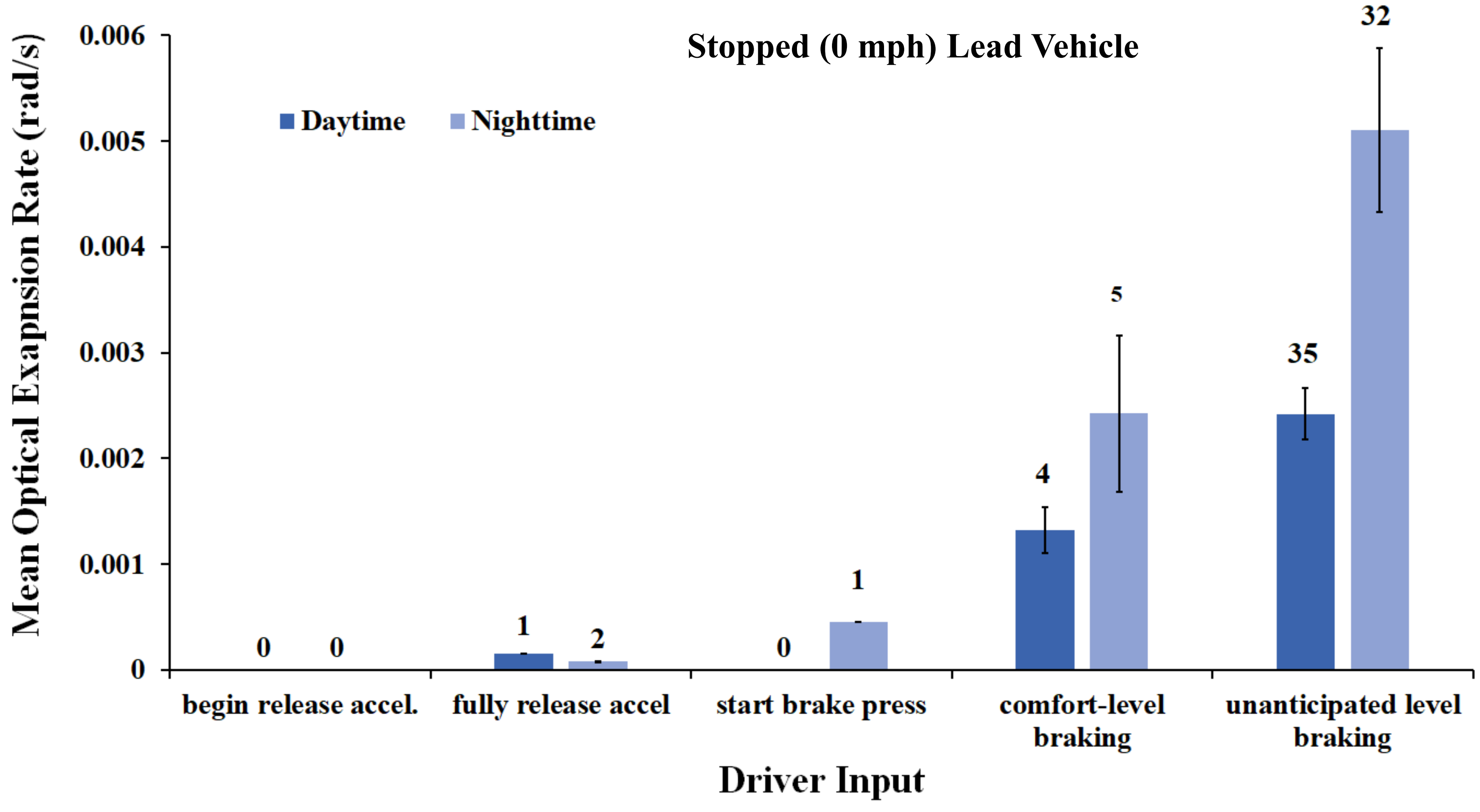
Example Scene

Nighttime Study: Preliminary Results



❖Oliver, M., DeLucia, P. R., Jupe, J., Dudley, L., & Weaver, B. W. (in progress)

Nighttime Study: Preliminary Results



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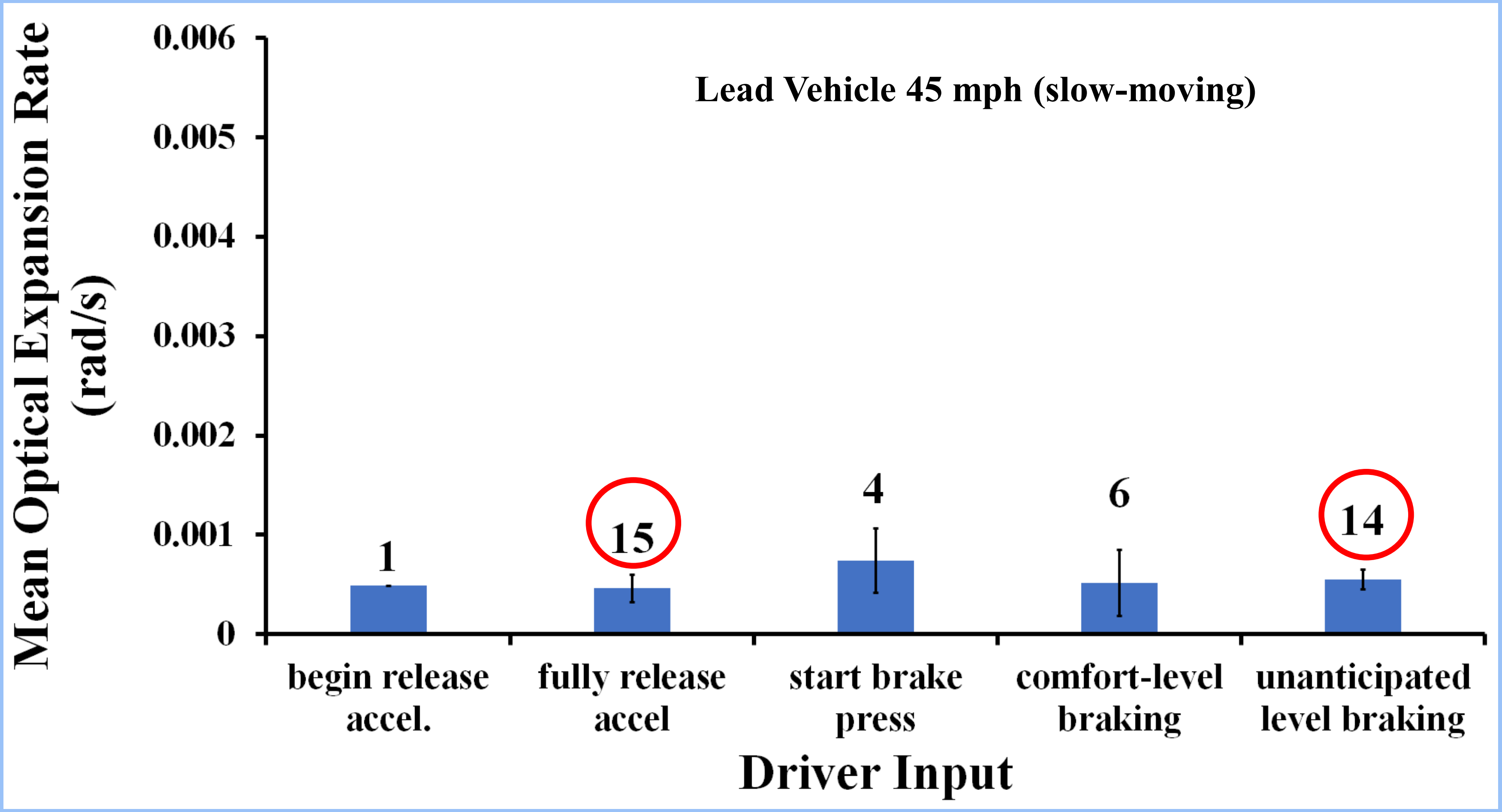
Nighttime Study: Preliminary Results



❖Oliver, M., DeLucia, P. R., Jupe, J., Dudley, L., & Weaver, B. W. (in progress)

Other preliminary results

- Drivers take longer to respond in daytime
- No effects of cell phone conversation on optical expansion rate
- No effects of expectancy (exposure to critical events)

Car-following Study

- Responses to deceleration of a lead car in car following scenarios (DeLucia & Tharanathan, 2009)
  - Are drivers' responses to a lead car's deceleration affected by optic flow information, and by discrete warning signals independent of optic flow?
    - Does this depend on distance and deceleration rate of lead car– that is, on the effectiveness of optic flow information?

