Measuring Human Performance: Maintaining Constant Relative Position to a Lead Vehicle in a Simulation

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Outline

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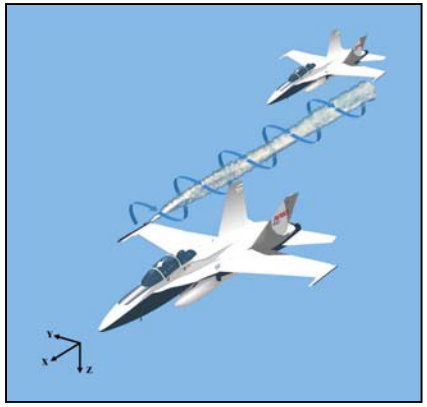
Motivation

1. Aerial Formation Flight
   - Fuel reduction benefits may only be realized by holding tight, close relative position
   - Will likely require new autonomous flight control capabilities with pilot(s) in supervisory role

2. Roadway Vehicle Following Situations
   - Intelligent Vehicle Systems are gaining increasing acceptance and usage in today's cars
   - Up to ¼ of all accidents are rear-end collisions, so development of reliable collision avoidance and headway warning systems is a priority



Source: Larson, G., "Autonomous Formation Flight," Presentation to MIT 16.886 Class, 05 Feb. 2004.

(Courtesy of Greg Larson. Used with permission.)

Need: To understand how humans control longitudinal distance when following very closely (in both flight and driving situations), in order to gain insight into how humans will interact with the new vehicle automation in these applications.

Experiment Outline

- Participant Goal:
  - Follow a randomly simulated lead vehicle with an unpredictable velocity profile
  - Try and maintain set separation distance of 150 feet as tightly as possible
- Conducted in “Miss Daisy” VW Bug driving simulator (MIT AgeLab)

Experiment Design

- Independent Variables
  - Primary: Type of Display Aid
    - No Aid (NA)
    - Distance Aid (DA)
    - Distance, Velocity Aids (DAVA)
  - Secondary: Behavior of the Lead Vehicle
    - Accelerating
    - Decelerating
    - Constant Speed
- Dependent Variables
  - Average Distance Headway (Separation)
  - Standard Deviation of Relative Velocity
  - Maximum/Minimum Headway

No Aid

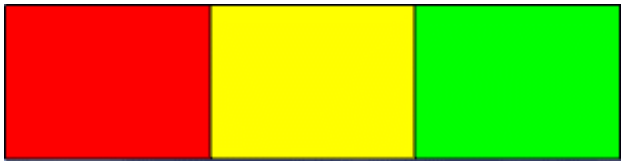
- Flat, straight, single-lane boring road
- Some trees on the side to add sensation of movement
- Lead car does not show brake lights
- Lead car is white for high visibility against the horizon

Distance Aid

- Lead vehicle larger than lines: Closer than 150ft
- Lead vehicle smaller than lines: Farther than 150ft

- Line placement exactly matches height and width of the lead car when at correct following distance

Velocity Aid



- Standard Traffic Light Convention
  - Colors and Order

- Red:

  Driver Speed > Lead Car Speed

- Yellow:

