

## APPENDIX A. LITERATURE REVIEW

Allen, R.W., Stein, A.C., Rosenthal, T.J., Ziedman, D., Torres, J.F., & Halati, A. (1991). A human factors simulation investigation of driver route diversion and alternate route selection using in-vehicle navigation systems. In *Vehicle Navigation and Information Systems Conference Proceedings* (pp. 9-26). Dearborn, MI.

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TOPIC: Decision making in diverting  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers, ages 18-29, 30-55, and >55

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### ABSTRACT

This paper describes a human factors simulation study of the decision-making behavior of drivers attempting to avoid nonrecurring congestion by diverting to alternate routes with the aid, of in-vehicle navigation systems. The object of the driver behavior experiment was to compare the effect of various experimental navigation systems on driver route diversion and alternate route selection. The experimental navigation system configurations included three map-based systems with varying amounts of situation information and a non-map-based route guidance system.

The overall study results indicated that navigation system characteristics can have a significant effect on driver diversion behavior, with better systems allowing more anticipation of traffic congestion. Subject route familiarity, commercial driving experience, and gender did not significantly affect the results. Alternate route analysis tended to confirm the main route diversion results and also showed that a majority of drivers were willing to accept alternate routes suggested by advanced navigation systems. Older drivers were more reluctant to divert from the main freeway route.

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### METHODOLOGY

1. Independent variables
  - a. Four different in-vehicle navigation systems (static map, dynamic map, advanced experimental, and route guidance).
  - b. Three congestion conditions (moderate, heavy, and jammed).
  - c. Three age groups (18-29, 30-55, and >55 years).
2. Dependent variables. Subject's willingness to choose alternate routes to avoid congestion.
3. Actual percentage of subjects who choose alternate routes.

4. Control conditions. Divided between commercial and non-commercial drivers, gender, and route familiarity.
  5. Data analysis techniques. X2.
  6. Methodology. Simulation on a personal computer that controlled visual and auditory displays simulating travel along a freeway. Rewards and penalties.
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## REVIEW OF ARTICLE

Somewhat useful. Data were obtained using a simulation rather than a real setting. Generally, the results suggest that subjects are influenced by in-vehicle navigation systems. However, these results could have been biased because of subjects' expectations. Experimenters failed to consider the fact that the alternate routes could become congested.

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## CRITICAL FINDINGS

1. Various classes of navigation systems: Class 0 (open-loop systems) to Class 4 (dynamic closed-loop systems). Class 0 includes simple directional aids, map display systems, route guidance aids (e.g., ETAK); Class 4 contains two-way communication between vehicle and control center, centralized vehicle tracking, optimal routing, and information transfer (e.g., Ali-Scout and Autoguide).
2. Driver's ability to navigate through a complex environment depends on knowledge of the surroundings and available navigational aids; driver's performance depends on trip purpose and driver's goals.
3. Older subjects took longer to divert in response to congestion.
4. A lower percentage of the older age group diverted as compared to the younger and middle-age groups.
5. Route familiarity and commercial driving experience did not influence diversion decisions.
6. The advanced experimental and route guidance systems encouraged subjects to divert sooner in anticipation of congestion.
7. Of the route guidance and advanced experimental groups, 70 to 85 percent followed the alternate route recommendation.
8. There was some tendency for drivers to select the shortest possible alternate route regardless of In-Vehicle Navigation System (IVNS) recommendations.

**Allen, T.M., Lunenfeld, H., & Alexander, G.J. (1971). Driver information needs. *Highway Research Record*, 366, pp. 102-115.**

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TOPIC: Driver information needs  
TYPE OF ARTICLE: Empirical study/position paper  
SUBJECT POPULATION: Not applicable

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### **ABSTRACT**

The driving task was analyzed to determine the nature and interrelationship of the subtasks the driver performs and the information needed to perform them safely and efficiently. Data were developed using a modified information-decision-action task analysis method applied to several long driving trips. The task analysis provided the basis for categorizing the various component driving subtasks, identifying information needs associated with the subtasks and their present methods of satisfaction, and providing a structure to the driving task. Driving subtasks were categorized in accordance with information-decision-action complexity and ordered along a continuum. The subtasks were found to fall along a hierarchical scale. Vehicle control subtasks, such as steering and speed control, were ordered at the lowest level and identified as micro-performance (control). At an intermediate level, subtasks associated with response to road and traffic situations were identified as situational performance (guidance). The highest level subtasks, encompassing trip planning and preparation and route finding, were identified as macro-performance (navigation). Performance of subtasks at the highest level of the hierarchy involves component performance at a lower level. Drivers search the environment for information needed to perform the various subtasks and shift attention from one information source to another by a process of load-shedding. When load-shedding is required due to the demands of the driving situation encountered, information associated with subtasks relative to the subjective needs of the driver is attended to, and other information sources are shed.

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### **REVIEW**

Somewhat useful even though the article is dated. The article provides a model to identify the interrelationships between the various levels of performance activities that a driver must accomplish.

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### **CRITICAL FINDINGS**

1. Driving task analysis procedure: Data were collected: (a) for each situation encountered in transit; (b) for each piece of information displayed; (c) on driver observations and expectancies relative to information needed; (d) to reflect road and traffic conditions; (e) on driver perception; (f) on driver cognition (evaluations, predictions, and decisions); (g) to show driver control responses; and (h) on feedback information.

## 2. Levels of performance

- a. *Micro-performance (control)*: vehicle-control subtasks low in the hierarchy. Two subtasks: steering control and speed control.
  - b. *Situational performance (guidance)*: responding to roadway and traffic situation. Numerous subtasks: car following, overtaking and passing, avoidance of pedestrians, response to traffic signals and advisory signs, etc.
  - c. *Macro-performance (navigation)*: large behavioral subtasks at the high end of the hierarchy. Two phases: trip preparation and planning (pre-trip) as well as direction finding (in transit).
  - d. Performance of a subtask at any level in the hierarchical scale affects each subtask lower in the hierarchy.
3. Attention: The hierarchy describes the load-shedding behavior of the driver. When the driver becomes overloaded by a subtask at one level of performance, he or she sheds all tasks higher, but not those lower. One way to avoid overloading is to apply the principle of spreading the tasks.

## 4. Primacy

- a. It is possible to establish a priority of subtasks and their associated information needs.
  - b. Information needs lower in the hierarchy have priority over needs higher in the hierarchy.
  - c. Because control (micro-performance) information is highest on the primacy scale, it must be presented before guidance (situational) and navigation (macro-performance).
5. Expectancy: It is necessary to respect driver's expectancy to maintain safe driving. This need is the greatest at the situational level as well as at the macro-performance level.

## 6. Information needs

- a. Vehicle micro-performance.
- b. ARI micro-performance (ARI refers to advisory, restrictive, or inhibitory factors that cannot be specifically categorized under vehicle, road, traffic, service, or directional).
- c. Road micro-situational performance.
- d. Traffic situational.

- e. ARI situational.
- f. Service macro-performance.
- g. Directional macro-performance.
- h. ARI macro-performance.

**Barrow, K. (1991). Human factors issues surrounding the implementation of in-vehicle navigation and information systems. *SAE Technical Paper Series* (SAE No. 910870, pp. 1-15). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: Human factors in In-Vehicle Navigation Systems (IVNS)  
TYPE OF ARTICLE: Literature review  
SUBJECT POPULATION: Not applicable

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## **ABSTRACT**

Many questions surround the possible implementation of an advanced driver information system into passenger vehicles. The technology to relieve increasing traffic congestion problems exists today, but the methods to safely use this technology do not. There are many concerns in the government, industry, and academic communities surrounding the implementation of graphic display monitors inside passenger vehicles. This concern stems from recent studies on the effect of cellular phones, touch panels, and electronic navigational systems on driver attention demands.

These studies show that driver attention is taken from the roadway to operate these systems. However, more research into basic human/vehicle ergonomics needs to be conducted in order to determine how the demands of in-vehicle electronics affect highway safety. Recommendations include maintaining and broadening the scope of human factors research, continued use of field testing, the implementation of pre-production standards and regulations, increased driver education and training, and continuation of realistically engineered systems.

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## **REVIEW**

This paper consists of an extensive review of the: (1) various Intelligent Vehicle-Highway Systems (IVHS), and (2) current human factors literature regarding the Advanced Traveler Information System (ATIS).

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## **CRITICAL FINDINGS**

### **1. Various functions of IVHS**

- a. ATMS: Advanced Traffic Management Systems (ATMS) uses traffic sensors to make real-time adjustments in ramp metering, traffic signals, and roadside message boards.