Slow Expansion vs Fast Expansion

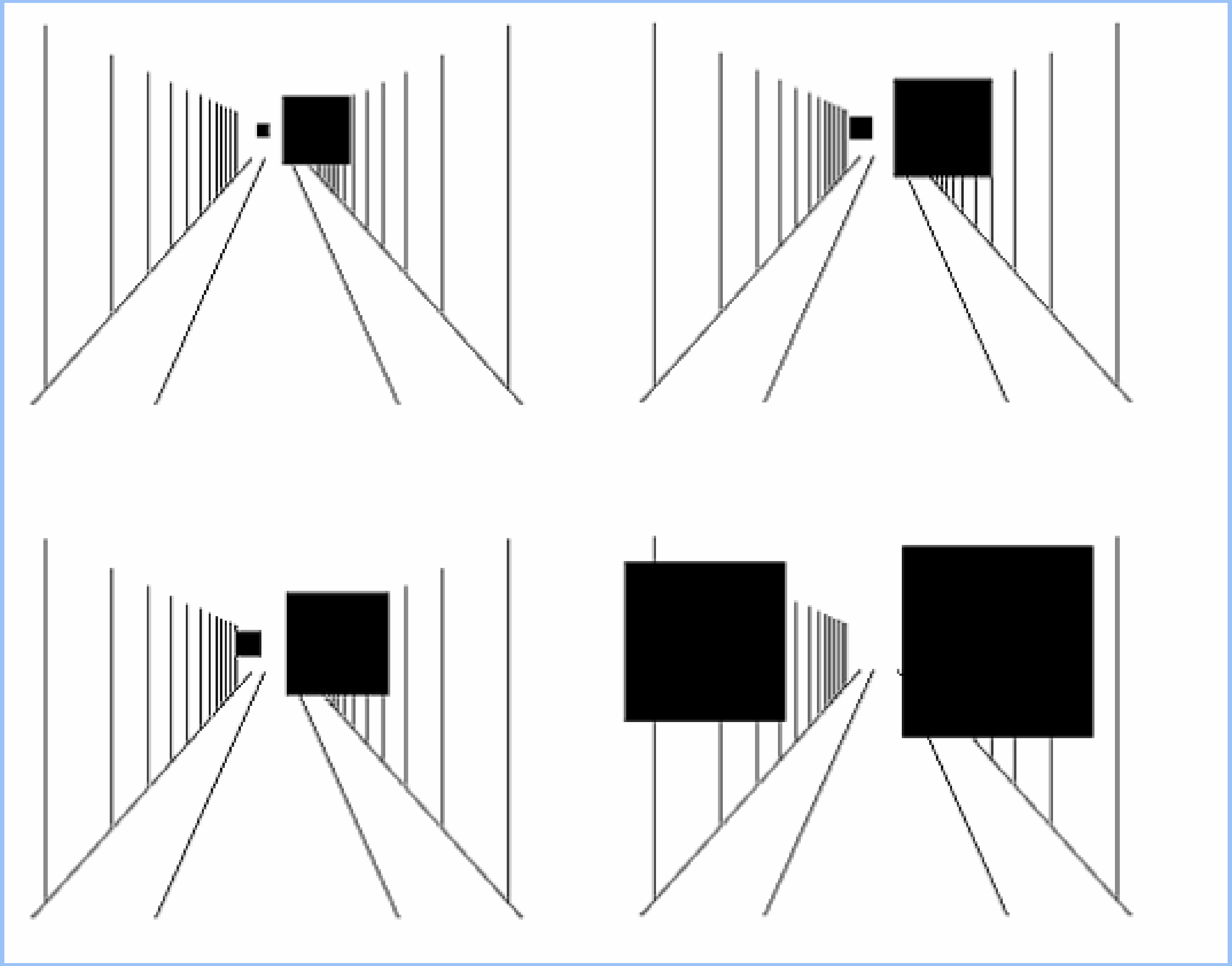
First Frame | Last Frame

Slow Expansion

("far")

Fast Expansion

("near")



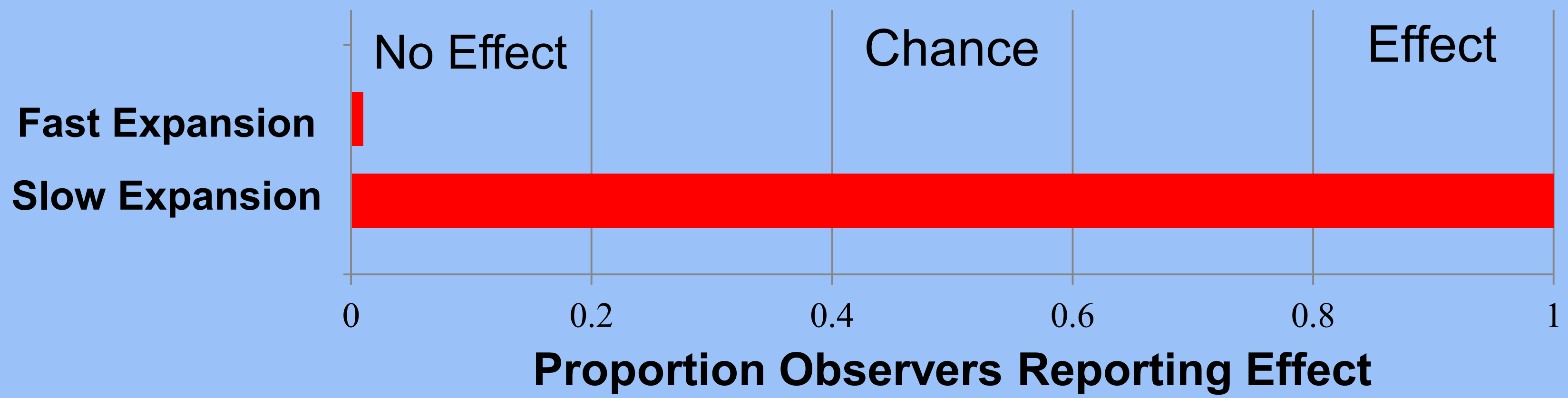
DeLucia, 1991

Example Scene

C:\cdpsdemos\cdpsfa1\winjul5.exe demofast.ord

Effects of Expansion Rate

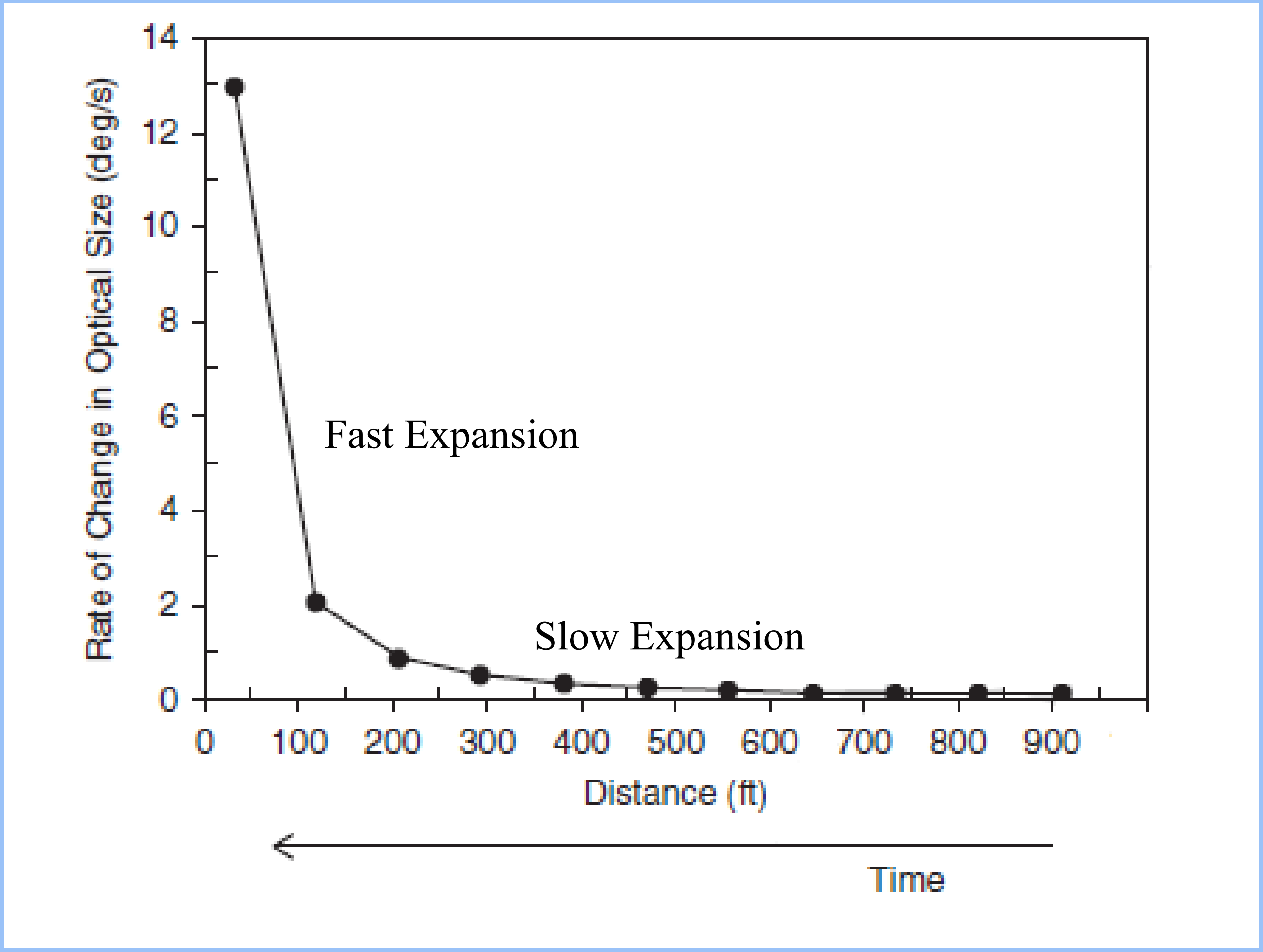
- Slow expansion: 20 of 20 participants selected large object
- Fast expansion: 0 of 20 participants selected large object