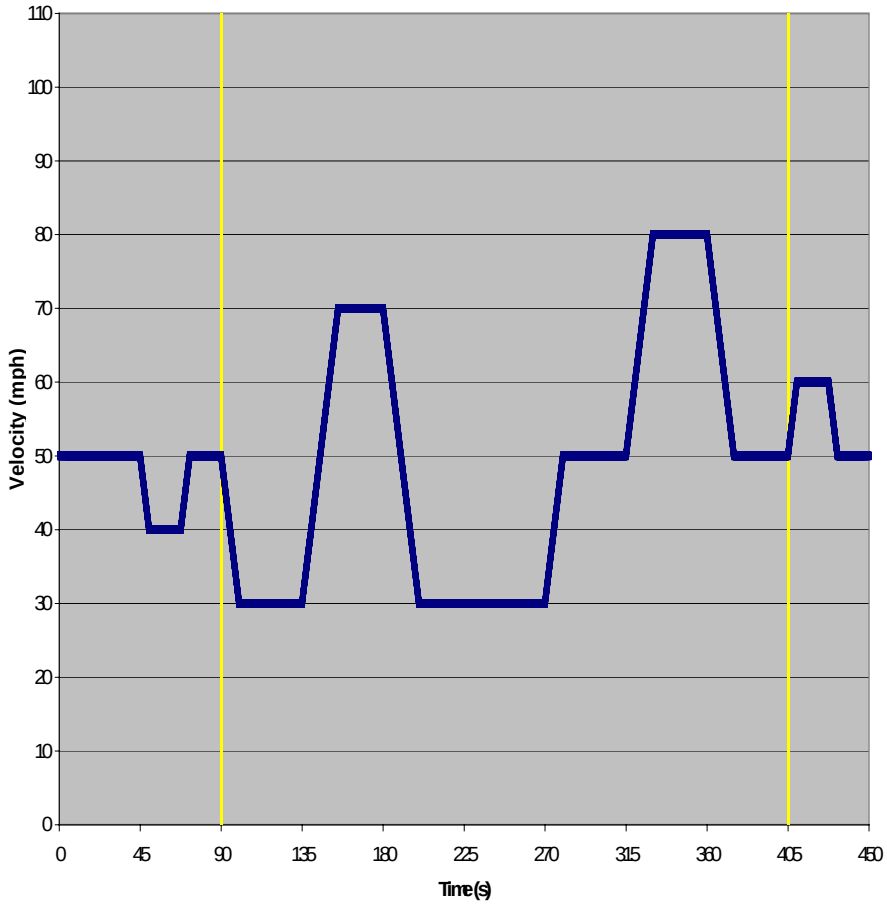
  Driver Speed = Lead Car Speed

- Green:

  Driver Speed < Lead Car Speed

Sample Lead Vehicle Velocity Profile

- Broken into 45 second increments
  - Allows driver to stabilize before next maneuvre
- To prevent learning, start and end of runs differ
- Common profile 90 - 405 seconds (5.25 minutes) for data collection
- 45 seconds total of pure acceleration and deceleration from three segments
- 45 seconds constant speed section in the middle
- Constant acceleration magnitude of two mph/s
- Total 7.5 minutes driving per trial
  - One trial each with no aid, the distance aid, the distance AND velocity aids



