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ABSTRACT

An analytical method for defining and describing the behavioral elements of those tasks that are inherent in the operation of large cargo trucks for mission durations ranging from four to eight hours was developed and validated in this study. The preliminary analysis of task elements was subjected to validation by several means: structured checklists and interviews with veteran truck drivers, en route observations, and activity analyses vis a vis such personnel, and by elicitation of driving "critical incident" reports. From the task data base, certain tasks were selected on the basis of their estimated (1) criticality to perational safety, (2) susceptibility to degradation as a function mission duration, and (3) "predictability," or the inverse of the proportion of occurrences that a given task is performed on a contingency or emergency basis. (Author/DB)

VALIDATION OF A TASK ANALYSIS METHODOLOGY APPLIED TO LONG - HAUL TRUCK DRIVER BEHAVIOUR*

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Abstract

An analytical method for defining and describing the behavioural elements of those tasks that are inherent in the operation of large cargo trucks for mission durations ranging from four to eight hours was developed and validated in this study. The effort represents an early phase of a research program called "an experimental study of transport vehicle control-display systems."

Methodological work by R. B. Miller and other AIR scientists provided the basis for the method employed in this study. Some off-road activity segments were omitted from the analysis. It was found that an event-based mission approach was more realistic than a time-lined one because of continous variations in traffic composition and density, roadway characteristics, lighting, and weather - as a function of specific driving missions.

The preliminary analysis of task elements was subjected to validation by several means: structured checklists and interviews with veteran truck drivers, en route observations and activity analyses vis a vis such personnel, and by elicitation of driving "critical incident" reports.

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From the task data base, certain tasks were selected on the basis of their estimated 1) criticality to perational safety, 2) susceptibility to degradation as a function mission duration, and 3) "predictability", or the inverse of the proportion of occurrences that a given task is performed on a contingency or emergency basis.

Identification of certain "safety-critical" truck driving behaviours provides a more realistic initial basis for the selection of specific on-the-road driver performance measures. Such measures, when selected will be employed to determine which elements of driver task performance are 1) most susceptible to degradation as a function of hours driven, and 2) most critical to operational safety.

In a final phase of this programme, the characteristics of some of the task elements also are expected to provide at least some basis for the selection of innovative design criteria for truck cab controls, displays and work place layout. The authors also expect that the task data will aid our group in the definition of both functional and design features of a laboratory simulator needed to evaluate alternative design solutions.

I. Introduction

A. Purposes of Study

This report of a development and validation of a task analysis method as applied to certain requisite behaviours of long-haul drivers of heavy highway tractor - semi-trailer vehicles has both an ultimate, or progamme purpose and several interim, or phase-peculiar purposes. These purposes are described under the appropriate subheads below.

1. Ultimate Purpose

The general program objective is one of evaluating the effects on driving safety certain equipment design variables vis a vis truck cab geometry, controls, displays and related features. The missions that concern the authors most are those of extended duration, e.g., six to ten hours.

In order to accomplish this overall goal one really should develop a "model" of driver behaviour as a basis of determining what design characteristics and what related driver behaviours appear to be critically related to driving safety. The authors did employ such an approach - with some trepidition - remembering the words of Chapanis (1961) who admonished that a man-machine system model is only an analog, or partial representation of the real system. An analysis and description of the relevant driver's tasks provides a basis for such a model.

2. Interim Purposes

Consonant with the foregoing, then, the following may be said to be objectives of the initial programme phase:

a. development and application of a method for analysis of the subject driver behaviours;

b. validation of the analysis by means of observational and interview techniques;

c. identification, description, and quantification (wherever possible) of the driver behaviours that appear to be critically related to safety.

At least three other "interim purposes" may be cited; they are out of scope, with respect to this presentation. These added purposes of later programme phases are as follows:

d. a preliminary determination of what types of measures (and measuring techniques) are needed to assess the effects of continued driving on certain "safety-critical driver behaviours;

e. experimental application of selected measurement techniques to determine how effectively such techniques measure variations in safety-critical driver performance;

f. comparative experimental and performance test evaluation of alternative cab interior design configurations against the established safety performance criteria.