- Implications: Drivers may use different information to judge far vs near objects

DeLucia, 1991

Slow vs Fast Rates of Optical Expansion



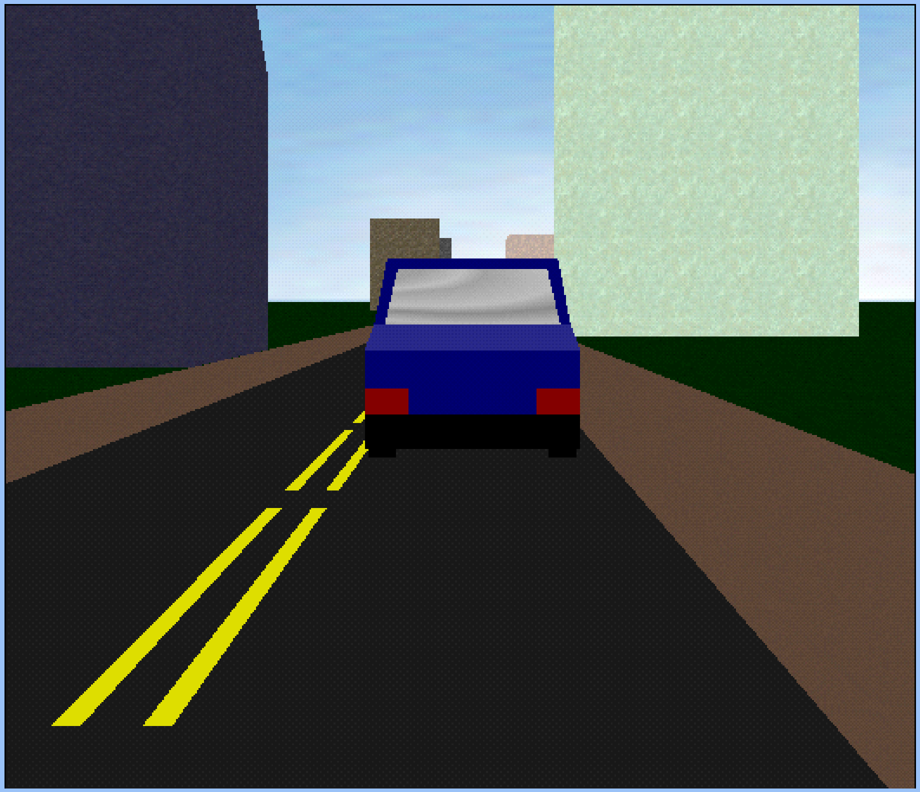
Implications for Driving

- Drivers might use different information and processes when viewing near and far spaces of traffic scenes
  - Near: optical expansion, tau
  - Far: cognitive processes, heuristics
- Drivers might need different types of decision aids to make judgments of events in near and far spaces

Car-following Study:

EXAMPLE SCENE

- Licensed drivers, custom driving simulations of car following scenario
- Task: Press button when lead car decelerated
- Varied: Deceleration time, time headway to lead car (.5 s, 1 s); deceleration rate of lead car (slow, fast); presence and onset of brake lights; presence of auditory tones

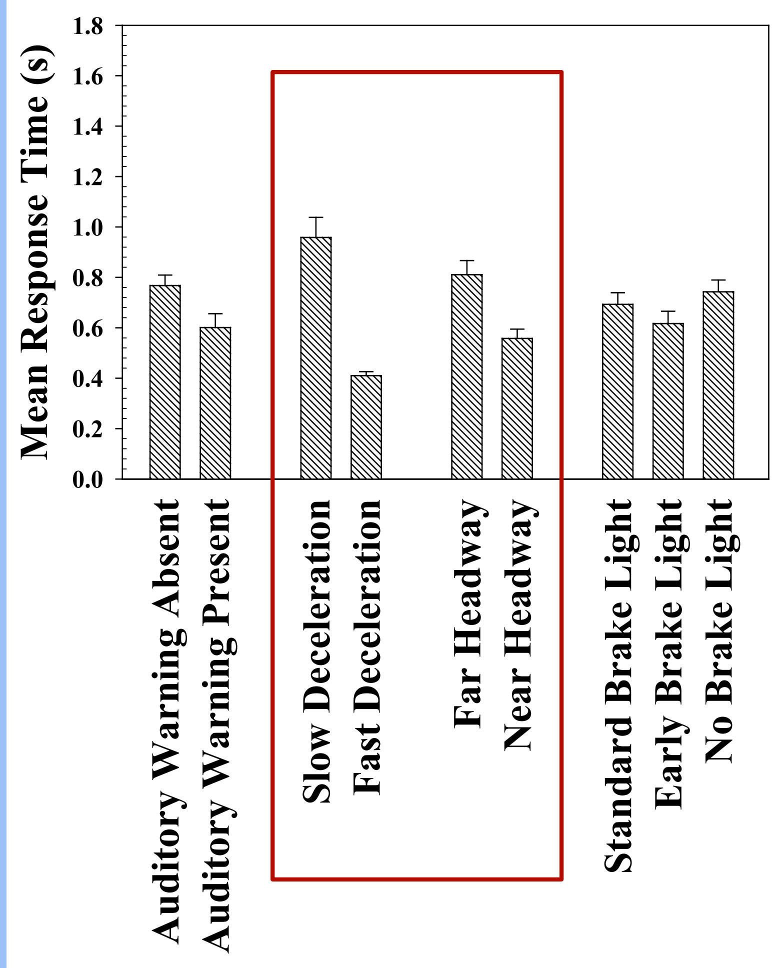


DeLucia & Tharanathan (2009)

Results (highlights)

❖ Response time to deceleration was relatively shorter for near headways, fast deceleration rates.

- ❖ Implication: Response to deceleration was affected by effectiveness of optic flow information



Results (highlights)

- ❖ Effects of auditory warnings and brake lights occurred when *deceleration rate was slow and headway was far*
  - ❖ Implication: Observers relied on discrete warnings when optic flow was relatively less effective
  - ❖ Counterintuitive: Drivers need warnings more when decelerating lead car is farther away and less when lead car is near (can use optical expansion information which is robust)

Collision Perception with Visual Impairment

- How are collision judgments affect by central vision loss?
- 7 million individuals in the United States; more than 250 million globally
- Loss of mobility; more isolation, depression and unemployment
- Age-related macular degeneration: central vision loss: degrades detection of optical expansion
- Compared to comparable age, normal vision

R01EYE030961 (PI DeLucia)

Team Members:Wykoff, Oberfeld, Baures, Kearney, Cormier, Jilla, Taylor, Cloutier

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Research Questions

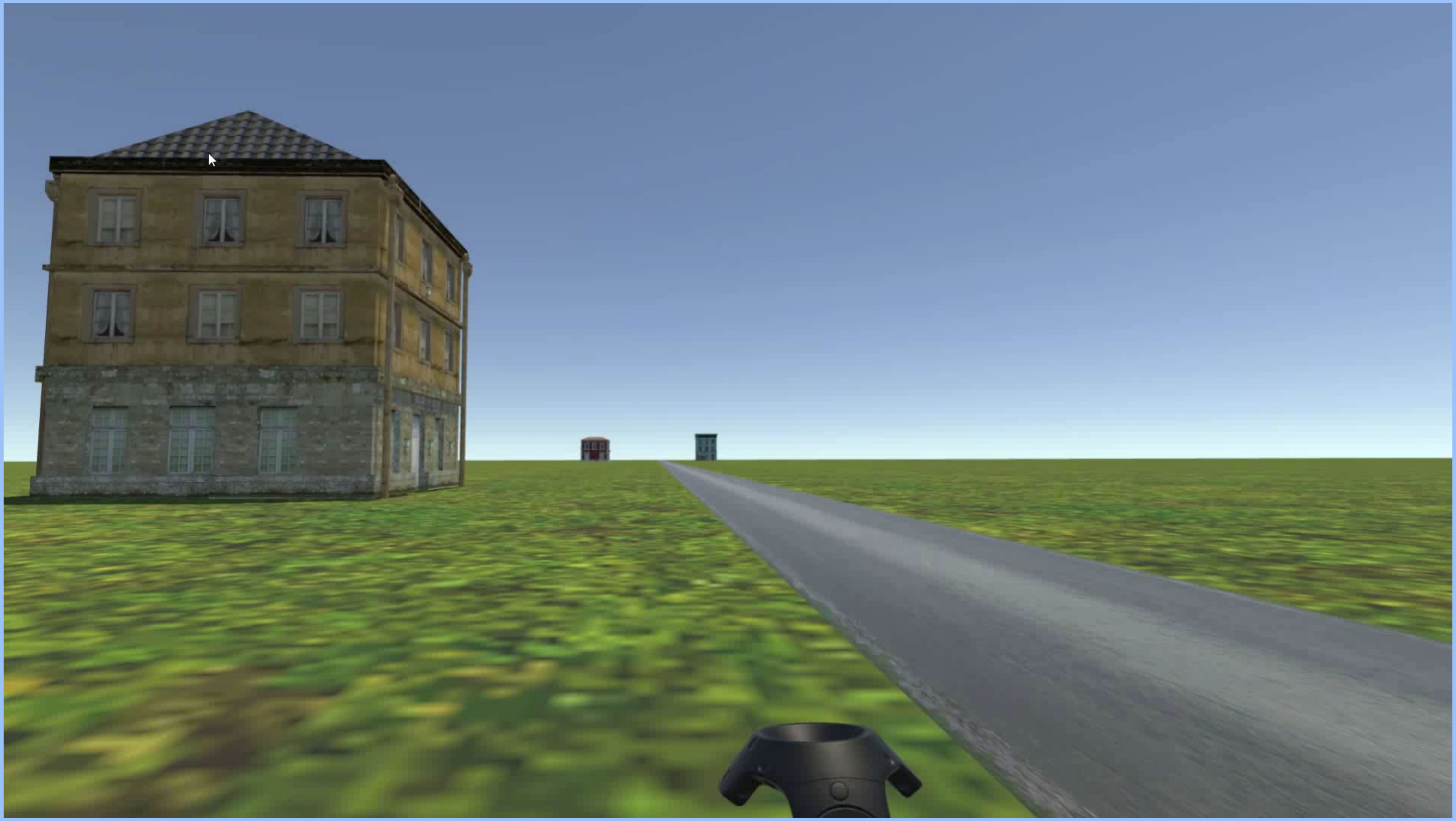
- Are collision judgments worse with AMD?
- Will AMD rely more on hearing than vision?
- Which cues do they rely on?

