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SAfety VEhicle(s) using adaptive Interface Technology (SAVE-IT): Phase I Progress

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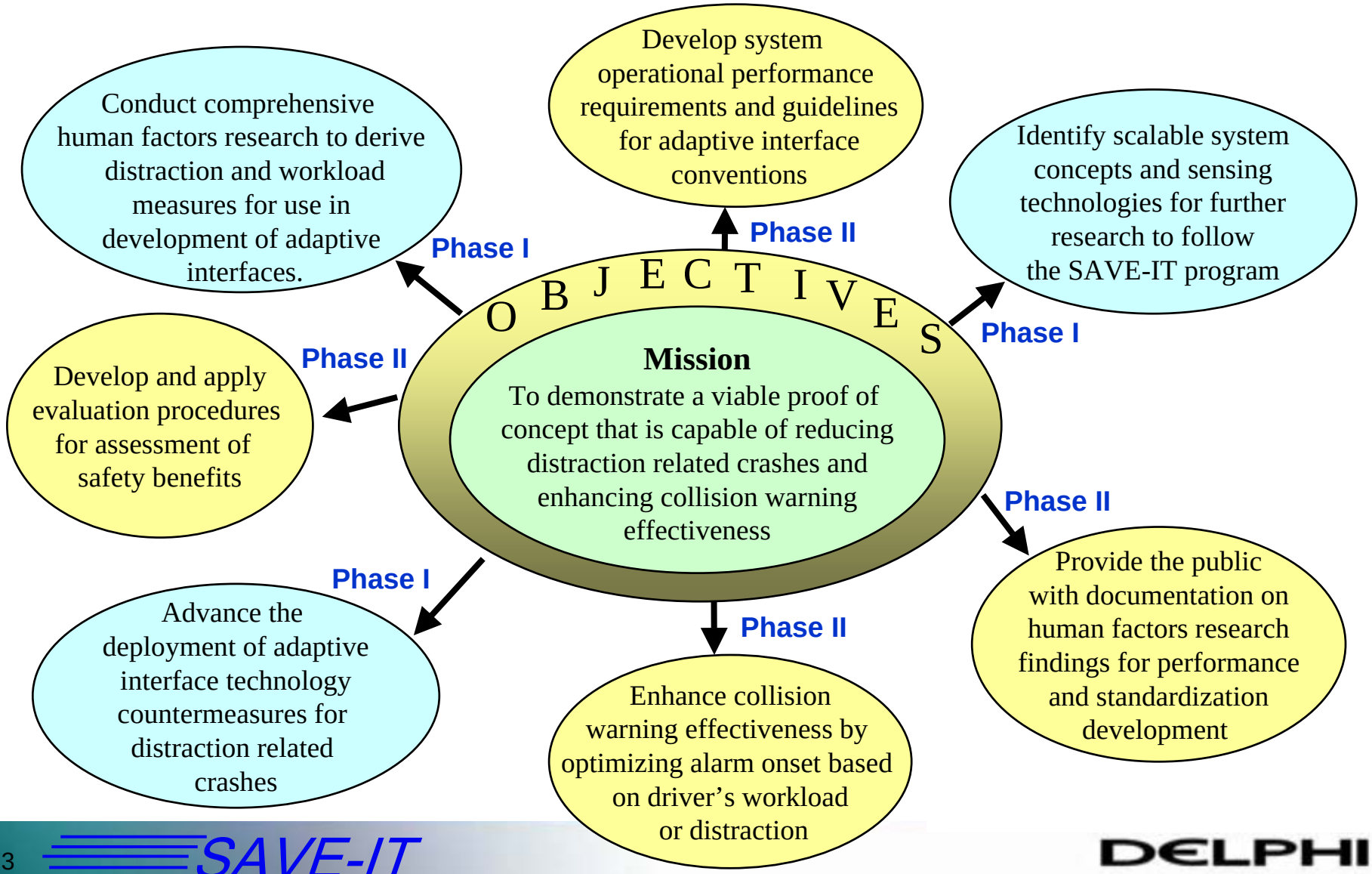
International Workshop on
Progress and Future Directions of Adaptive Driver Assistance Research
May 13-14, 2004

SAVE-IT

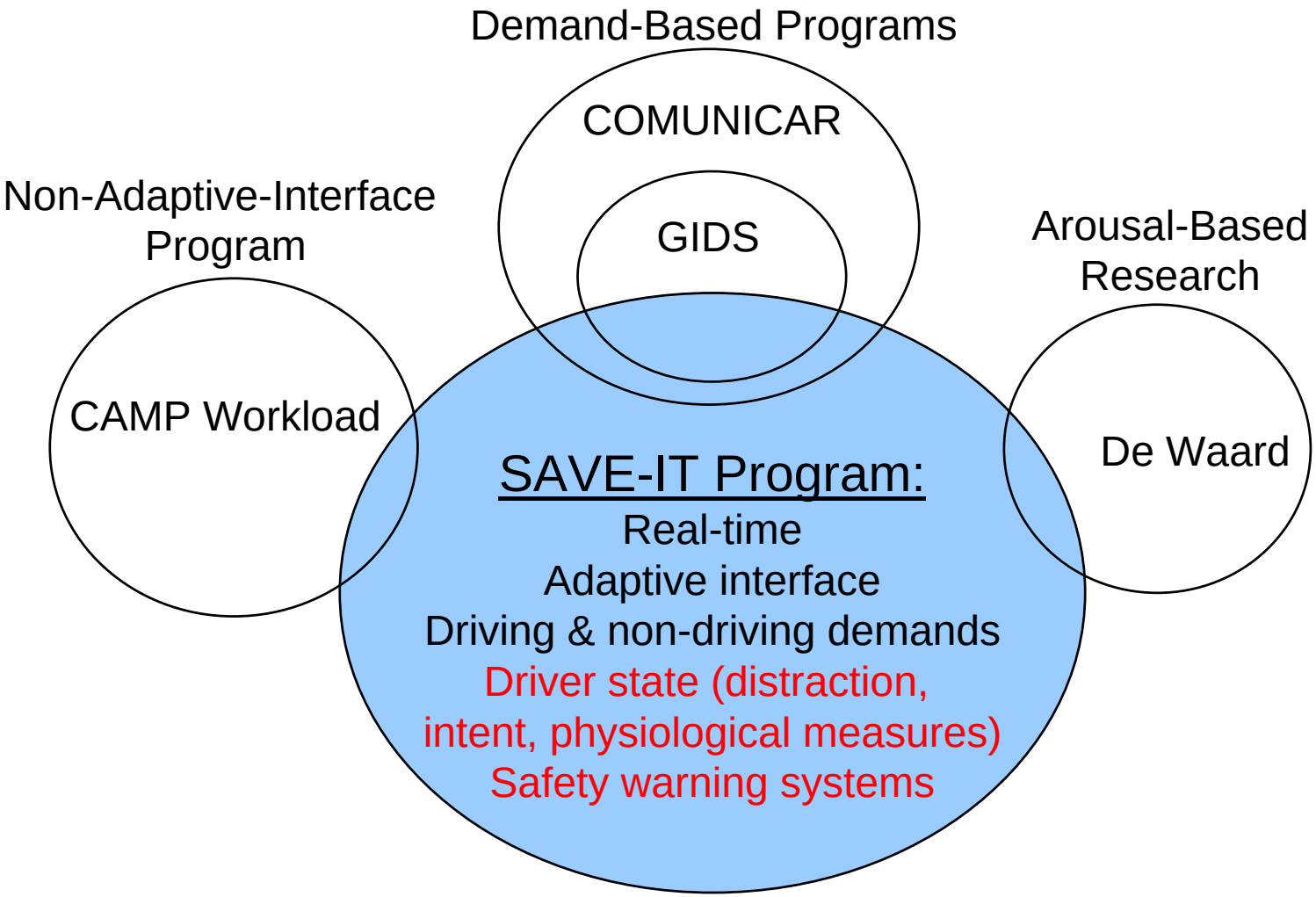
SAVE-IT Research Program

- Description
  - Program start date: March 2003
  - Program mission: To demonstrate a viable proof of concept that is capable of reducing distraction related crashes and enhancing collision warning effectiveness
    - » NHTSA has estimated that approximately 25% of crashes are attributed to driver distraction and inattention (Wang, Knipling, & Goodman, 1996).
  - $6M, 2-phase, 3-year research development program sponsored by NHTSA, administrated by Volpe
    - » Phase 1 (2003-2004): human factors and technology identification research.
    - » Phase 2 (2004-2006): Algorithm and guideline development, data fusion, integrated countermeasure development, vehicle demonstration and evaluation of benefit.
  - Development team participants: Delphi (lead), GM, Ford, University of Iowa, University of Michigan Transportation Research Institute, Seeing Machines

Mission and Objectives



Comparisons With Other Programs



Comprehensive Safety Management Systems

Non-Adaptive-Interface Approach

Objectives:

- Develop distraction & workload performance metrics and methods that can be used in non-adaptive-interface design (CAMP workload study, IVIS DEMAnD).

Similarities with SAVE-IT

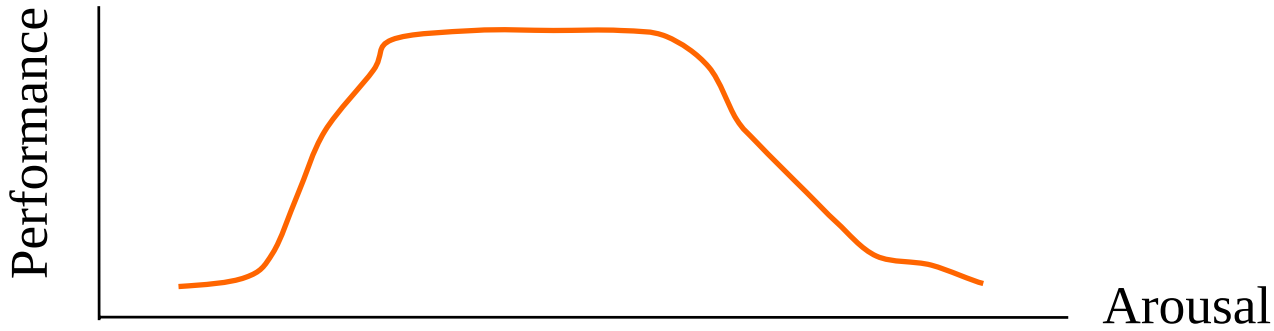
- Investigation of workload and distraction issues and measures.