B. Background

It is appropriate, at this point, to briefly review the methodological background that characterizes task analysis.

This kind of analysis, initially documented by Miller (1953), is an outgrowth of job analysis, although it does differ from the latter in terms of its orientation toward S-R components of human task behaviour and its interest in the "interfaces" among environment, machine characteristics, and human performance. With respect to its molecular nature task analysis is also(to some degree) like industrial engineering motion and time study analyses.

There are several principal forms of task analyses: 1) that described by Miller which emphasizes stimulus and channel, perception, decision making and response behaviour; 2) information, decision and action analysis, a diagrammatic and sometimes time-based analysis of event sequences, as documented by Coakley and Fucigna (1955); 3) operational sequence diagramming, a somewhat similar technique expecially adaptable to coordinated, multiple crew member interactions, including intercommunication among such personnel, as originally described by Kurke (1961); and 4) time-line analyses, which, in its most automated form, is essentially a computerized data base that lists estimated or actual times required to perform given task elements against a mission profile that imposes certain event time requirements. The last one of these - the time-line-was done, for example for the Apollo spacecraft missions prior to the initiation of the first manned mission.

All of the methods just described have one thing in common: they are very time-consuming to perform. When done competently, however, they provide data of real value to: equipment design, the design of job positions, personnel selection, and training programme development. Most recent coverage of these applications may be found in Van Cott and Kinkade (1972), especially in Chapters 1 and 13.

The analysis reported in this paper was done simply because no previously reported work of this kind concerning drivers' activities has covered this kind of professional driving mission in a depth sufficient for the authors' purposes. This is not to say that no work has been done at all. Driver training, for example, has received the attention of McKnight and Adams (1970 a, 1970 b).

II. Conduct of Study

This section describes the methodological considerations for the three phase objectives, task analysis, validation, and identifying safety-critical behaviour.

A. Task Analysis Method

1. Source of Method

A formal analysis was made of certain driving behaviours, some of which may be said to have had "tracking" elements and others, procedural elements. The method used by the authors is an adaptation of that described by Miller (1953); it was selected because of its simplicity and ease of utilization and because, with it, one can readily record the behavioural detail, complexity and fine distinctions among task elements. Miller pointed out that his method possesses to considerable degree the following desirable characteristics:

a. Reliability. It can be checked for methodological flaws; the method is repeatable to generate further data for comparison.

b. Levels of Description. Consistent Levels of Description between different tasks allows comparisons of characteristics and requirements.

c. Guide to thorough analysis. The format reduces or prevents omissions.

d. Control of depth in behavioural description. This leads to internally consistent levels of description.

e. Open-Ended Nature. It is (apparently) open ended and may be extended to as much detail as required.

f. Ease of Conceptualization. Compartmentalizing of behavioural elements averts semantic confusion in the resultant descriptions.

2. Selection of Specific Behaviours to be Analyzed

Because the conditions under which driving missions are performed varies from mission to mission, it was decided to conduct the analysis by treating safe driving as a continuous feed back skill (or set of skills) with some often-repeated discrete subtasks treated as procedures. For the same reason, an event-based approach was chosen over a time or distance-based one. The variability of driving environments would prevent either time - or distance - based approaches from being accurate except for very short time periods or distances or under tightly controlled conditions.

Early examination of accident damage statistics indicated that the majority of costly mishaps occured during the route driving section of a transport truck mission (as opposed to parking, reversing and dock area driving). Hence it was decided to limit the major driver functions to: 1) maintaining appropriate forward motion, and 2) maintaining appropriate path and direction of motion. Obviously, combinations of these functions are performed with many variations to accomodate differences in the driving environment such as traffic density, weather conditions, and road design.

