Multimodal Representations of Time-to-Collision on Lane-Changing Decision -Making

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Today's Overview

History of vehicular Technology	• In-vehicle Information System (IVIS) & Advanced Driver Assistance System (ADAS)
Multisensory interface design & Situation Awareness (SA) model	• Information-processing model in Driving : SA, performance and environment complexity
The adventures of audio cue over perform visual display	• *Time threshold setting in alerting function should be correspondent with sensory threshold*
Hypothesis and experiment design	• Optimal decision-making bias by Signal detection Theory (SDT) and Receiver Operating characteristic plot

1990s: The Era of intelligent vehicles and IVIS

- Most interaction in IVIS Belong to parallel Visual-Manual tasks

(a) (b)

FIGURE 11: Early car navigation systems (Toyota 1987 (a) and BMW 1994 (b)).

Toyota Ardeo 1998

Nissan Primera 2001

BMW i-drive 2001

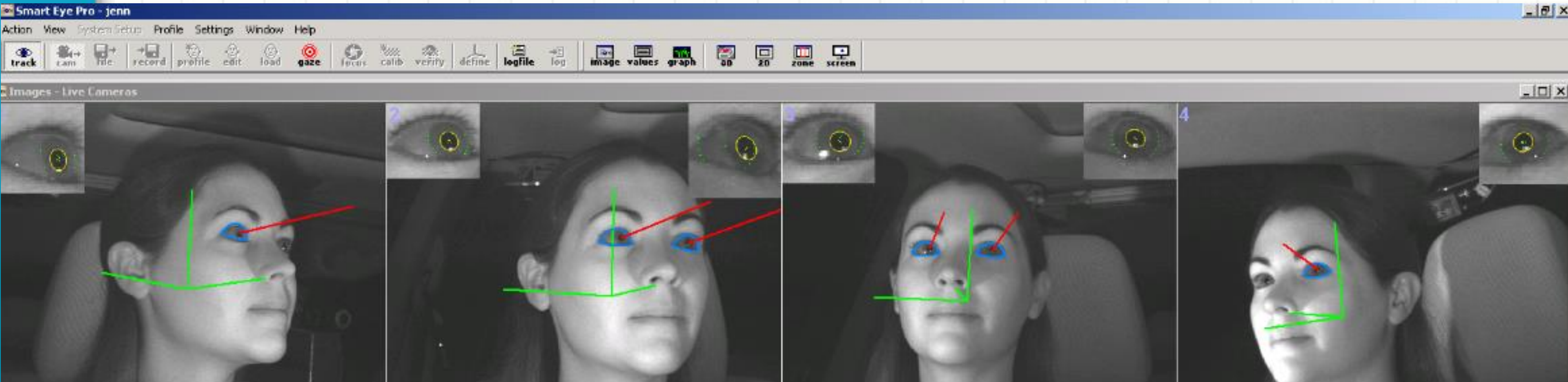
Test methods of mental workload

- Occlusion method with shutter goggles

AAM Guidelines (Alliance of Automobile Manufacturers, 2003)

2.1a Glance behavior, (Alternative A) Single glance durations should not be > 2s and total glance time =< 20 s