Differences

CAMP	SAVE-IT
Not Real-Time	Real-Time
Not Adaptive Interface Design	Adaptive Interface Design
Not focused on "ground-truth" measures, e.g., eye glances.	Focus on "ground-truth" measures, e.g., eye glances.

The Arousal Approach

- Apply "Yerkes-Dodson law" to workload management (De Waard, 1996).
- Measure autonomic arousal with heart rate, respiration rate, & pupil diameter.
- Human performance is optimal with intermediate level of arousal.
- Increase arousal when it's low, and decrease arousal when it's high.



Limitations

- Many-to-one mapping: High level of arousal may be caused by many factors, e.g.,
  - Physical workload.
  - Mental workload.
  - Distraction.
  - Emotion, anxiety, stress.
- Pupil diameter may vary with ambient lighting, which has little to do with distraction.
- Lack of adequate countermeasures.
  - Technology can offer little help to calm down emotional drivers.

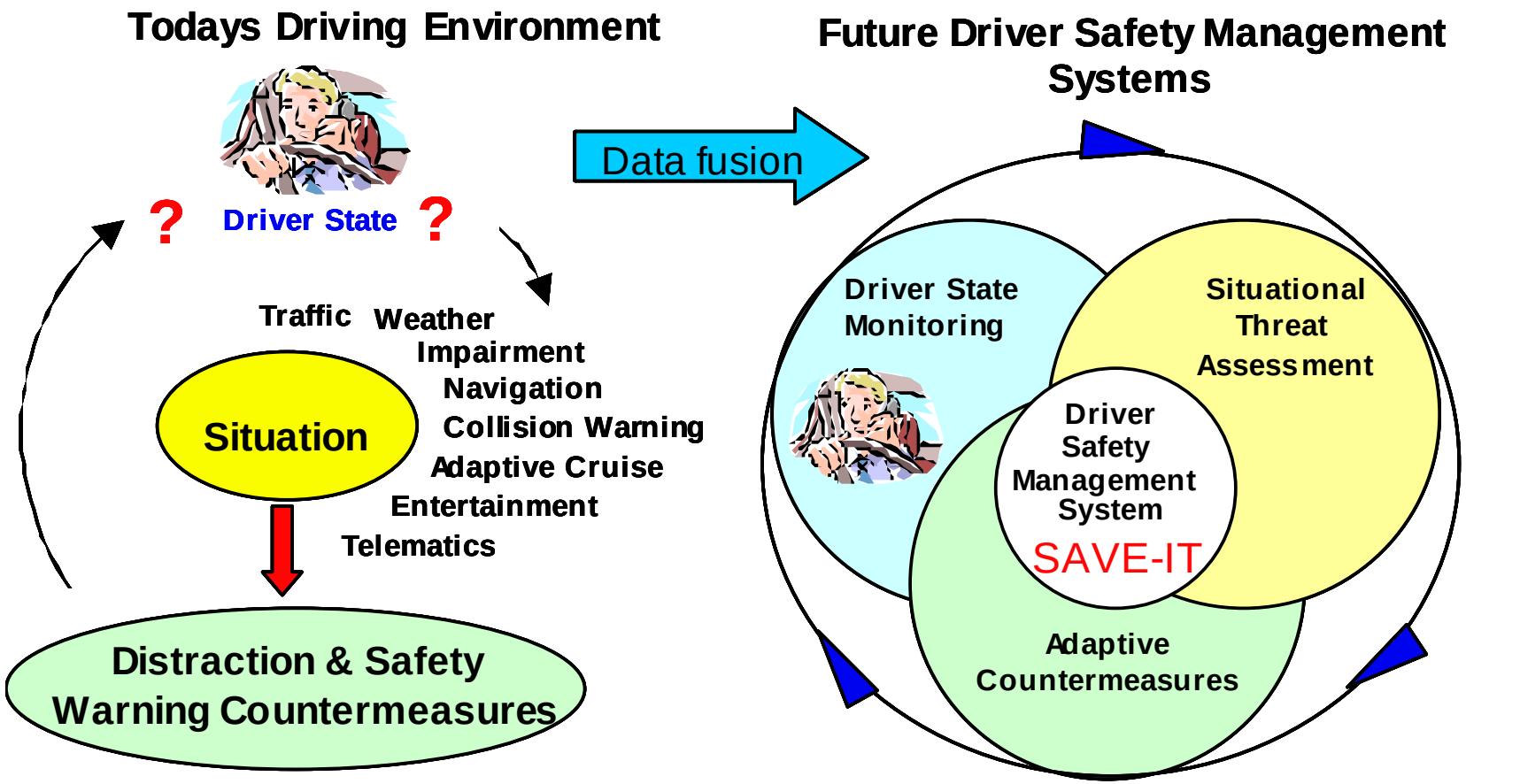
The Demand Approach

- Focus on driving & non-driving demands, e.g.,
  - GIDS (Generic Intelligence Support System) (Michon, 1993).
  - COMUNICAR (Communication Multimedia UNit Inside CAR).
  - Demand determined by expert opinions & neural net models.
- Inspired by aviation human factors, use task analysis & de-clutter methods.

- <u>Advantages</u>
  - Uses real-time, adaptive interface technologies.
  - Focus on driving (road, traffic, weather) and non-driving task demands.
  - Prioritizes in-vehicle information (e.g., COMUNICAR).
  - Investigates user acceptance issues.

- <u>Disadvantages</u>
  - Driving a car is not flying a fighter airplane.
    - » Drivers are not pilots: Selection & training.
    - » Information flow much higher in military flying than in driving.
  - Disregard individual differences
    - » Driver state is not directly assessed.

SAVE-IT Vision



The driver will become a key component in a closed loop vehicle environment

Status as of May 2004

	Phase I (2003-2004) Research and Concept Development		Phase II (2004-2006) Data Fusion, System Integration and Evaluation			
Scenario Identification	Crash Statistics Analysis 1			Data Fusion	System Integration	Evaluation 14A Iowa 14B Ford 14C UMTRI 14D GM 14
Driving Task Demand	Literature Review 2A	Identify Diagnostic Measures 2B	Develop and Validate Algorithms 2C			
Performance	Literature Review 3A	Identify Diagnostic Measures 3B	Develop and Validate Algorithms 3C			
Distraction Mitigation	Literature Review 4A	Identify Countermeasures 4B	Validate Countermeasures 4C	11A Distraction Mitigation		
Cognitive Distraction	Literature Review 5A	Identify Diagnostic Measures 5B	Develop and Validate Algorithms 5C	11B Safety Warning Countermeasures		
Telematics Demand	Literature Review 6A	Identify Demand Levels 6B	Validate Demand Levels 6C	Subcontractors: Iowa, UMTRI	Vehicle build	
Visual Distraction	Literature Review 7A	Identify Diagnostic Measures 7B	Develop and Validate Algorithms 7C		Demo.	
Intent	Literature Review 8A	Identify Diagnostic Measures 8B	Develop and Validate Algorithms 8C	11		
Safety Warning Countermeasures	Literature Review 9A	Identify Countermeasures 9B		Establish Guidelines & Standards 12	13	Program Summary and Benefit Evaluation 15
Technology Development	Tech/Architecture Concept ID 10A	Tech/Architecture Concept Car 10B				

Completed As of May '04

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SAVE-IT Phase 1 Research Model

Human Factors Research

Scenario Identification

Diagnostic Research

Driving Performance
Cognitive Distraction
Visual Distraction

Telematics Demand

Driving Task Demand

Intent

Mitigation Research

Safety Warning Countermeasures

Distraction Mitigation

Technology/Architecture Concept Development

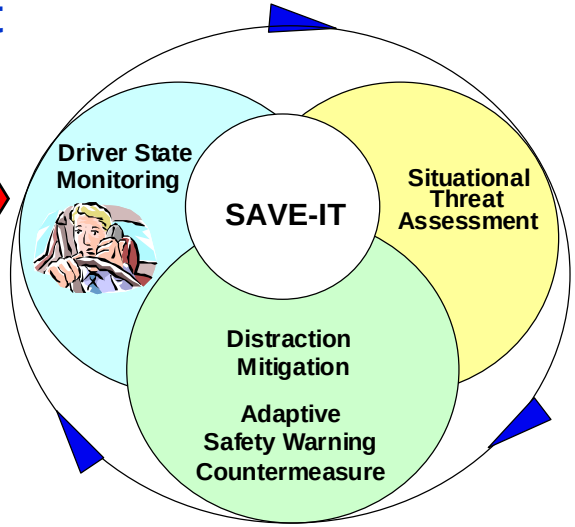
Adaptive Safety Warning And Distraction Mitigation System Architecture Concepts