3D Audiovisual Virtual Reality System

- HTC VIVE Pro
- Ambisonics

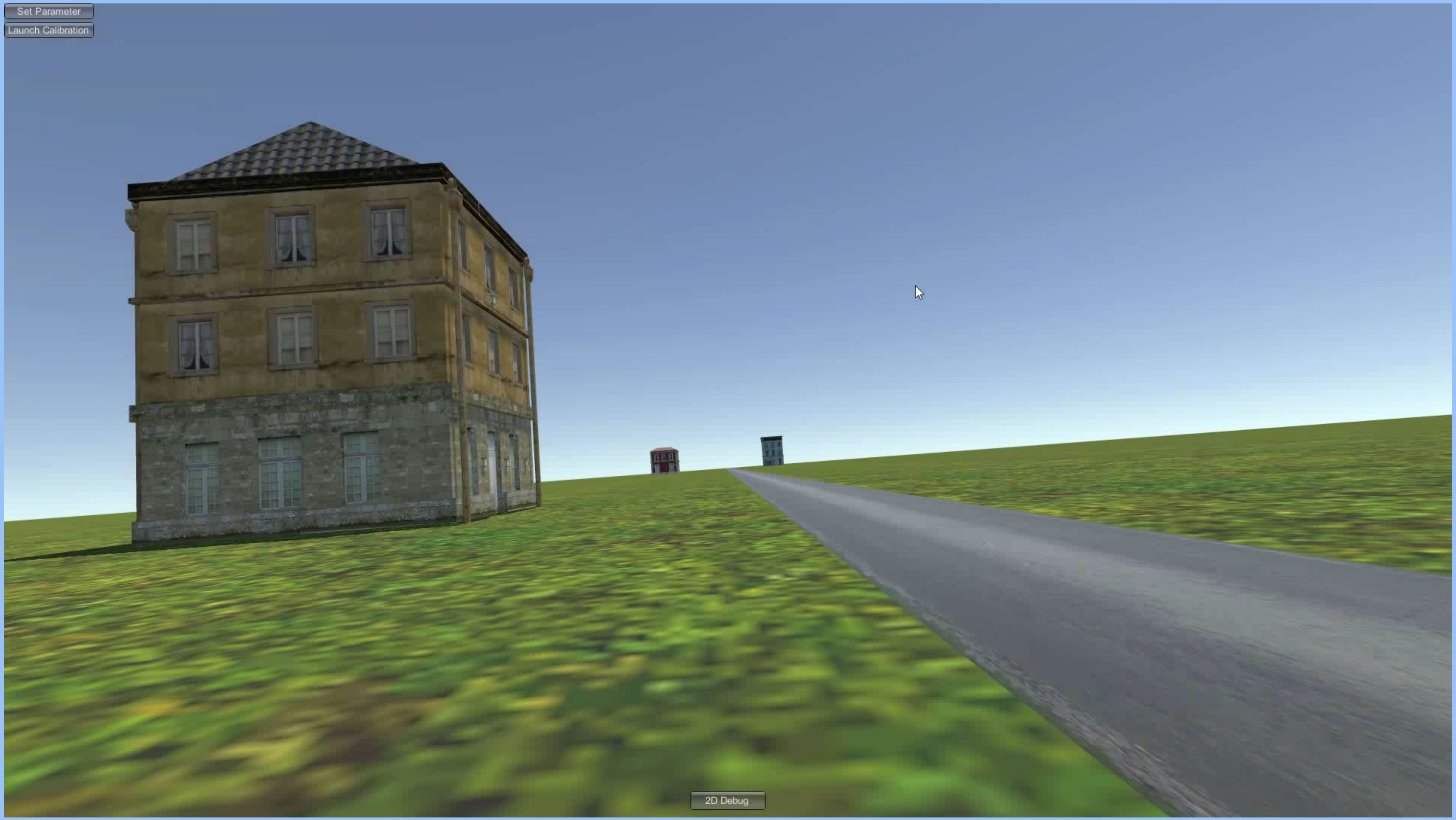
Oberfeld, Wessels, & Büttner, 2022

Example Scene: TTC Estimation Task



Video

Example Scene: Street-Crossing Task

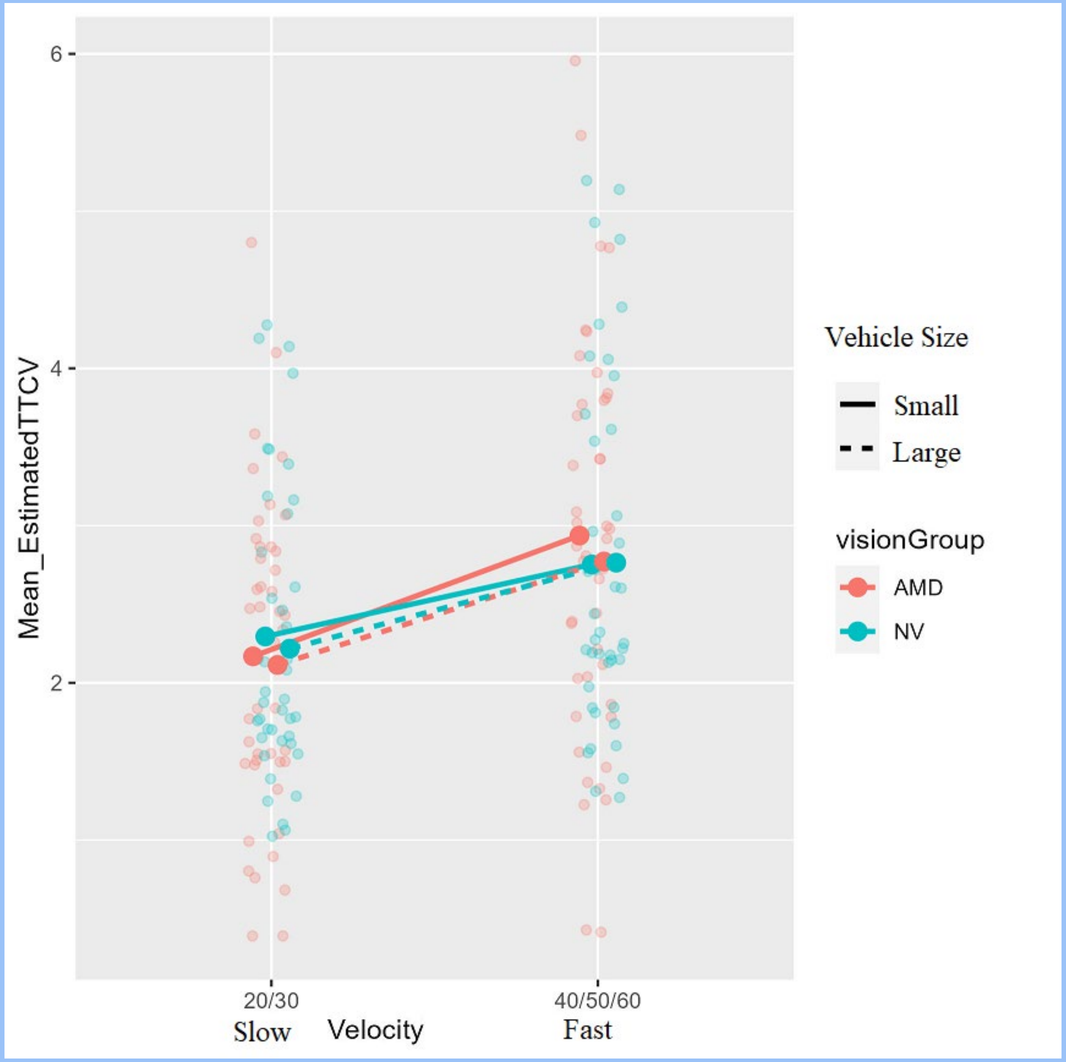


Video

Modality Conditions

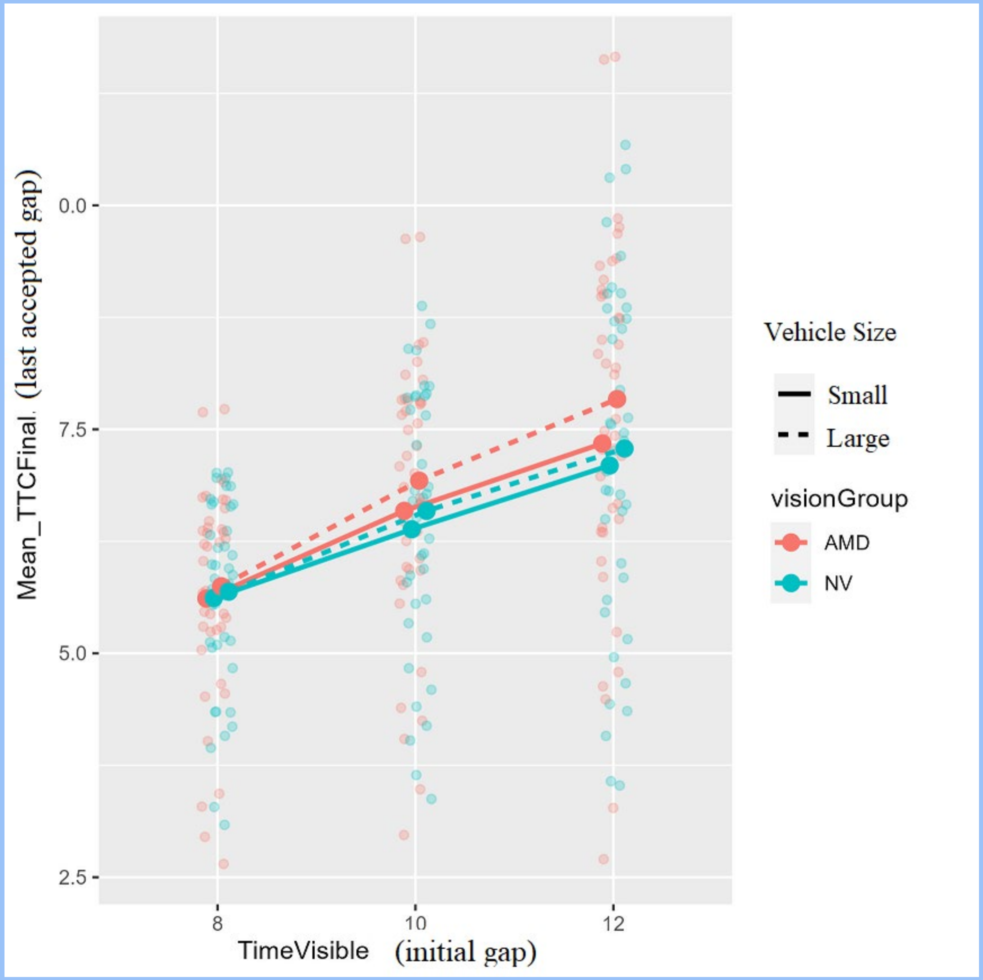
- Vision only, auditory only, both vision and auditory
- Derive weights of different visual and auditory cues (e.g., tau, optical size)
- Data analysis is in progress