3. Conduct of the Analysis

The task analysis was performed as described below. The two basic driver functions were used for the simplest case of driving on a straight, empty roadway with the major environmental constraint being a posted speed limit. This constraint exists at all times and therefore was common to all subsequent analysis. Information categories, such as those shown in Table 1, were filled in by the analyst in as much detail as possible in order to assure accuracy and rigorous coverage.

Variations on the basic task analysis were then performed by changing or adding single environmental factors and constraints. This would change the critical stimulus variables, and the original task analysis would be repeated, changing or adding things where appropriate. In this way it was possible to build up a wide range of possible variations on the basic analysis.

a. Procedural Tasks. The procedures were identified and referred to by "name" and "number" for reference; these latter tasks were analysed at a later time using a similar set of categories.

b. Non-Manadatory Operator Behaviours. A list also was made of minor "non-mandatory" tasks which the driver could perform but which are not cued directly by the driving environment. Comfort adjustments and vehicle condition monitoring are two examples.

TABLE 1

Information Categories used in the Driving Behaviour Task Analysis

Category	Example
TASK IDENTIFICATION	maintain required forward motion and path within posted speed limit
DISPLAY	
Problem	- drive truck at speed limit on straight road - assume no curves or traffic - assume level, positive, and negative roadway grades
Critical Stimulus Variables	- speed limit - grade of road (present and approaching) - engine speed and characteristics - loading of vehicle - position of accelerator pedal - gear in use and characteristics - camber in road surface - obstacles on roadway
Time Values	- steering corrections before truck leaves lane (dependent on speed and yaw angle) - other times, e.g., optimum shift points, optimum braking times when over speed limit, not safety-critical
Display Noise	- poor visibility (includes sun glare) - unknown speed limit - awkward or heavy boots - "deadband" in steering mechanism
REQUIRED DECISIONS	- speed up or slow down now - speed up or slow down soon - move steering wheel
CONTROLS	- 1) accelerator pedal, 2) brake pedal, 3) clutch pedal, 4) gear selector, 5) steering wheel
CONTROL ACTIVATION	- 1) move up or slow down to position yielding desired speed/acceleration - 2) push down to produce desired decelleration - 3)4) described in shifting procedure - 5) turn in direction to be taken, then straighten out

TABLE 1 (cont'd)

CONTROL ACTION	- 1) determined by acceleration/ deceleration properties of truck for particular gear, grade and loading - 2) rate of deceleration dependent upon (a) grade, (b) speed, (c) vehicle weight, (d) force on pedal - 3) (a) amount of rotation depends on steering ratio of vehicle (b) force depends on ratio, loading, amount of power assist, road surface, speed, and tire pressure
FEEDBACK	
Cues	- visual and auditory sensations of speed change - speedometer reading changes
Time Delay	- virtually no time delay to onsets of change - completion time varies with conditions
Criteria of Response Adequacy	- adequacy indicated by speedometer reading same as posted limit - also vehicle perceived as centered in own lane
Critical Values	Corrective Actions
- stalled engine	restart (procedure)
- locked brakes	release pedal pressure
- "missed" shift	repeat (shifting procedure)
- wheels out of lane	turn steering wheel in smooth motion as required to correct latefal position

CHARACTERISTIC ERRORS

- "hunting" around speed limit due to accelerator overcorrection
- weaving down road due to steering overcorrection
- excessible frequencies of change in;
  - (1) acceleration (increases fuel consumption)
  - (2) braking (increases break wear)

c. Generation of Operational "Programmes". Next, a series of programmes or 'scripts' for short arbitrary time periods were developed. The content of a programme is based upon: 1) the particular driving environment and 2) stimuli chosen to be present in the programme period. Such environments may be chosen probablistically, randomly or both. From the programmes, time-shared behaviours and times of maximum behavioural load may be deduced. Work, incidentally, is now underway to develop a computerized model for generating and applying the above programmes to the analytically-derived task data base.