Real Time Distraction Sensing Requirements

Distraction Assessment Data Fusion Concepts

Situational Threat Assessment

Countermeasure Technology Identification and HMI Concepts



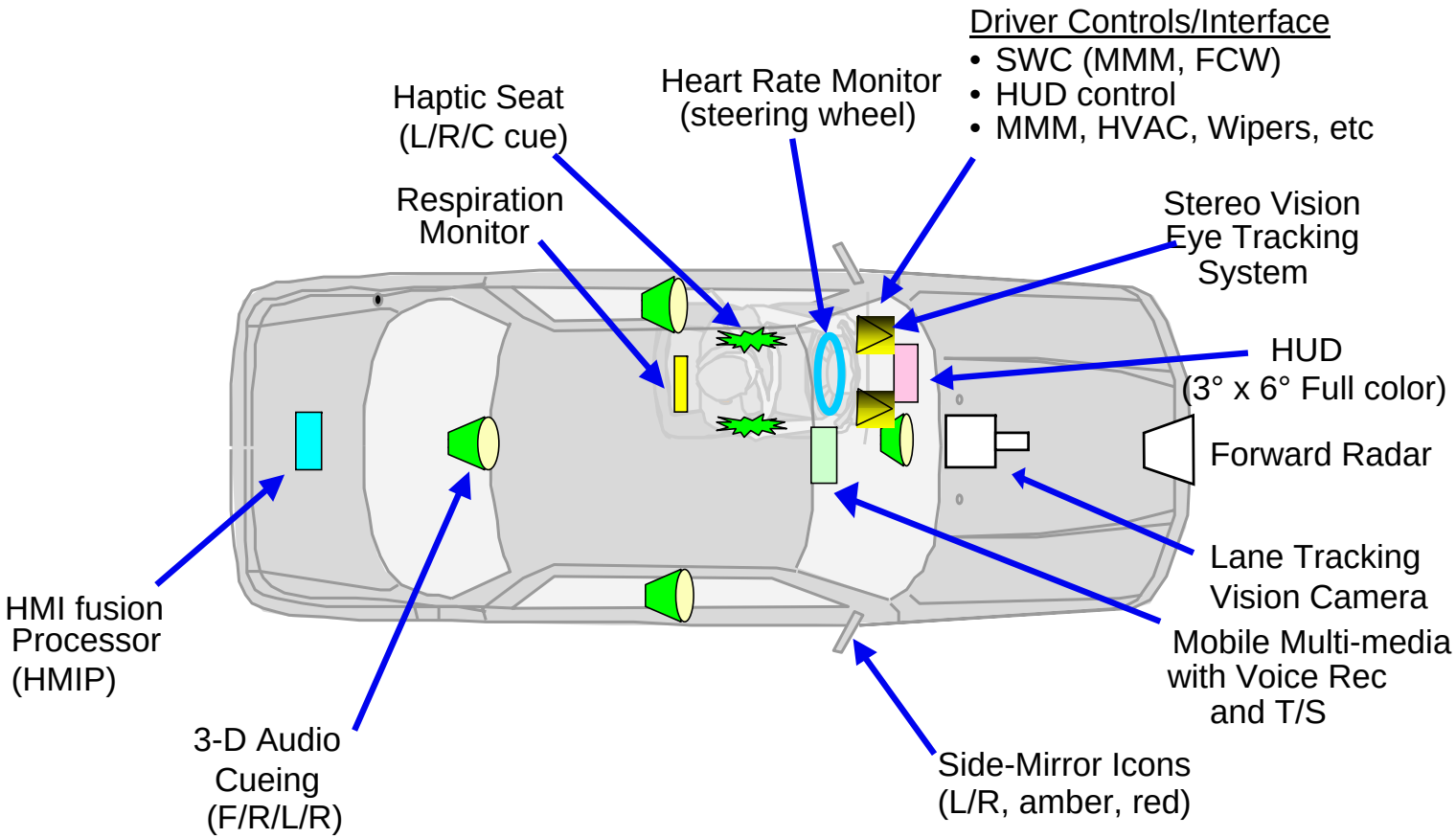
Phase 2 a
(Algorithm development)
Data fusion)

Phase 2 b
(Evaluation of benefit)

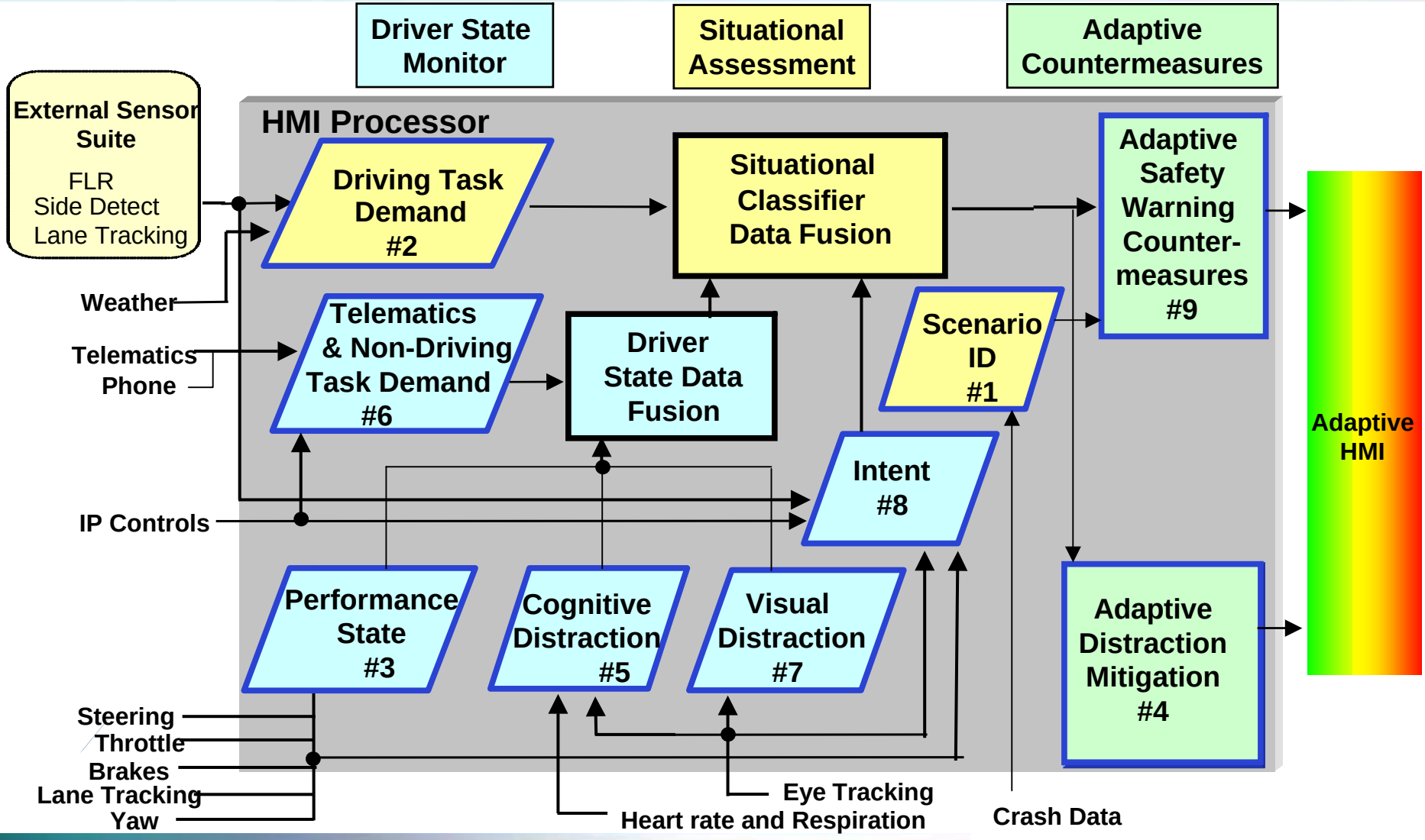
SAVE-IT Progress

- **Phase 1 Complete**
  - Relevant crash scenarios identified which will most benefit from the use of adaptive interface technologies: Rear End Collision, Lane Departure and Intersecting traffic conditions.
  - Diagnostic measures identified for visual and cognitive distraction, driving task demand, driving performance and level of intent.
  - Concepts of operation developed for Adaptive Distraction Mitigation and Safety Warning Countermeasures as will be demonstrated.
  - Support technologies identified for test vehicle incorporation

Driver HMI and Sensor Concept



Conceptual Model: Main Menu



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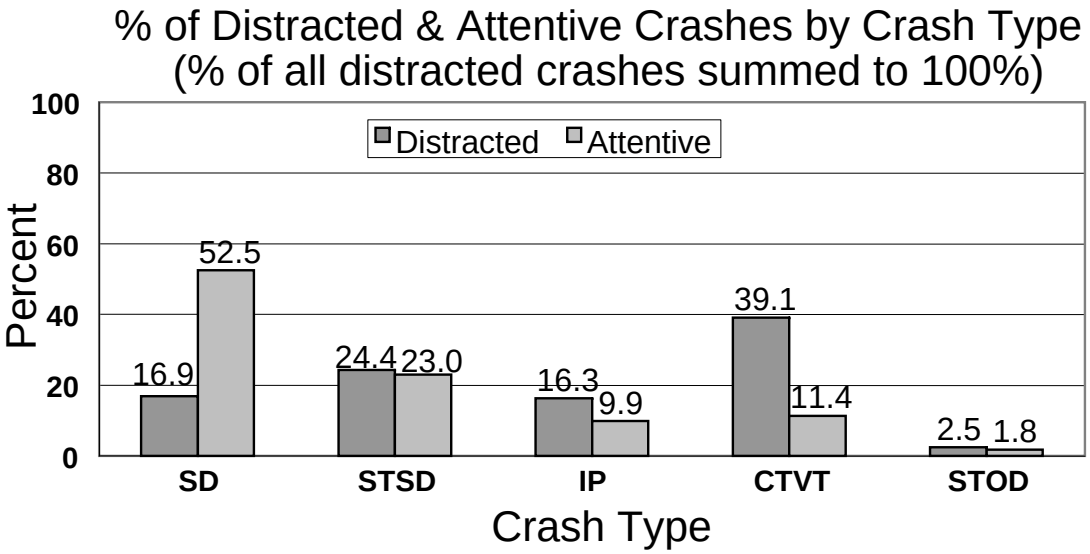
Crash Scenario Identification (Task 1)