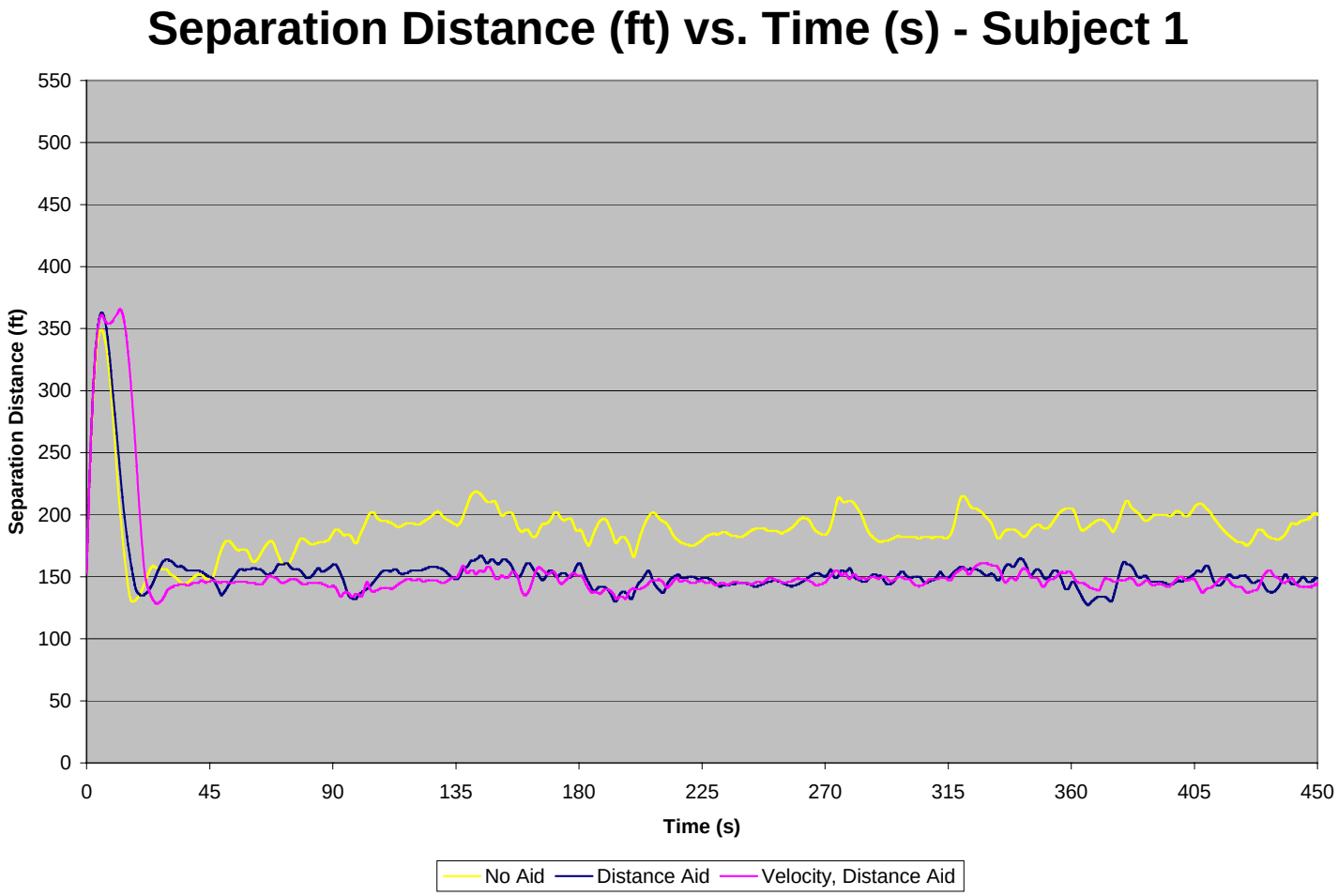
Subjects

- All MIT students or friends of students
- Relevant statistics:

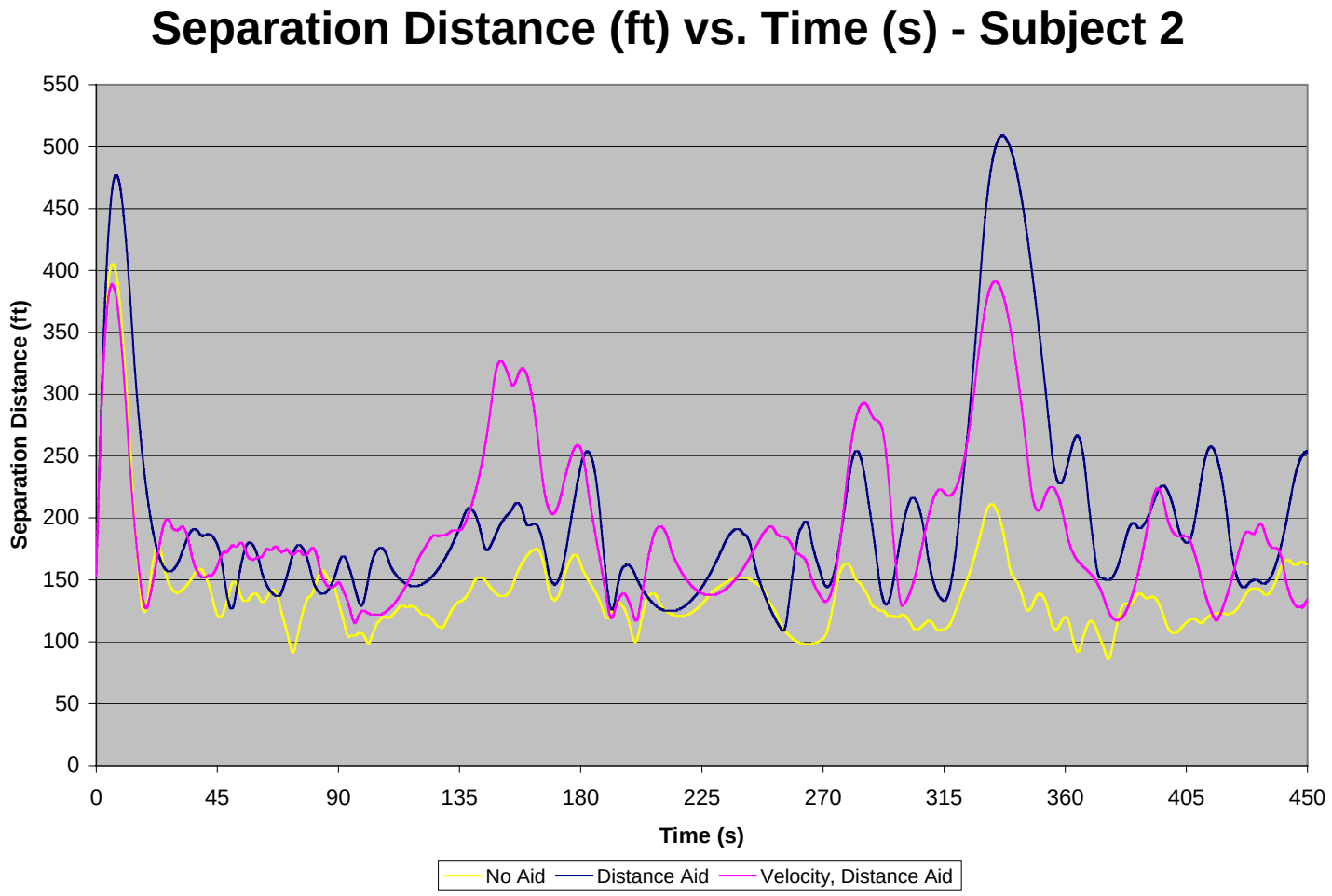
	Female	Male
Number of Subjects	12	12
Average Age (years)	24.00	25.50
Range of Ages (years)	22 - 28	21 - 29
Average Driving Experience (years)	6.38	8.88
Range of Driving Experience (years)	2 - 10.83	4.58 - 13
Last Year's Average Mileage (miles)	3122.92	5508.33

- Relatively few subjects regularly play video games
  - 25% of males, 0% of females
- Considerably more males indicated they had been in a rear-end collision than females
  - 58% of males, 17% of females