TTC Estimation Task: Visual Modality



AMD group affected more by velocity

Street-Crossing Task: A+V condition

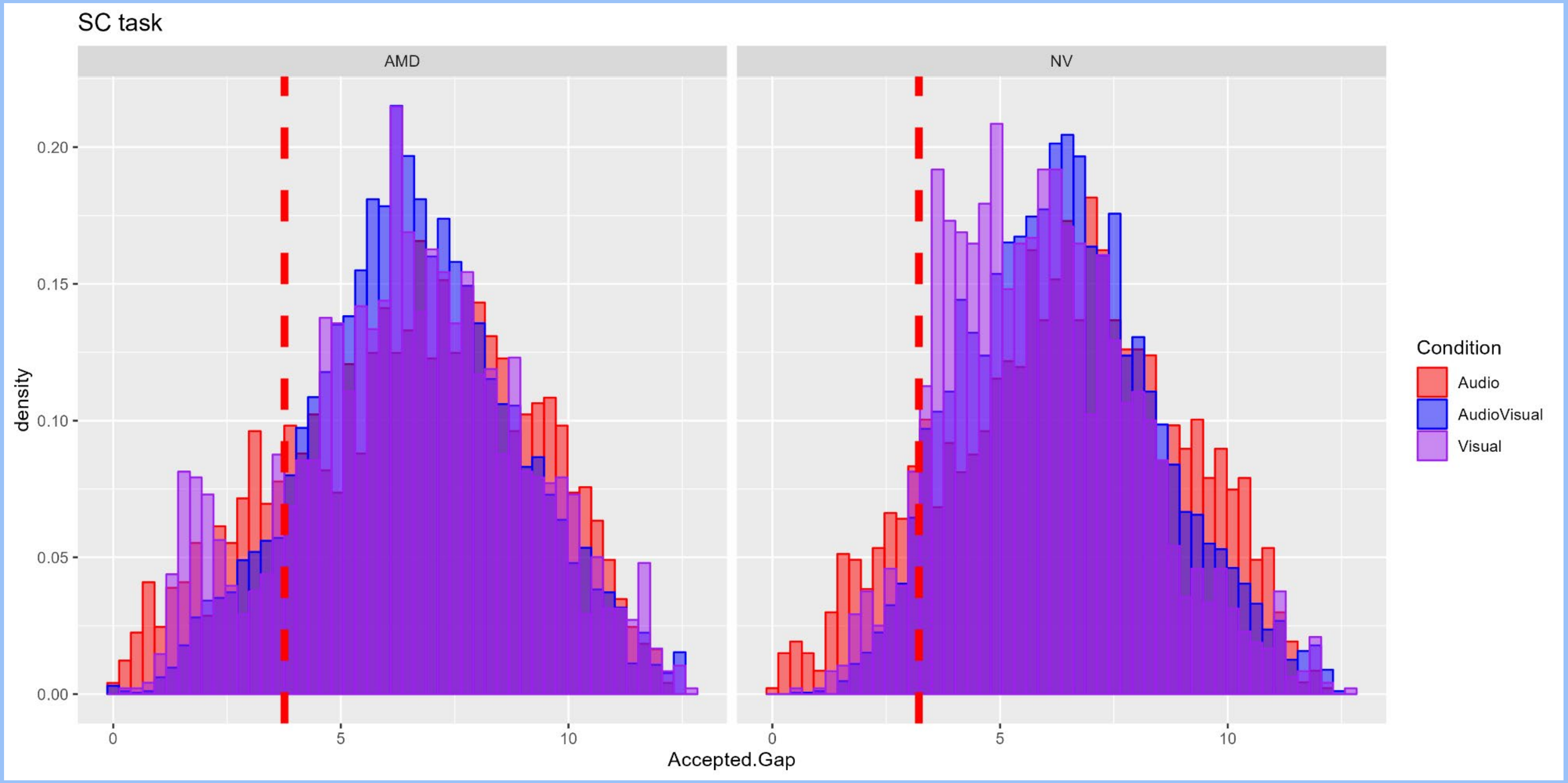


AMD group may want more time to cross

Street-Crossing Task: Collisions

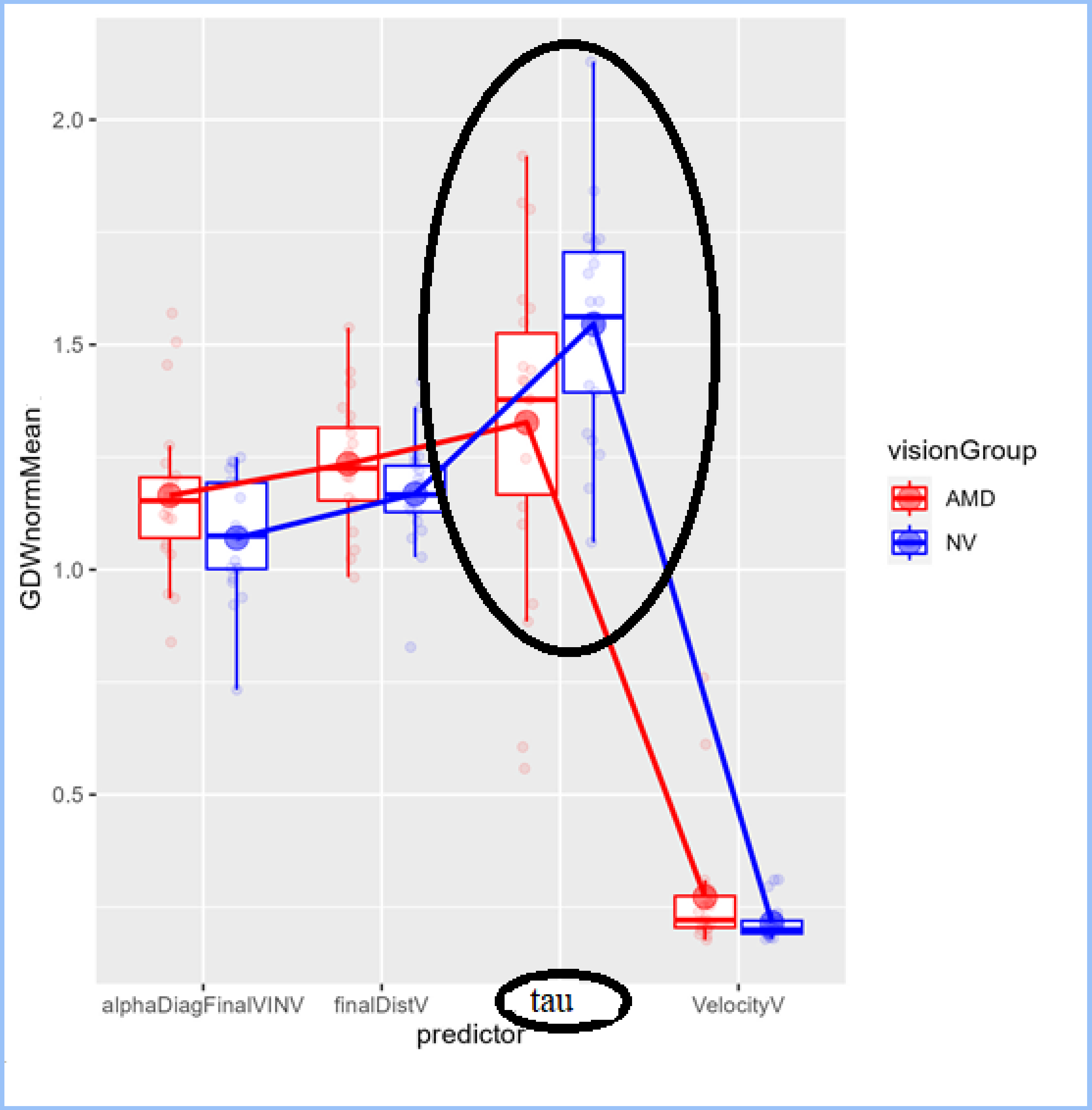
AMD

Normal Vision