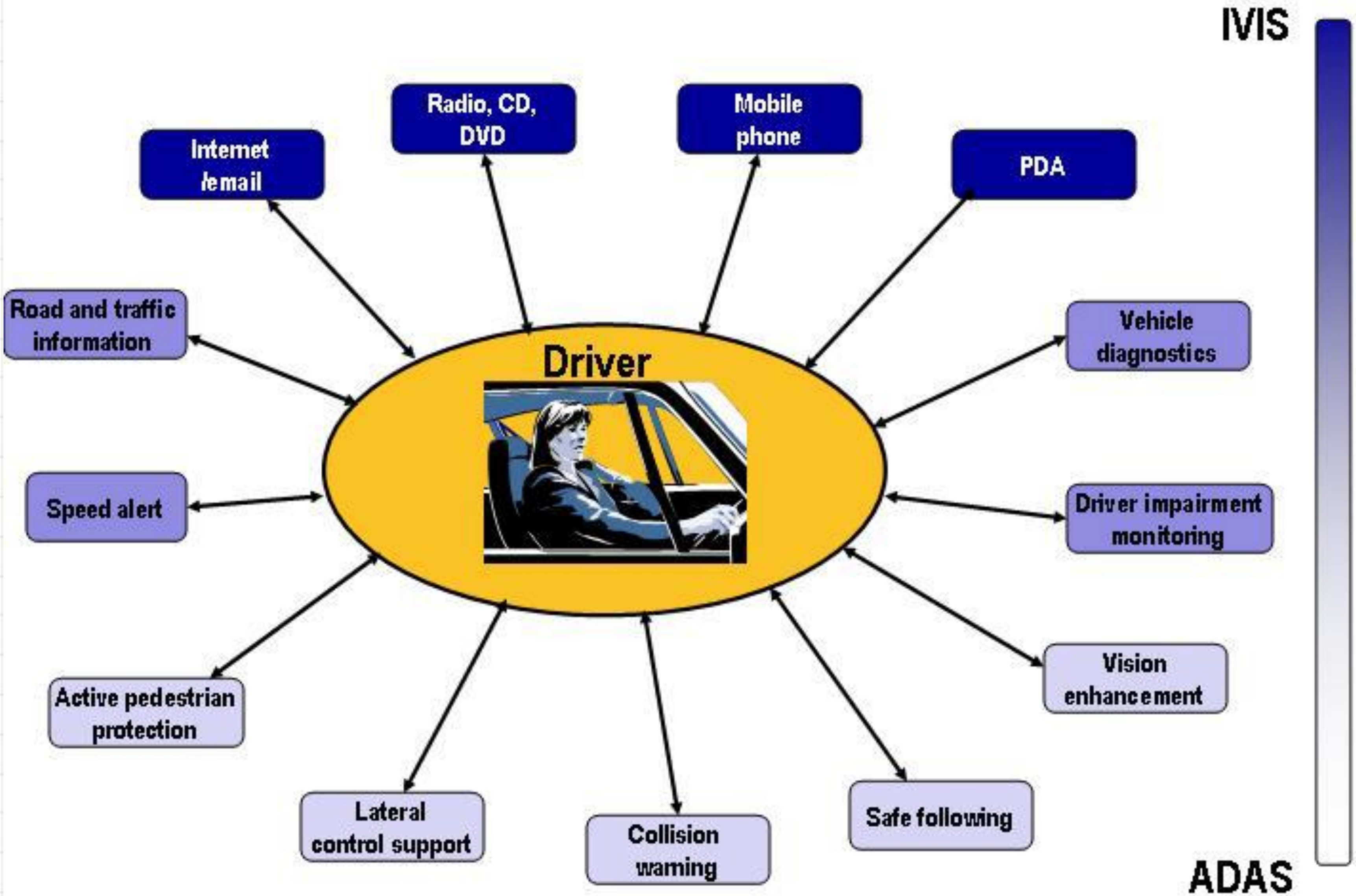
2.1b Reference task (Alternative B) # of lane exceedances should not exceed reference task, car following should not be worse



Self-report subjective workload measure: NASA-TLX

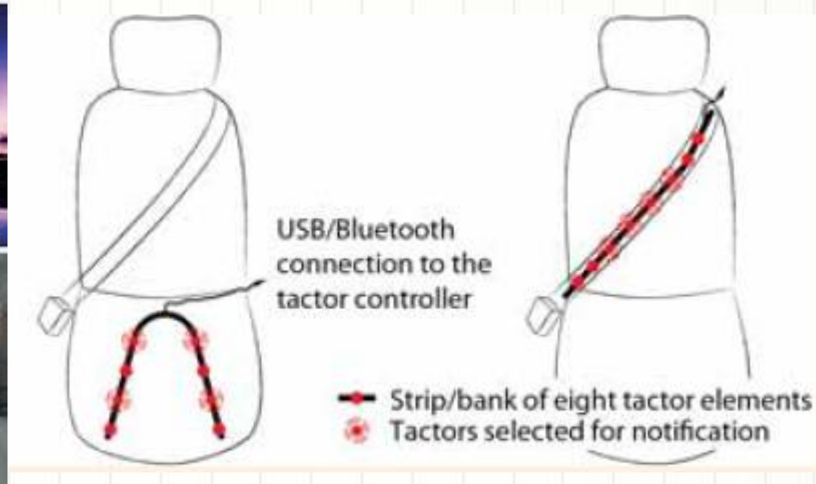
Title	Endpoints	Descriptions
MENTAL DEMAND	Low/High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	Low/High	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	Low/High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	good/poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
EFFORT	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	Low/High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

