Ford SAVE-IT Update to NHTSA

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Ford SAVE-IT Objectives Development Derivation

- Ford objectives were derived from …
  - SAVE-IT's original key research questions
  - SAVE-IT Partners' key objectives, experimental design, lessons learned, and findings
  - What was of most interest to Ford's active safety goals

Approach to achieving these two objectives

- A two-stage study was implemented in the VIRTTEX simulator that involved:
  - 40 – 48 participants per stage
  - 1-hour study session per participant
- **Stage I** focused on Adaptive LDW Safety & Acceptance
- **Stage II** focused on Task Mitigation Safety & Acceptance

LDW Safety & Acceptance

- **Overview**
  - Study Objectives
  - Experimental Design
  - Study Introduction & Driver Training
  - Study Drive
  - Methods
  - Results:
    - Objective Data Analysis (Mike Blommer)
    - Subjective Data Analysis

LDW Study Objectives

Key research questions being addressed by the Ford Team:

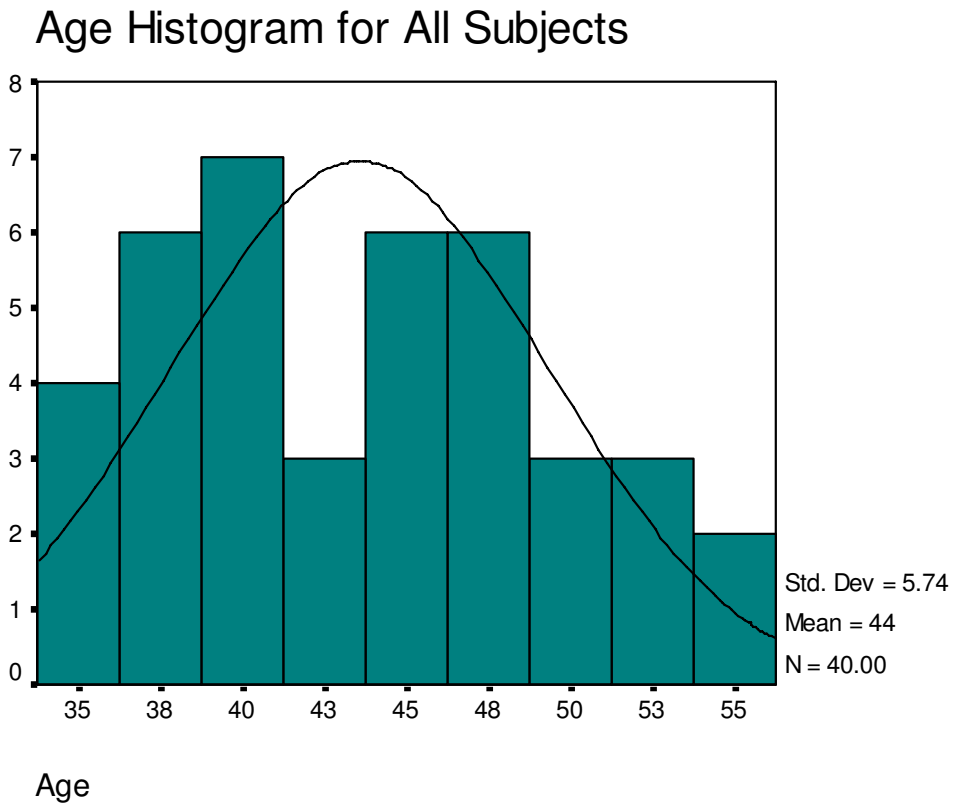
- How does LDW adaptation affect driver response to a lane departure?
- How does LDW adaptation affect overall feature satisfaction?
- How does the LDW experience coincide with the driver's mental model of LDW?

LDW Experimental Design

- Study Factors:
  - LDW mode: Within-subject, randomized & balanced 2-block design (adaptive LDW vs. non-adaptive LDW)
  - Gender: 50/50 split
- Tasks within each block (+ "no task" baseline):
  - Cycling through IP message center
  - Adjusting left rear-view mirror
  - Adjusting climate control temperature
  - Seeking to IVIS NAV Map screen
  - Sequence numbers reading

LDW Experimental Design

- Sample size: 40 participants
- Participant Demographics:
  - Ford employees with no active or passive safety experience
  - 35 – 55 years old
- Study Factors:
  - Gender
  - LDW Mode



LDW Study Introduction & Driver Training

- **Study Introduction**
  - Participants were only given *conceptual* information about non-adaptive vs. adaptive LDW
  - Drivers were shown the following two demos:
    - Non-Adaptive LDW Video Demonstration
    - Adaptive LDW Video Demonstration
- **Driver Training**
  - In-vehicle training on the 5 voice-prompted tasks participants would be completing during the drive
  - Simulator acclimation drive
  - Demonstration of LDW modes

LDW Study Drive

- 20-minute drive
- Daytime with moderate traffic volume
- One lane each direction
- Combination of urban and rural roadways
  - Urban: 35 mph (56 kph)
  - Rural: 55 mph (88 kph)
- LDW mode switched ½-way through drive
  - Order of mode randomized across participants
  - Driver informed of mode switch

LDW Methods

- A forced lane departure was implemented while subjects looked away from road for Number Reading task
- Successful task completion required drivers to read each number aloud as it appeared (1 every half second)
- Subjects were highly motivated to get all six numbers correct.

LDW Post-drive Questionnaires

- Four questionnaires were completed by the participants after the drive.
  - Adaptive and Non-Adaptive LDW Systems
    - 2-page questionnaires with multiple-choice (i.e., *van der Laan*) and open-ended queries
  - Comparing both LDW modes
    - 1-page questionnaire with multiple-choice queries
  - Adaptive LDW Mental Model Exercise
    - This short form asked them to list the *inputs* required to produce **warning** and **no warning** Adaptive LDW *outputs*
- Questionnaires took approximately 20 minutes to complete.

Stage I LDW: Data Analysis

- **Objective Findings** (Mike)
  - Steering reaction time
  - LDW system performance

Stage I LDW: Data Analysis

- **Subjective Findings**
  - Ordinal analysis of system validity, confidence, and annoyance
  - *van der Laan* overall usefulness/satisfaction ratings
  - Open-ended comments
  - LDW System Mode Comparison results
  - Adaptive LDW Mental Model *input* frequencies

Subjective Results

- LDW System Questionnaires were outlined as follows:
  - I. System Validity: 4 questions
  - II. System Trust/Confidence: 2 questions
  - III. System Annoyance
    - 2 questions, both with a follow-up question depending on 1st answer
  - IV. Overall Acceptance:
    - *van der Laan* scale + System on/off options
  - V. Open-ended Feedback: 3 questions

LDW System Questionnaires Result Summary

I. System Validity:

Adaptive LDW System median responses were significantly more favorable for the follow questions:

- Were you warned when you should NOT have been?
- Were you warned when you should have been, but didn't think it was necessary?

II. System Trust/Confidence:

No significance differences between the systems with respect to trust and confidence, both receiving median ratings of 90%.

III. System Annoyance:

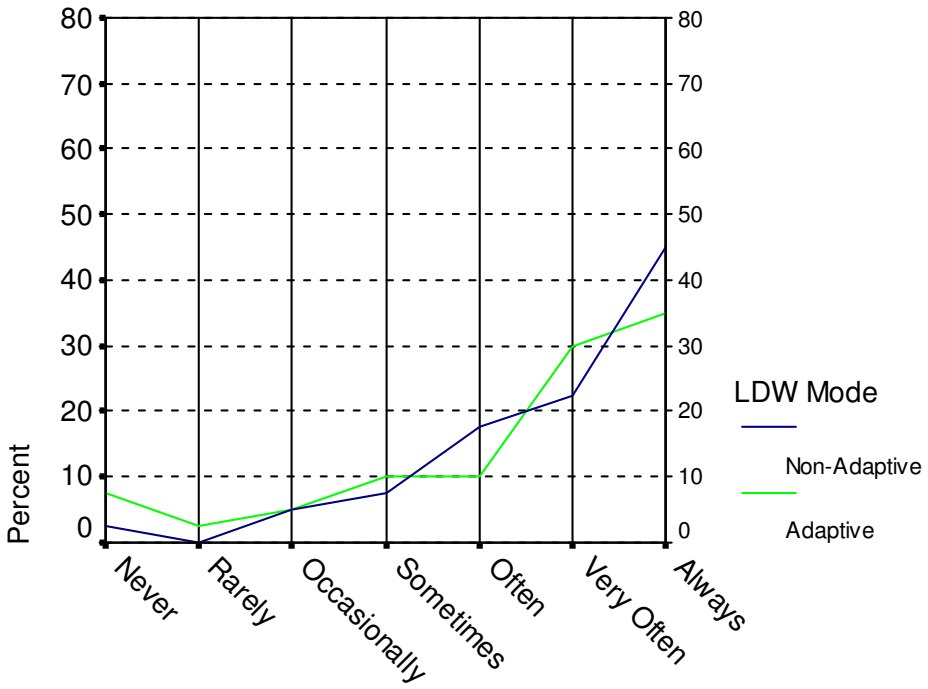
No significance differences among the systems in *annoyance with unnecessarily warnings* **or** *annoyance with not being warned.*

IV. Overall Acceptance:

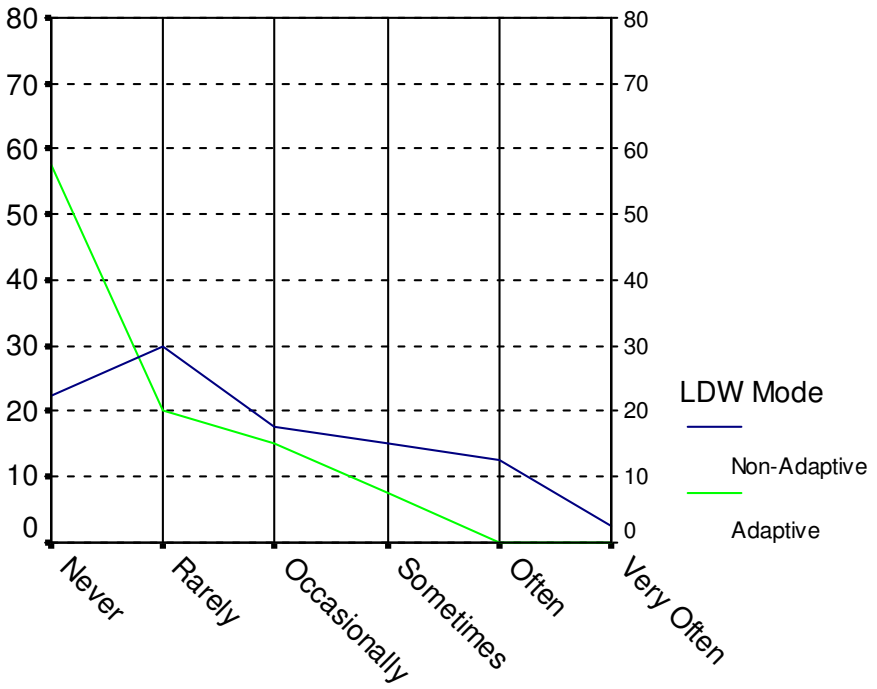
- *van der Laan* Ratings: For both LDW Modes, drivers rated the system's usefulness better than their satisfaction of the system's implementation Drivers were also more Satisfied with the Adaptive vs. the Non-adaptive LDW System.
- System On/Off Options: Drivers were significantly less likely to turn off the Adaptive System vs. the Non-adaptive LDW system.