Main Menu

- **Task 1**
  - Objective: Identify crash scenarios that SAVE-IT systems should be designed to prevent.
  - Task Lead: David Eby (UMTRI)
- **NASS CDS 2001 data indicated the following scenarios**
  - SD (single driver)
  - STSD (same trafficway, same direction)
  - IP (intersecting path)
  - CTVT (change trafficway, vehicle turning)
  - "Looked but did not see" included as "distracted" crashes
  - CDS & GES good databases
- **Literature review and the Delphi procedure (expert panel) Identified 2 scenarios:**
  - Rear-end collisions (STSD)
  - Single vehicle run-off-road collisions (SD)



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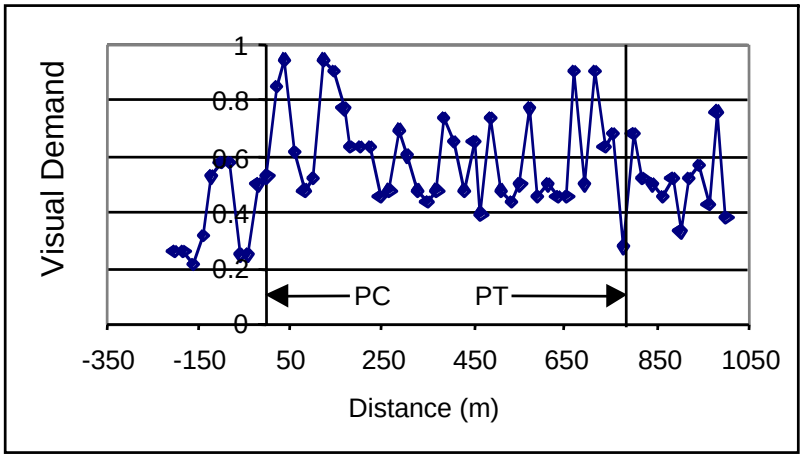
Driving Task Demand (Task 2)

Main Menu

- **Task 2**
  - Objectives:
    - » Identify relevant factors for driving demand
    - » Determine response requirements as a function of workload/visual demand.
  - Sub-tasks
    - » 2A: Literature review & crash data analysis (Task lead: David Eby)
    - » 2B: Occlusion experiment in UMTRI simulator (GlobalSim) (Task lead: Paul Green)
- **Major Findings**
  - Visual demand increased
    - » with presence of lead vehicle
    - » at point of curvature
  - Both visual demand and RT increased
    - » as curve radius decreased
    - » as sight distance decreased
  - Other factors
    - » Traffic volume (ADT)
    - » Road culture (urban/rural),
    - » Road type
    - » Lane width
    - » Weather

Visual demand profile for a sample subject



PC=Point of Curvature; PT=Point of Tangency

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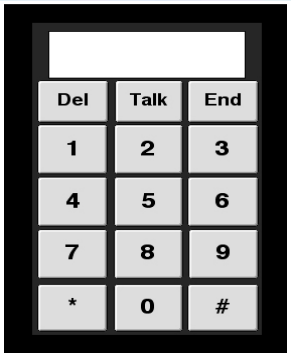
Performance (Task 3)

Main Menu

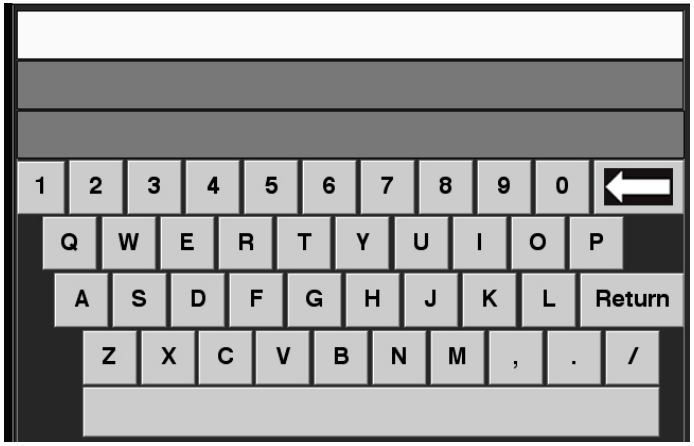
- Task 3
  - Objective: Determine performance variables that are indicative of distraction.
  - Task Lead: Paul Green (UMTRI)



Phone Dialing Task

- Method
  - On-road study
    - » Honda Accord LX wagon
    - » Expressways
    - » Rural 2-lane
  - 16 subjects
  - In-vehicle tasks
    - » Radio tuning
    - » Phone dialing
    - » Destination entry
    - » 10-s, 30-s glance task

Radio Tuning Task



Dest. Entry Task

Performance (Task 3)

Main Menu

- Major Findings
  - Relevant variables
    - » SDLP
    - » Speed drops
    - » Reduction of speed SD
    - » Throttle holds

SDLP (m): Mean (SD)

	Simulator	On-Road
Baseline	0.23 (0.14)	0.20 (0.10)
Distraction	0.31 (0.20)	

- Linkage with countermeasures:
  - Task 4 (distraction mitigation)
    - » Warnings for excessive distraction
  - Task 9 (adaptive safety warning countermeasures)
    - » Distraction-based adaptation of alert timing

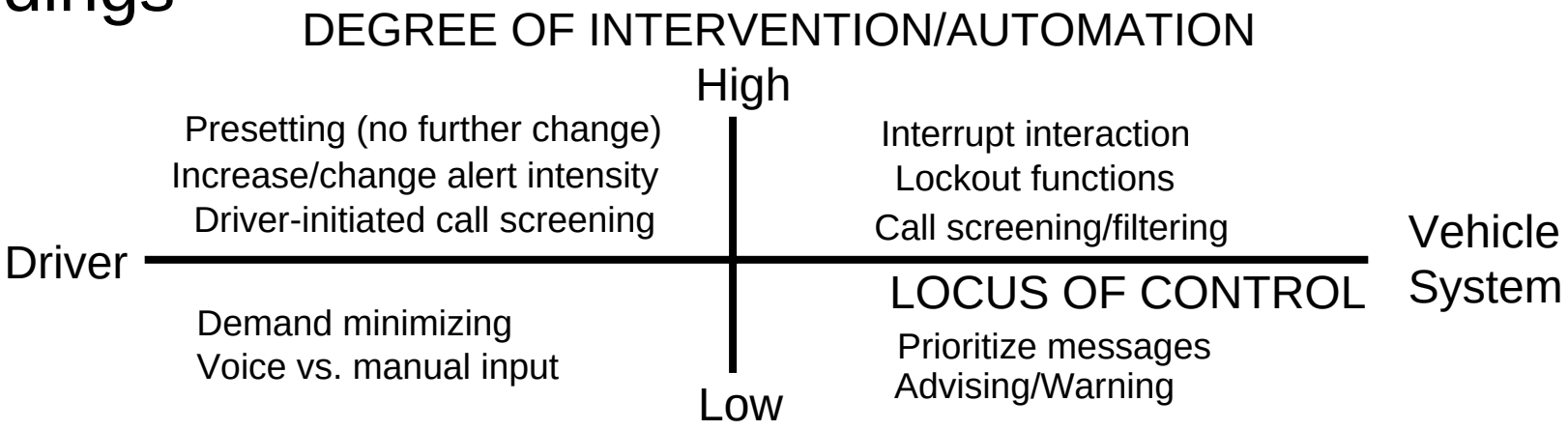
Sensitivity of the "Throttle Hold" Algorithm

Subject	d'
1	0.663
2	0.878
3	0.633
4	0.695
5	1.303
6	0.35
7	0.218
8	1.08
9	1.27
10	0.615
11	0.605
12	0.585
13	1.103
14	1.518
15	0.358
16	0.943
Average	0.801

Adaptive Distraction Mitigation (Task 4)

Main Menu

- Task 4
  - Objective: Identify & validate mitigation strategies & their appropriate application
  - Methods: Literature review, focus group, & simulator experiment
  - Task Lead: John Lee (Iowa)
- Findings