Results: Large Subject Differences

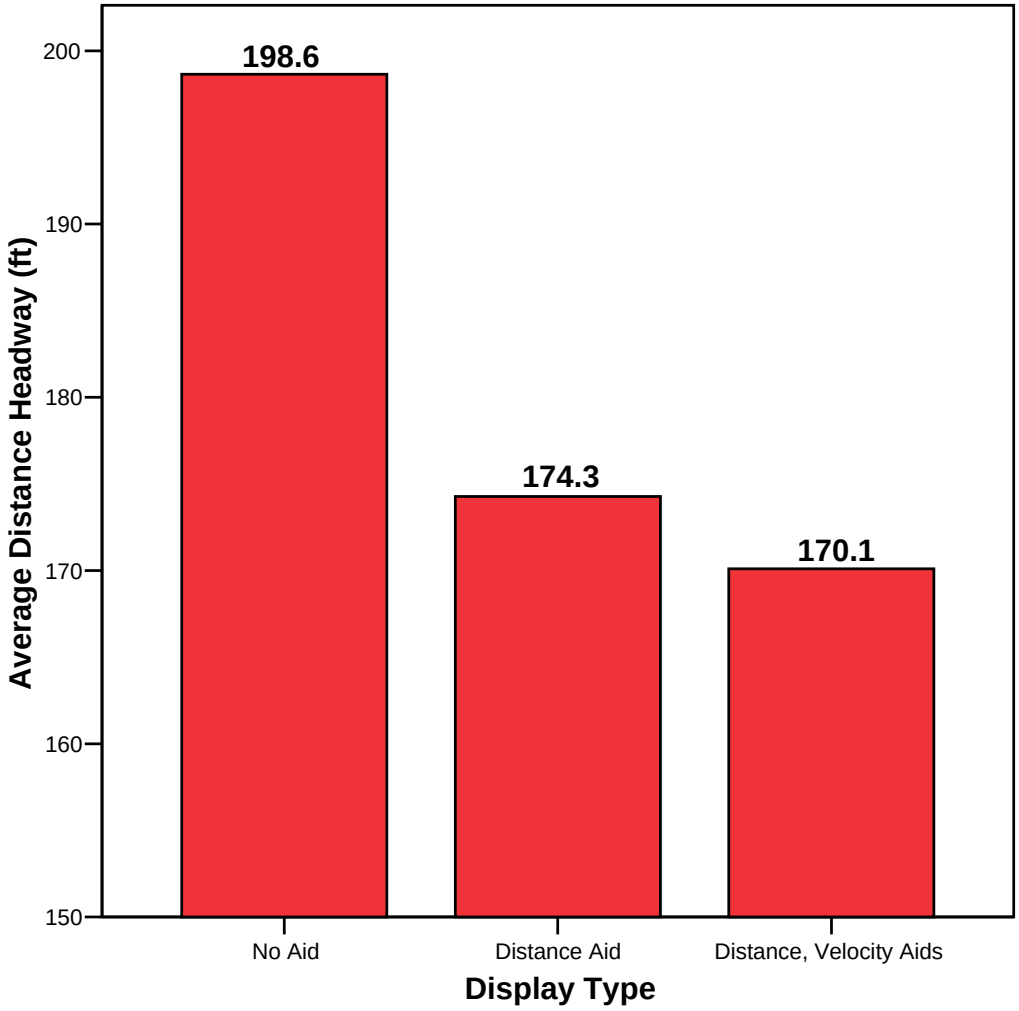


Large Subject Differences Cont.