Subjective Results

- LDW System Validity Responses



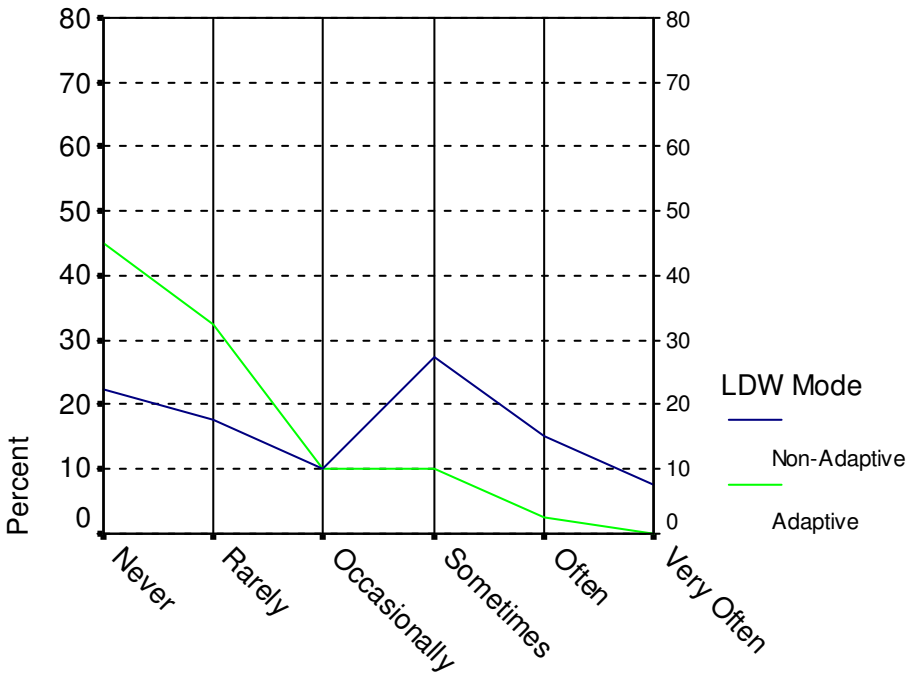
Warned when you should have been?



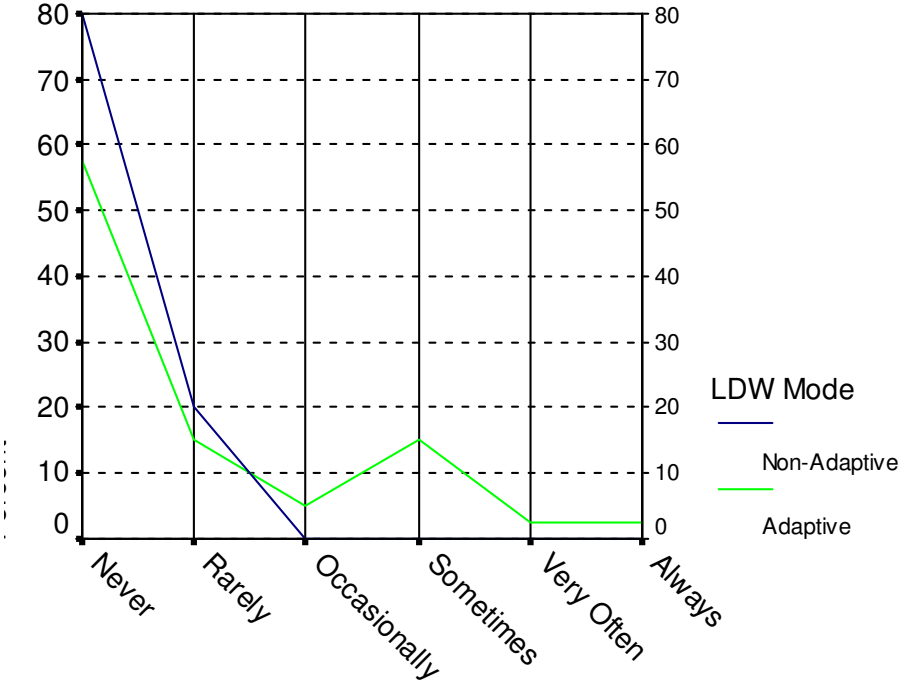
Warned when you should NOT have been?

Subjective Results

- LDW System Validity Responses



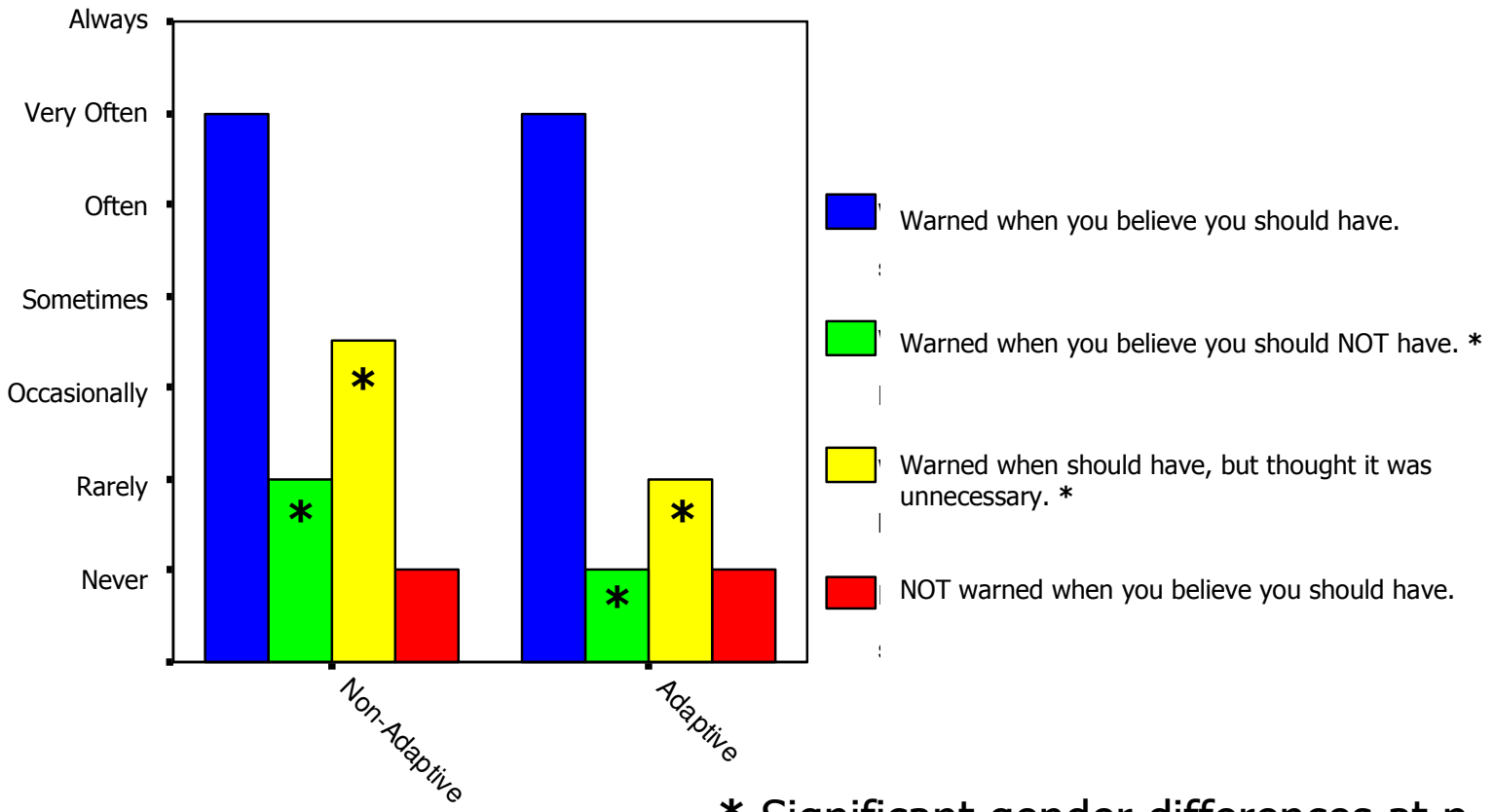
Warned when should've been, didn't think it was necessary?



NOT warned when you should have been?

Subjective Results

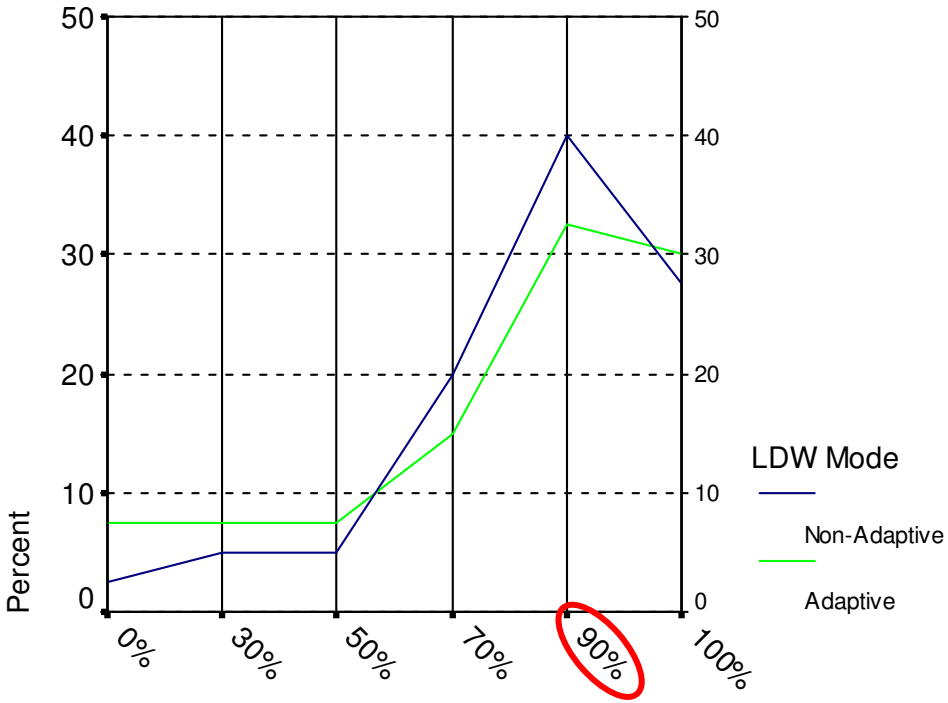
- LDW System Validity Medians



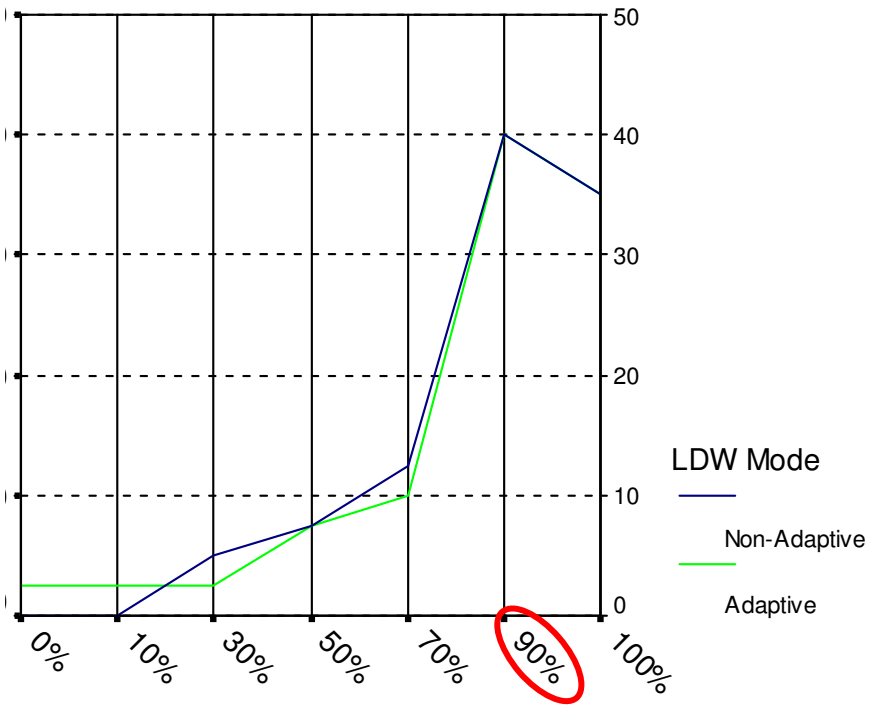
* Significant gender differences at $p < 0.05$.