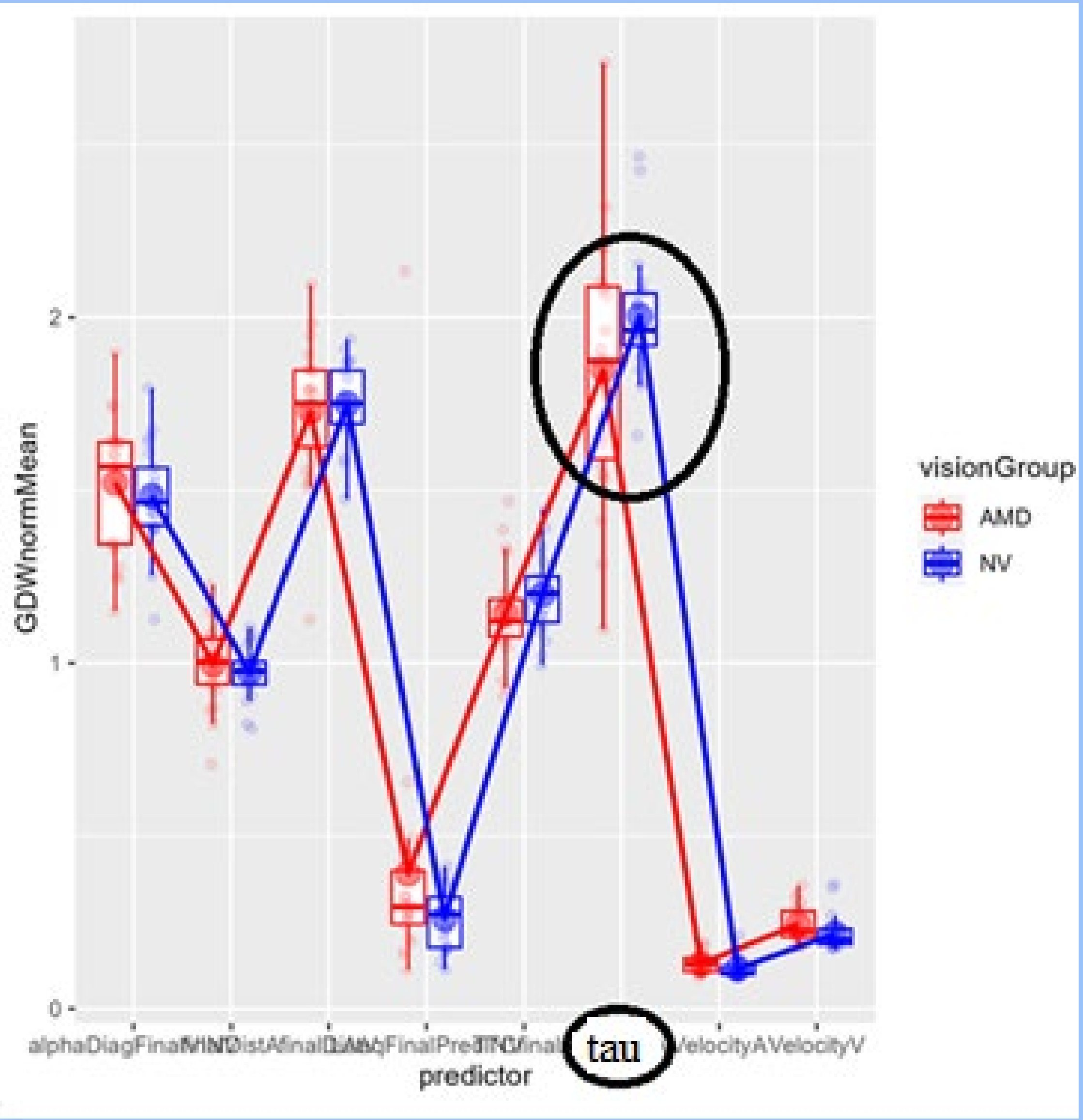
AMD group has higher frequency of getting hit by vehicle

Time Estimation Task: Visual condition



AMD group relies less on tau

Time Estimation Task: A+V condition



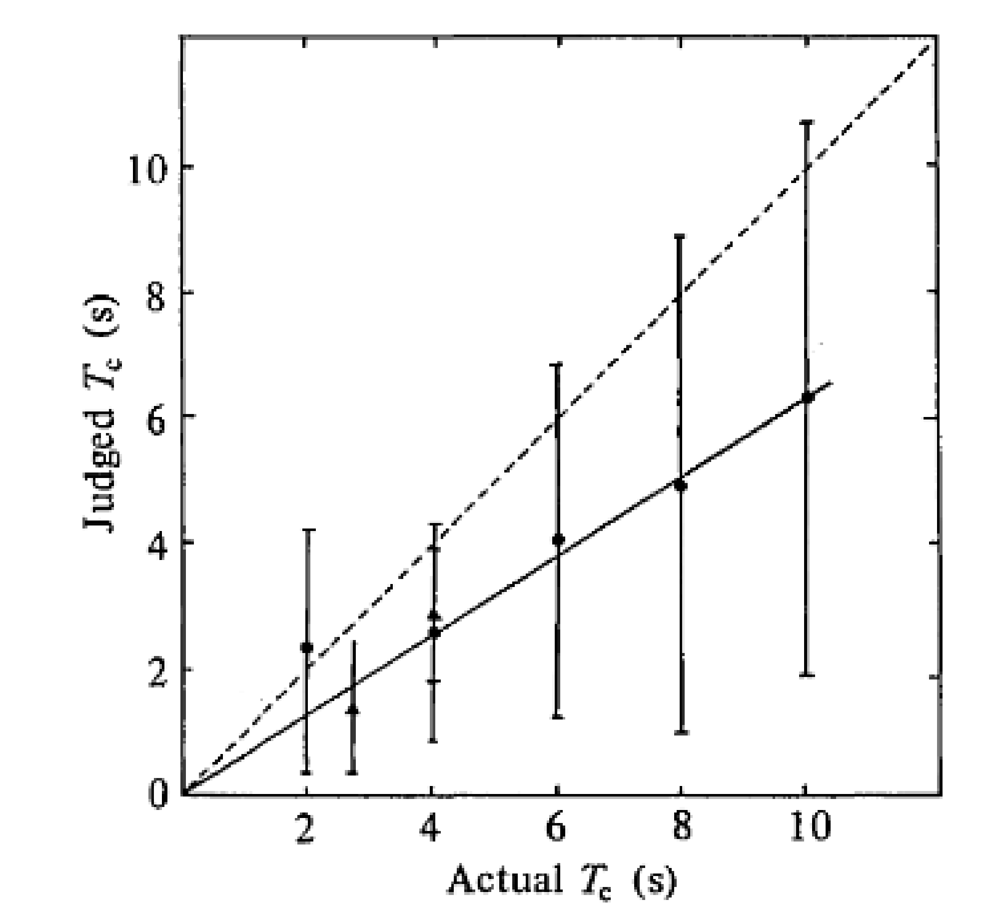
AMD and NV groups more similar in reliance on tau