- b. ADIS: Advanced Driver Information Systems (ADIS) uses monitors to inform drivers of current traffic situations. May contain some route guidance capabilities.
  - c. CVO: Uses automatic vehicle tracking, two-way communications, in-vehicle text, and map displays.
  - d. AVCS: Advanced Vehicle Control Systems (AVCS) will warn drivers of approaching objects and to apply brakes to avoid collisions.
  - e. ERGS: Electronic Route Guidance Systems (ERGS) technology of the 1960s. Project scrapped.
  - f. PATHFINDER: Field evaluation of ETAK system, map-based driver information system. Little human factors involved so far, but there will be an extensive evaluation process to consider the driver task load.
  - g. TRAVTEK: A lot of human factors considerations.
2. Two types of driver information systems
- a. Basic congestion information system; map is overlaid with the current congestion.
  - b. Route guidance system.
3. Results from various studies
- a. *Dingus & Wierwille*: Little difference between time to reach a destination using conventional or electronic map: conventional-looked before onset of trip; electronic-looked during driving.
  - b. *Greeter, Vitello, & Wonsiewicz*: Drivers with audio-only drove to their destinations more quickly, with fewer miles driven and with fewer errors, than groups with maps and groups with maps and audio instructions.
  - c. *Department of California Highway Patrol/Zwahlen*: Largest deterioration of safety occurred when people dialed a long string of numbers on car phones. Dialing pre-set numbers were no worse than tuning the radio.
  - d. *Zwahlen*: Probabilities of “lane exceedance” during the operation of a CRT are 15 percent for a 10-ft-wide (3.0-m-wide) lane, which is unacceptable.
  - e. *Labial*: A map with written communication is the easiest for drivers to recall, with map and audio being the next easiest, and map alone being the hardest to recall. Amount of information that could be handled depended on amount of attention that

could be given to navigational systems. Lateral commands were used with fewer errors than when street names were used. Audio was preferred by 3 to 1 over the text; plain maps were preferred by 2 to 1 over maps with text. The navigator task required the most assistance, but tuning the radio, adjusting power mirror, and inserting a tape caused the largest “lane exceedance.”

4. Design philosophy. Instead of controlling the amount of information, it is more desirable to control the characteristics of the display. It is better to specify a standard or regulation that indicates how much workload a display can place on a driver rather than a design standard that attempts to predict what that workload would be (e.g., number of items, size, shape, etc.).

Coury, B.G., Weiland, M.Z., & Cuqlock-Knopp, V.G. (1992). Probing the mental models of system state categories with multidimensional scaling. *International Journal of Man-Machine Studies*, 36, pp. 673-696.

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TOPIC: Mental models/multidimensional scaling  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Students (20 subjects)

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## ABSTRACT

Identifying the underlying decision criteria used by people to classify system state is one of the major challenges facing designers of decision aids for complex systems. This research describes the use of multidimensional scaling (MDS) to probe the structure and composition of the mental models employed by users to identify system state and to evaluate the impact of different display formats on those models. Twenty people were trained to classify instances of system data. Pairwise similarity ratings of instances of system data were analyzed by MDS to reveal the dominant dimensions used in the task. Results showed that significant individual differences emerged and that the dimensions used by people were also a function of the type of display format.

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## METHODOLOGY

### 1. Independent variables

- a. Four system-state categories.
- b. Two types of displays (digital and configural).
- c. Uncertainty.

### 2. Dependent variables

- a. Similarity of a subset of instances of system data.
  - b. Performance measures (e.g., accuracy and response time).
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## REVIEW

Somewhat useful, with the exception of some of the conclusions the authors reached regarding display designs. The methodology and system studied are too different from Task

E's purpose and interest; however, some of the general conclusions they reached should possibly be considered in working on Task E.

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## **CRITICAL FINDINGS**

### **1. Conclusions**

- a. The information used by the two display groups to identify system state was qualitatively different.
- b. Despite differences in the composition of the mental model, the structure of those models appeared to be relatively stable across people.
- c. The format of the display has a major impact on the user's knowledge about state category membership and will significantly influence the composition of that person's mental model of the decision problem.
- d. It is important to separate the issues related to uncertainty in a decision task and the selection of the appropriate display format of system data. The degree of uncertainty determines the mapping of system data to state categories, while the display format affects a person's ability to process and use system data to identify the state of the system.
- e. There were differences between individuals, which suggests that focusing on an aggregate analysis and ignoring the unique way in which individuals internally represent decision criteria can be dangerous; MDS provides the data necessary for assessing the disparity between the group analysis and individual dimensional configurations.

### **2. Design concepts**

- a. Choice of a display is dependent upon:
  - (1) Underlying statistical properties of the task.
  - (2) Type of task.
  - (3) Degree of uncertainty involved in identifying the state of the system.
- b. Display format can significantly affect performance in decision-making tasks, especially when the status of the decision problem is uncertain or the task incorporates severe time constraints.

- c. Uncertainty is the primary factor that significantly affects the way people process information in a display and determines the utility of a particular type of display format.
- d. When display elements were mapped directly to a particular system-state category, displays that possessed object-like properties (emergent features) were found to enhance the operator's ability to quickly process system data and accurately identify the state of a system. Once uncertainty reached a given point, a precise representation of system data provided by a separable display was necessary and allowed the operator to focus on specific, critical display elements.

### 3. General concepts

- a. *User interaction with a system.* Movement through a state space that begins with the user's problem in some initial state and progresses through a series of intermediate states towards one or more goal states.
- b. *Decision making.* A cognitive process employed by the user to guide movement from one state to the next, with feedback providing the necessary information to determine the success or failure of manipulations of the state space.
- c. *Decision problem.* Defined by an initial state, one or more goal states, and a set of actions that can transform one state to another state. Once the state of the decision problem has been identified, the decision maker develops a plan of action to change the current state to some future state.
- d. *User's mental model.* Must contain knowledge of the attributes that define a decision state, the relative importance of those attributes in identifying a specific state, the operations and actions to change the current state to a future state, the decision rules used to evaluate and select a course of action, and knowledge of the costs and benefits of specific actions.
- e. *User's performance.* Is dependent upon the ability to match the data from each information source to an internal model, accurately classifying the state of the decision problem, and then constructing and executing a plan of action.

Denning, S., Hoiem, D., Simpson, M., & Sullivan, K. (1990). The value of thinking-aloud protocols in industry: A case study at Microsoft Corporation. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 1285-1289). Santa Monica, CA: Human Factors Society.

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TOPIC: Verbal protocol  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Computer users

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## ABSTRACT

Thinking-aloud protocols traditionally have been used by academic researchers as a qualitative data collection method. This method is currently gaining acceptance in industry usability testing. The Usability Group at Microsoft has adopted the thinking-aloud protocol as a primary method for obtaining data from users. The authors found the method valuable, not only because it is valid for gathering qualitative data, but also because it is responsive to the constraints faced and the organizational culture in the workplace. The issue of validity has been discussed in detail by researchers, such as Deffner and Rhenius, and Ericsson and Simon. The case study further pursues the validity of thinking-aloud protocols and also discusses how this method allows the researcher to work within industry constraints and incorporate changes into the product within a small timeframe. Finally, the case study demonstrates how thinking-aloud protocols fit in well with Microsoft's corporate culture, where understandable and persuasive results are needed. This case study will have particular relevance for usability practitioners in industry.

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## REVIEW

Although this article is directed towards the usability testing of products at Microsoft, it is very useful. It describes a time-saving method that is very useful in analyzing verbal protocols. In addition, it emphasizes the value of thinking-aloud protocols when evaluating incomplete products or products at the conceptual stage.

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## CRITICAL FINDINGS

### 1. General

- a. Results are especially convincing when product designers are presented with a video of the subject actually using the system. Subjects' verbatim comments are also effective in written reports.

- b. Aside from thinking-aloud protocols, triangulation is used across various methods: direct observations of users, questionnaires, interviews, and performance data (error rates, frequency of occurrences, and time intervals).

## 2. Time-saving methods

- a. Engage the designer to observe test sessions to get an immediate auditory and visual picture of the usability of the system.
- b. Analyze data while testing. Developed a categorizing scheme specific to the product, with categories based on particular parts of the interface that were tested. Any episode or discussion that fell under a pre-defined category was immediately marked with the time, the category, and a summary of the discussion. These entries were not used as data per se, but rather as an index to data on the videotapes of each test session. After all of the test sessions were recorded, the word processor files were imported into a spreadsheet and then sorted by category. Subcodes for second-level sorting were added according to patterns when they occurred. This two-level sorting served as a look-up table for relevant parts of the videotape where the verbatim protocol data resided. Thus, only the episodes of verbalization that were directly relevant to the pieces of the interface being tested were examined and transcribed. When it was necessary to look in closer detail at data collected on use of a particular component, relevant episodes on the videotapes were found quickly and easily.
- c. The index described above was used to quickly make a highlights videotape containing thinking-aloud data of interest.