Subjective Results

- LDW System Trust & Confidence Responses



How much did you trust the system during your drive?

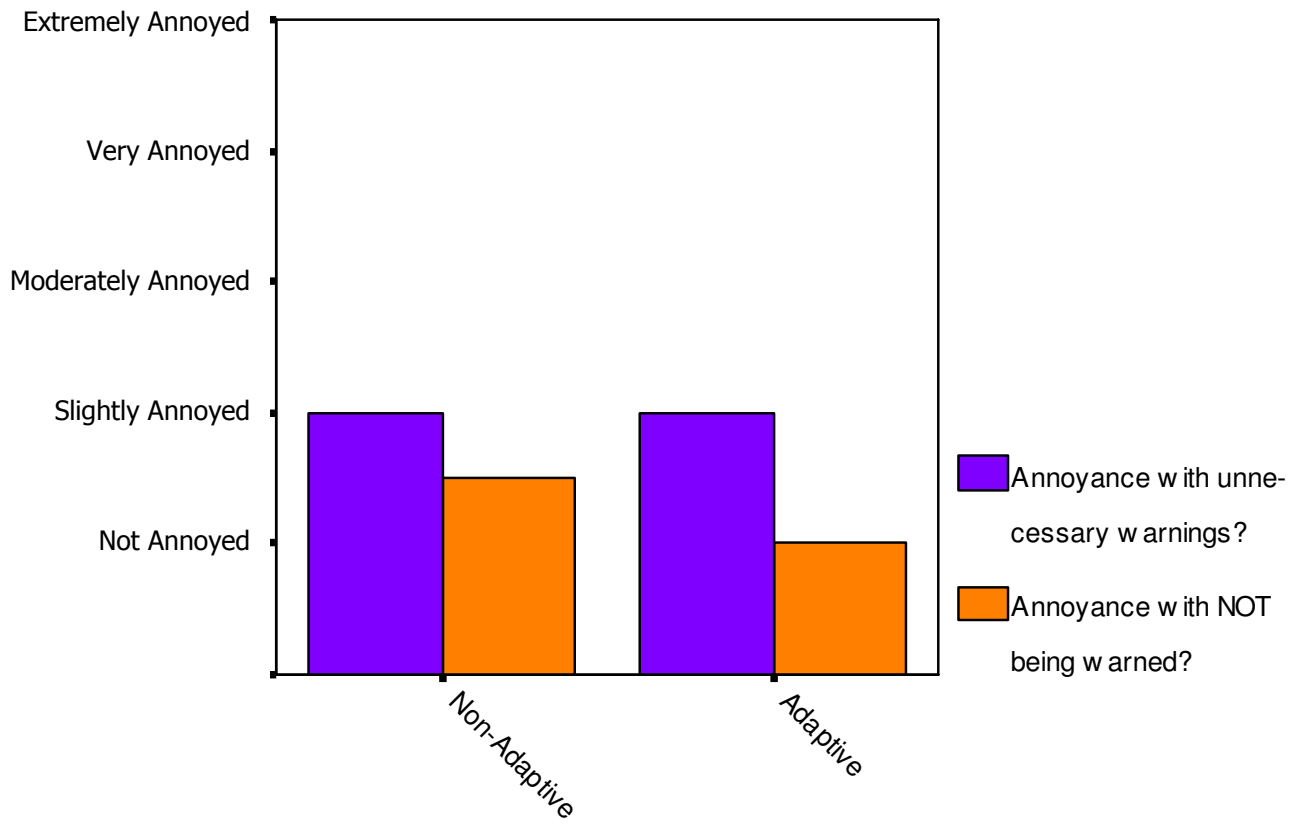


How much confidence do you have in the system after your drive

Subjective Results

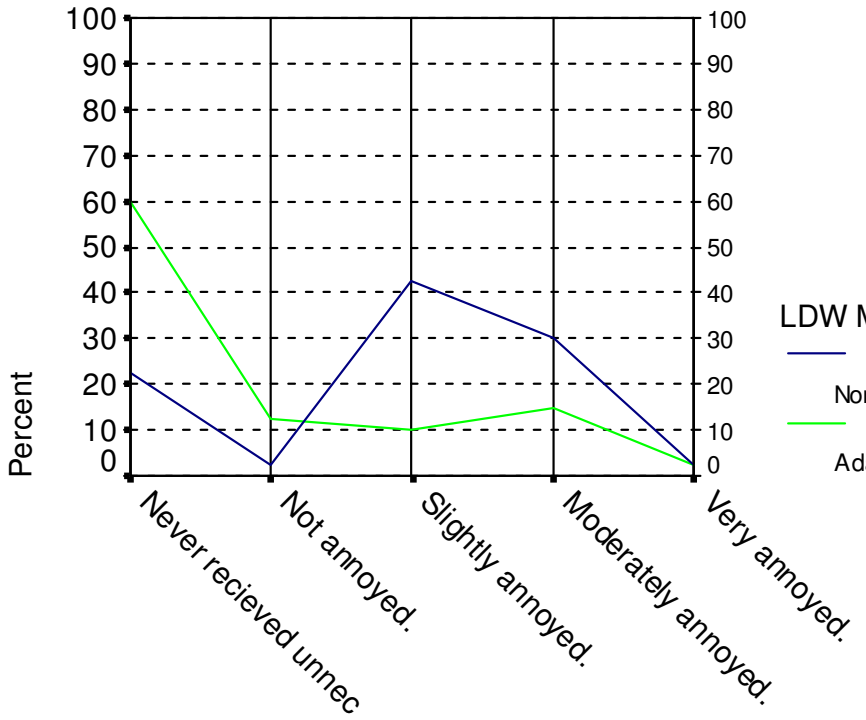
- LDW System Annoyance Medians

Overall, there were slight annoyance issues with unnecessary warnings for both systems, but there was nothing significant.

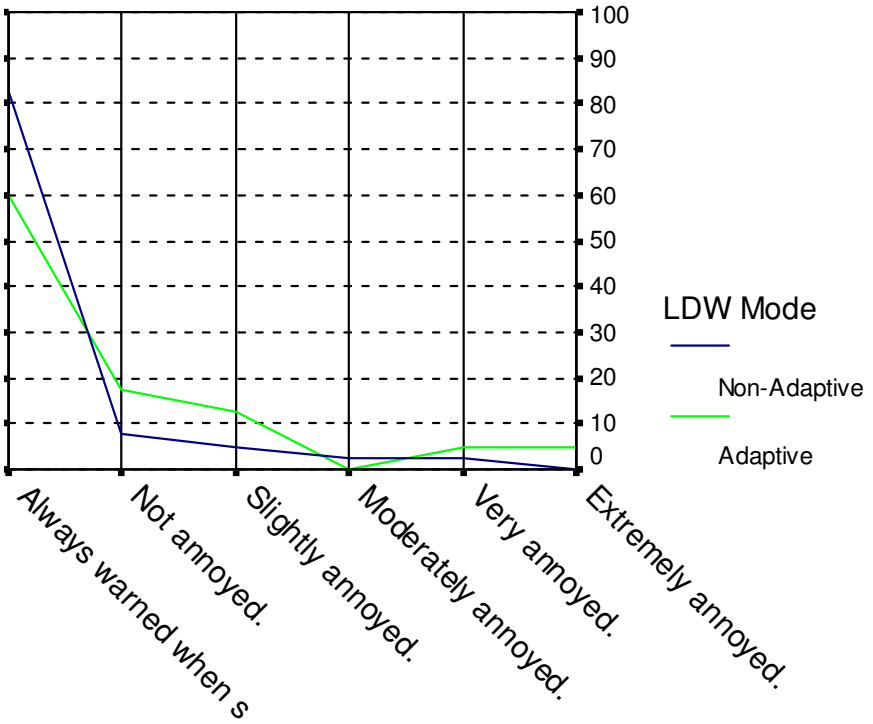


Subjective Results

- LDW System Annoyance Responses



Annoyance with unnecessary warnings?



Annoyance with NOT being warned?

Subjective Results

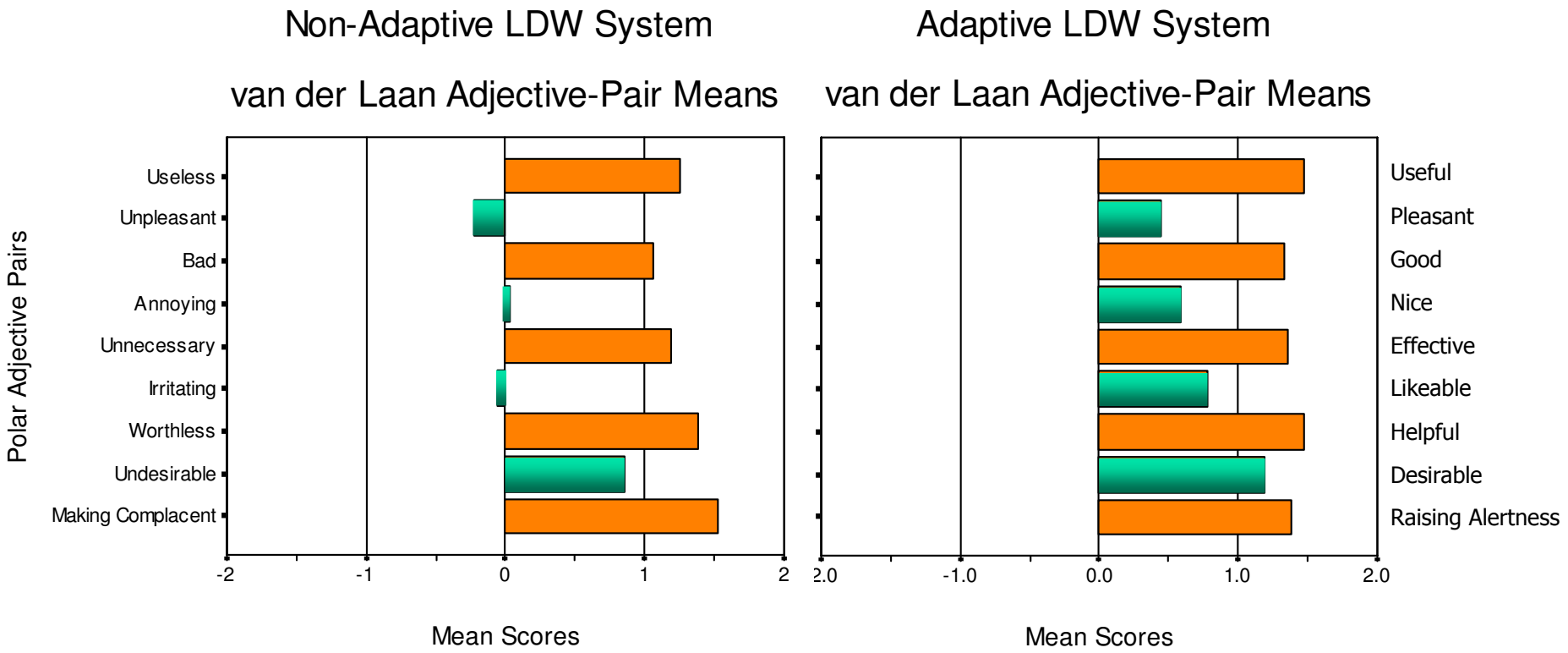
- *van der Laan* Usefulness & Satisfaction Ratings
  - Given 9 polar-adjective word pairs, subjects were asked to select a rating on a 5-pt discrete scale between the pairs. The 9 word pairs were:
  - Usefulness components
    - Useful – Useless
    - Good – Bad
    - Effective – Unnecessary
    - Helpful – Worthless
    - Raising Alertness – Making Complacent
  - Satisfaction components
    - Pleasant – Unpleasant
    - Nice – Annoying
    - Likeable – Irritating
    - Desirable – Undesirable

Subjective Results

- *van der Laan* Usefulness & Satisfaction Ratings
  - 5-pt scale scores are coded from -2 to +2 with positive adjective on the right/negative on left
  - Reliability tests for the Usefulness & Satisfaction components exceeded the minimum requirement of 0.65.