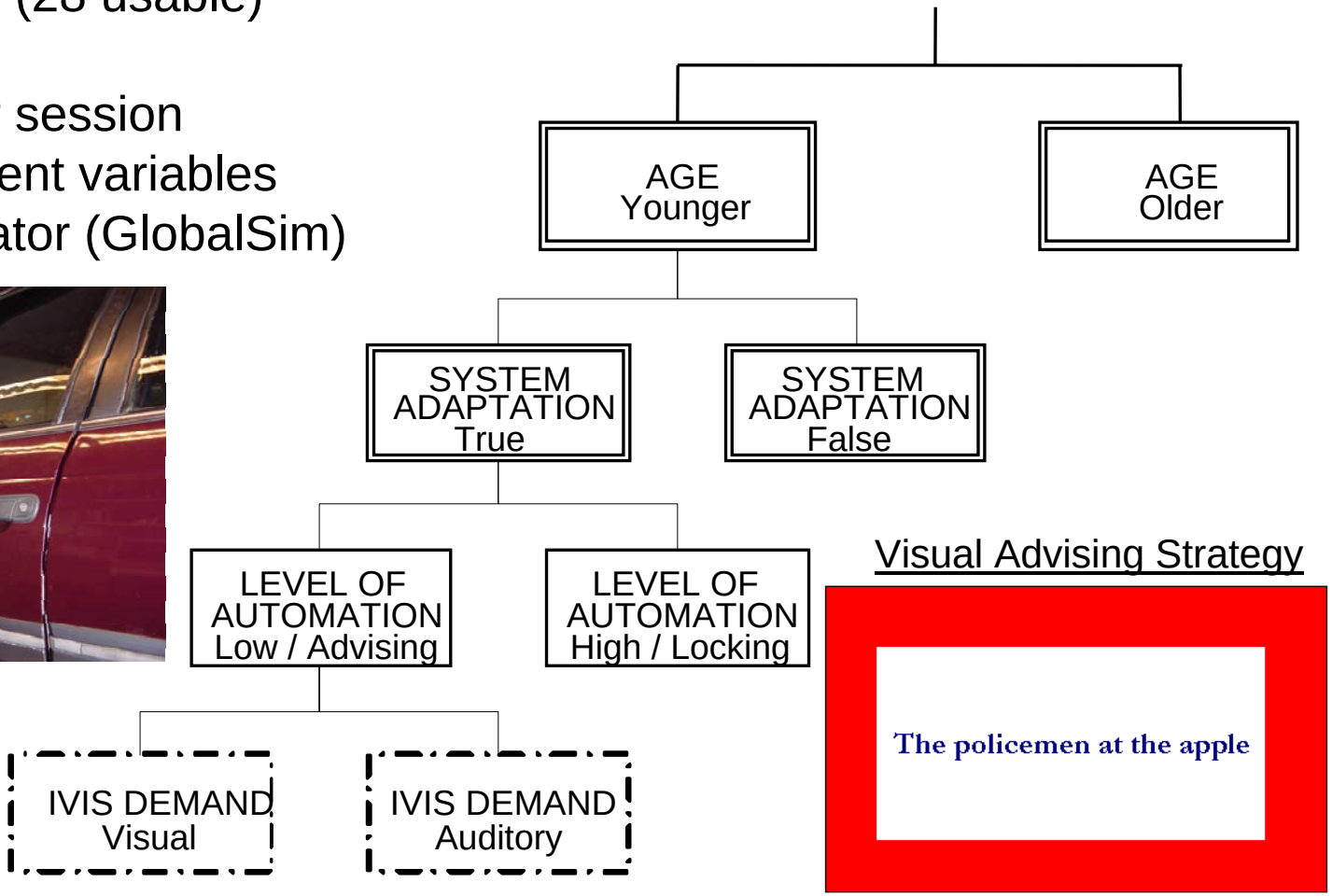


  - Driver-initiated strategies are more acceptable than system-initiated ones.
  - Automation level should change based on driver state & driving task demand.
  - Simple and intuitive interface design is critical.
  - Technology should be helpful “co-pilot”, not annoying “back seat driver”.
  - There are large individual differences in what degree drivers want help.

Adaptive Distraction Mitigation (Task 4)

Main Menu

- **Simulator Experiment**
  - 36 subjects (28 usable)
  - 2 sessions
  - 2 hours per session
  - 5 independent variables
  - Iowa simulator (GlobalSim)



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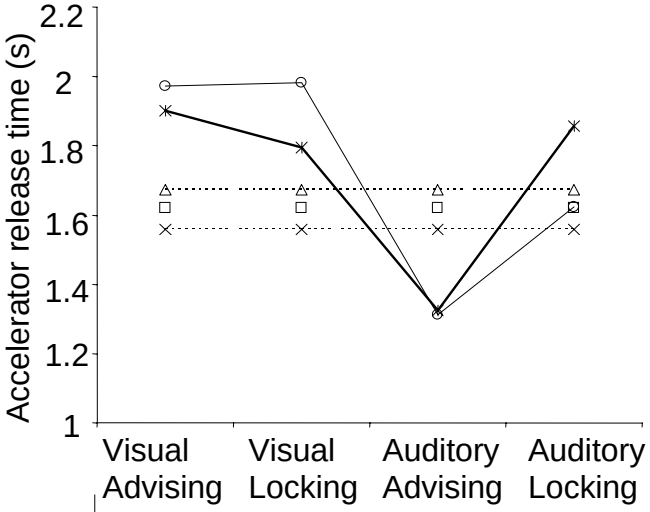
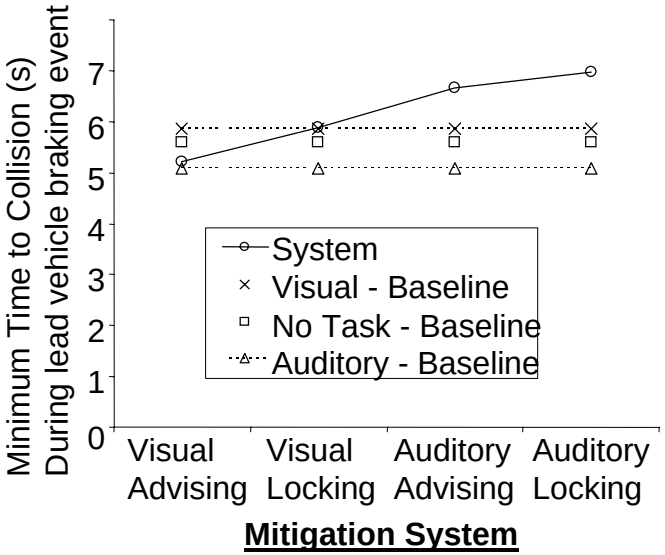
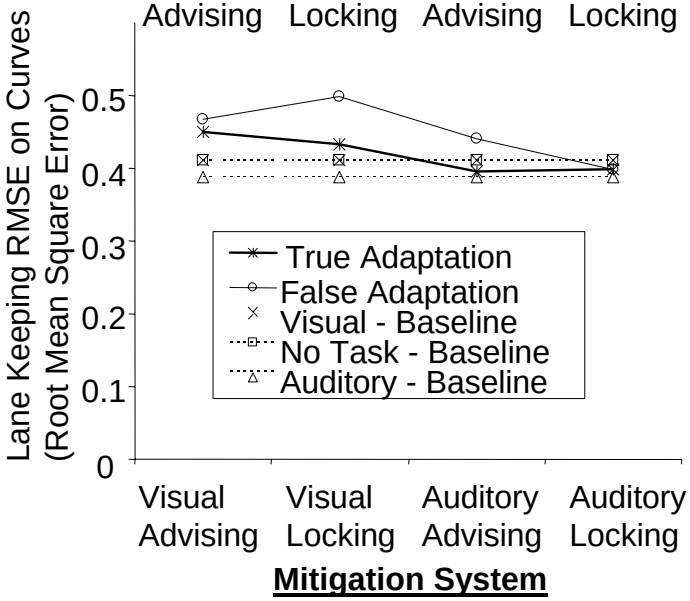
Adaptive Distraction Mitigation (Task 4): Results from Simulator Experiment

Main Menu







Major Findings

- Auditory advising was the best mitigation.
- Auditory locking was a good strategy.
- Visual adaptation was good for lane keeping performance.
- Drivers perceived mitigation strategies useful & somewhat satisfying.

Driver-Initiated Mitigation (Task 4)

Main Menu

- Findings
  - Task 4 (Distraction Mitigation) demonstrates that
    - » Driver-initiated strategies are more acceptable than system-initiated strategies.
    - » Drivers perceive simple and intuitive interface design as critical

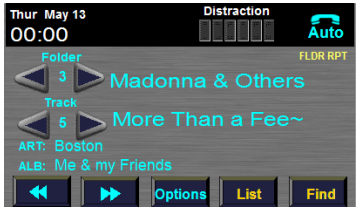
Example:

The “driver-initiated call screening” button on the steering wheel. When it is activated, incoming phone calls will be screened out (no ring).

Demand-Based Distraction Mitigation (Task 4)

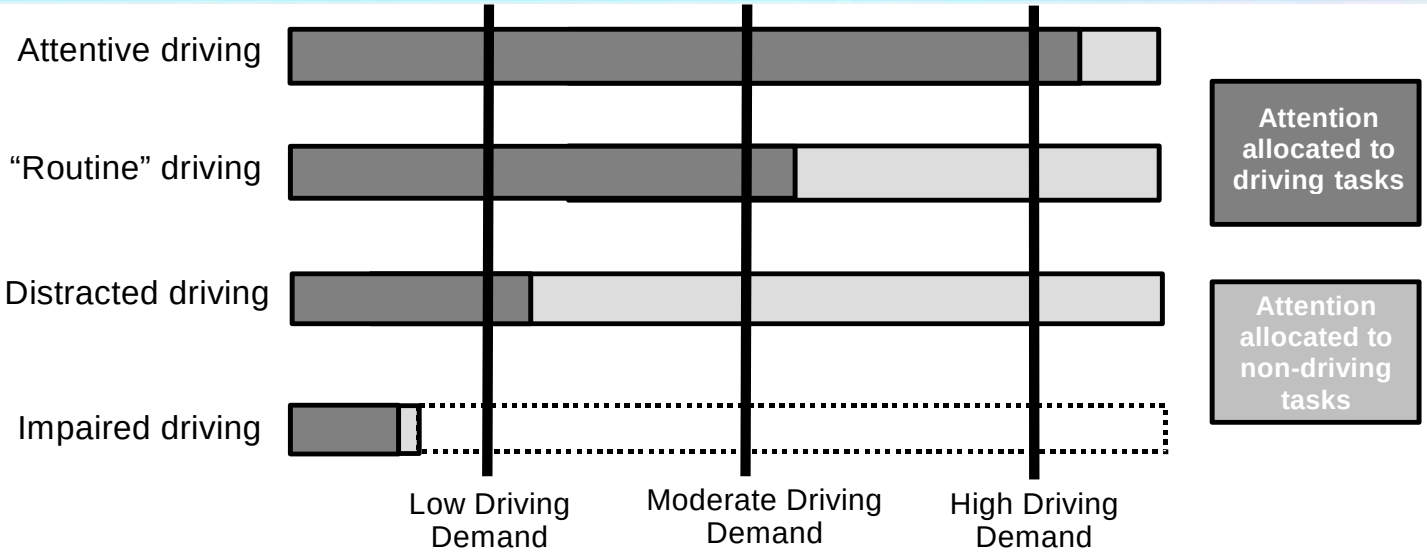
Main Menu

- **Findings**
  - Safe driving requires “attention allocated to driving” to match driving task demand.
  - Multiple strategies can be employed
    - » Advising
    - » Locking out features
  - Effective strategies are
    - » Acceptable to users
    - » Enhancing safety margin
- **Examples**