B. Validation of the Task Analysis

Validation activities to date have involved both structured interviews of the operational sort described by Rabideau (1964) and on-the-road activity sampling, the dimensions of which are also described by Rabideau (1971). Application of these methods is described on the next page.

1. Interviews

A number of professional truck drivers were questioned in structured interviews on topics which were open ended in that they could lead into discussions of personal habits and techniques in driving. Attempts to "fish" for answers were avoided. Drivers were also asked to rank order groups of interchangeable techniques based on personal preferences. Specific questions were directed towards determining control activation methods including critical values and error correction. Drivers were encouraged to recall personal critical incidents ("close calls", or near accidents) and speculate upon causes. The rankings and all comments were used to set up a large table of topics about which some frequent comment or attitude was expressed. The comments were categorized as expressing either a positive or negative sense (or both) as appropriate. Inferences were then made concerning driver information processing and behaviour based on the comments as they would apply to a driver-truck-highway model. (Briggs, 1968) The task analysis was then examined to determine if all inferences generated were also present in it in some form. Omissions were inserted where necessary and any contradictions removed.

2. Activity Sampling

Driver behaviour was monitored for specific time periods at randomly spaced intervals during a driving mission. Control activations and other activities during each period were noted and tabulated.

Using the tabulation, estimates of gross time allocations, time-shared activities, and frequency of task repetition were made and checked against the predictions of the task analysis. Observed time-shared activities not connected in some procedural sense were examined in the light of the task analysis to determine if a cause of sharing had been predicted. Changes were made wherever necessary.

In addition, two sensing or information gathering behaviours were monitored under different driving environments. The relative rates for various conditions were compared with those predicted by the task analysis.

C. Identifying "Safety-Critical" Behaviour

One might justifiably assert that a precise statement of exactly what constitutes "safe driving" is virtually impossible, mainly because whether or not given driver behaviours may be considered safe is dependent upon the driving environment and the driver's psycho-physiological condition, truly dynamic situations. However, one could say that it is a combination of sufficient and adequate behaviours of the following kinds: 1) observation or sensing, 2) processing of imputs, 3) outputs of appropriate action, 4) skill in outputs, and 5) parallel, or time-shared information processing and action. Safe driving could be called a skill in the sense that a very safety-motivated driver may use a different and usually larger set of abilities than would be required for the basic skill of controlling the motion of a vehicle. Use of these extra abilities may be generally designated "safety-critical driving behaviour", or "SCB".

In developing the "SCB" concept, the authors have applied to the driving context the concept of the "critical incident" described by Flanagan and Burns (1955) as a method of rating of subordinates' performances. The technique also has been applied to identification of human initiated malfunctions in missile system operations by Shapero et al (1960) A critical incident may be defined as any event or sequence of events in which the observed (or reported) characteristics of the behaviour of a given individual served to cause an operation to either succeed or fail. Hence, it is possible to define "positive", or "safe" safety critical behaviour in specific situations. Such behaviour is designated "SCB+". Conversely, unsafe behaviour is identified as SCB-. All behaviour which (in a given driving situation) is non-relevant to operational safety is called "non-SCB".

1. Criteria to Identifying "SCB+" Behaviour

To identify positive safety-critical driving behaviour (SCB+) one must examine those input, decision, and output elements of the tasks required for a given mission programme (script or scenario), identifying and describing the following: 1) sensing and recognition of stimuli which are criterion inputs for SCB+ perception; 2) decisions which can assure that the resultant action will be SCB+; 3) outputs, or driver responses which must be within present levels of the operators driving skill in order that the response be SCB+.

Going to the task analysis to do this requires definitions of safety-critical stimuli and safety-critical actions. An SCB+ stimulus is simply defined as one which is properly sensed and interpreted in time to prevent the vehicle from leaving the roadway at speed and/or colliding with some objects. Similarly, an SCB+ action is defined as one which directly or eventually prevents the vehicle from leaving the roadway at speed or colliding with some object(s).