Subjective Results

- Drivers were significantly less satisfied (*p=0.008*) with the Non-adaptive System vs. the Adaptive System.



Subjective Results

Non-Adaptive vs. Adaptive LDW vander Laan Ratings

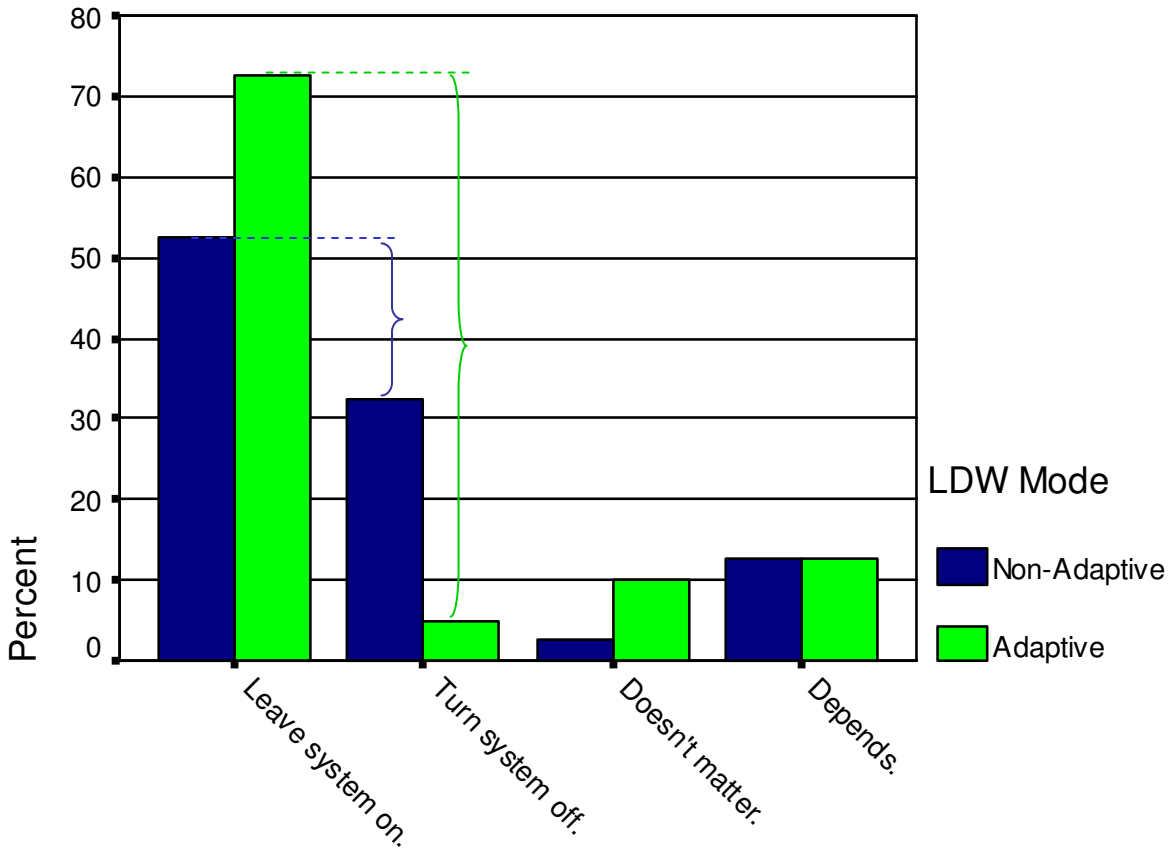
- *van der Laan* system Usefulness & Satisfaction Ratings
- No significant Gender differences in the ratings per system.

van der Laan Mean Ratings

LDW Mode		Usefulness	Satisfaction
Non-Adaptive	Mean	1.2833	.1528
	Std. Deviation	.8020	1.0877
Adaptive	Mean	1.4056	.7500
	Std. Deviation	.8532	.7392
Total	Mean	1.3444	.4514
	Std. Deviation	.8244	.9711

Subjective Results

- Drivers are far more likely to turn off the Non-adaptive vs. the Adaptive LDW system. This was a significant finding (*p=0.007*).



Choice to turn system off, would you:

Subjective Results

- The LDW Questionnaires wrapped up with 3 open-ended questions:
  1. If you had trouble trusting the system, what were your reasons?
  2. What would you change to improve the overall performance of the system?
  3. Can you describe an instance when the system behaved differently than you expected?

Subjective Results

- If you had trouble trusting the (Adaptive LDW) system, what were your reasons?
  - System alerted me when I did not go out of the lane
  - Felt I was more distracted than it measured.
  - When doing mirror, message center, and NAV tasks, I crossed lane line, but was not warned.
  - Don't understand how (the) system judges, causing uncertainty regarding trust.
  - I did not receive any warnings.
  - What if someone was asleep at the wheel, but looking forward?
  - Not sure if I would be alerted in time.

Subjective Results

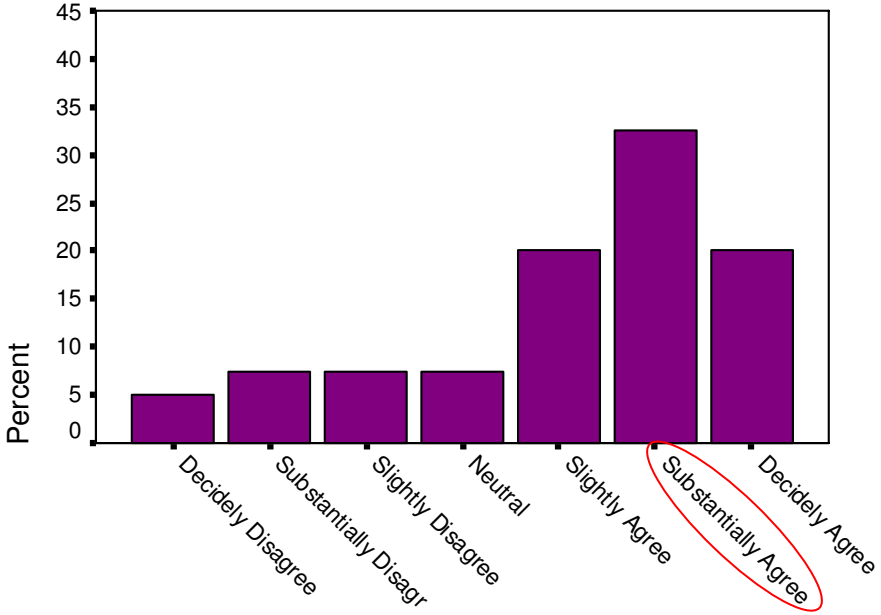
- What would you change to improve the overall performance of the (Adaptive LDW) system?
  - Earlier alert because I was well to the right before being alerted.
  - Have more pleasant tone; tone was obnoxious; tone too harsh.
  - Warn each time you cross lane line even though head is upright, one could be looking in rearview mirror or daydreaming.
  - Ability to turn on/off lights, tone, or vibration.
  - Warn when cross line regardless of distraction state.
  - Make it so the severity of the alarm can be adjusted.
  - If system could incorporate traffic density that would be great.
  - Turn down tone volume; make the warning gentler.
  - Variable warning depending on severity of departure based on surroundings.
  - Directional haptic feedback in the seat.

Subjective Results

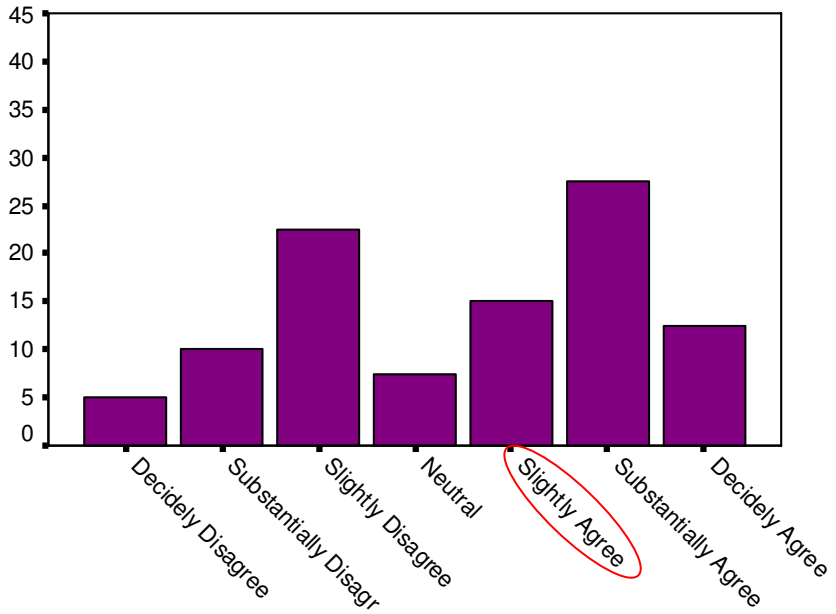
- Can you describe an instance when the (Adaptive LDW) system behaved differently than you expected?
  - System alerted me once when I did not expect it.
  - Expected to be warned more often when drifting out of lane.
  - While using NAV, I crossed over line, but was not warned.
  - Expected more warnings as to distractions.
  - System never warned me.
  - System warned when I was attentive.

LDW System Mode Comparison Post-Questionnaire Results

It was easy to tell if the LDW system was set to adaptive by how it behaved.



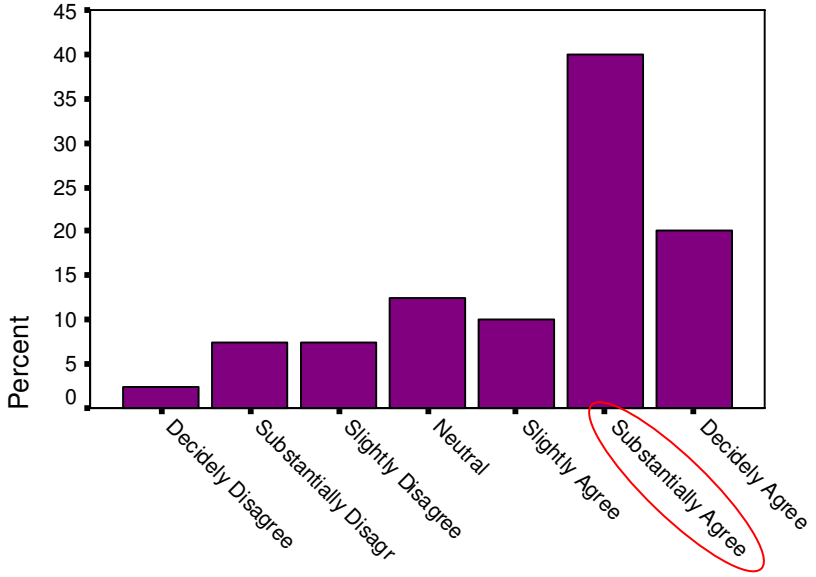
Adaptive LDW will increase driving safety more than Non-adaptive LDW.