Driving Demand				
IVIS Availability	Many IVIS Features Are Advised Against	Some IVIS Features Are Advised Against 	Destination Entry Is Grayed Out	All IVIS Features Are Available

State-Based Distraction Mitigation (Task 4)

Main Menu



- **Examples**

Distraction Level: Low
No warning

Distraction Level: Medium
Warning: Amber Bezel

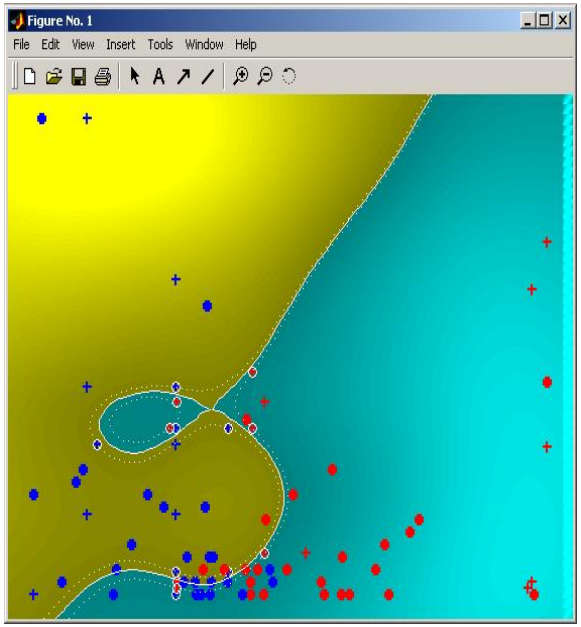
Distraction Level: High
Warning: Red Bezel

Cognitive Distraction (Task 5)

Main Menu

- Task 5
  - Objective: Determine diagnostic measures of cognitive distraction & their RT effects.
  - Task Lead: John Lee (Iowa)

- Major Findings
  - Converging estimate based on following information
    - » Driver state (eye movements, scan patterns)
    - » Driver performance
    - » IVIS, roadway state, & associated cognitive demand
  - Models are useful
    - » Multiple resource theory
    - » Hidden Markov Models
    - » Support Vector Machines
  - Eye movement patterns indicative of distraction
    - » Gaze variability effect by Recarte & Nunes (2000)



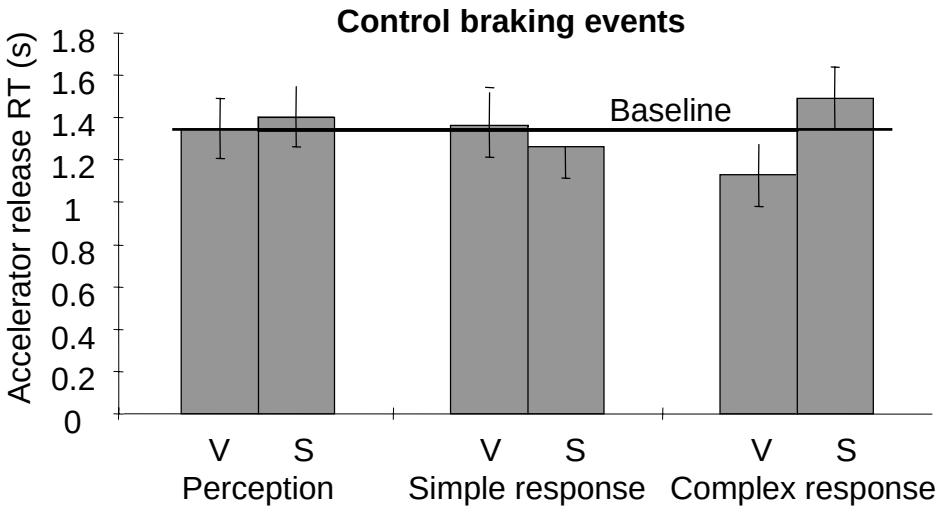
Support Vector Machines

Red dots=distraction, blue dots =no distraction (+ from training data, • from experimental data). Using SD of saccade distance & fixation duration as input data.

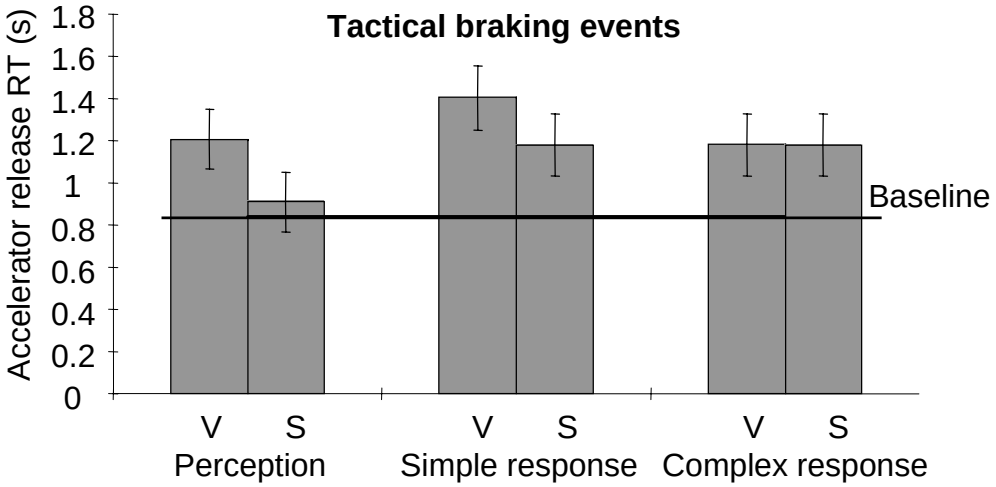
Cognitive Distraction Simulator Experiment (Task 5B)

Main Menu

- Method
  - 22 subjects
  - 4 independent variables
    - » Lead vehicle braking (control vs. tactical)
    - » Verbal vs. spatial tasks
    - » Perception vs. response
    - » Simple vs. complex response



- Findings
  - Modest performance effects due to strategic adaptation & individual differences
  - IVIS task degraded tactical more than control performance
  - Response stage more demanding than perception stage
  - Spatial task did not degrade
  - Performance more than verbal task



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IVIS/Telematics Demand (Task 6)

Main Menu

- **Task 6**
  - Objective: Determine distraction potential of common IVIS/telematics tasks.
  - Task Leaders: Paul Green (Task 6A) and Barry Kantowitz (Task 6B) (UMTRI)

- **Major findings from literature review (Task 6A):**
  - » Large variations for dynamic task time & glance frequency

In-Vehicle Task	Dynamic Task Time	Glance Frequency
Radio Tuning	8-22 s	3-15
Phone Dialing	5-39 s	4-13
Destination Entry	50-140 s	19-34

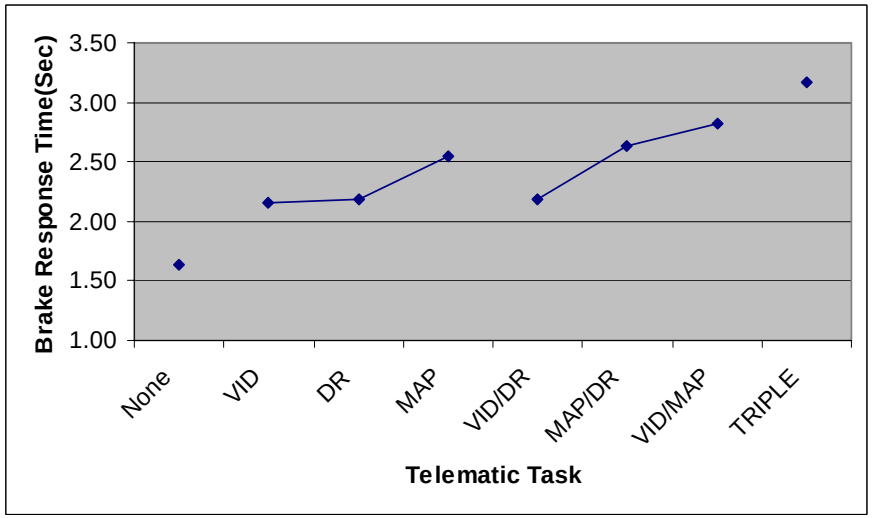
  - » Variations due to
    - Driving situation, vehicle, driver interface/device were different and unspecified.
    - Tasks, measures were different and unspecified.

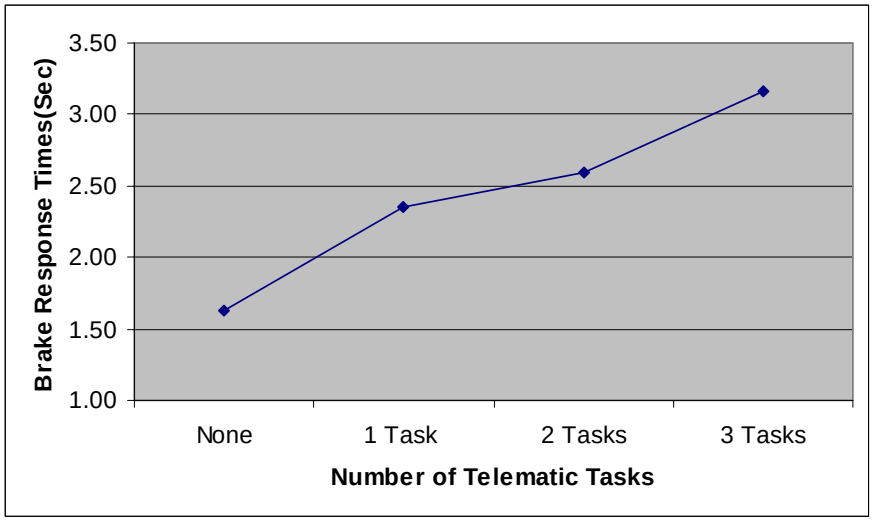
IVIS/Telematics Demand: Simulator Experiment (Task 6B)

Main Menu

- **Method**
  - Using UMTRI simulator
  - 32 subjects

- **Tasks**
  - Map reading
  - Delayed recall
  - Visual identification/detection
  - Combinations of the tasks above
- **Major Findings**
  - RT increased as
    - » task difficulty increased.
    - » number of tasks increased.