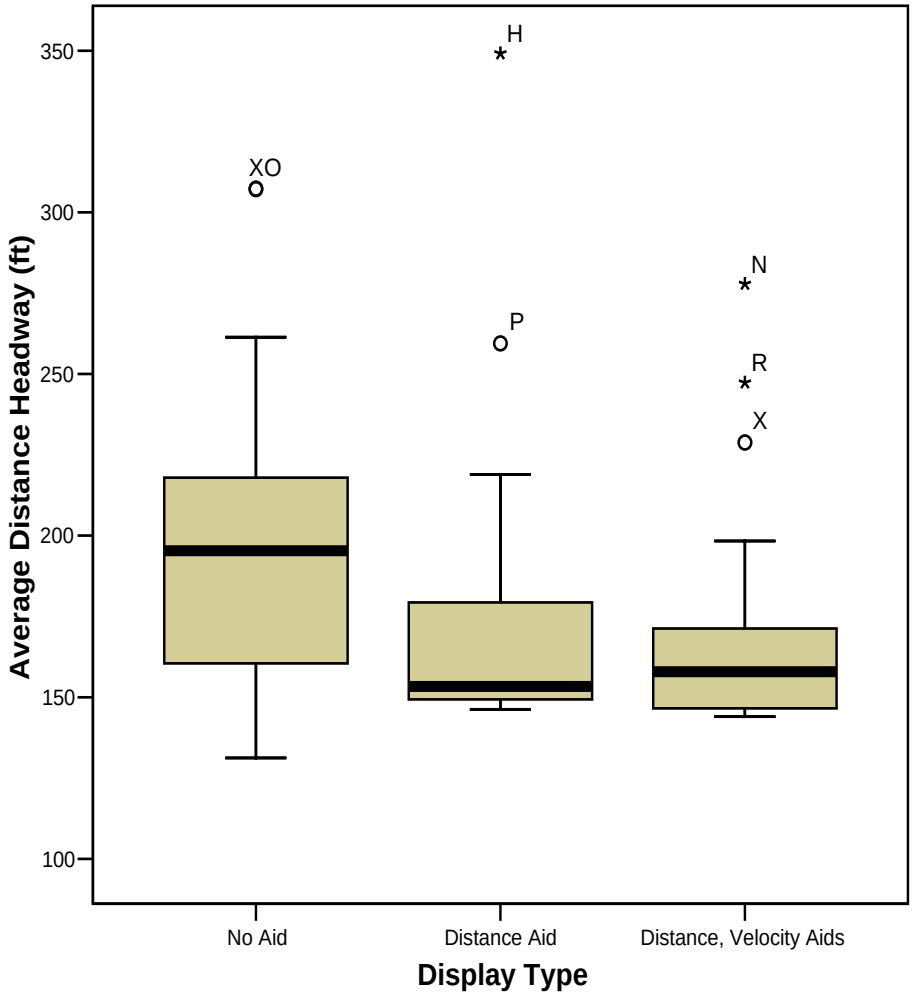
Average Headway

- Average separation distance over the entire run
- Target is **150ft**
- ANOVA significance:
  - Overall, p = 0.027
  - NA/DA, p = 0.067
  - NA/DAVA, p = 0.039
  - DA/DAVA, not significant



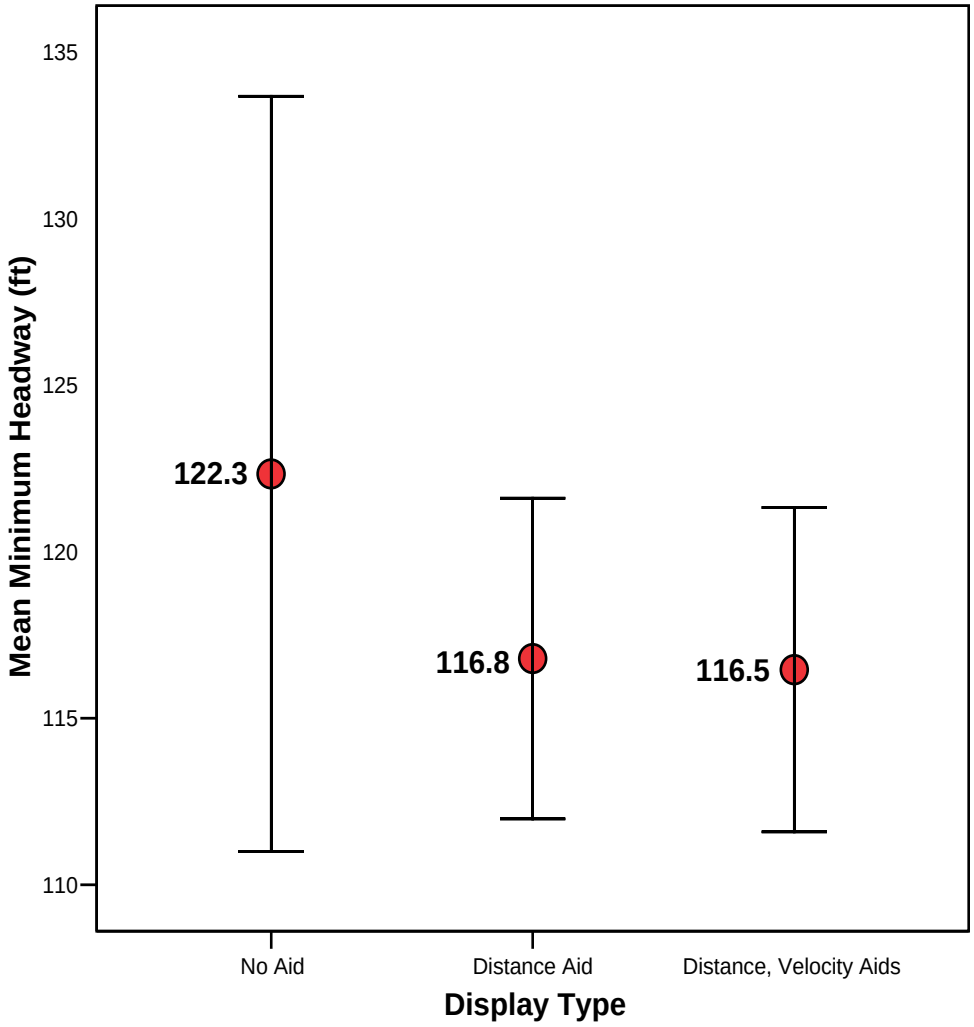
Average Headway Cont.