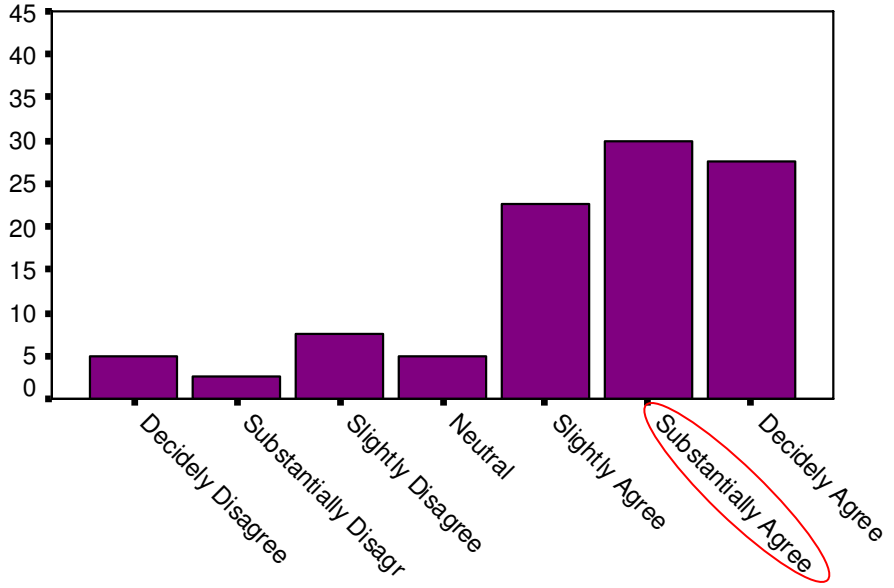
October 31st, 2008

LDW System Mode Comparison Post-Questionnaire Results

Adaptive LDW will increase driver acceptance of LDW more than Non-adaptive LDW.



Should be able to select from 3 LDW settings: LDW off, Adaptive off, or Non-Adaptive off.



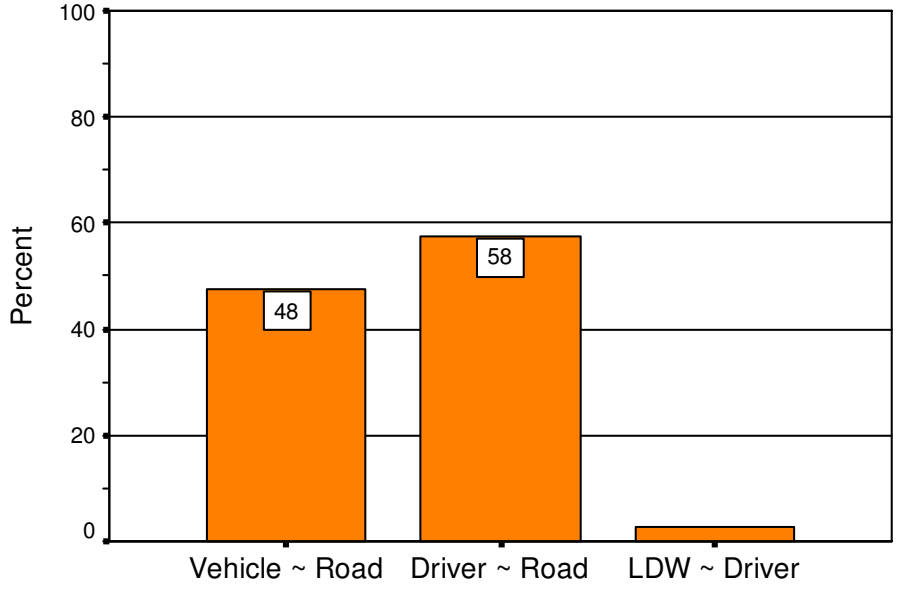
Subjective Results

- **Adaptive LDW Mental Model Results**
  - Mental Model Questions:
    - What needs to occur for the Adaptive LDW system NOT to warn you?
    - What needs to occur for the Adaptive LDW system TO warn you?
  - Mental Model feedback focused on categorizing three key relationships of the possible 2-way links between the vehicle, driver, road, and LDW system:
    1. The vehicle's relationship to the road (e.g., in or out of lane).
    2. The driver's relationship to the road (e.g., was driver attending to the road or not).
    3. The Adaptive LDW system's relationship to the driver (e.g., time-delay related warning).

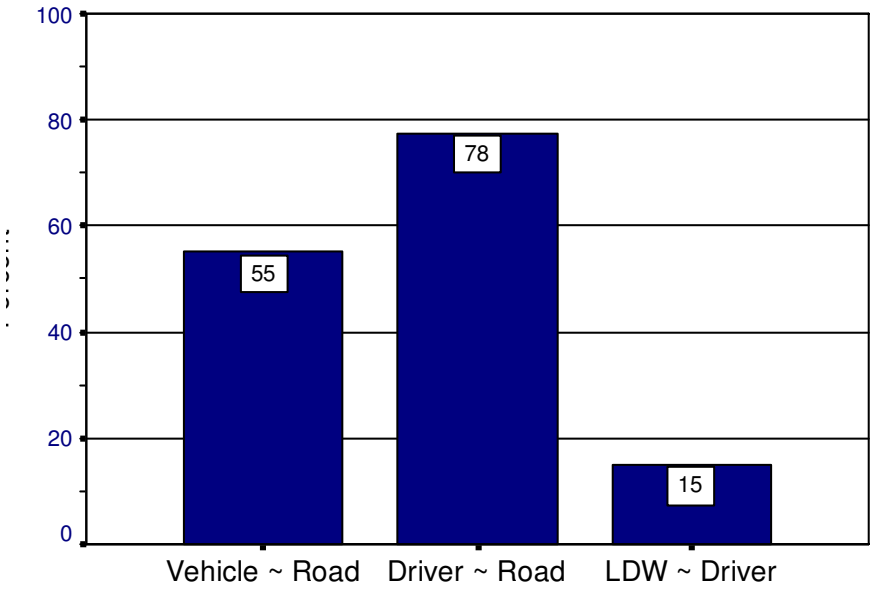
Subjective Results: Adaptive LDW Mental Model

- Drivers had a much clearer mental model of the Driver~Road (*p=0.094*) and LDW System~Driver (*p=0.108*) relationships from the perspective of being warned vs. NOT being warned.

What needs to occur for the Adaptive LDW system NOT to warn you?



What needs to occur for the Adaptive LDW system TO warn you?



Subjective Results

- Additional Adaptive LDW Mental Model Results
  - What needed to occur for the Adaptive LDW System NOT to warn you?
    - 75% (30 or 40) identified at least 1 of the 3 key relationships
    - 30% (12 of 40) identified 2 of the 3 key relationships
    - 0% (no one) identified all 3 key relationships
    - 3.3% (1 of 40) identified the time-delay relationship
    - 25% (10 or 40) could not identify any of the 3 key relationships

Subjective Results

- Additional Adaptive LDW Mental Model Results
  - What needed to occur for the Adaptive LDW System TO warn you?
    - 85% (34 of 40) identified at least 1 of the 3 key relationships
    - 52.5% (21 of 40) identified 2 of the 3 key relationships
    - 7.5% (3 of 40) identified all 3 key relationships
    - 15% (6 of 40) identified the time-delay relationship
    - 15% (6 0f 40) could not identify any of the 3 key relationships
  - Other identified relationships for both questions included: LDW system ⇔ vehicle control (i.e., speed, steering rate), time of day; driver's state of being drowsy; road conditions (i.e., weather or surface roughness)

Mitigation Safety & Acceptance

- **Overview**
  - Evaluation Objective
  - Experimental Design
  - Study Introduction & Driver Training
  - Methods
  - Study Drive
  - Results:
    - Objective Data Analysis (Mike Blommer)
    - Subjective Data Analysis

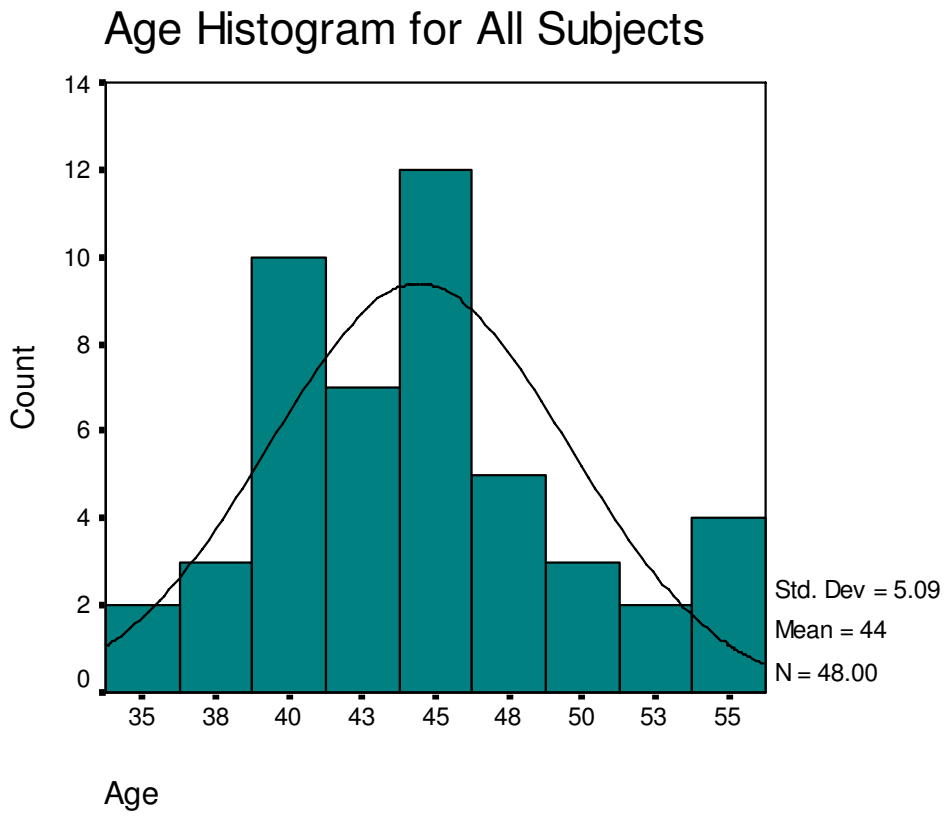
Ford's Evaluation Objectives

II. Mitigation Safety & Acceptance:

- Key research questions being addressed by the Ford Team:
  - Is mitigation effective in improving driver response in a dangerous situation?
  - How does mitigation affect overall feature satisfaction?
  - How does the mitigation experience coincide with the driver's mental model of mitigation?

Mitigation Experimental Design

- 48 participants
  - Ford employees with no active or passive safety experience
  - No VIRTTEX experience
- 50/50 gender split
- One age group:
  - 35 – 55 years
- Study Factors:
  - Gender
  - Mitigation level



Mitigation Study Introduction & Driver Training

- **Study Introduction**
  - Participants given minimal information about LDW (haptic seat only) and IVIS Task Manager
- **Driver Training**
  - In-vehicle training on voice-prompted IVIS tasks participants would be completing during the drive
  - Simulator acclimation drive
  - Demonstration of LDW system

Mitigation Study Drive

- Participants completed the following 4 tasks:
  - **Non-IVIS:** Cycling through IP message center
  - **Non-IVIS:** Adjusting climate control temperature
  - **IVIS:** Dial office or phone number (time limited)
  - **IVIS:** Retrieve & read text message (time limited)

Mitigation Study Drive

- Within-subject *mitigation task situation* design
- Each subject completed two repetitions of the following 3 mitigation task situations (+ "no task" baseline) where they were …
  1. Allowed to complete the task with no interruptions during the allotted time
  2. Denied access to the task during the entire allotted time
  3. Interrupted at least once during the allotted time they were given to complete the task
- Study drive ended with a non-adaptive between-subject FCW event.