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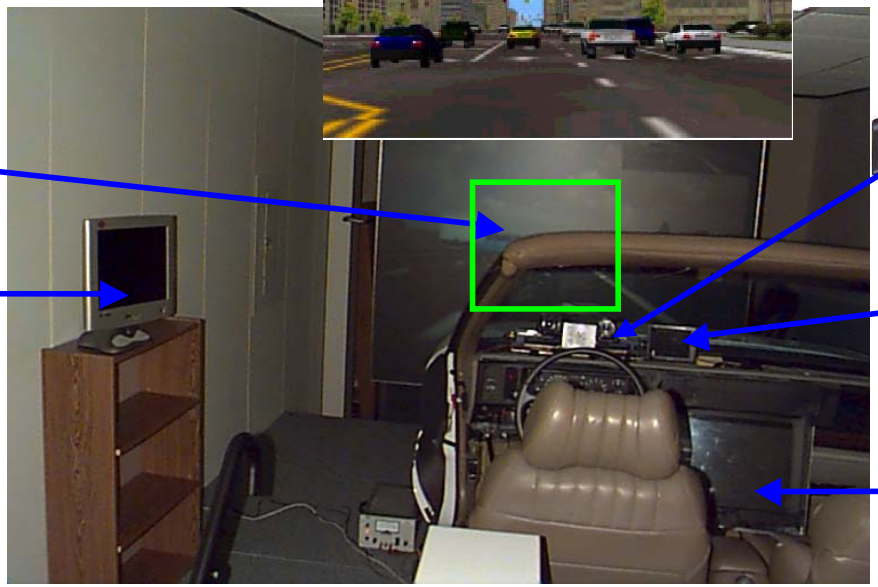
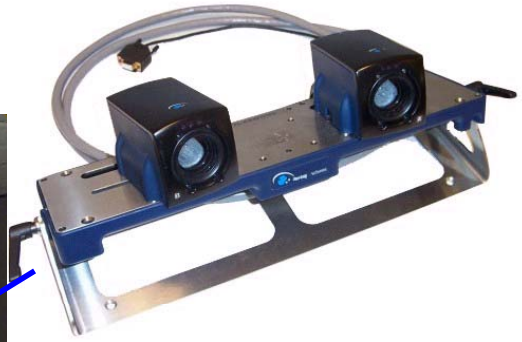
Visual Distraction (Task 7)

Main Menu

- **Task 7**
  - Objective: Determine eye glance measures that are diagnostic of visual distraction and their performance (e.g., reaction time or RT) effects.
  - Task Lead: Harry Zhang (Delphi)

- **Method**
  - 2 experiments
  - 14 subjects/experiment





Eye Tracking System

Forward Road

Side Display (75° H, 2° V)

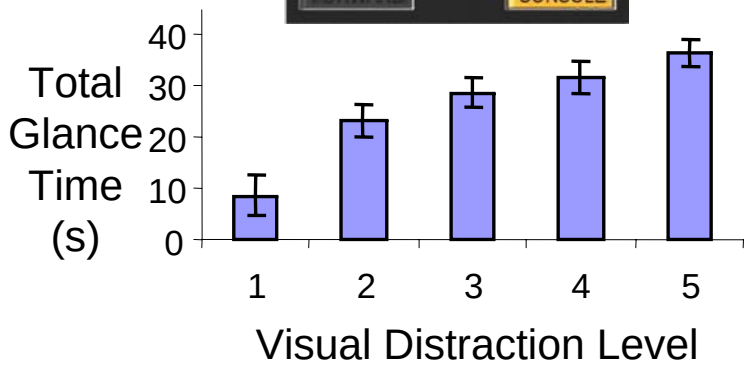
Dashboard Display (-22° H, -10° V)

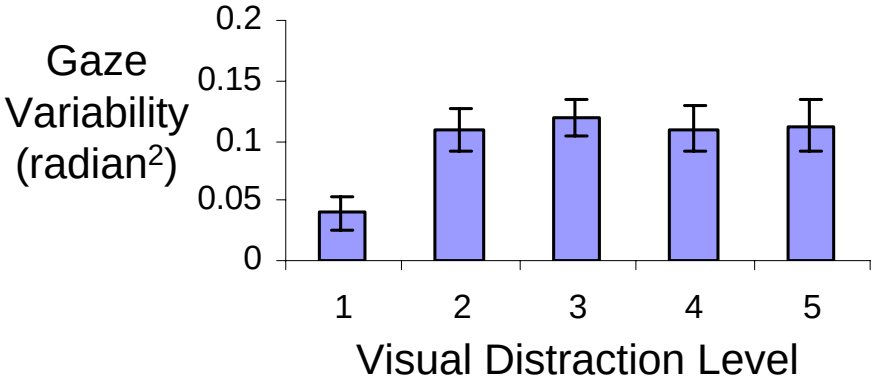
Center Stack Display (-33° H, -28° V)

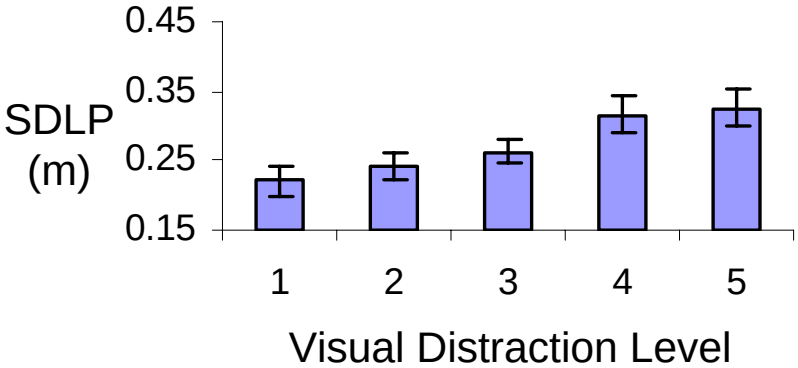
Visual Distraction (Task 7): Major Findings

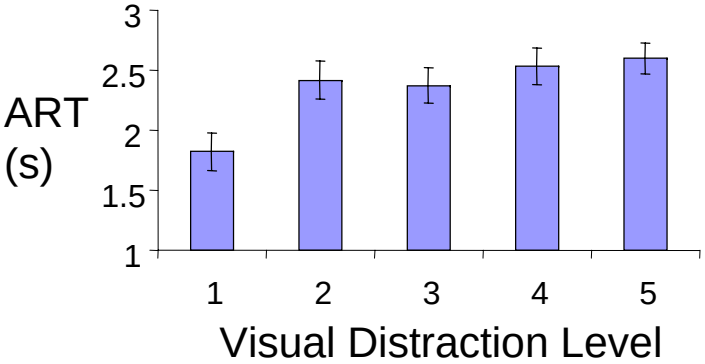
Main Menu

Ref: Visual Distraction Video









Visual Distraction (Task 7) Diagnostic Measures

Main Menu

Type-I eyes-off-road exposure, total glance duration, attention vector, & attention variability can be used as diagnostic measures of visual distraction

	(Mean Glance Duration)$^{0.5}$ * (Glance Frequency)	(Mean Glance Duration) * (Glance Frequency)	(Mean Glance Duration)$^{1.5}$ * (Glance Frequency)	(Mean Glance Duration)^{2} * (Glance Frequency)
ART	0.591**	0.597**	0.429	-0.516*
BRT	0.608**	0.639**	0.518*	-0.441
Steering Entropy	0.902***	0.917***	0.784***	-0.367
SDLP	0.62**	0.733***	0.757***	-0.058
# of Lane Departures	0.502*	0.614**	0.641**	-0.057
Lane Departure Duration	0.53*	0.657**	0.691***	-0.056
TLX	0.858***	0.939***	0.919***	-0.167

Based on 60-s time window N = 14 *: $p<0.10$ **: $p<0.05$ ***: $p<0.01$

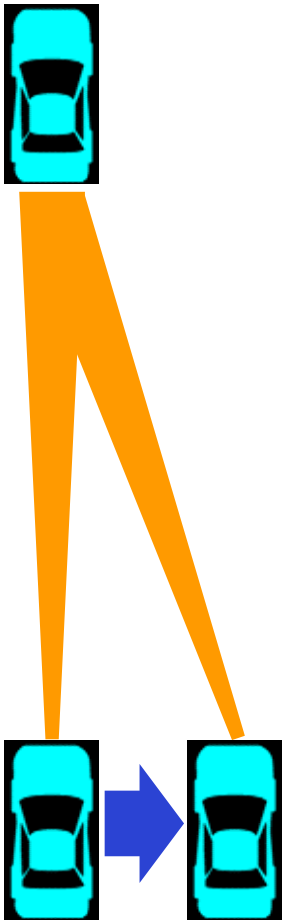
Intent (Task 8)

Main Menu

- **Task 8**
  - Objective: Determine diagnostic measures for drive intents such as intent to change lane.
  - Task Lead: Matthew Smith (Delphi)

- **Major Findings**
  - Intent info can be used to reduce nuisance alarms and increase user acceptance.
  - 4 types of information can be used to detect intent
    - » Motive: Is there a reason?
    - » Affordance: Does the environment allow the maneuver?
    - » Intent Indicators: Head/eye movement
    - » Execution Indicators: Steering movement, change in lane position & azimuth angle

Ref: Intent Video



Azimuth moves to left as host moves to right

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Adaptive Safety Warning Countermeasures (Task 9)