2000s: Semi-automatic Advanced Driver Assistance system

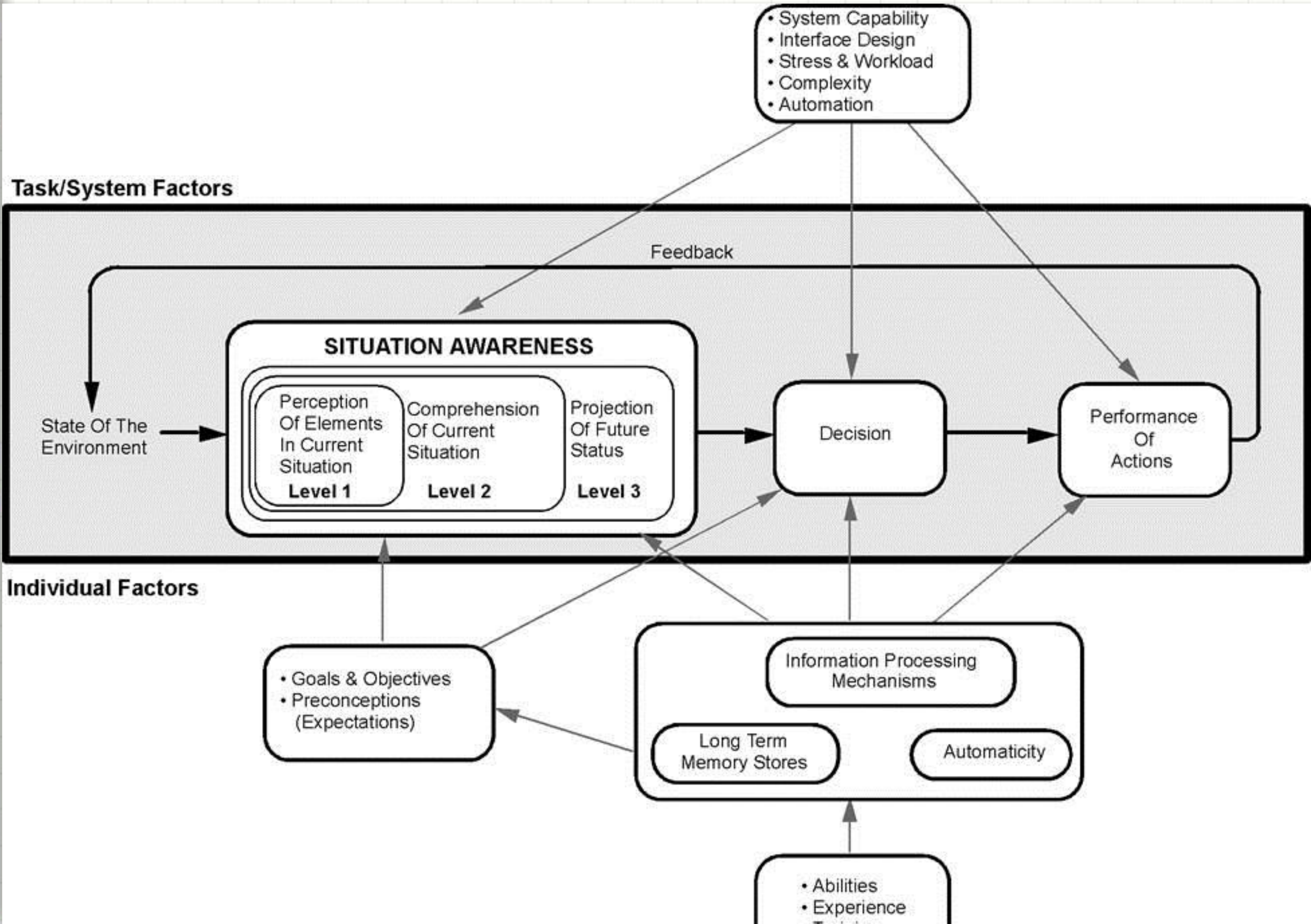


2010s: Multimodal Human Machine Interaction

- Automatic Speech Recognition and voice control interface



Metrics to evaluate IVIS -Situation Awareness



Situation Awareness(SA) vs. Task Complexity

- SA(Uncertainty of environment)+ Task Performance (Reaction pattern based on experience)*Task Complexity (The extend to understand the situation)=Attention Resource (differ from individual's WM)