Mitigation Study Drive

- 20-minute drive
- Daytime with moderate traffic volume
- One lane each direction
- Combination of urban and rural roadways
  - Urban: 35 mph (56 kph)
  - Rural: 55 mph (88 kph)
- Completed non-IVIS tasks in rural areas
- Completed IVIS tasks in urban areas

Mitigation Post-drive Questionnaires

- Two questionnaires were completed by the participants after the drive.
  - Task Mitigation System
    - Web-based questionnaire with multiple choice (i.e., *van der Laan*) and open-ended queries
  - Mitigation Mental Model Exercise
    - Web-based form asked them to list the *inputs* required to produce **lock out** and **no lock out** mitigation *outputs*
- Questionnaires took approximately 20 minutes to complete.

Stage II Implementation: Mitigation Safety & Acceptance

- Objective Findings (Mike)

Stage II Task Mitigation: Data Analysis

- Subjective Findings
  - Ordinal analysis of system validity, confidence, annoyance, and lock-out distraction
  - *van der Laan* overall usefulness/satisfaction ratings
  - Open-ended comments
  - Task Mitigation Mental Model *inputs* frequencies

Subjective Results

- **Task Mitigation System Questionnaire was outlined as follows:**

I. System Validity: 4 questions

II. System Confidence: 1 question

III. System Annoyance
  - 2 questions, both with a follow-up question depending on 1st answer

IV. Locked-out vs. Allowed Tasks - Distraction Comparison
  - 1 question

V. Overall Acceptance:
  - *van der Laan* rating + System On/Off options

VI. Open-ended Feedback: 3 questions

Task Mitigation System Questionnaire Results Summary

I. System Validity:

Task Mitigation System responses were more widely distributed when compared to the Adaptive LDW system responses.

II. System Confidence:

This response was also dispersed with a 70% confidence median rating.

III. System Annoyance:

Drivers were more annoyed with unnecessarily lock outs **vs.** very little annoyance with not being locked out.

IV. Is being locked-out a distraction?

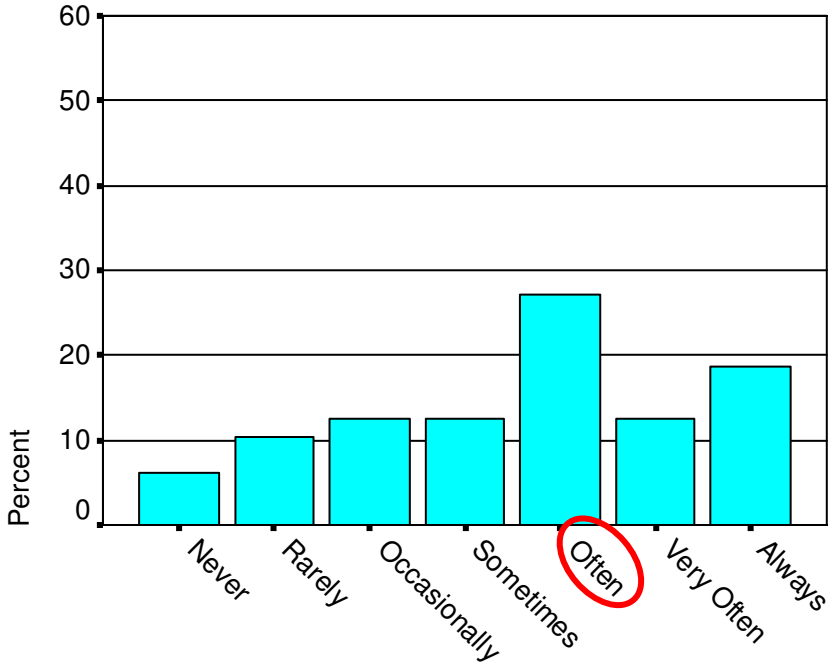
- Drivers believed **allowed IVIS tasks** were *less distracting* that **locked-out IVIS tasks**.

V. Overall Acceptance:

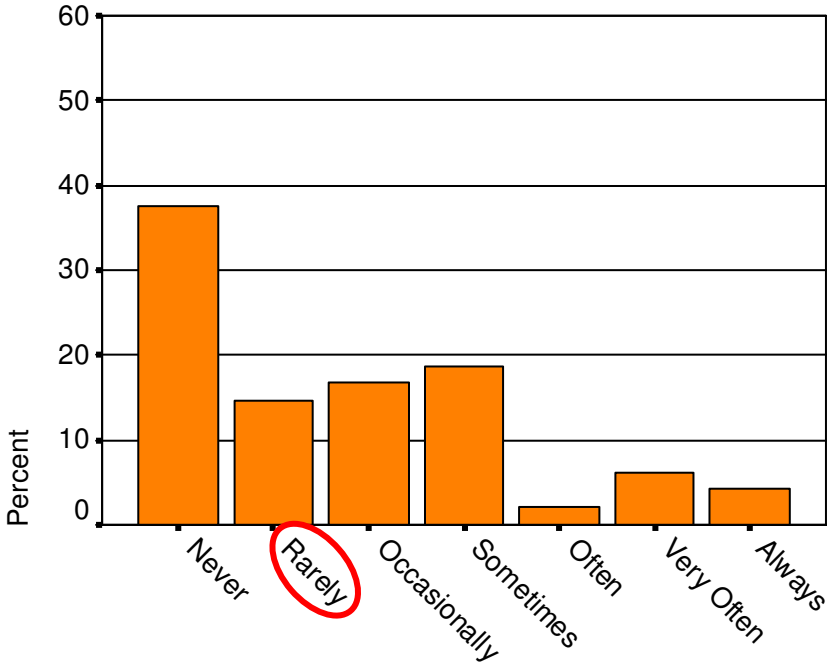
- *van der Laan* ratings: Drivers rated the system's usefulness better than their satisfaction of the system's implementation.
- System On/Off options: ~50% of drivers wanted to have some control over being able to turn the system on/off depending on the situation.

Subjective Results

- IVIS Mitigation System Validity Responses



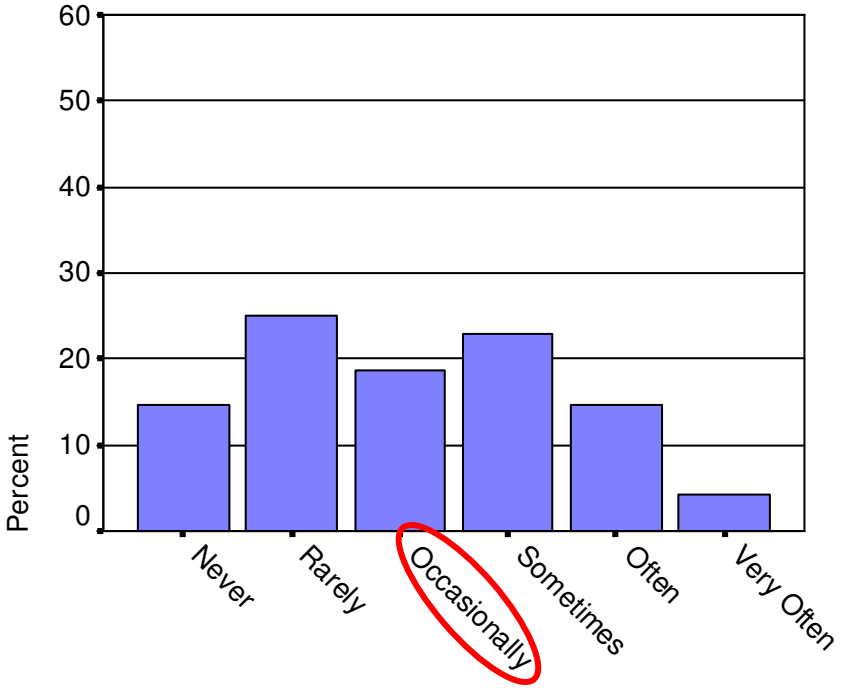
Locked out when you should have been?



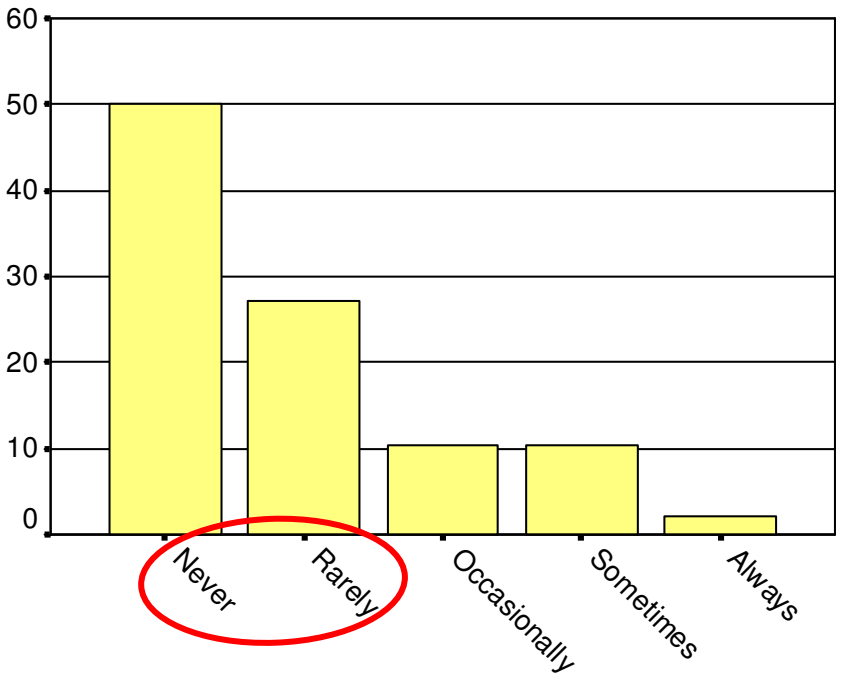
Locked out when you should NOT have been?

Subjective Results

- IVIS Mitigation System Validity Responses



Locked out when should've bee , but not necessary?

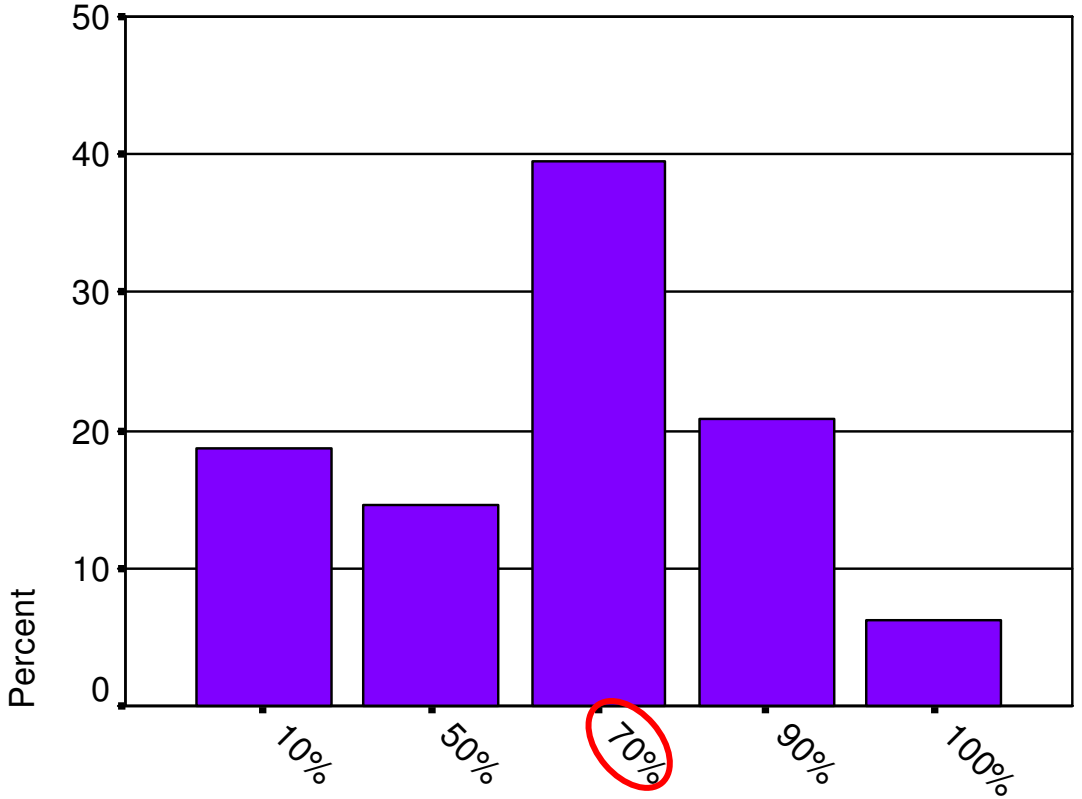


NOT locked out when should have been?