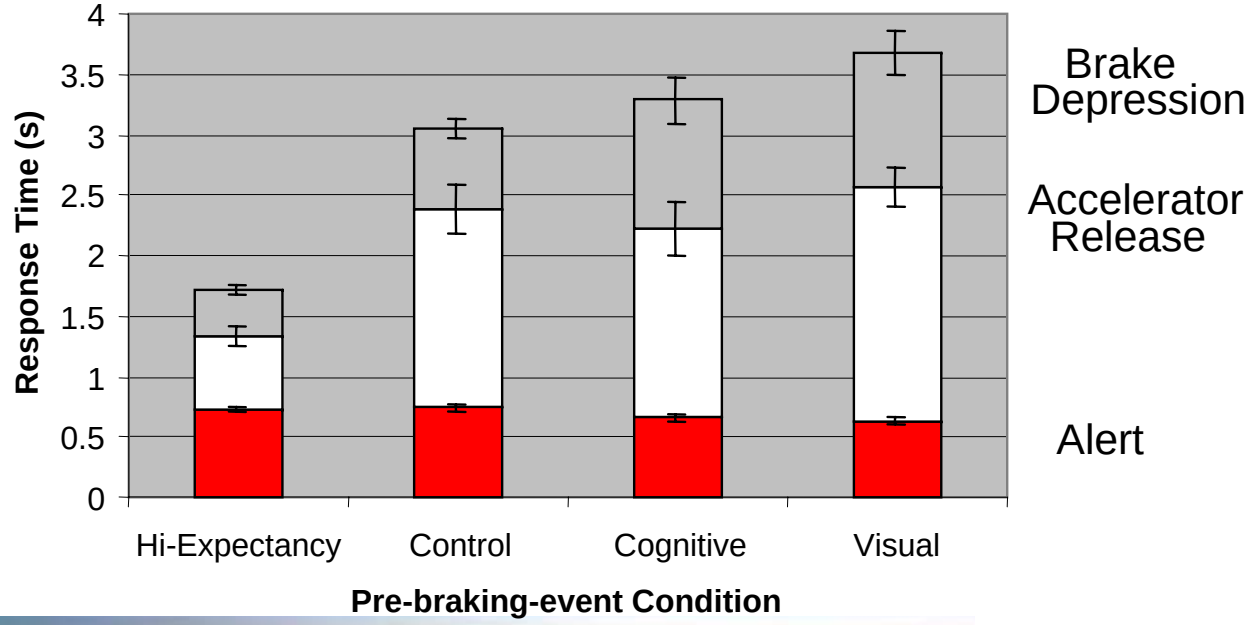
Main Menu

- **Task 9**
  - Objective: Enhance system warning effectiveness to adaptively respond to distraction, demand, & intent.
  - Safety Warning System focus: Forward Collision Warning (FCW), Lane Drift Warning (LDW)
  - Task Lead: Matthew Smith (Delphi)
- **Method**
  - Delphi simulator (GlobalSim)
  - 36 subjects; Between-subjects design (12 each condition)
  - Experiment 1: Imminent Alerted Brake Reaction Time (BRT)
    - » Measure RT to FCW alerts while visually or cognitively distracted
  - Experiment 2: Comparison of Different Adaptive Enhancements
    - » No adaptation
    - » Timing (change timing of alert based on distraction)
    - » Suppression (suppress auditory alert when attentive)
    - » Auditory (cautionary voice when distracted)

Adaptive Safety Warning Countermeasures (Task 9)

Main Menu

- **Major Findings From Experiment 1**
  - Brake reaction time longer in visual condition than in control or cognitive condition
  - No distraction effect in accelerator release reaction time
  - Transition time (from accelerator release to brake depression) longer in
    - » Cognitive distraction condition (distraction effect)
    - » Visual distraction condition (distraction effect)
  - Expectancy effect in
    - » Transition time
    - » Accelerator release reaction time



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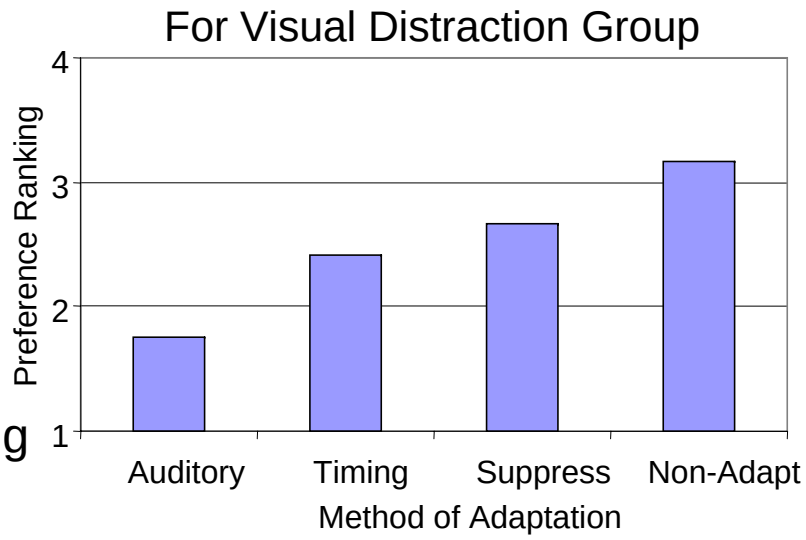
Adaptive Forward Collision Warnings (FCW) (Task 9)

Main Menu

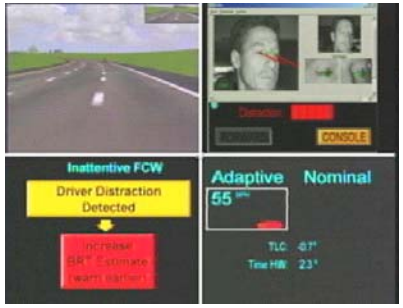
- **Findings**
  - Visually-distracted subjects demonstrated a preference for the auditory adaptation over the non-adaptive condition
  - Cognitively-distracted subjects appeared to have no obvious preferences for any of the adaptive conditions
  - Hybrid method of adaptation may be good
    - » Distraction-based change of alert timing
    - » Suppress auditory alerts if attentive
    - » Intent-based suppression of alerts
    - » Use voice alerts for caution



- **Examples**

Ref: FCW Videos

No Distraction



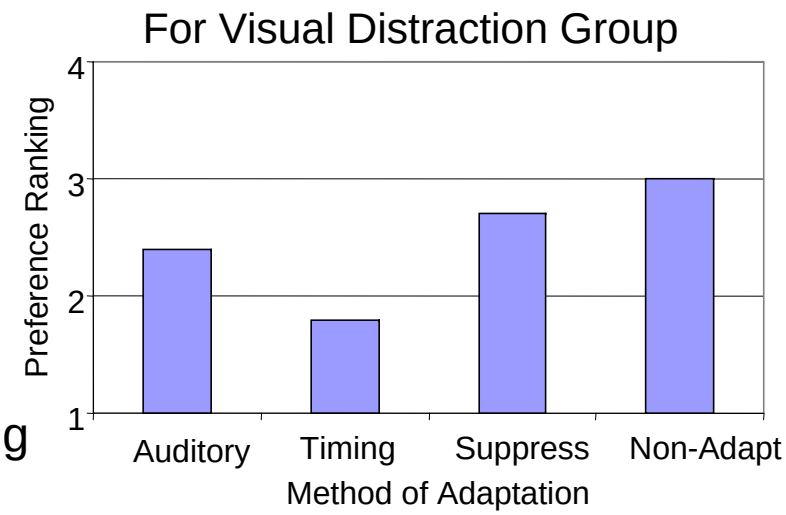
Distracted

Intent to change lane

Adaptive Lane Drift Warnings (LDW) (Task 9)

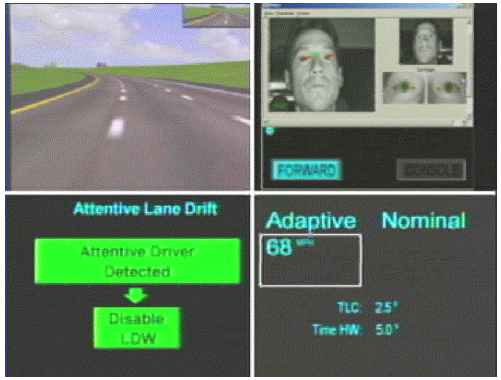
Main Menu

- **Findings**
  - Visually-distracted subjects seemed to prefer timing and auditory adaptations over non-adaptive condition
  - No effect of adaptation found for cognitively-distracted subjects
  - Adapt LDW only for visual distraction
    - » Distraction-based change of alert timing
    - » Suppress auditory alerts if attentive
    - » Use voice alerts for caution

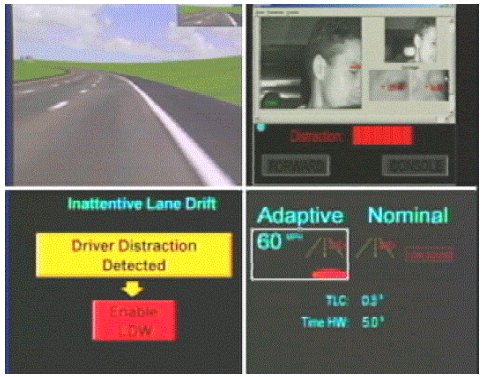


- **Examples**

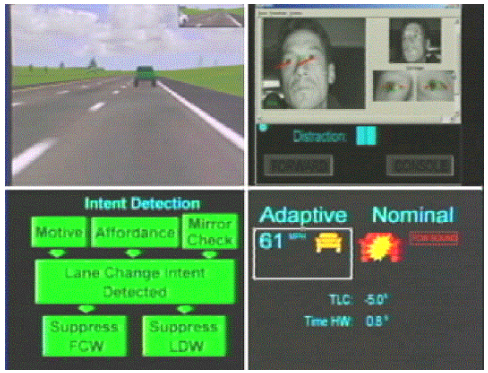
Ref: LDW Videos



No Distraction



Distracted



Intent to change lane

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