- Adding in more aids lowers variability slightly
- Significant skew in DA/DAVA data
  - High: 233% target (+133%)
  - Low: 96% target (-4%)
- Addition of any aid tends to on average prevent going far below and staying below the target distance



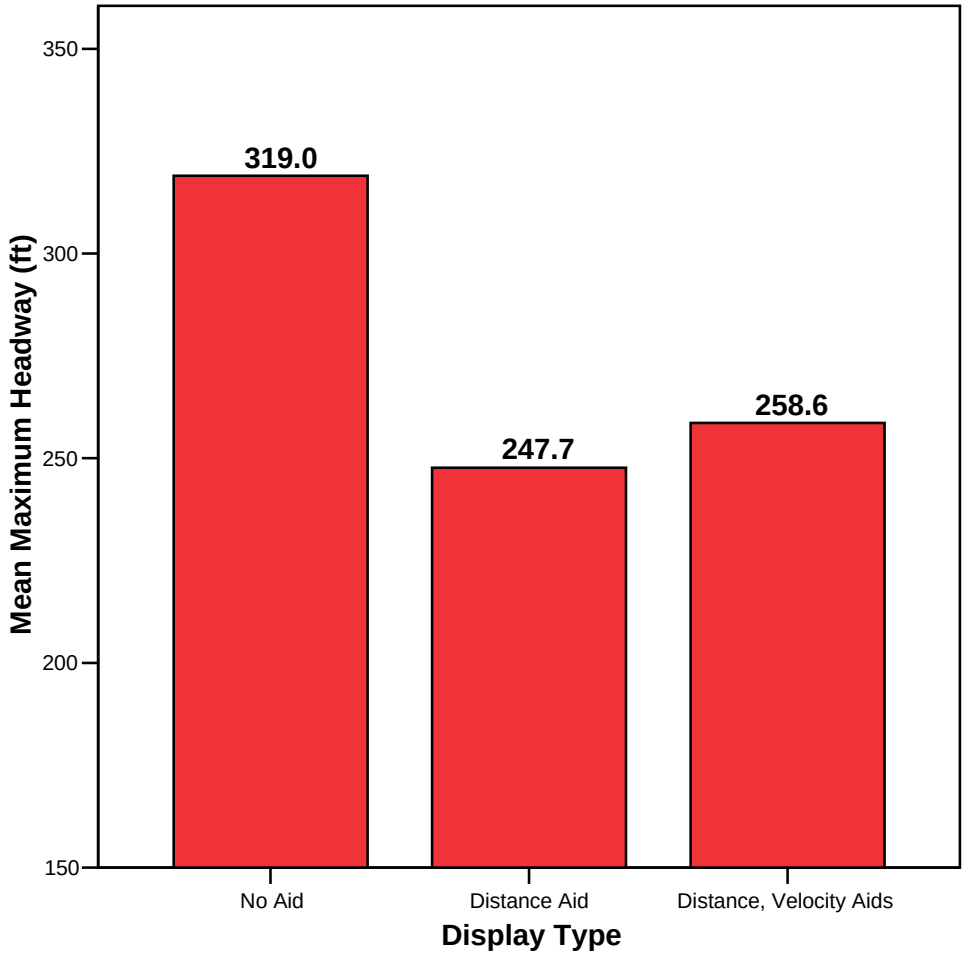
Minimum Headway

- Variance is significantly larger with no aids than with any
- Weak trend of decreasing average with more aids, opposite of expected
  - Likely no true average difference
- Indicates that display aids do not prevent extreme minimum separations from occurring on occasion
  - Reaction time is probably a factor here