Subjective Results

- IVIS Mitigation System Confidence Responses

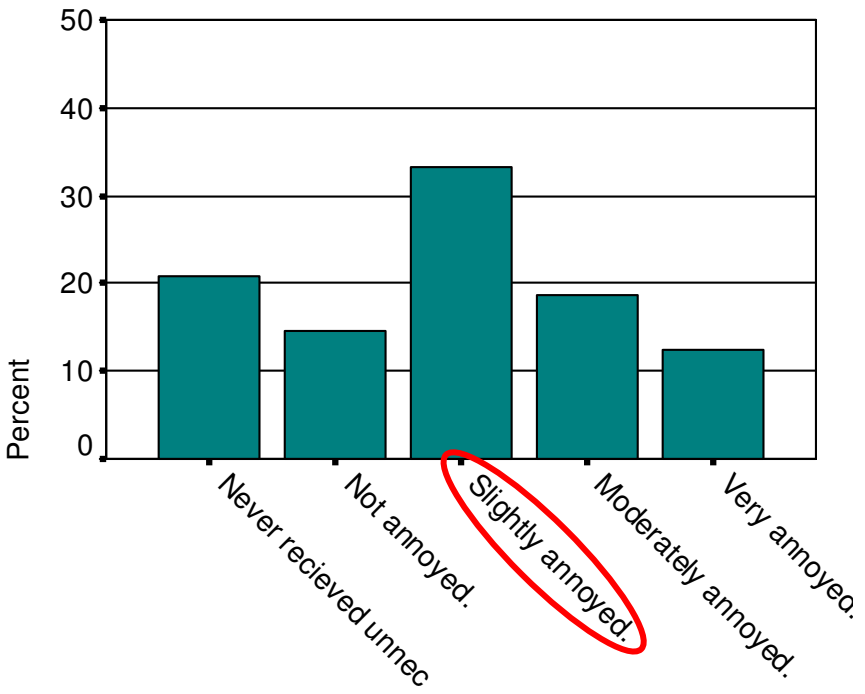
  - How much confidence do you have in the IVIS Mitigation System after your interaction with it? (Select a percent)
  - No gender significance
  - Median = 70%



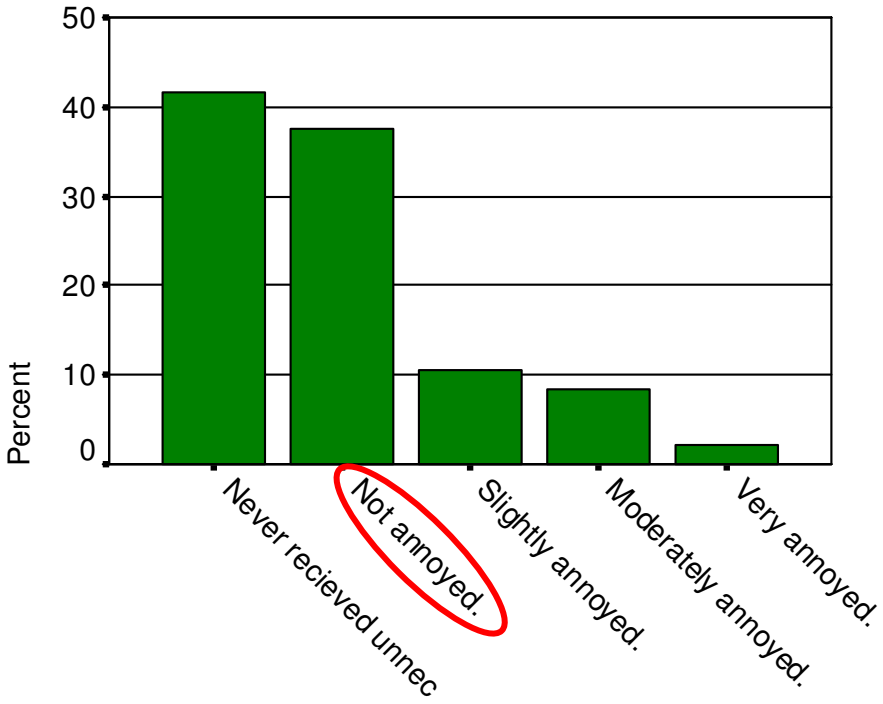
Subjective Results

- IVIS Mitigation System Annoyance Responses

Overall, there were slight annoyance issues with unnecessary lock outs of the IVIS Mitigation system.



Annoyance of unnecessary lock outs?

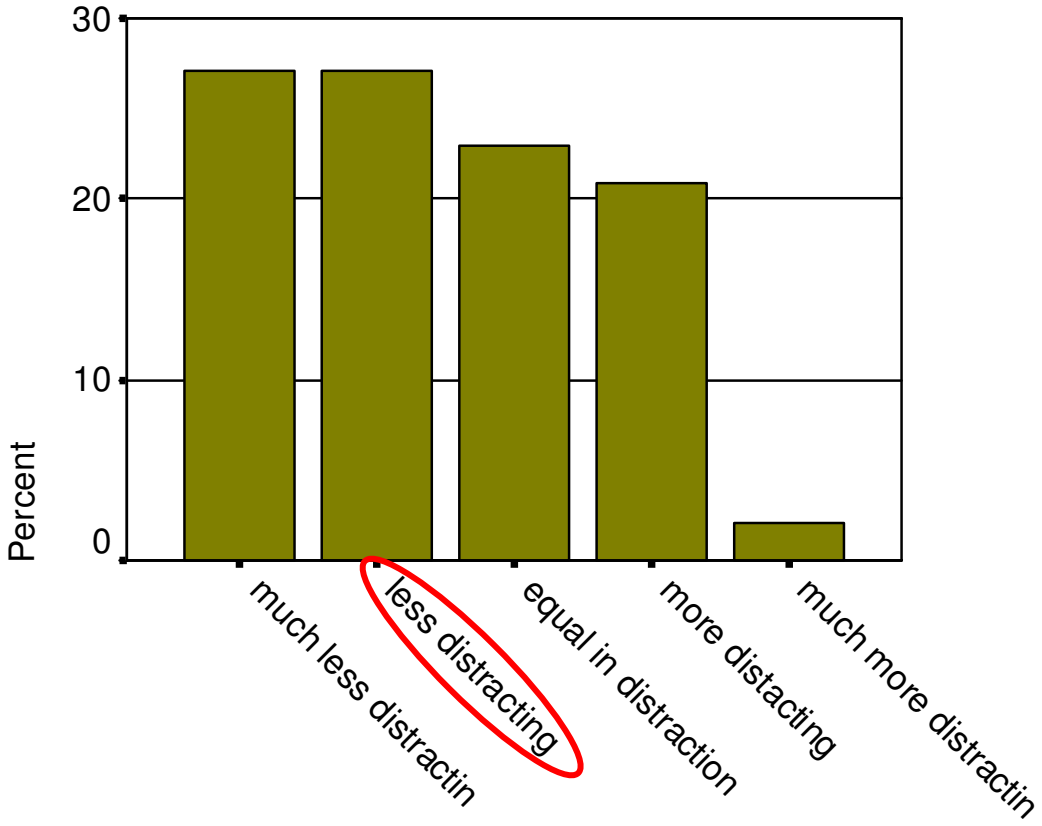


Annoyance by not being locked out?

Subjective Results

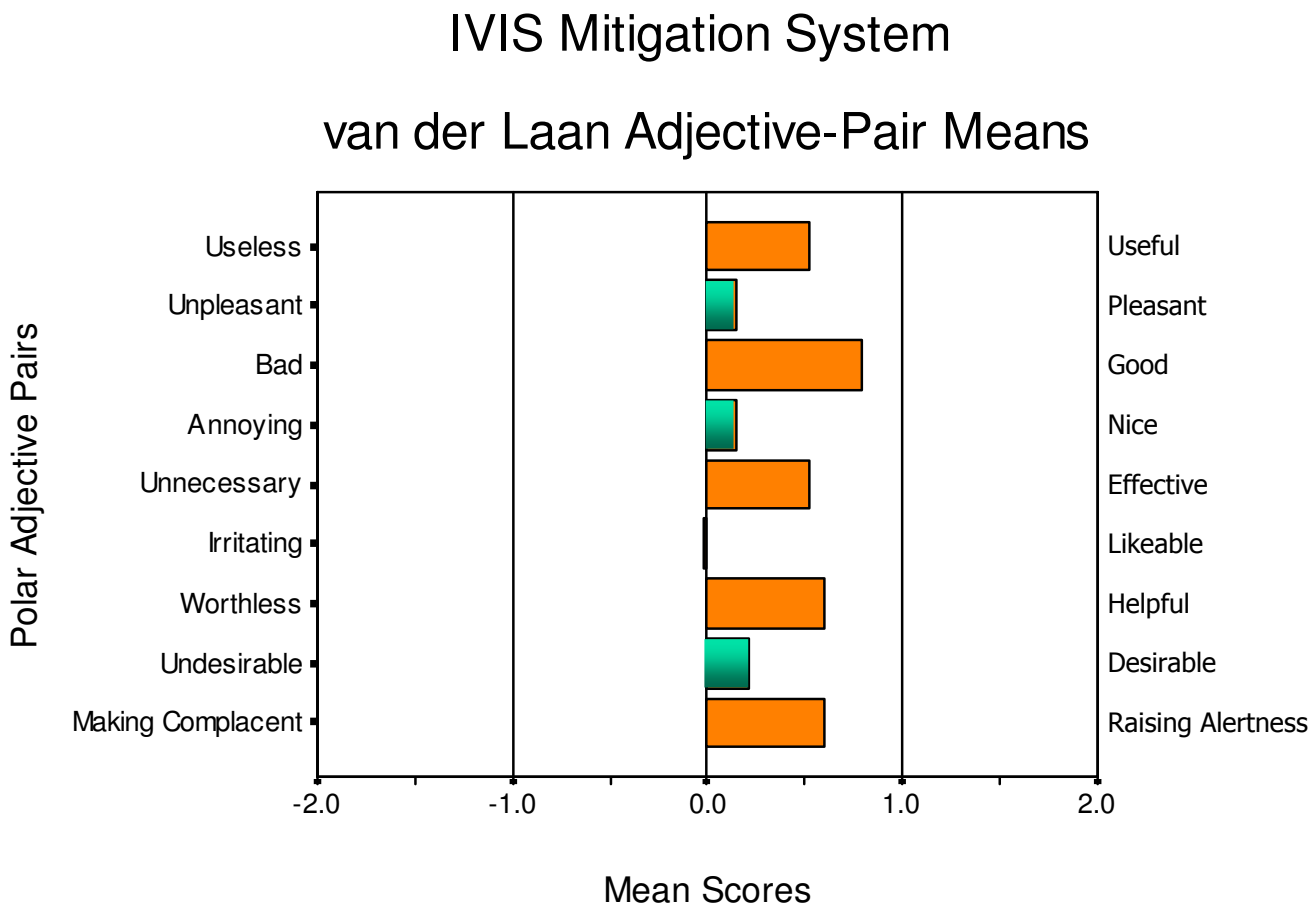
- Lock-out Distraction Comparison Responses

- **Median:** Allowed IVIS tasks were *less distracting* than locked-out IVIS tasks.
- No gender significances



Allowed IVIS tasks were _____ than (to) locked-out IVIS tasks.