Table 2 presents an example of typical SCB+ driver behavioural requirements for the sensing - perceptual and the decision making elements. One will note that the table omits reference to SCB+ response elements. In the current study it was assumed that the subjects - all licensed professional drivers - have the requisite skills to make the response within required time and error tolerances. Thus the authors have concentrated on the behavioural elements which have the greatest payoff potential.

2. SCB- Behaviour

The principal criterior for the identification of SCB- driver behaviour is that it is the converse of SCB+. The assumption was made that non-safe driving behaviour will differ from safe driving in 2 respects:

1) omission of SCB+ acitons.
2) deliberate choice and use of SCB- actions over SCB+ actions.

TABLE 2

Examples of SCB+ Behaviour to Two Behavioural Categories: Sensing/Recognition and Decisions

1)	Sensing and recognition of	- obstacles on road - air temperature falling below 32°F. - brake lights on forward vehicles - loose gravel at corners
2)	Decisions	- reduce speed during periods of uncertain visibility. - increase following distance on wet roads. - speed to enter curve. - rate of closure with oncoming vehicles during overtaking.

The first case (omission) will apply to situations where a driver either fails to sense or perceive the stimuli for an SCB+ action, or does not possess the knowledge to recognize the stimuli to be connected to a given situation requiring SCB (rather than some non-SCB behaviour). It is also possible that, with inexperienced drivers, the stimuli may be sensed and recognized but that the proper response is unknown. An example of the foregoing may be seen in the incidence of low-traction skidding accidents experienced by those drivers who are relatively naive vis a vis skid control behaviour and its associated psychomotor skills.

The second case, that of deliberate selection of SCB- actions, can occur for two reasons, both of which involve driver decisions. Due to a lack of experience, inaccurate recall of past experience, or incorrect stored information, the driver may make a decision about a situation which results in his selecting an SCB- action. This might be called learning the hard way!

a. The Role of Subjective Probability of Success. A decision may also be made in which the driver either fails to assign accurate probabilities to the future consequences of the present situation, or he assigns payoff values which are ridiculous. For instance, he may estimate his chances of successfully completing a passing maneouver on a two-lane road at 90%, when they are really more like 30%, or he may momentarily decide that completion of the maneouver is more important than staying out of the hospital. At his point it does appear to the authors that <u>both</u> kinds of deliberate choice of SCB action - based on inadequate information and inaccurate judgements regarding probabilities of success - enter into a subjective "payoff matrix", such as suggested by Edwards (1968), when the driver decides to deviate from appropriate SCB+ action.

III. Results and Discussion

Because this paper is essentially a progress report vis a vis this methodological study, the results obtained to date are preliminary and will serve to guide a larger-scale data collection in coming weeks. Therefore, the remainder of this section will present some of the data already collected and discuss the inferences and implications that my be tentatively made at present.

A. The Task Analysis Data

Table 3 lists seven task titles, or designations vis a vis those driver behavioural elements which the authors feel are essential to the definition of SCB's. Space, of course, does not permit inclusion of the body of the analysis in this report.

One will note that the table also identifies subtasks into which each of the tasks has been divided during the course of the anaylsis. It is quite apparent that the functional nature of several of the subtasks is virtually identical across those tasks of which they are a part. They do differ, one from the other, however, as a consequence of the basically different input stimulus characteristics, perceptual characteristics, required decisions and response dynamics involved in satisfactory performance of each of the tracking tasks. The reader is also asked to remember that such task elements also are time-shared with a number of procedural, discrete tasks that have not been analyzed in detail to date.