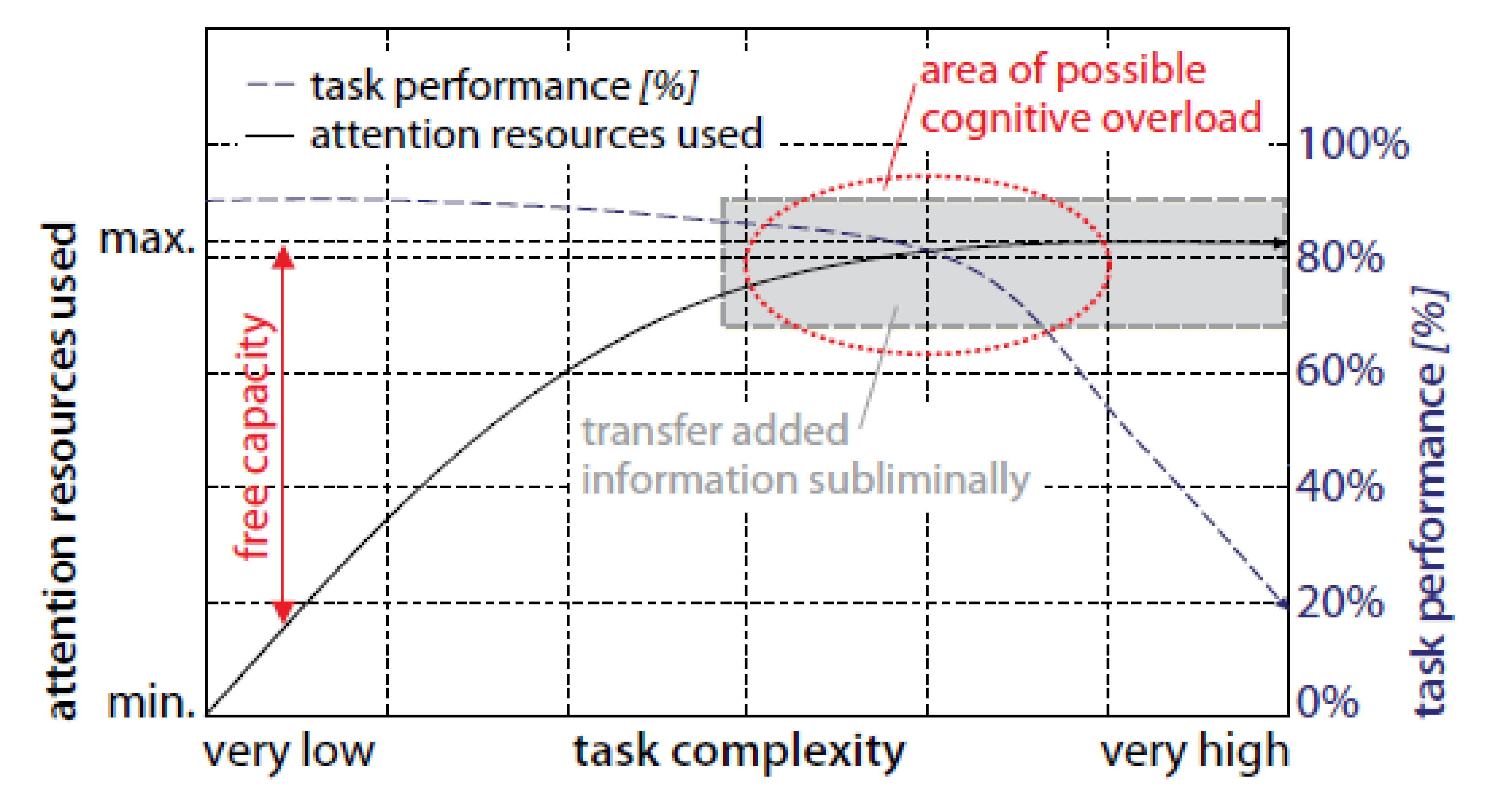
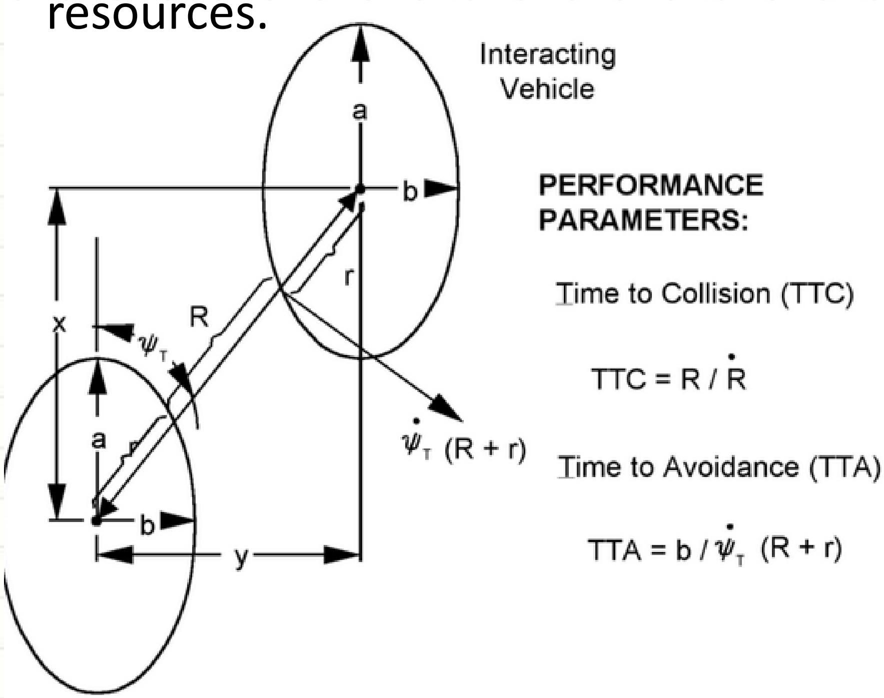