## 3. Incomplete products

Thinking-aloud protocols can encourage discussion about a product even when it is in an unfinished state, especially when used in a co-discovery setting (teams of subjects read the introductory guide and worked together in a co-discovery situation to explore the system's interface and the concept introduced in the training). Microsoft had a prototype of the application that was not fully functional. Tasks were designed to allow subjects to use the pieces of the interface that were functional and to come into contact with the pieces that were still to be implemented. Subjects were instructed to verbalize all their thoughts while they used functional parts of the product and to verbalize their expectations when they tried to use something that obviously was not implemented.

**Drury, C.G., Paramore, B., Van Cott, H.P., Grey, S.M., & Corlett, E.N. (1987). Task analysis. In G. Salvendy (Ed.), *Handbook of Human Factors* (pp. 370-401). New York: Wiley & Sons.**

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TOPIC: Task analysis  
TYPE OF ARTICLE: Literature review/summary paper  
SUBJECT POPULATION: Not applicable

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## **ABSTRACT**

Task analysis is a formal methodology, derived from systems analysis, which describes and analyzes the performance demands made on the human elements of a system. By concentrating on the human element in systems analysis, it can compare these task demands with known human capabilities. The goal of task analysis is to provide the basis for integrating humans and machines into a total human-machine system. A task analysis defines the performance required of humans, just as an engineering analysis defines the performance required of hardware and a program flowchart defines the performance of software. All three are necessary. In this chapter, the origins and antecedents of task analysis are explored for the understanding they can provide of modern developments in both military and industrial systems. These modern developments are described in some detail to show that there is no single method of task analysis applicable to all jobs. Finally, an example of a large, complex system is presented in detail to illustrate both the techniques of task analysis and the methods of collecting the information required.

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## **REVIEW**

Useful to identify some of the numerous approaches that have been used in task analysis. Not detailed enough to follow any one specific method. Some examples could help in the understanding. Good theoretical reference material if a justification or an introductory paragraph needs to be written on the subject.

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## **CRITICAL FINDINGS**

1. Human performance in technological systems
  - a. System functions are activities that control the variables that influence the goal output of a system.
  - b. The human constituents of a system bear the responsibility for recognizing, interpreting, compensating for, and correcting or mitigating the consequences of

deficiencies, failures, and malfunctions in the hardware and software and in their own performance.

- c. Task analysis should describe, evaluate, and facilitate the human performance required by the system.

## 2. Nature of tasks in technological systems

- a. *Task*: A set of human actions that contributes to a specific functional objective and ultimately to the output goal of a system.

- b. *Task characteristics*:

- (1) Task actions are related to each other not only by their objective, but also by their occurrence in time.

- (2) Task actions include perceptions, discriminations, decisions, control actions, and communications.

- (3) Each task has a starting point and a stopping point.

- (4) Task cues and feedback are important.

- (5) A task is usually defined as a unit of action performed by one individual.

- c. *Three types of tasks*:

- (1) Discrete or procedural tasks require an individual to execute a series of separate action elements in response to specific stimuli and/or instructions given in a procedure document.

- (2) Continuous or tracking tasks require an operator to work a control continuously and to maintain an output within given limits while sampling deviations from those limits that are viewed directly or displayed. Extends over a relatively long period of time. While a continuous task is being sustained, various discrete tasks may have to be executed.

- (3) Branching tasks are variants of a discrete task where the task sequence is determined largely by the outcome of particular choice tasks in the operation. A typical task description for branching operation is done at a cruder level than for sequential operations.

## 3. Definitions in task analysis

- a. Distinction between task and job analysis.

- b. Distinction between task description and task analysis.
  - c. *Three different kinds of activity for task analysis:*
    - (1) System description and analysis.
    - (2) Specification of the human task requirements of the system (*task description*).
    - (3) Analysis, synthesis, interpretation, evaluation, and transformation of the task requirements in light of knowledge and theory about human characteristics (*task analysis*).
4. Recent developments in task analysis
- a. *Drury's approach:* Uses the following categories-task number, purpose, action, check, control problems, display problems, and postural problems.
  - b. *Hierarchical task analysis:* Starts with the overall objectives of the system and describes an operation that fulfills these objectives. The operation is then redefined as a series of sub-operations plus a plan that defines how these sub-operations are linked. When to stop: apply the PxC rule >>; further re-description is unnecessary where the product of Probability of inadequate performance and the Cost of inadequate performance is acceptable.
  - c. *Signal-flow graph analysis:* Links the variables in the system together so that a diagram is formed to indicate the control complexity of the system. The variables are drawn as nodes and are linked together by branches that represent the system functions, or the causal dependency relating two variables. It is a way of presenting the system information so it is simple to analyze and it can aid in task analysis by making explicit the decisions involved. Information needed to perform a signal-flow graph: aims of the system, how the system works, and the part the operators play in the system.
  - d. *Position analysis questionnaire:* Consists of 187 job elements (organized in 6 divisions) that characterize or imply various types of basic human behaviors involved in jobs in general. Different from other instruments in that it provides for the analysis of jobs in terms of basic human behaviors that cut across various types of jobs.
  - e. *Ergonomic job analysis:* First it describes the work system and the task. Then it analyzes this task in terms of job demands for perception, decision, and response. The integration of the task with equipment and environment in the same analysis procedure gives a unique tool for detecting potential mismatches between job demands and human capabilities.

- f. *Postural task analysis*: Concentrates on a detailed recording of the angles of each limb at each step in the task. Sequential task description format. The task analysis compared angles and forces recorded with human abilities to produce these angles and forces without injury.

5. Planning for task analysis

- a. Establish the objectives and scope of the task analysis.
- b. Establish a task data collection model that reflects the needs of the task analysis.
- c. Identify the personnel requirements of individuals on the task analysis team.
- d. Prepare a schedule for the task analysis effort.
- e. Obtain management support.
- f. Develop a task analysis program plan and uniform procedures for the team to follow.
- g. Set up a quality control method for reviewing the task descriptive data for completeness and technical accuracy.

6. Phases of task analysis

- a. *System description and analysis*:
  - (1) System functional analysis: Review the organizational context and specify the goal outputs of the systems and any specific constraints and criteria. Define system functions based on modes of operation or major system states. Examine the equipment configuration. Describe the general process of function execution.
  - (2) Operational sequence analysis: Describe the operational flow and the relationships of functions and human and equipment actions in time. Develop an operating sequence profile, a narrative description of the sequence, and functional flow diagrams. Develop an action-decision diagram and an operational sequence diagram.
- b. *Task description task list*: First step in task description is to prepare a list for each mission or operating sequence from the results of the system description/analysis. The task list indicates the scope and sequencing of the total array of human performance requirements in the sequence.
- c. *Descriptive data collection*: Four different techniques are available for data collection: documentation review, questionnaire survey, interviewing, and observations.

d. *Applications analyses:* Author describes several other analyses that could be based on the task analysis in domains such as human engineering, performance prediction, personnel selection, training, human/system reliability, and modeling of mental activity.

**Erlichman, J. (1992). A pilot study of the in-vehicle safety advisory and warning system (IVSAWS) driver-alert warning system design. In *Proceedings of the Human Factors Society 36th Annual Meeting* (pp. 480-484). Santa Monica, CA: Human Factors Society.**

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TOPIC: Warning systems  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers (13 subjects)

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## **ABSTRACT**

This pilot study was conducted to obtain preliminary information regarding alternative signaling presentations and symbologies for the Driver-Alert Warning System (DAWS) design within the In-Vehicle Safety Advisory and Warning System (IVSAWS) program sponsored by the Federal Highway Administration. Preliminary analysis had been conducted by both Hughes Aircraft Company and the University of Michigan Transportation Research Institute. The pilot study concentrated on the driver attributes of understanding, relative effectiveness, and signaling format. Thirteen subjects were exposed to the new pictograms prototyped on a Macintosh computer and were requested to verbalize their understanding and preferences with regard to varying signaling characteristics. These characteristics included: (a) monochrome, (b) color, (c) blink, (d) tone, (e) text message, and (f) voice message. The results indicated that as a group, the combination of color, audio tone, text, and voice message was the preferred signaling presentation. Gender differences were noted with the female subjects indicating a preference for the combination that included color and blink. All pictograms were recognizable by the subjects, and all subjects agreed that IVSAWS would be a substantial aid to the driver.

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## **METHODOLOGY**

### 1. Independent variables

- a. Eight pictograms of emergency hazards.
- b. Six different formats: monochrome, color, flash, audio tone, long voice and text messages, and short voice and text messages.
- c. Age, sex, group, and height.