B. Validation Data

Although the method and procedural model for collecting data designed to

TABLE 3

LAST OF TASK TITLES, WITH IDENTIFICATION

OF SUBTASKS, OR ELEMENTS

TASK	SUBTASK
1. Maintaining Forward Motion Within a. Speed Limit b. Directional Constraints	1.1 Control Center-Lane Tracking 1.2 Adjust Vehicle Speed
2. Maintaining Forward Motion Within a. Safety Limit b. Directional Constraints	2.1 Control Center-Lane Tracking 2.2 Adjust Vehicle Speed
3. Maintaining Forward Motion on Highway Shared with Other Vehicles a. Task 1 Constraints b. Task 2 Constraints	3.1 Control Center-Lane Tracking 3.2 Adjust Vehicle Speed 3.3 Monitor other Vehicle Courses and Positions

TABLE 3 (Cont'd)

TASK	SUBTASK
4. Controlling Acceleration During Turning Movements a. Cornering b. Entering Highway c. Exiting Highway	4.1 Control Rate of Turn 4.2 Decelerate Vehicle Movement 4.3 Accelerate Vehicle Movement 4.4 Monitor other Vehicle Courses and Positions. 4.5 Monitor Fixed Object Locations
5. Controlling Acceleration During Overtake and Passing a. Fixed Aperture - No Traffic b. Fixed Aperture - Traffic c. Variable Aperture	5.1 Control Lane Track of Vehicle 5.2 Adjust Vehicle Speed 5.3 Monitor Passing Aperture 5.4 Monitor other Vehicle Courses and Positions
6. Controlling Acceleration During Stopping Maneuvers a. Normal b. Emergency	6.1 Control Center-Lane Tracking 6.2 Decelerate Vehicle Movement 6.3 Monitor Available Stopping Distance 6.4 Select "Escape Route"
7. Controlling Track During Obstacle Avoidance a. Fixed Obstacle b. Moving Obstacle	7.1 Control Rate of Turn 7.2 Decelerate Vehicle Movement 7.3 Accelerate Vehicle Movement 7.4 Monitor Relative Position and Course/Rate if Moving

verify and/or modify the task analysis has been developed, at the time of this writing relatively little on-the-road data has been collected. However, the reader will undoubtedly be interested in some examples of the kinds of data collected. These are covered under observational and interview headings below.

1. Observational Data

A random selection of 20-second mission periods or segments was selected so as to provide 60 such segments per eight hours of actual driving time. During each observation period, the observer - a passenger in the right-hand seat - logged, or checked each of a pre-established set of driver behaviours that the driver exhibited during that observation segment.

Table 4 shows the actual observations logged during a typical driving mission. Examination of the "total" and "percentage of samples" columns to the right of 60th segment reveals that frequency-of-occurence behaviour ranges from one to 60 in terms number of segments during which a given driver behaviour was observed, or from 1.7 to 100 percent of the total number of segments. The only exception is the tuning or adjusting of the radio which was not observed during any of the cumulative 20 minutes of observation time. Other conditions, e.g. density of traffic, nature of road segment and principal driver task also were noted for the observational segments, although those conditions are not identified in the table.

TABLE 4

ACTIVITY SAMPLING SEGMENT

(Segment Duration = 20 Secs.)

No. of Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Activity																																				
Watch road, steer press throttle	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Check mirror(s)	x	x	x	x	x			x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Depress Clutch pedal			x			x			x					x												x	x								x	
Shift lever moved			x			x			x					x												x	x								x	
Directional signal						x							x		x			x																	x	
Shift in body position													x	x		x				x				x	x				x							
Smoking Cigar-ette	x											x					x						x												x	x
Lisghting Cigarette											x										x									x						
Clearance Lights							x		x	x			x																							
Instrument-check												x		x														x								
Shift Splitter																											x									
Headlights																		x																		
Foot Brake									x																											
Wipers																																				
Air Conditioning																								x												
Windows																			x																	
Radio																																				

TABLE 4 (Cont'd)