Figure1. Cognitive resources and its relation to task performance (Riener, 2012).

Definitions, maneuver sequence, and relevant parameters of the Lane Changing task

Goal: compare different combinations of multimodal warning formats to efficiently convey more information and to enhance lane-changing decision making accuracy without distracting drivers' attention resources.



Car	SV,POV	Leading/Following	
Lane	Original/Destination Lane		
Speed	Volecity	ΔV	
Distance	Range	r=Range Rate=Range/ΔV	
Time	TTC	TTA	

Optimal Warning design

- Mapping context and environment evaluation with Representation modality
- Warning algorithm and threshold setting convey appropriate urgency perception

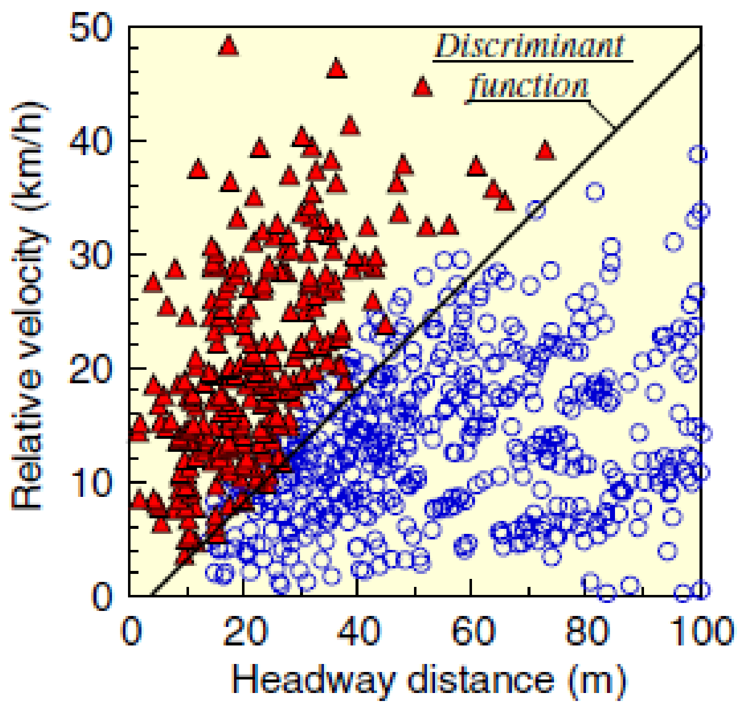


Figure 4. Relationship between headway distance and relative velocity of target vehicles (○ :Lane change execution ▲ :Cancellation).