### 2. Dependent variables: Rank order judgments (ordinal), commentaries, and opinions (nominal).

## REVIEW

Somewhat useful if interested in drivers' preferences for the design of DAWS. This study was a pilot study evaluating alternative signaling presentations, codes, and symbologies.

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## CRITICAL FINDINGS

1. Subjects preferred a signaling presentation (pictogram) that added each of the following characteristics: color, audio tone, text, and visual message (with both long and short messages).
2. Females subjects (4 out of 13 subjects) preferred the color + blink option. They interpreted the blink as a more immediate danger.
3. Long message and short message text and voice options rank higher than other options. Preferred by the 16- to 30-year-old group, followed by the age 5 1+ group.
4. Monochrome pictograph was ranked the lowest.
5. In general, data showed a preference for associating the pictogram to a voice and a text message that provided meaningful hazard/traffic recommendations.
6. Disparity between females and males for these categories only.
7. The audio tone would be more meaningful if they represented the sounds associated with the expected emergency. In general, audio tones were associated with a need to attend to a function and, therefore, should not be eliminated.

Fath, J.L., & Bias, R.G. (1992). Taking the task out of task analysis. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 379-383). Santa Monica, CA: Human Factors Society.

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TOPIC: Cognitive task analysis  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Not applicable

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## **ABSTRACT**

Task analysis is a well-accepted component of user-centered design. It is often left out of the design process, however, due to a lack of practical methods, the difficulty in predicting the amount of resources required to perform it, and a short supply of people with the appropriate skills. A solution to these problems is a structured set of activities that make up a task analysis and relate to the overall design process.

The general framework into which these activities fit has three phases: data collection, data analysis, and design. During the data collection phase, user and task data are collected and validated. The data analysis phase requires analysis of user and task data in a way that results in suggestions for information representation, navigation, terminology, and consistency. Finally, the design phase requires translating the suggestions from the data analysis phase into a viable product.

A prototype task analysis workbook was developed to assess the feasibility of the structured approach to task analysis. The workbook includes tools for data collection, data analysis, and design, as well as instructions on how to use the tools. Over a period of 2 years, the workbook was used in five different development projects. A representative from each group was interviewed to determine how the workbook was used and which parts were most useful. Results of the interviews indicate that the workbook approach has merit.

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## **REVIEW**

Very useful in providing a structured approach and method to conduct a task analysis. Easy to follow and well organized. For each set of activities, the authors provide a set of tools that help perform these activities. It might be interesting to ask for a copy of their workbook (1992). Even though it is directed to the development of computers (IBM), it still might prove useful, especially for what is called "Phases 1 and 2."

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## CRITICAL FINDINGS

### 1. Structured activity set for Task Analysis (TA)

#### a. *Phase 1: Data Collection*

- (1) Define user group.
- (2) Define tasks.
- (3) Validate user and task data.

#### b. *Phase 2: Data Analysis*

- (1) Determine relationships between groups of objects.
- (2) Determine all actions performed on each object.
- (3) Determine product-specific terminology.
- (4) Analyze and classify likely errors for each task.
- (5) Validate analysis (map tasks to objects and actions).

#### c. *Phase 3: Design*

- (1) Design individual screens.
- (2) Design the way to navigate between screens.
- (3) Determine which terminology to use.
- (4) Determine appropriate areas for consistency.
- (5) Prototype the design.
- (6) Evaluate the design.

### 2. Useful tools

#### a. *Phase I: Data Collection*

- (1) User description tables that map the user groups to attributes related to users' backgrounds, jobs, and environments.
- (2) User-task matrix that indicates the frequency with which each user group performs each task, including critical tasks.
- (3) Task worksheets that document task assumptions, triggering events, inputs to the task, action sequences, outputs, common errors, and notes.
- (4) Measurable usability objective tables that document the objectives for each task.

b. *Phase 2: Data Analysis*

- (1) Object-object matrix in which frequencies of object pairs are tabulated and cluster analyzed.
- (2) Object-action matrix is a frequency matrix that matches objects with the actions that are performed on them.
- (3) Terminology analysis and error analysis.

c. *Phase 3: Design*

- (1) User interface style guidelines.
  - (2) Prototyping tools.
3. Usefulness of workbook. Provides users with a starting point; it helps to organize task information and to identify gaps in that information, as well as to allocate design resources.

Haselkorn, M.P. (1992). Making sense of advanced traveler information systems by understanding travelers. *ZTE Compendium of Technical Papers*, pp. 52-56.

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TOPIC: ATIS - users' behavior  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Seattle users

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### **ABSTRACT**

This paper has three parts. The first part examines the informational approach to dealing with traffic congestion, placing this approach in the context of other approaches to transportation problems. The second part looks at the complexities of ATIS design and technology. The third part looks at traveler behavior as a way to deal with these complexities.

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### **REVIEW**

Very useful. Describes some of the functions that ATIS should have. Describes drivers' behavior (four groups of drivers) and how they will react to ATIS based on a study done in Seattle.

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### **CRITICAL FINDINGS**

1. Goals of IVHS and ATIS. Give people more choices, make those choices easier to access, and give accurate information on the consequences of those choices.
2. Control system
  - a. ATIS is a type of control system. A control system is simply a system that gathers data from its operating environment, does something with that data, and produces a response intended to improve the functioning of that environment. Response time requirements depend on the specific control system. Like response time requirements, there is a range of human response requirements that depend on the specific control system's goals and environment.
  - b. The message produced by an ATIS cannot be viewed as the system response. That is because messages cannot improve the operating environment. Only people's reactions to those messages-changes in travel behavior-can improve the environment.

### 3. Functions

- a. Post-trip information can provide essential feedback for long-term behavior modification (traveling habits).
- b. Designers must not only consider where and when the information will be delivered, but also the trip being addressed. Information on special trips has its own requirements; for example, including a focus on route navigation information for trips in a rental car.
- c. Each trip and information type has its own requirements for data gathering and delivery.
- d. Different information types lead to the issue of different information purposes.

### 4. Users' behavior

- a. Marketing techniques (cluster analysis) were applied to identify types of commuters in terms of their need for and response to traveler information.
- b. Types of commuters in Seattle:
  - (1) Twenty-three percent of the people who are unlikely to change anything about their trip are male and are highest on the socio-economic scale.
  - (2) Twenty-one percent of the route changers who are willing to change route both before and especially during the commute respond more to visual congestion than information; are unlikely to change departure time; never get out of their cars (e.g., transit system); and are predominantly male.
  - (3) Forty percent of the people who change both route and time are inflexible about transportation modes and show no willingness to get out of their cars. Slightly more are females.
  - (4) Sixteen percent of the pre-trip changers who are very flexible prior to traveling-even showing a willingness to change transportation mode-are not flexible en route (more committed to their choices). They access traveler information an average of 3+ times before leaving in the morning, have the highest female ratio, and are lowest on the socioeconomic scale. In addition, they tend to live farther from work; have the longest commute; and care the most about saving time, making the trip more pleasurable, increasing safety, and decreasing travel distance. They also have jobs where there is high stress related to being on time.

**King, G.F. (1986). Driver attitudes concerning aspects of highway navigation. *Transportation Research Record, 1093*, pp. 11-21.**

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TOPIC: Driver attitudes  
TYPE OF ARTICLE: Survey  
SUBJECT POPULATION: Automobile drivers

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### **ABSTRACT**

A comprehensive questionnaire dealing with various aspects of highway navigation was developed, pretested, and administered to a demographically representative sample of the United States driving population. The sample was drawn from a group of paid subjects engaged in highway navigation experiments. The analysis of 125 completed and usable questionnaires is presented. In addition to background information on demographics and driving experience, topics addressed included route selection, behavior under directional uncertainty, distance-time-cost trade-offs, and attitudes toward proposed remedial measures. The data obtained indicate that drivers are, generally, fairly satisfied with their ability to perform route-planning or route-following tasks effectively and believe that the major constraints on their effectiveness arise from the unavailability of adequate and accurate route and traffic information. This satisfaction, however, is not supported by data on the extent of excess travel due to navigational waste. Furthermore, answers to a number of questions indicated an insufficient appreciation of the complexities of determining optimum routes and of the extent and seriousness of the problem of navigational waste.

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### **REVIEW**

Somewhat useful for obtaining an idea of how drivers view their own navigation and map-reading skills, what they feel are their weaknesses, as well as their willingness to have an automated system doing some of the work for them.

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### **CRITICAL FINDINGS**

1. Efficiency of route selection and route following may be affected by driver age, sex, education, and driving experience. The degree of trip optimization may be affected by driver attitudes; beliefs; and behavior patterns, such as selection of route choice criteria, perceived driving costs, and distance-time trade-off patterns.
2. Perceived driving costs. Subjects' estimated costs were of the correct order; however, female estimations were higher and more variable.