No. of Sample / Activity	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	TOTAL	Percentage of Samples
Watch road, steer press throttle	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	60	100
Check mirror(s)	x	x	x	x	x		x	x			x		x			x	x	x		x	x		x	x	48	80
Depress Clutch pedal				x												x	x							x	11	18.3
Shift lever moved				x												x								x	10	16.7
Directional Signal		x																		x			x		9	15
Shift in body position														x											8	13.3
Smoking Cigarette											x									x					7	11.7
Lighting Cigarette										x															4	6.7
Clearance Lights																									4	6.7
Instrument check																									3	1.7
Shift splitter						x											x								3	1.7
Headlights																									1	1.7
Foot brake																									1	1.7
Wipers																									1	1.7
Air Conditioning																									1	1.7
Windows																									1	1.7
Radio																									0	0

A comparison of predicted and observed frequencies of driver eye fixations on rear view mirrors and on panel instruments as a function of driving environment, or conditions is presented in Table 5. It tends to verify the assumption that truck drivers allocate more time to mirror viewing than to monitoring of instruments, in this instance about 9 times more fixations.

The relative frequencies of the above two kinds of behaviour predicted a priori on the basis of off-road interviews with drivers and from the initial task analysis were found to be comparable to the actual observed frequencies, when frequency was ranked from "low" to "high".

2. Interview Data

In addition to personal data, e.g., age, driving experience, etc., the structured interview covered 10 topics, or categories of information. These were designated as follows: 1) general safe driving, 2) risk avoidance in unfamiliar situations, 3) other vehicle behaviour, 4) day versus night driving, 5) visual search techniques, 6) critical incident causes, 7) route pacing, 8) rest stop criteria (timing), 9) mechanical failures in truck, 10) vehicle characteristics. The tenth topic was in turn subdivided into six areas ranging from vehicle controllability characteristics to seat comfort.

TABLE 5

VISUAL INFORMATION COLLECTION

Mirror and Instrument Fixations vs. Driving Environment

(Random Samples - 2 Minutes Duration)

	No. of Samples	Mean fixations per sample ($\bar{x}$)	Approx. σ	$(\frac{\sigma}{\bar{x}})100$	RELATIVE RANKINGS FREQUENCY		VARIABILIT	
					Observed	Predicted	Observed	Predicted
1) Mirror Fixations								
a) Freeway driving Light traffic	7	5.96	2.43	40.8	LOW	LOW	HIGH	HIG
Overtaking	5	8.80	2.11	24	HIGH	HIGH		
b) Urban Driving	3	6.00	0.82	13.7			LOW	LOW
c) Total mission	15	6.07	4.13	68				
2) Instrument Fixations								
a) Freeway driving Light traffic	7	0.43	0.50	1.15				
Overtaking	5	1.20	1.17	97	HIGH	HIGH	LOW	LOW
b) Urban Driving	3	0.33	0.47	142	LOW	LOW	HIGH	HIGH
c) Total mission	15	0.67	0.87	130				

Listed in Table 6 are the "positive" (favourable or most important) comments, "negative" (unfavourable or least important) comments, and inferences drawn from those comments by the authors. The reader is reminded that these data reflect only what professional drivers such as those sampled feel is most comfortable, convenient, and essential to safe driving, rather than what actually may be the bare essentials of SCB behaviour. In other words this represents the "phenomenological and operational world" of the drivers who were interviewed - what they believe is important to successful task performance.

In light of what was just said above, it would appear essential to compare stated techniques and attitudes, as obtained from interviews, with both actual on-the-road activity sampling and related observational data, as well as some of the experimentally verified hypotheses concerning driver behaviour. One would expect some relationships would be found; the question is one of degree of relationship (or agreement) among those sources.

C. Safety-Critical Behaviour

A complete listing of all safety-critical behaviours was in process at the time of preparation of this paper. Some of the more important behaviours appear to be very obvious while others might be considered fairly subtle. A breakdown of the emerging points into Input, Information Processing, and Output catagories is given below.