Tactile Time-to-Collision

Mini Guide Mobility Aid

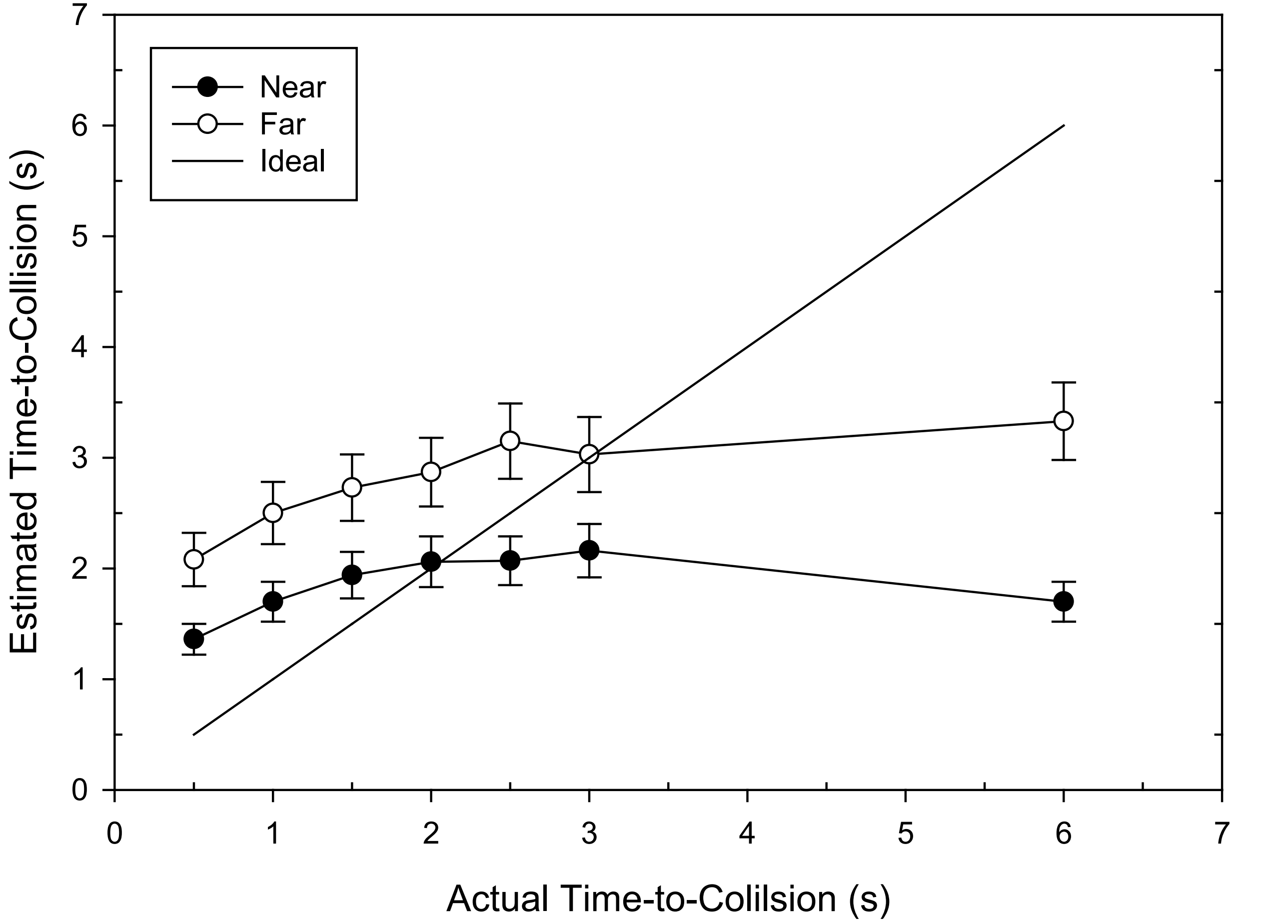
Hill & Black, 2003 https://lssproducts.com/miniguide-mobility-aid/

Classic Visual TTC Data



Schiff & Detwiler (1979)

Tactile Time-to-Collision



DeLucia & Oberfeld (in progress)

Vigilance During Automated Driving

- Semi-autonomous driving
- Driver monitors road for hazards
- Must be ready to take over control of vehicle if automation fails
- Does vigilance decrement occur in driving?

Greenlee, DeLucia, Newton (2018)

Displays

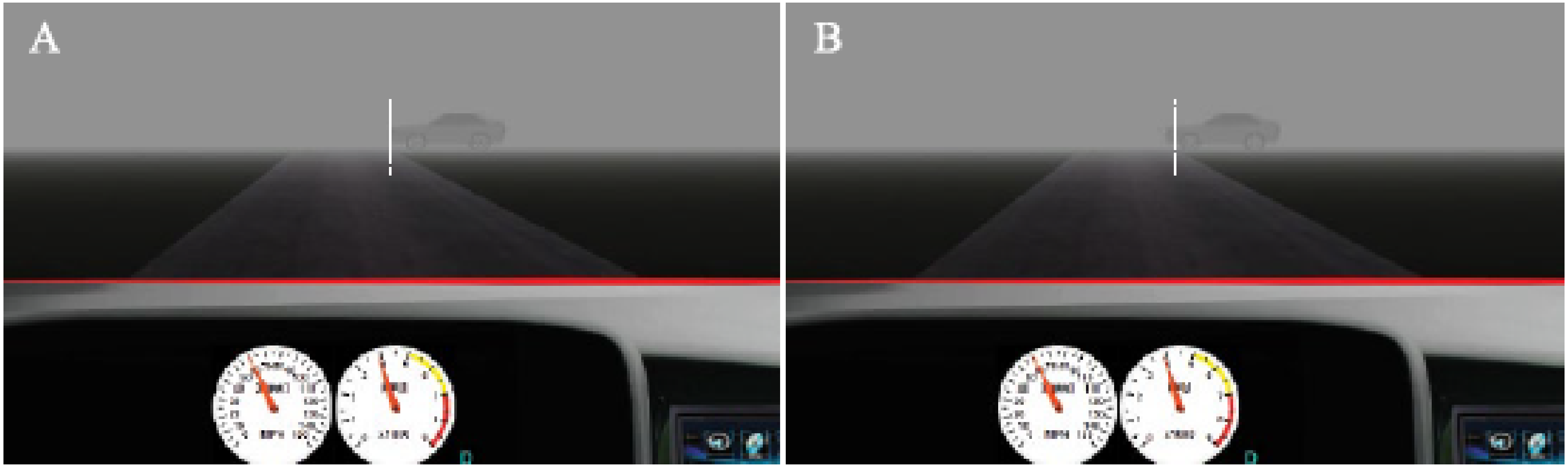
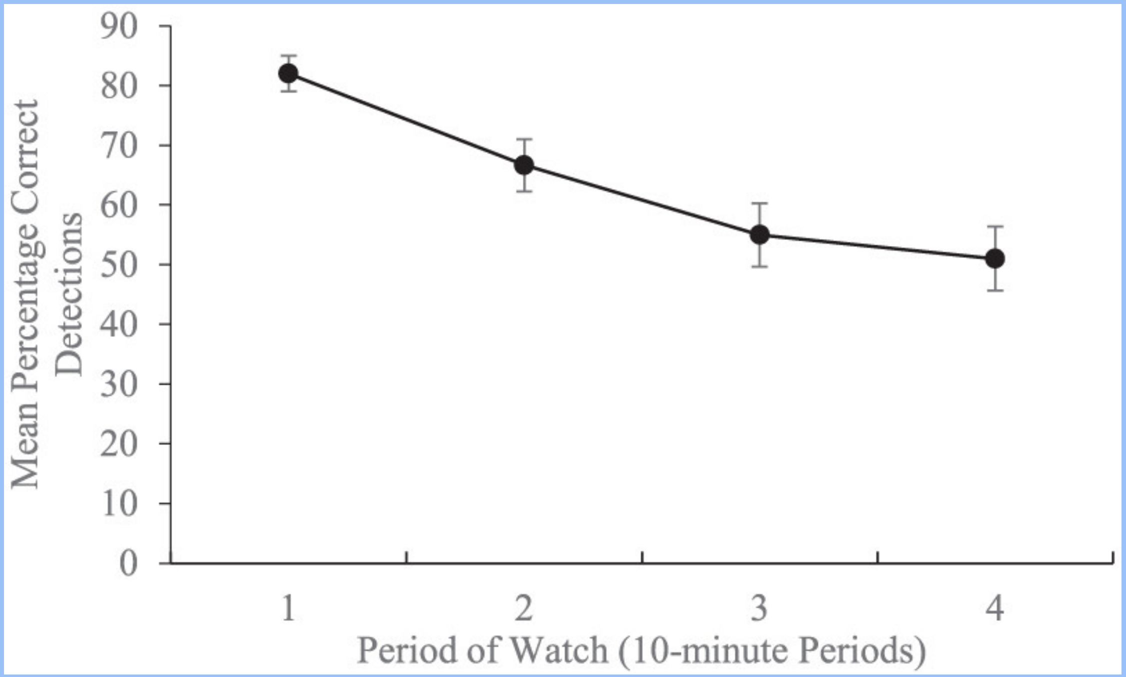
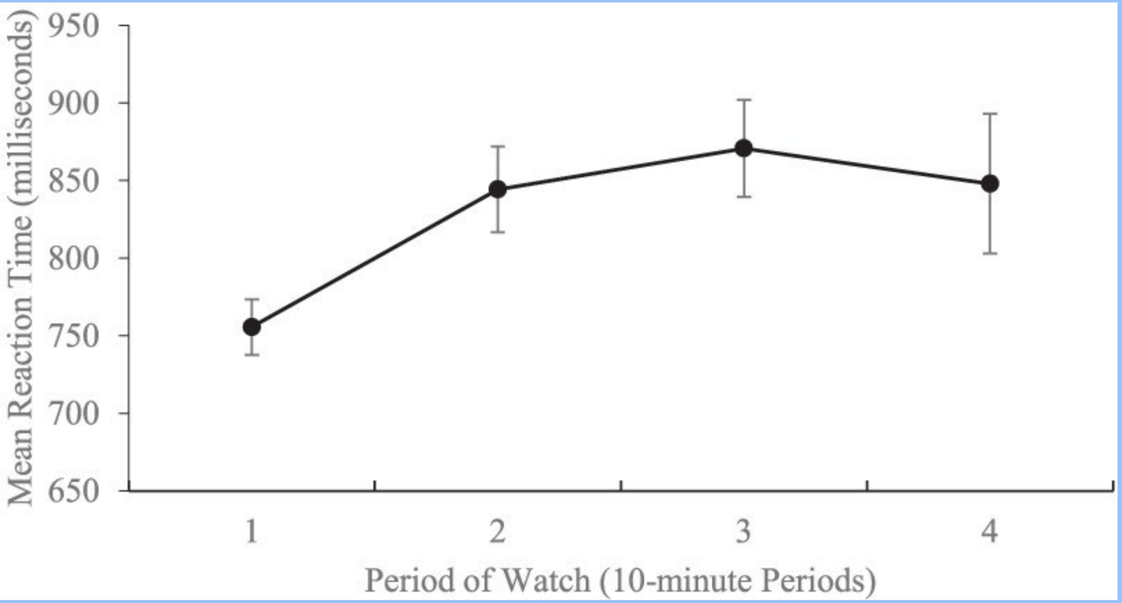


Figure 1. Depiction of (A) “safe” neutral stimuli and (B) “dangerous” critical signals. Dotted lines are presented for the reader’s benefit but were not presented to participants.