3. Distance-time trade-offs. Less than one-fourth of all respondents were willing to make any trade-offs for savings of 1 min.
4. Trip planning behavior and skills. Subjects had a fairly high opinion of their route-planning and route-following skills. Male subjects were more likely to resort to maps and female subjects were more likely to ask for directions. Most subjects tried two or three alternate routes, and evaluation of four or more routes was infrequent.
5. Evaluation of candidate remedial measures. Improvements in signing, in map availability and accuracy, and in real-time traffic information were rated as being of greater importance by the subjects. Improving skills was considered less important than improving performance aids. Assistance in, or delegation of, the trip-planning and route-following tasks was ranked rather low.
6. The low rating of navigation and guidance systems might have been due to the relative unfamiliarity of the concepts involved, which would also be explained by the highest variability in the data.
7. Willingness to pay for improvements. Subjects' willingness to pay was considerably less than the anticipated probable costs for the various measures suggested.
8. These results suggest that subjects appear to have an insufficient appreciation of the complexities of determining and following optimum routes.

**Labiaie, G. (1989). Influence of in-car navigation map displays on drivers' performance. SAE Technical Paper Series (SAE No. 891683, pp. 11-18). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: Map displays  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers

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## **ABSTRACT**

Different in-car navigation map displays have been tested with 60 drivers in real driving situations. The independent variable took into account three variables of guidance information (map alone, map associated with auditory guidance information, and map associated with written guidance information); two variables of itinerary complexity (number of turns); and two variables of information complexity (number of symbols). The dependent variables were composed of visual explorations, the memory recalling performance, the preference of map designs, the steering-wheel movements, and the speed variations of driving. The results have shown that map presentation associated with written directions resulted in a majority of the drivers being able to recall the route to follow. The complexity of map display designs had significant effects on the number and the duration of visual explorations and memorization performances. In the case of subjective preferences, most drivers preferred the simple map display design. Moreover, it was found that drivers reduced the speed of their vehicles while consulting the map displays. In conclusion, it was possible to propose some recommendations concerning the designs of navigational maps on board vehicles.

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## **METHODOLOGY**

1. Independent variables
    - a. Map alone, map with auditory information, and map with written information.
    - b. Route complexity.
    - c. Map viewed at stops versus during driving.
  2. Dependent variables. Time spent looking at display, memory recall of route, preference of map display, steering-wheel movements, and speed variation of driving.
  3. Data analysis techniques. ANOVA, X<sup>2</sup>.
-

## REVIEW

Useful only if we are interested in driver's preference and performance using various map displays. No task analysis or task descriptions.

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## CRITICAL FINDINGS

1. Less time is spent glancing at a visual display when it is combined with auditory information than compared to a map alone or a map combined with written information.
2. Complexity of the routes has a negative influence on drivers' ability to recall an itinerary, especially when driving.
3. Average glances at the display are 1.28 s; 92.3 percent of all glances were 2 s or less (some could be as long as 4.8 s).
4. This effect was independent of the type of maps. Many more errors and omissions were noted for road names than for the drivers' ability to find their way.
5. Drivers preferred maps with auditory information (48 percent) over maps alone (34 percent) and maps with written information (17 percent), even though maps with written information led to the best recall (69 percent).
6. Author recommended:
  - a. Maps should be supplemented with voice messages when used while driving or with written information to be viewed when stopped.
  - b. Maps should be simplified for use while driving and have more detailed information for use when stopped.

**Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentations. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors Society.**

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TOPIC: Map displays  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers

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## **ABSTRACT**

Two studies investigate the effects of presentation modalities (visual/auditory/repeated auditory) and complexity levels of different in-car road information on subjective preferences and on perceptual and cognitive performances of drivers. In real driving situations, each driver was alerted by a ringing signal prior to the presentation of a road information message or a map display associated with a road guidance message; the experimenter asked each driver 30 s later to recall the message or the itinerary. Results suggest that in real driving situations, short auditory road information messages or those associated with map displays optimize perceptual and cognitive performances and driving safety; written messages are of greater interest if screened when the vehicle is at rest.

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## **METHODOLOGY**

1. Independent variables
    - a. Visual or auditory information.
    - b. Four levels of road information: 4 units; 7 to 9 units; 10 to 12 units; and 14 to 18 units.
    - c. Two experiments that are similar, except that this time, maps were presented along with this visual or auditory information. The number of route changes was also manipulated.
  2. Dependent variables. Recall performance, subjective preferences of modalities, visual exploration, vehicle course, and speed control.
  3. Data analysis techniques. ANOVA, X2.
-

## REVIEW

Somewhat useful. The findings are similar to the ones found in another study by Labiale. It is useful to identify the amount of information that a driver can handle, both visual and auditory.

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## CRITICAL FINDINGS

1. Drivers feel that auditory information is safer than visual information and it is preferred for messages of Levels 3 and 4. Drivers prefer maps associated with auditory guidance (71.8 percent) to the ones with visual guidance (28.1 percent).
2. Visual stimulus disturbed the driving task at higher levels of display complexity, both in course deviation and slowing of speed.
3. The optimal perceptual and cognitive solution seems to be an auditory message using a maximum of 7 to 9 informational units for road information, or if used visually, as a prompt to a very simple visual map or guidance presentation.
4. Recall at Level 1 is 100 percent and 48.4 percent at Level 4.
5. Increasing the message length increases the number of visual fixations and the overall duration of visual explorations, but not necessarily the average duration of each visual fixation.

**Lunenfeld, H. (1990). Human factor considerations of motorist navigation and information systems. In *Proceedings of First Annual Vehicle Navigation and Information Systems Conference* (pp. 3542). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: Human factors - IVNS  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Not applicable

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## **ABSTRACT**

In-Vehicle systems have the potential for ameliorating problems associated with navigation and operations, including delay, excess fuel consumption, congestion, and increased safety risk. A proliferation of vehicle-based systems, however, has resulted in a lack of standardization and a diversity of functions. User interfaces are crucial to system effectiveness. Therefore, while display and control configurations will ultimately be determined by the marketplace, it is important that human factors be addressed and guidelines be developed. This will ensure standardization and display and control optimization. Human factors have been considered in terms of seven questions: Why? What? When? Where? How? Who? and Can?

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## **REVIEW**

Very useful with respect to describing the individual task of driving, as well as in terms of the nature of the information required, display characteristics, users' limitations, and characteristics to enhance the efficiency of these systems.

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## **CRITICAL FINDINGS**

### 1. Driving task

- a. Characterized as an Information Decision Action (IDA) activity, where information received in-transit is used with information and knowledge in-storage to make decisions and perform actions in a continuous feedback process.
- b. Driving consists of a number of discrete, interrelated subtasks. These subtasks can be arranged into three levels of performance:
  - (1) Control: Vehicle control.
  - (2) Guidance: Road following; safe path maintenance.
  - (3) Navigation: Two phases-pre-trip and in-transit.

## 2. Navigational information

- a. *Trip purpose*: commuting, family/personal, and social/recreational.
- b. *Drivers*: locals, strangers, and local-strangers.

## 3. Navigational error

- a. *Control and guidance errors's*: near misses, traffic conflicts, and accidents (due to improper speed, wrong path, and hazards).
- b. *Navigation errors*: slow driving, erratic maneuvers, delay, and lost or confused drivers (due to stranger's planning and poor direction-finding).
- c. *Pre-trip errors*: due to trip planning deficiencies.
- d. *In-trip errors*: due to lack of trip planning; erroneous plan; deficient information display; unforeseen events; and/or task demands that lead to overload, missed choice points, and confusion. Deficiencies in navigational display can result in errors due to missing information carriers; illegible carriers; obscured signs; signs blocked by trucks or foliage; and information that is ambiguous, confusing, or with too high an information challenge.
- e. *Manifestations*: slow, stop, or directional uncertainties (last-minute lane changes, stopping and backing on exit ramps, and illegal U-turns).

## 4. Purpose

- a. Could develop a trip plan; optimize a route in real time; ensure error-free route following; aid in recovery if errors occur; and provide information regarding services, attractions, weather, sources of delay, congestion, road conditions, and road hazards.
- b. Could provide collision avoidance information, vehicle status information, inter-vehicle communications, and communications with a central authority. Could aid in congestion relief by enabling users to report incidents and road/traffic conditions by inputting delay and travel time data to a central traffic management authority.
- c. *Types of communications*: none, area broadcasting and/or local roadside transmission (one-way), or mobile radio systems and/or local roadside transponders (two-way).

## 5. Display considerations

- a. *Allocation of functions on displays*: a display dedicated to a particular function or whether there will be shared functions.