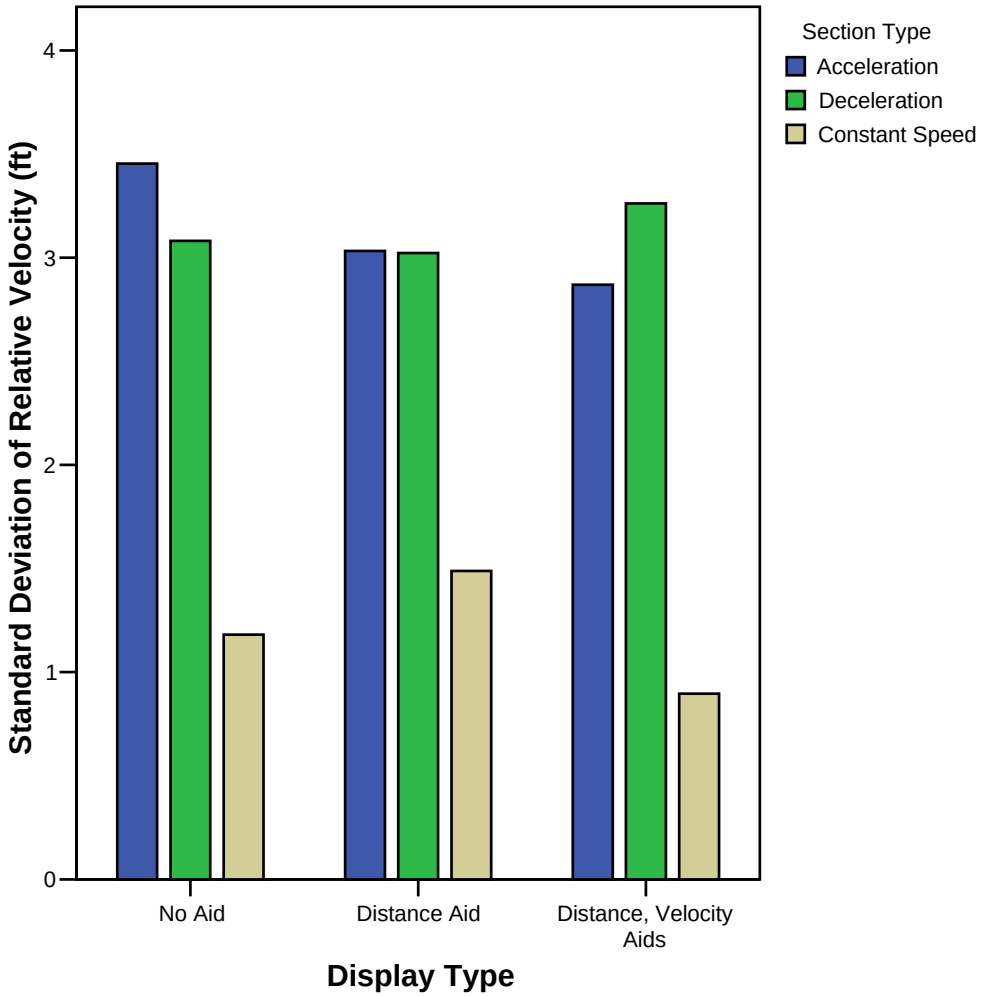


Maximum Headway

- Maximum distance the lead car was ahead over the entire trial
- ANOVA significance:
  - Overall, p = 0.044
  - NA/DA, p = 0.078
  - NA/DAVA, p = 0.074
  - DA/DAVA, not significant



Vehicle Behavior Influences



- Display type has little effect on tracking performance across vehicle behaviors
- For combined data encompassing entire trials (all section types and transitions), ANOVA of relative velocity significant only at $p = 0.31$
- Tracking of a constant speed lead vehicle is considerably better than one who is accelerating or decelerating by a factor > 2.4
- Makes no difference if the vehicle is gaining or losing speed
  - Across all section types, averages and standard deviations are within 3%

Conclusions

- Extreme differences in data collected from individuals and a lack of power in analyzing it speaks to the need for more subjects.
- Having any sort of valid display aid will, on average, improve most aspects of tracking performance dramatically.
  - Exception: Standard (not predictive) aids will likely not help in maintaining a minimum separation distance.
- The impact on performance of receiving relative velocity information in addition to relative position is not conclusive.
- Humans are able to maintain a relative position in a following situation far better when the vehicle is not changing speeds or directions, even in a continuous way.

Acknowledgements

- MIT AgeLab
- Bryan Reimer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