Greenlee, DeLucia, Newton (2018)

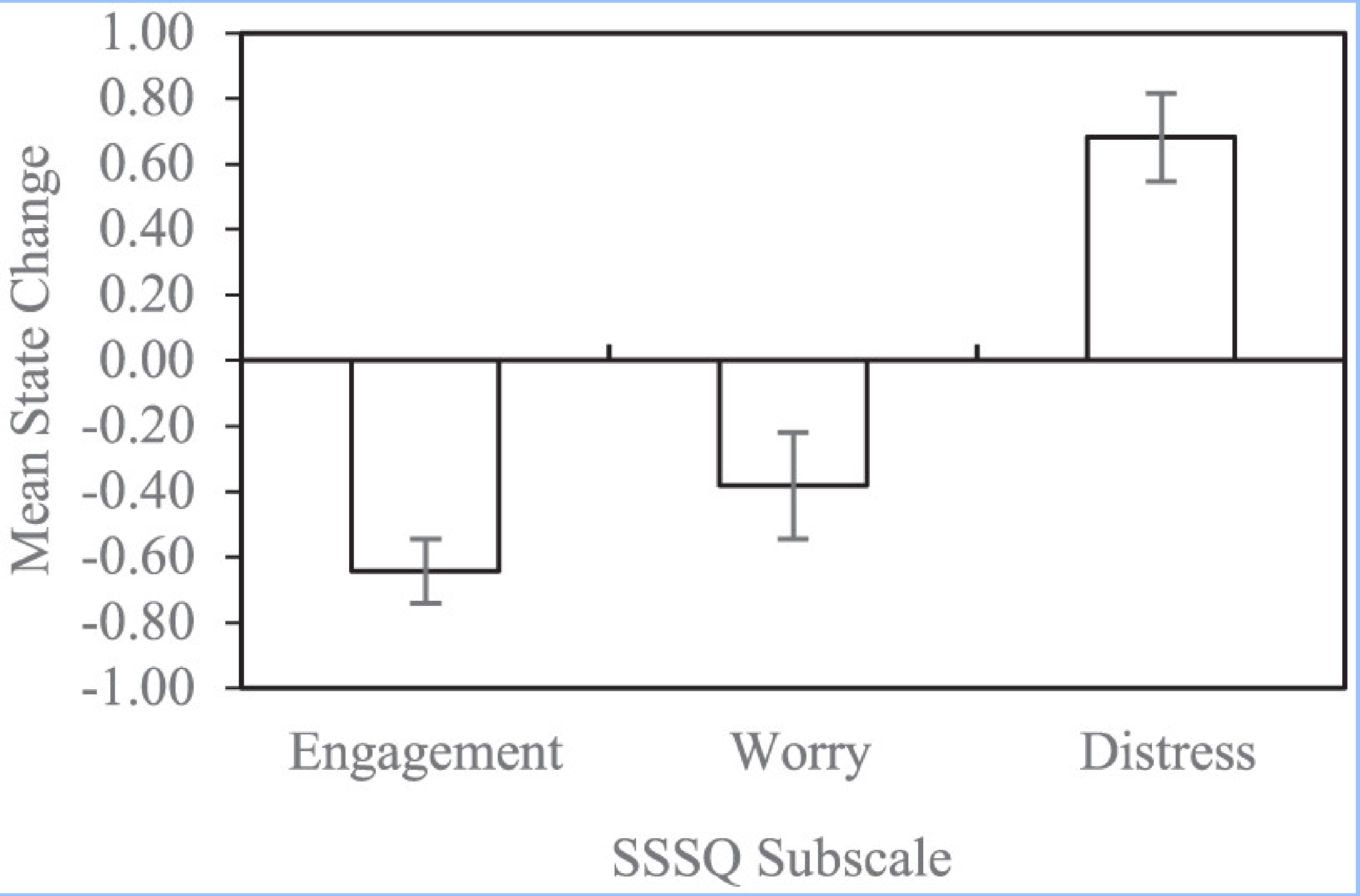
Results





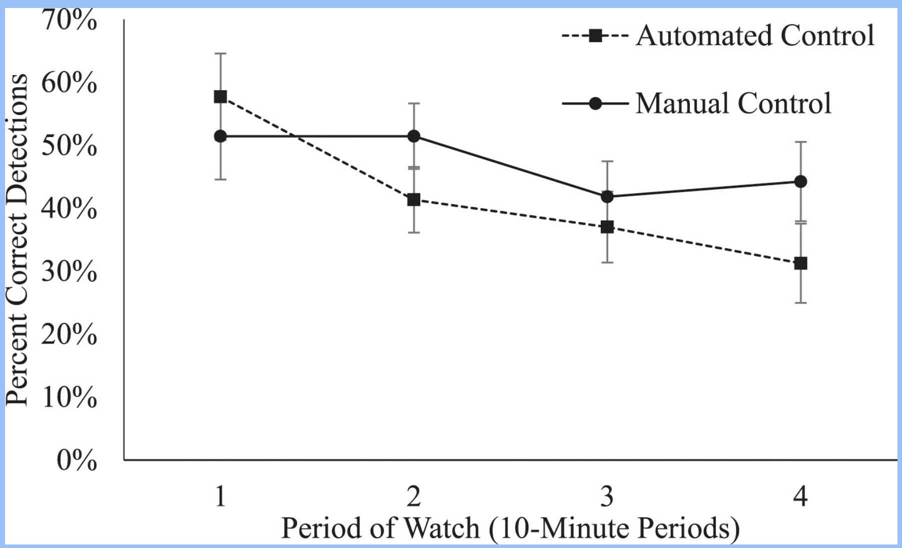
Greenlee, DeLucia, Newton (2018)

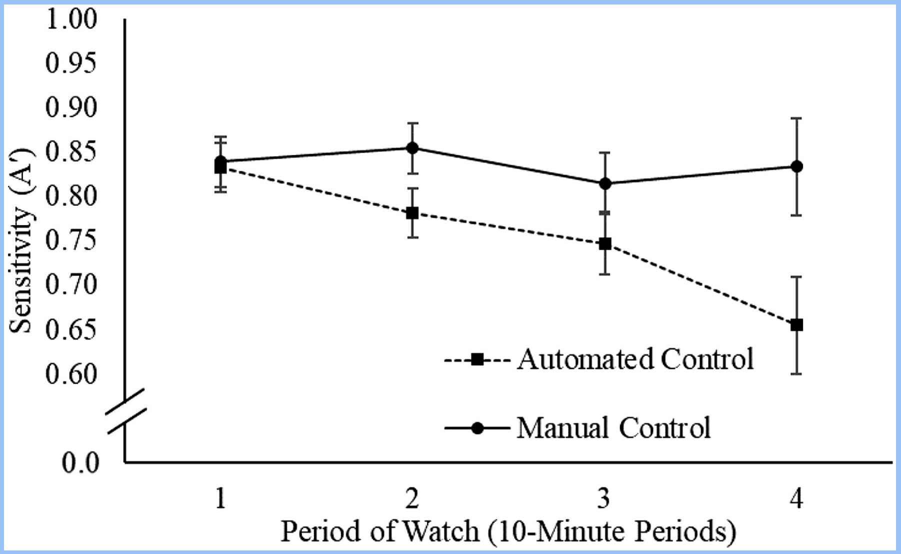
Results



Greenlee, DeLucia, Newton (2018)

Automated vs Manual Driving





Greenlee, DeLucia, Newton (2022)

Future Directions

- ❖ Identify the conditions under which different sources of information are used in collision judgments
- ❖ Examine wider range of visual impairments
- ❖ Examine effects of hearing impairments
- ❖ Determine whether and how training or assistive technologies can help people avoid collisions
- ❖ Examine use of multimodal information to mitigate the vigilance decrement

Acknowledgments

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- Undergraduate assistants
- Collaborators
- National Science Foundation
- National Eye Institute/National Institutes of Health
- National Aeronautics and Space Administration
- Study participants

Questions and Discussion

THANK YOU!

www.acct.org/acct-awards-nominations.php