- b. *Three display modes:* visual, auditory, or combined visual/auditory. Cross-modal redundancy (e.g., continuous visual information versus repeated auditory).
  - c. Focus on integrating navigational and vehicle status displays whenever possible.
  - d. *Visual displays:* analog, digital, verbal, symbolic, and/or maps, or combinations. Size and location, conspicuity. Stimulus characteristics: color, brightness, contrast, and legibility.
  - e. *Auditory displays:* non-verbal warning signals, tones, verbal speech synthesis. Loudness and location. Stimulus characteristics: tone, fidelity, repetition rate, and message understandability.
  - f. *Display grouping:* level of interpretation, reading errors, and ambiguity.
  - g. *Control design and panel layout:* several factors to consider.
6. User characteristics. Anthropometrics, vision, hearing, time and task sharing, and memory.

## 7. Decrements

- a. *Transitory states:* alcohol, drugs, fatigue, distress, attitudinal problems, and lawbreaking.
- b. *Long-term states:* illiteracy, inexperience, lack of knowledge (overcome by experience, training, and a user-friendly system), color weaknesses, visual acuity and accommodation, hearing loss, and inattention.
- c. *Older drivers.*

**Noy, Y.I. (1989). Intelligent route guidance: Will the new horse be as good as the old? In *Vehicle Navigation and Information Systems Conference Proceedings* (pp. 49-55). Toronto, Ontario, Canada: International Ergonomics Association.**

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TOPIC: Intelligent route guidance systems  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers (20 subjects)

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## **ABSTRACT**

Automobile navigation systems are undergoing rapid technological evolution following advances in microprocessors and artificial intelligence. The present study was initiated to investigate the human factors of intelligent automobile displays with a view towards determining the need for design guidelines. The experiment was designed to examine the relationship between drivers' visual attention and performance under concurrent multi-task conditions. Twenty young male and female students with normal vision and a minimum of 3 years of driving experience were randomly assigned to two groups in a mixed, three-factor experiment. Subjects drove in a moving-base simulator and performed cognitive tasks on a CRT display that was located on the instrument panel to the right of the driver. The two display tasks—a spatial perception task and a verbal memory task—were designed to place differential demands on cognitive resources. Subjects were instructed to perform their best on the display and driving tasks, giving priority to the driving. Display task difficulty and driving difficulty were manipulated within subjects. Task type (memory and perception) was the between-groups factor. Eleven dependent variables provided measures of driving performance, attentional behavior, display task performance, and workload. In addition, on-line eye movement sampling indicated whether the subject looked at the roadway or at the computer display. Results are discussed in relation to the need for ergonomics guidelines for the design of navigation displays.

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## **METHODOLOGY**

1. Independent variables. Simulated driving task.
  - a. *Two auxiliary tasks*:
    - (1) Memory task based on Sternberg paradigm (four levels of difficulty).
    - (2) Perceptual task: line length distinction (four levels of difficulty).
  - b. *Driving difficulty*: four levels of curve type.

## 2. Dependent variables

- a. *Auxiliary task performance*: reaction time.
  - b. *Driving performance* lane position, lane exceedance ratio, time-to-lane crossing, headway, and velocity.
  - c. *Attention behavior*: dwell time, look frequency, and viewing ratio.
  - d. *Mental workload* time load index, mental demand, physical demand, temporal demand, effort, performance, and frustration.
3. Controls. Measures were taken for driving alone, auxiliary task alone, and auxiliary tasks with simulated movement to reduce confounds.

## 4. Purpose of research

- a. Investigate the effects of auxiliary task load, resource structure, and driving load on driving performance in order to assess the need for ergonomics guidelines for the design and use of such displays.
- b. Test/demonstrate a methodology that could be used to evaluate the intrusiveness of an intelligent display on driving.

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## REVIEW

Very useful. Provides interesting findings regarding driver behavior when working on an auxiliary task, which could be compared to using an intelligent route guidance system.

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## CRITICAL FINDINGS

### 1. Effects of auxiliary task load on driving

- a. The presence and nature of the auxiliary task affected the quality of driving observed as measured by time-to-lane crossing, standard deviations of lane position, headway, and standard deviations of velocity.
- b. However, there was no strong evidence that auxiliary task load (difficulty) affected driving.
- c. The increased variance of speed and lane position are particularly important to traffic safety since these measures have been shown to correlate well with accident experience.

2. Effects of driving load on driving performance

- a. The more difficult the driving, the shorter the time margin for initiating correcting responses (time-to-lane crossing increased monotonically with road curvature).
- b. Higher road curvatures yielded larger decrements in time-to-lane crossing.

3. Effects of task load on attention

- a. Attentional response did not appear to be mediated by task difficulty, suggesting that attention is allocated primarily on the basis of driving load.
- b. In many respects, attentional response is a more useful indicator of task intrusion than driving performance, reflecting the drivers' perceptions of road performance requirements and experiences of workload.

4. Effects of driving load on attention

- a. Look frequency was highly dependant on driving load as well as the type of auxiliary task.
- b. Increased driving difficulty caused subjects to pay less attention to the auxiliary display.
- c. Look frequency more than doubled over the range of curve type, whereas dwell time increased by about 30 percent.
- d. The marginal increase in spare visual capacity associated with decreasing driving load was directed towards the auxiliary task primarily through increased sampling frequency.
- e. Glance duration also increased, although to a lesser extent.
- f. Viewing ratio increased from 20 percent for high driving load conditions to 50 percent for relatively low driving load conditions.

5. Effects of gaze direction on driving

- a. Driving variability was larger in magnitude while looking outside the vehicle than while looking inside; hence, drivers tended to look at the auxiliary display when they considered that it was relatively safe to do so.
- b. A major factor underlying subjects' scanning strategy was their estimation of their driving performance. They adopted switching strategies that were designed to maintain driving quality within individually set limits.

Nystuen, J.D. (1990). A framework for assessing travel behavior response to Intelligent Vehicle-Highway Systems. *SAE Technical Paper Series* (SAE No. 901509, pp. 103-111). Warrendale, PA: Society of Automotive Engineers.

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TOPIC: IVHS - Transportation System Model  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Automobile drivers

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## ABSTRACT

Identification of a framework for assessing the consequences of adopting IVHS applications is presented. IVHS applications modify vehicle-highway capacities by enhanced information processing. Mobility opportunities change and, if acted upon, change individual travel behavior. Changes in individual travel behavior affect aggregate travel behavior and transportation network loadings. Decisions to change the transportation system cycle through a three-step social action process involving goals and aspirations, knowledge and technology, and financial and legal capacity to act. Action is then constrained by opportunities available in the environment. The transportation system model presents a framework for designing research to estimate the requirements and consequences of adopting the new technology.

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## REVIEW

Limited use except maybe for the Transportation System Model. The model possibly could be used to identify the chain of consequences that flow from adoption of physical devices or systems to travel behavior responses to secondary responses, and to the distribution of benefits between users and non-users.

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## CRITICAL FINDINGS

1. The Transportation System Model shows the relationship between evaluation of mobility opportunities, individual and aggregate travel behavior, and spacial choice over a range of time frames. In summary, the models seems to indicate:
  - a. All innovations that change system parameters will cycle through a three-step social action process that, subsequently, is constrained by what the environment offers. The social actions are factors such as goals and aspirations, knowledge and technology, and power of money and legal issues.
  - b. At the environmental level, there are the transportation facilities (mobility opportunity) and the land-use pattern (mobility needs).

- c. The transportation facilities supply the means for mobility (traffic flow and aggregate trips at three different levels-modal split, route assignment, and traffic load by network links). The land-use pattern creates the demand for mobility in the form of individual trip generation.
2. There is an implicit assumption that the IVHS research and development community holds, that as a society, we want to keep out individual, high-speed mobility.
3. The main thrust for policy planning is that IVHS is evolving in a distributed system where no one is in charge (may have been true in 1990; is it nowadays?).
4. New travel behavior may call for new rules for governing transport as risk and responsibility shift.

**Petchenik, B.B. (1989). The nature of navigation: Some difficult cognitive issues in automatic vehicle navigation. In *Vehicle Navigation and Information Systems Conference Proceedings* (No. CH2789-6/89/0000-0043). Toronto, Ontario, Canada.**

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TOPIC: Automatic vehicle navigation system  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Not applicable

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### **ABSTRACT**

If one believes everything one reads in the newspapers, a technology for providing automatic car navigation is virtually in place. But, in fact, this is far from true. It is the purpose of this paper to demonstrate that finding one's way from place to place while driving a car is a complex cognitive task, and that if there is to be authentic computer-based assistance to drivers, it must come from devices and systems significantly different from the digital dashboard maps that have been offered to date.

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### **REVIEW**

Not very useful. Very general and broad approach. Does not add much to what we already know. Actually, in some cases, the article makes wrong assumptions.