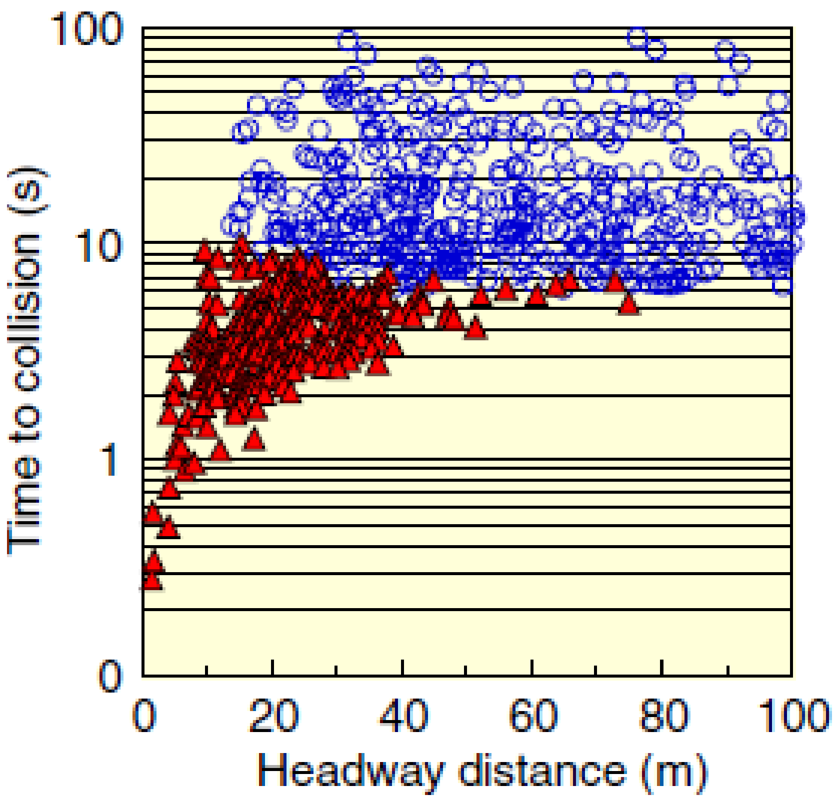
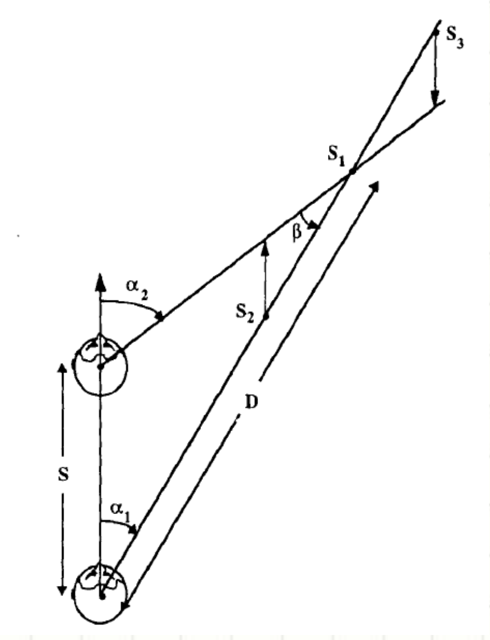


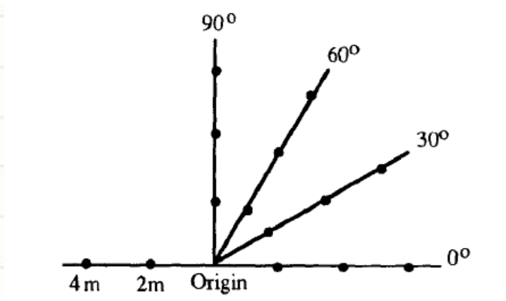
Figure 5. Distribution of time to collision (○ :Lane change execution ▲ :Cancellation).