Subjective Results



Subjective Results

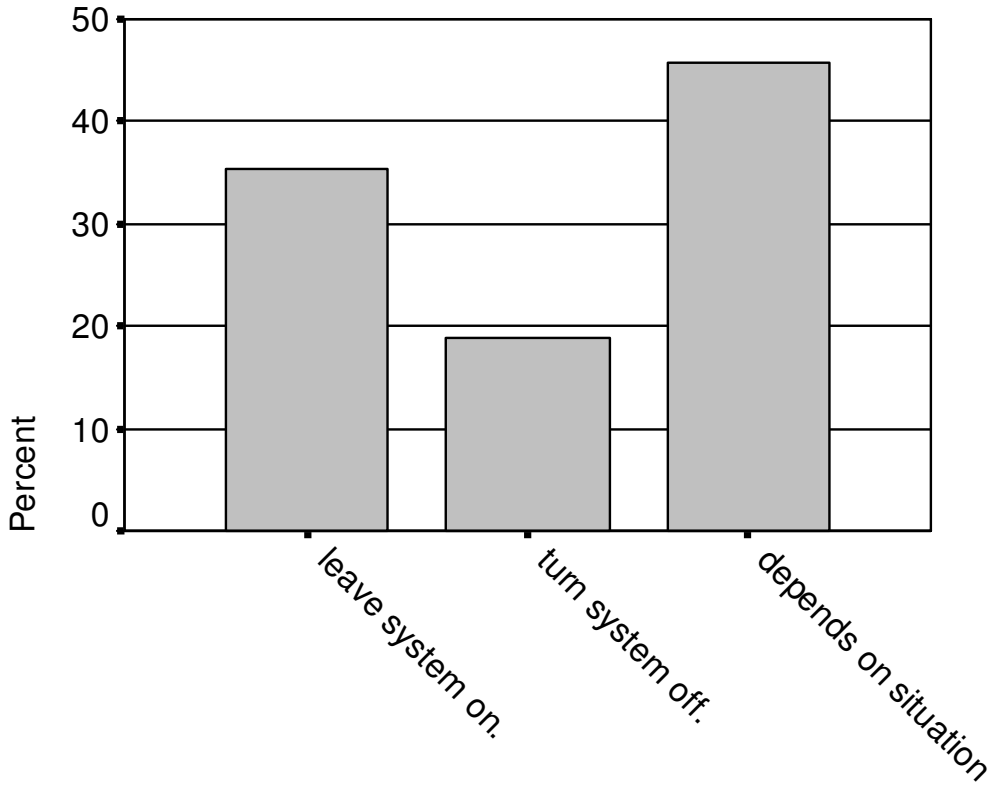
- *van der Laan* IVIS Mitigation System Usefulness/ Satisfaction Ratings
- Males were significantly (*p=0.013)* less satisfied with the system than females.

IVIS Mitigation System van der Laan Mean Ratings

Gender		Usefulness	Satisfaction
Female	Mean	.8000	.5000
	Std. Deviation	.6802	.9029
Male	Mean	.4167	-.2604
	Std. Deviation	.9173	1.1240
Total	Mean	.6083	.1198
	Std. Deviation	.8220	1.0793

Subjective Results

- After their experience with the Task Mitigation system, only ~35% of the drivers would leave the system on, while ~50% wanted control over when to leave the system on vs. turning it off.



Subjective Results

- **Mitigation System On/Off "depends on situation" Comments**
  - It depends on how often it locked me out.
  - If I had to make an important call while the system thought I shouldn't, I would turn it off. I would also make sure it was on when my teenager is driving the car.
  - Not sure I'd want it on while driving - for me it was very distracting. I noticed my direction drifted and I sped up almost every time I tried to use it.
  - If I was in really bad weather, it might help me to remind me that I should be paying attention. If I had teenagers, I might leave it on all the time. But there may be times that I really need to make a call whether there is traffic or not.
  - Probably depends on short trip to the store vs. longer drive to work.
  - I may turn it off if my kids were driving. It would depend on their ability to deal with the frustration of not being able to do what they wanted. Would their frustration and subsequent re-trying to get it to work cause more issues than performing the actual task? I would probably turn it off.
  - If I had a passenger that could operate the system for me, I would like to option to turn it off.

Subjective Results

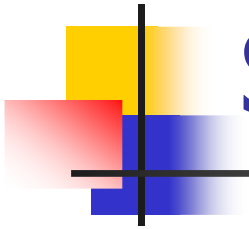
- Questionnaire wrapped up with 3 open-ended questions about Task Mitigation System:
  1. If you had trouble trusting the system, what were your reasons?
  2. What would you change to improve the overall performance of the system?
  3. Can you describe an instance when the system behaved differently than you expected?

Subjective Results

- If you had trouble trusting the system, what were your reasons?
  - As long as it was (in) my control, I would trust me....not a machine.
  - Locked too often.
  - I want to control the system. I need to have the final decision when lock out or not.
  - I think it should have locked out more than it did.
  - I spent too much time checking to see if it was locked out or active.
  - Too much time used to see if it's locked or not locked.
  - IVIS lockout feature gives false sense of security.
  - I think that the look-down to key in numbers or scroll through text is EXTREMELY dangerous. It requires too much system involvement.

Subjective Results

- What would you change to improve the overall performance of the system?
  - The buttons were difficult to push.
  - Of course, I think it should be voice activated with a choice of switching between voice activation to manual activation.
  - Mount the screen a little higher (closer to the dashboard).
  - TO reduce the lock out rate.
  - Increase the font size of the text messages.
  - Make it easier to over ride the system.
  - Different sounds for activation and deactivation of the system would have helped.
  - I'd make it more visually obvious, the difference between when it's enabled or disabled.
  - Make it more restrictive in urban settings.



Subjective Results

- Can you describe an instance when the system behaved differently than you expected?
  - I didn't expect it to lock me out so much.
  - Became dysfunctional in the middle of a task.
  - It was disabled more than I'd expect.
  - It 'grayed out' in what I considered light traffic.
  - I would have expected it to lock me out in town at all times.

Subjective Results

- Task Mitigation Mental Model Results
  - **Mental Model Questions:**
    - What needs to occur for the Task Mitigation system NOT to lock you out?
    - What needs to occur for the Task Mitigation system TO lock you out?

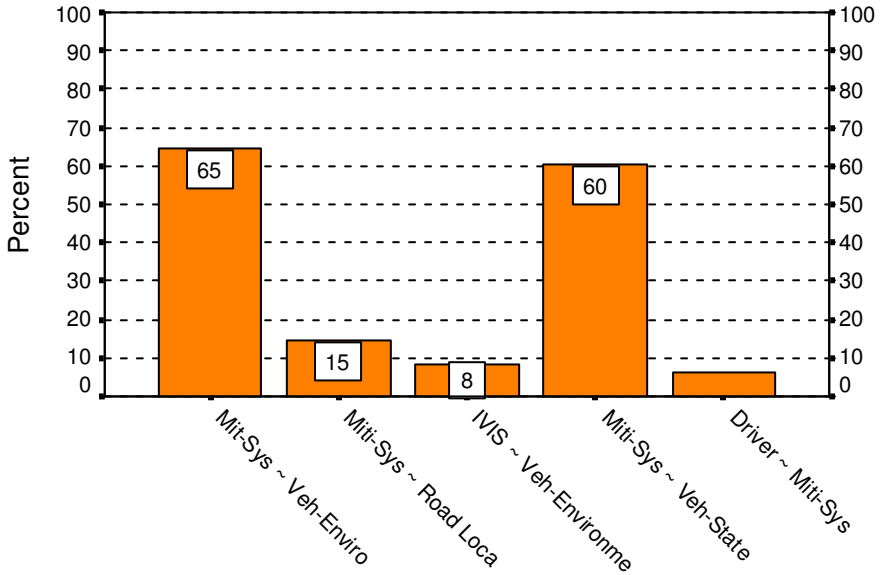
Subjective Results

- Mental Model feedback focused on categorizing five key relationships between the vehicle, driver, environment, and Task Mitigation system:
  1. Mitigation system's relationship to the vehicle external environment (e.g., traffic, weather, parked cars, pedestrians, construction, obstacles).
  2. Mitigation system's relationship to vehicle road location (e.g., city vs. rural, curves vs. straights, freeway vs. roads, intersections, multi-lane roads, tunnels).
  3. IVIS Task complexity relationship to vehicle external environment (e.g., task difficulty vs. vehicle's surroundings).
  4. Mitigation system's relationship to vehicle state (e.g., parked or stopped, in motion, overtaking/passing, doors closed, seat belt buckled, erratic vehicle control, speeding, lane departures, changing lanes, radio on/too loud, reverse, braking, trailer in tow).
  5. Driver's relationship to Mitigation System (e.g., distracted, drowsy, changing non-IVIS in-vehicle states).

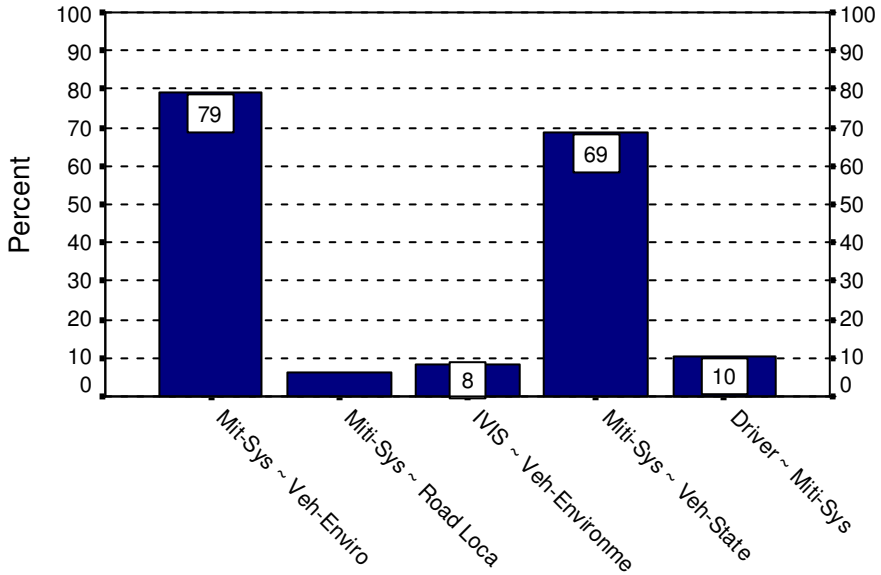
Subjective Results
Task Mitigation Model

- No significant mental model relationships from the perspective of being locked out vs. NOT being locked out.

What needs to occur for Mitigation System NOT to lock you out?



What needs to occur for the Mitigation System TO lock you out?



Subjective Results

- Additional Task Mitigation Mental Model Results
  - What needed to occur for the Task Mitigation System NOT to lock you out?
    - 85% (41 or 48) identified at least 1 of the 5 relationships
    - 56% (27 of 48) identified 2 of the 5 relationships
    - 12.5% (6 of 48) identified 3 or more the 5 relationships
    - 8.3% (4 of 48) correctly identified the IVIS Task complexity relationship
    - 6.25% (3 or 48) incorrectly associated driver state with Mitigation system
    - 14.6% (7 of 48) could not identify any of the 5 relationships

Subjective Results

- Additional Task Mitigation Mental Model Results
  - What needed to occur for the Task Mitigation System TO lock you out?
    - 71% (34 of 48) identified at least 1 of the 5 relationships
    - 44% (21 of 48) identified 2 of the 5 relationships
    - 6.2% (3 of 48) identified 3 or more of the relationships
    - 12.5% (6 of 48) correctly identified the IVIS Task complexity relationship
    - 21% (10 or 48) incorrectly associated driver state with Mitigation system
    - 12.5% (6 0f 48) could not identify any of the 5 relationships

Questions