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### **CRITICAL FINDINGS**

1. Navigation environment falls into four categories:
  - a. *Static macro-environment*: landscape (e.g., roads, buildings, cities, rivers, etc.).
  - b. *Static micro-environment*: physical landscape attended to by the driver (e.g., road, lanes, exits, ramps, overpass, curbs, signs, etc.).
  - c. *Dynamic macro-environment*: overall driving conditions that change with time (e.g., traffic flow, congestion, weather, etc.).
  - d. *Dynamic micro-environment*: constantly shifting milieu that is unique to each driver (e.g., proximate vehicles and objects, ice, water on the road, etc.).
2. In addition to these visible environments, the driver must be aware of and integrate information from at least five additional domains:

- a. Place identifiers (e.g., names and numbers that identify places, areas, roads, highways, etc.).
- b. Regulatory environment (e.g., signs or signals).
- c. Tool environment (e.g., maps, directions, telephones, radios, etc.).
- d. Driver's knowledge.
- e. Driver's affective/sensory makeup (e.g., motivation, sensations, fatigue, etc.).

**Redding, R.E. (1990). Taking cognitive analysis into the field: Bridging the gap from research to application. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 1304-1308). Santa Monica, CA: Human Factors Society.**

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TOPIC: Cognitive Task Analysis (CTA)  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Not applicable

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## **ABSTRACT**

Cognitive methods of task analysis have been used for training development. Although quite promising, these methods are generally time consuming, labor intensive, and require considerable expertise. This has precluded their full use in field training situations. Economical, practical, and user-friendly methods are needed that can be integrated easily with current approaches. This symposium paper discusses the potential of cognitive task analysis as well as the practicality problem. Of particular concern is how cognitive methods can receive widespread application among training practitioners-how to transition theory and research in cognitive task analysis into mainstream training development programs.

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## **REVIEW**

Somewhat useful in terms of the elements to be considered when performing a cognitive task analysis. Aside from these points, the article is quite basic and general in its content.

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## **CRITICAL FINDINGS**

### 1. Goals of CTA

- a. Identification of task components.
- b. Identification of the conceptual and procedural knowledge required for performance of similar components.
- c. Identification of differences between novices and experts as well as intermediate knowledge states.
- d. Specification of learning conditions that best facilitate progress from one knowledge state to the next.

2. Difference between traditional and cognitive task analysis

- a. Traditional task analysis identifies the skills and knowledge for each subtask or activity, but does not address overall knowledge organization. Segments the components into behaviorally distinct tasks.
- b. Cognitive task analysis analyzes knowledge base organization for the job as a whole, examining the interrelationship between salient concepts. Emphasis is on mental models used in task performance and the identification of components that can be trained to automaticity. The tasks are segmented according to the types of underlying skills involved and consistent task components that can be trained to automaticity.

3. Methods used in CTA

- a. Scaling techniques and protocol analysis.
- b. Interviews and observations must be structured to determine mental models, information-processing steps and strategies, task components that can be trained to automaticity, differences between novices and experts, and potential conceptual errors.

4. Tasks that should be analyzed. Tasks that require a high degree of problem solving and decision making place high workload requirements on the individual, require a well-developed conceptual knowledge base, and represent bottlenecks or problems in job performance or in which there are frequent errors.

Roth, E., Bennett, K., & Woods, D.D. (1988). Human interaction with an “intelligent” machine. In E. Hollnagel, G. Mancini, & D.D. Woods (Eds.), *Cognitive Engineering in Complex Dynamic Worlds*. New York: Academic Press.

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TOPIC: Problem solving/expert systems  
TYPE OF ARTICLE: Position paper/empirical study  
SUBJECT POPULATION: Technicians

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### ABSTRACT

This paper reports the results of a study of technicians diagnosing faults in electro-mechanical equipment with the aid of an expert system. Technicians varying in level of experience and interactive style (active or passive) diagnosed faults varying in level of difficulty. The results indicate that the standard approach to expert system design, in which the user is assigned the role of data gatherer for the machine, is inadequate. Problem solving was marked by novel situations outside the machine’s competence, special conditions, underspecified instructions, and error recovery, all of which required substantial knowledge and active participation on the part of technicians. It is argued that the design of intelligent systems should be based on the notion of a joint cognitive system architecture: computational technology should be used to aid the user in the process of solving his or her problem. The human’s role is to achieve total system performance as a manager of knowledge resources that can vary in kind and amount of intelligence or power.

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### REVIEW

Useful for its innovative approach on how support systems should be designed. The authors divert from the traditional approach to design support systems as *prostheses* (replacement or remedies for deficiencies) to a more innovative approach that considers support systems as a *cognitive instrument* (deploy machine power to assist human performance).

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### CRITICAL FINDINGS

1. Two fundamental approaches to system design
  - a. *Prosthesis paradigm*: The primary design focus is to apply computational technology to develop a stand-alone machine expert that offers some form of problem solution. The machine expert guides all problem-solving activities, dictating what observations and actions the user is to take to solve the problem. The user is assigned the role of data gatherer and action implementer.
  - b. *Cognitive instrument paradigm*: The focus is to design a support system that uses computational technology to aid the user in the process of solving his or her problem.

Thus, the human's role is to achieve total system performance objectives as a manager of knowledge resources that can vary in intelligence or power.

2. Analysis of protocols. Problem-solving episodes were analyzed by charting the flow of judgments and actions that were made either by the machine or by the operator, and comparing the actual path of each episode to the canonical path.
3. Performance analysis
  - a. Differences in performance were reflected in the amount of time required to solve a problem and in the number and substance of user-initiated activity and experimenter's interventions.
  - b. Technician experience level and level of initiative turned out to be critical factors in determining the accuracy and speed of person-machine performance.
  - c. Contrary to the assumption of the machine-as-prosthesis paradigm, the technicians did not and could not function solely as passive data gatherers.
  - d. Successful performance depended on the ability of the technician to apply knowledge of the structure and function of the device and sensible troubleshooting approaches.
  - e. Once the machine expert was off track, it could not recover by itself. The burden to detect and recover from deviations fell on the human.
4. Reasons for deviations from the canonical path
  - a. Mismatches between the technician's state of knowledge and the one assumed by the machine expert.
  - b. Technician entry errors due to slips, mismeasurements, n&observations, or misinterpretations.
  - c. Technician installation errors.
  - d. Technician errors due to inability to assess the intentions of the machine expert.
  - e. Inherent variability of actual devices.
  - f. Existence of multiple simultaneous faults.
  - g. Unavailability of test equipment.
  - h. Bugs in the machine expert's knowledge system.

5. How to convert to a cognitive instrument machine

- a. Build displays that provide a shared frame of reference.
- b. Provide more capabilities for a human to direct the machine's reasoning.

Senders, J.W., Kristofferson, A.B., Levison, W.H., Dietrich, C.W., & Ward, J.L. (1967). The attentional demand of automobile driving. *Highway Research Record, 195*, pp. 15-33.

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TOPIC: Attentional demands  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers (five subjects, including two of the authors)

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## ABSTRACT

A theoretical analysis and an experimental investigation of certain aspects of automobile driver information processing were undertaken. The theoretical analysis was the result of an effort to avoid difficulties associated with a servomechanistic approach to the automobile driving problem. The analysis is predicated on the assumption that a driver's attention is, in general, not continuously, but only intermittently, directed to the road. Between observations, uncertainty about both the position of his own vehicle on the road and the possible presence of other vehicles or obstacles increases until it exceeds a threshold. At that moment in time, the driver looks again at the road. This simple model appears to be a useful analog of the driving process. The analysis makes specific predictions about the form of the functional relationship between intervals and between observations and vehicle speed. The experimental program had two goals. One was the empirical investigation of the relation between amount of interruption of vision and driving speed. The other was the determination for various drivers and various roads of the values of some of the parameters in the mathematical model. This report presents the results of the theoretical and experimental investigation. In general, the model is a fair approximation of actual behavior and it remains for future work to determine whether this approximation is good enough to be useful for the specification of vehicle, highway, and user characteristics.

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## METHODOLOGY

1. Independent variables. Four experiments using two kinds of roads (easy and difficult) and two procedures (fixed occlusion and viewing time, fixed velocity and viewing time).
  - a. *Fixed occlusion and viewing time*: used a constant period of occlusion and a constant observation time, with driver controlling speed to his or her maximum.
  - b. *Fixed velocity and viewing time*: used a constant speed and permitted the driver to look when he or she wished.
    - (1) Experiment 1: Easy road, fixed occlusion and viewing time.
    - (2) Experiment 2: Easy road, fixed velocity and viewing time (voluntary control of occlusion).