Auditory display design

- Event onset intuitively map to sound onset.
- Level of priority or urgency can be represented systematically with variety in rhythm, tempo, pitch and harmonic complexity
- Drawing attention to, or indexing, a specific location in space –a form of deixis (Ballas,1994) accomplished with 3D audio-rendering techniques

Four heuristic evaluation factors for Distinction from each other (**acoustic properties, ecological frequency causal uncertainty , sound typicality**)





Auditory displays out-perform visual displays in representing dynamic distance

- The TTC assumes a constant speed and does not account for vehicle acceleration.
- monitor the changing velocity and estimate motion trajectory for front, rear and side cars Both normally means 2 things, not 3.
- Perceive distance by distorted 2D image in rear and side mirrors
- Frequent eye glance (saccade and fixation) require high workload hurt SA
- Doppler effect and Inter-aural Time difference (ITD) indicate human can sense azimuth of source to detect motion trajectory

Time threshold setting in alerting function should be correspondent with sensory threshold

- The parameter selection and threshold setting should be modified iteratively based on performance outcome of results.
- The uncertainty in environment is the most difficult part.

- The threshold between executing and cancelling LC range from 6.17s~9.98s

- Duration time of Lane Changing
- **5.3±1.0 s**

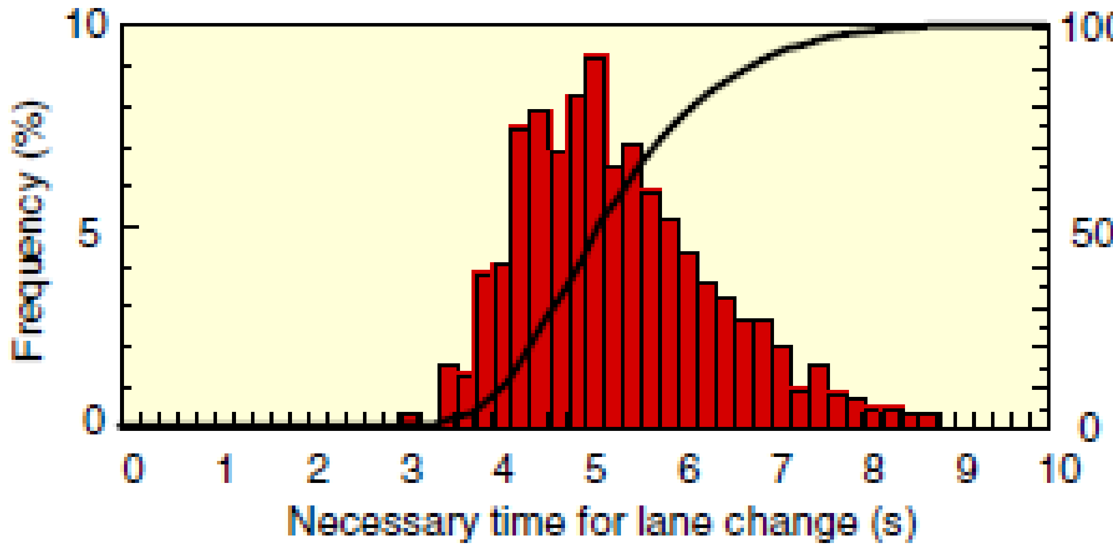
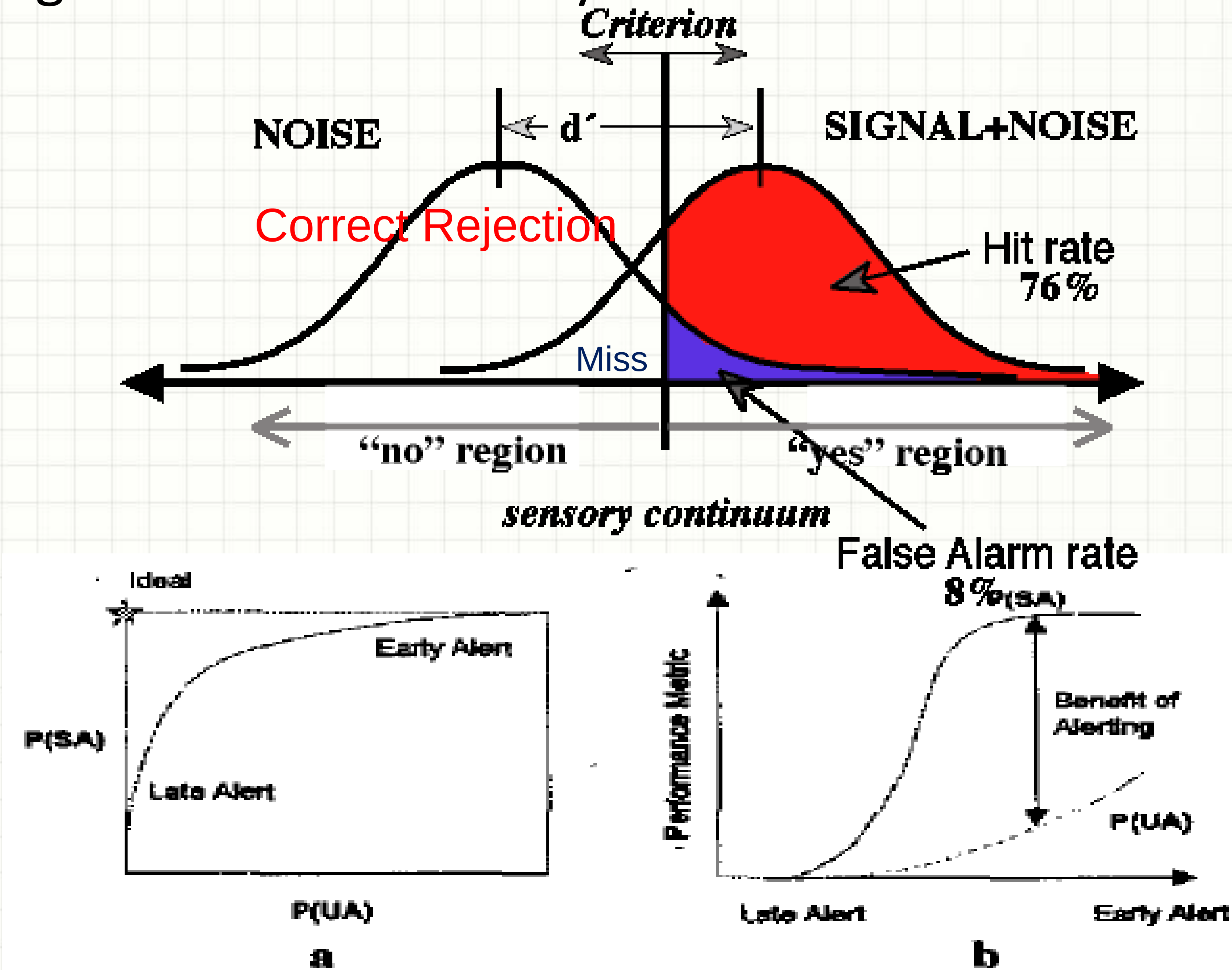


Figure 6. Distribution of required time f
lane change.

Experiment-Stimuli group

Group	Summary	Pros & Cons
Control	a video simulating a six second scene in the rear and side mirrors will be displayed	
Control+ Digital Number in dial gauge	changing numbers to represent the dynamic distance from POV	• Precise but abstract • Vision display contradict to scan
Control+ Audio	• 10 seconds and over : Unnecessary (no beep sound) •5 to 10 seconds : Adjustable range (2000Hz 60dB, three impulse per second) • 3 to 5 seconds : Recommended(2000Hz,60dB,ten impulse per second) •TTC Under 3 seconds : Imperative(Continuous sound)	Interfere by environmental noise and head movement; Which direction? Hazard or Evasive Nuisance cause ignorance
Omni	All	Reliability vs. warning pollution

Signal Detection Theory &



Conclusion

- The control of speed is solution to avoid collision in lane changing.
- system delay and driver's reaction time should be considered in a high-fidelity experiment
- The alert function to display TTC differ from vehicles attributes, driving type, driving style and traffic complexity.
- Spatial sound stimuli need customized setting depend on difference in head diameter

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