- (3) Experiment 3: Difficult road, fixed velocity and viewing time.
  - (4) Experiment 4: Difficult road, fixed occlusion and viewing time.
2. Dependent variables. Speed (Mi/h), viewing time (s), and occlusion time (s).
  3. Control conditions. Not applicable.
  4. Data analysis techniques. Not applicable.
  5. Methodology. Test track road.
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## **REVIEW**

Not useful for this task. It is useful in determining how much attention may be demanded of a driver for varying road types and speeds and to compare these results using a mathematical approach.

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## **CRITICAL FINDINGS**

1. The higher the speed, the shorter the interval needed between observations.
2. The less frequent the observations or the shorter the period of observations, the slower the speed the driver can maintain.
3. Authors suggest that drivers tend to drive to a limit and that limit is determined by the point when the driver's information-processing capacity, either real or imagined, is matched by the information generation rate of the road, either real or estimated.

Smiley, A. (1989). Mental workload and information management. In *Vehicle, Navigation, and Information Systems Conference Proceedings* (pp. 435-438). Toronto, Ontario, Canada.

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TOPIC: Subjective workload  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Not applicable

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### ABSTRACT

The use of high technology in vehicles has the potential of greatly increasing the amount of information presented to a driver. The need for the new support systems to be sensitive to the mental workload experienced by the driver is discussed. Primary task, secondary task, and physiological and subjective measures of mental workload are described. The contribution of task difficulty, effort, and arousal to the driver's subjective mental workload is discussed. The manner in which each of these factors might be measured on-line is described. Finally, system adaptations that might be made at high levels of mental workload are suggested.

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### METHODOLOGY

Not applicable.

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### REVIEW OF ARTICLE

Somewhat useful for its theoretical approaches to workload measures and their usefulness in in-vehicle support systems. Does not add much that is not already known.

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### CRITICAL FINDINGS

1. Important not to overload drivers at critical times during the driving task (e.g., intersections, curves, and heavy traffic). Have to consider more than just task difficulty because the same task can be perceived differently by different drivers.
2. The high technology support systems will have to be:
  - a. Evaluated according to the level of mental workload they create.
  - b. Designed to measure and respond to a driver's mental workload as it changes during the trip.

3. Two major uses of the four mental workload measures are:
  - a. Designing and evaluating support systems to ensure that they present information in a way that does not overload the driver.
  - b. Determining subjective mental workload while the car is in operation so that the support system can reduce any load it is placing on the driver when he or she is busy.
4. Visual capacity: a driver of a 1.8-m car traveling in a lane 3.7 m wide, at 50 km/h, and reading text in a vehicle for 2, 4, and 6 s would have probabilities of laterally deviating out of the lane of 0.05 percent, 1.1 percent, and 8.7 percent. Reducing the lane width increases these probabilities. *Mental workload can be reduced if visual material is presented in small chunks and at a slow rate.*
5. Contributing factor to subjective mental workload: task difficulty, driver effort, and driver arousal.

**Thordsen, M.L. (1991). A comparison of two tools for cognitive task analysis: Concept mapping and the critical decision method. In *Proceedings of the Human Factors Society 35th Annual Meeting* (pp. 283-285). Santa Monica, CA: Human Factors Society.**

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TOPIC: Cognitive task analysis  
TYPE OF ARTICLE: Position paper  
SUBJECT POPULATION: Not applicable

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## **ABSTRACT**

Two knowledge elicitation tools for cognitive task analysis are described and compared: Concept Mapping (CM) and the Critical Decision Method (CDM). CM is a procedure that can be used to represent the interviewee's conception of a task by developing a graphical schematic of the perceptions of the task's components. It is appropriate when one needs to capture the interviewee's cognitive organization of the task's routine elements and how these elements fit together. CDM is highly effective at eliciting tacit knowledge about perceptions, expertise, and aspects of a domain that are often difficult for experts to articulate. It has proven to be an effective tool for capturing the deeper, difficult-to-articulate knowledge that separates experts from novices. Used together, these techniques can be very complementary and effective. CM provides an overview of the user's image of the task, including information about the clustering of and flow between concepts. CDM is an effective tool for identifying decision strategies, critical cues, situation assessment, goals and intent, expectancies, mental simulation strategies, and improvisation. Used in combination, the techniques can effectively generate recommendations for training and display design.

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## **REVIEW**

Useful. Some aspects of these two task analyses could be useful to Task E. The Critical Decision Method is an interview process that has been developed for the analysis of critical incidents. As a consequence, it might be difficult to transfer to the type of usage required for Task E, but it is recommended as a method for providing display design recommendations. Concept Mapping is also an interview process that produces a schematic representation of the relationships among a task's components. It might be applicable to this project.

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## **CRITICAL FINDINGS**

### 1. Concept Mapping (CM)

- a. Interview process that results in a schematic representation of the relationships among a task's components.

- b. Specific concepts are represented by notes that are linked with directional arrows that are labeled, thus giving information about the nature of the link.
- c. Can be used to examine the commonalities and idiosyncracies that exist in a knowledge base. Also can be used to generate a comprehensive knowledge representation of domain expertise.

## 2. Critical Decision Method (CDM)

- a. Uses recollection of a specific incident as its starting point and is a method of eliciting the tacit knowledge about perceptions, expertise, and aspects that differentiate experts from novices.
- b. Interviewees are asked to identify a non-routine event where their expertise made a difference and then a timeline of the event is constructed. From that timeline, questions are asked regarding goals; options that were generated, evaluated, and chosen; cue utilization; contextual elements; situation assessment factors; and decision strategies.
- c. Useful to identify cognitive elements that are central to its proficient performance.

## 3. Steps to the approach (CM + CDM together)

- a. Construct a concept map of the task, beginning with higher concepts and descending to more specific ones.
- b. During the CDM interview, generate examples of incidents that underlie these concepts.
- c. Determine, in advance, the type of information that is needed.
- d. During the CDM interview, work from specific examples and work back towards more general concepts.
- e. Go back to the concept map and identify and circle the larger conceptual clusters that are present.

## 4. Four types of knowledge elicited

- a. Concepts and relationships among them.
- b. Higher level clusters of groups of concepts.
- c. Detailed enhancements of the critical concepts derived from the CDM.
- d. Incidents identified as being representative of the critical concepts.

Wierwille, W., Hulse, M., Fisher, T., & Dingus, T. (1988). *Effects of variations in driving task attentional demand on in-car navigation system usage*. General Motors Research Laboratories Contract Report No. CR-SS/02/05. Warren, MI.

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TOPIC: Attentional demands  
TYPE OF ARTICLE: Empirical study  
SUBJECT POPULATION: Automobile drivers (24 subjects)

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## ABSTRACT

Earlier studies have shown that drivers' visual scan patterns and dwell times are changed when using an in-car navigation display system. The fact that these changes occur raises questions about a driver's ability to adapt appropriately to high-demand driving situations. Thus, additional experiments were conducted to determine whether or not drivers adapt appropriately to high driving task demands while simultaneously navigating. One experiment was designed to investigate adaptation to high anticipated driving task demands, and a second was designed to investigate adaptation to high unanticipated driving task demands. The results of the two experiments demonstrate clearly that as driving task demands increase, drivers do indeed shift their visual sampling strategy appropriately. However, variability in the data suggests that good human factors design and appropriate placement of the display remain important issues.

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## METHODOLOGY

1. Independent variables. Two experiments:
  - a. *Anticipated attentional demand*: low, medium, and high.
  - b. *Unanticipated attentional demand*.
2. Dependent variables
  - a. *Attentional demands* rated both subjectively and objectively.
    - (1) Objectives: sight distance, curvature, road width, and lane restriction.
    - (2) Subjectives: ratings of road segments by human factors graduate students.
  - b. *Eye movements*: eye scanning measures of roadway center, roadway off-center, signs, displays/controls, mirror, navigator, etc.

3. Data analysis. ANOVA, MANOVA.
  4. Controls. Subjects were trained. They drove to unknown destinations all the time. They were used for both experiments (two runs in the first, three in the second).
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## REVIEW

Somewhat useful if the reader's interest is in finding out how a navigation system affects drivers' attention, as measured by eye movements. The article has implications for the positioning of these instrumentations and their impact on the driving task.

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## CRITICAL FINDINGS

1. For increases in both anticipated and unanticipated driving demands, drivers *increased* the proportion of time spent on the forward central view and *decreased* the proportion of time spent observing the navigator.
2. Increased anticipated demands resulted in *an increased* visual sampling rate by the drivers. The length of the sampling rate was shorter for anticipated driving demands and longer for unanticipated driving demands.
3. For increased unanticipated demands, the visual sampling rate *decreased* and drivers concentrated on the forward view with longer glances.

## ADDITIONAL RELEVANT LITERATURE

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