TABLE 6

VALIDATION DATA - INTERVIEWS

Topic	Positive Comments	Negative Comments	Inferences
1. General Safe Driving	attention to driving plus sensible decisions ranked highest	skill in handling rig ranked as low requirement.	information processing is more important than effector output skills.
2. Risk avoidance in unfamiliar situations	caution and planning ahead for worst case possibilities	quick thinking and use of avoidance or escape techniques downrated.	maneoverability and braking abilities of trucks is poor. Use of caution is easier on driver over many hours than being tensed and ready for instant accident avoidance.
3. Other vehicle behaviour		lack of signaling of intentions and general lack of predictable behaviour	contingency planning by truck driver is difficult if not useless.
4. Day vs. Night Driving	day driving preferred by 40% (approx.) because of ease of staying awake, better scenery and greater number of interpersonal contacts.	night driving preferred by approx. 50% because of reduced traffic density, and ease of other vehicle location using headlamp glare or aura.	day driving reduces problems of alertness but night driving allows for easier sensing of certain critical stimuli.
5. Visual Search techniques	all drivers had great difficulty in verbalizing their techniques yet all admitted it was one of the most important aspects of safe driving. General feeling was that a driver could not be too observant - he had to see everything		visual search patterns are relatively automatic or non-conscious, but quite complex and rigorous. Likely require much practice to develop to highly effective stage.

INTERVIEWS (con't.)

Topic	Positive Comments	Negative Comments	Inferences
6. Critical Incident Causes		unexpected behaviour by other vehicles which is often very dangerous by itself. Lack of attention to driving task either thru daydreaming or actually starting to fall asleep.	situation in which driver finds himself is impossible to predict except on contingency basis and may be impossible to avoid. Lack of attention causes immediate stop or reduction of information gathering and processing and subsequent similar changes to outputs.
7. Route pacing		drivers disliked working for companies which had specific route schedules for time to distances etc.	drivers preferred to set speeds to road and personnal conditions; to set objectives based on variable fatigue rates etc. Different road speeds allow driver to modulate information processing rates to suit his abilities at that time.
8. Rest Stop Criteria (timing)	most drivers used criteria of physical feeling (discomfort) and noticeable performance decrement (poor shifting) or availability of a familiar pleasant stop point. On familiar routes former criteria were not used as frequently as latter.	worst time to be on road is period from 4-6 am. Most drivers try to eat through it or sleep 2-4 hrs. in this area.	drivers recognize a diunral low point in performance. Subjective self evaluation of performance by driver does not generally yield clear, repeatable criteria for taking breaks. Driver will disregard fatigue symtoms to drive to a desirable stop.

INTERVIEWS (CONT'D)

Topic	Positive Comments	Negative Comments	Inferences
9. Mechanical Failures in Truck	this particular sampling of drivers used new fully instrumented cabs with low incidence of mechanical failures. In most cases they would have sufficient failure warning to prevent accidents.	most drivers mentioned that possibility of mech. failure and accident does occure to them. Types of failure mentioned were catastrophic and would cause immediate accident.	drivers were aware of their limitations within vehicle control system and tended to investigate malfunctions or noises quickly to maintain reliability of rest of system.
10. Vehicle Characteristics			
a. Braking	brakes in proper working order were judged to be adequate for most loadings of trailer.	heavy or tandem trailers were said to be underbraked under all conditions and very dangerous to drive at higher speeds. Difference in loading on rear (trailer) wheels between no-load and full-load conditions requires different actuation pressures for pedal.. Accidental locking of rear wheels occurs more frequently when empty.	rate of decelleration possible with heavy loading is under that which is frequently required in traffic. Maintaining low cruising speed necessary is difficult. Modification of pedal actuation pressure in panic (or near panic) stops is not always remembered.
b. Steering & Handling	straight line tracking and high speed stability were judged to be very good.	in town and dock area driving tired drivers arms quickly. Power steering which had no effect on highway was mentioned as desirable	control effort at low speed was to high. Control accuracy and feedback at high speed was judged good.

INTERVIEWS (CONT'D)

Topic	Positive Comments	Negative Comments	Inferences
c. Transmission and Shifting Gears	splitter systems which are actuated by a small control on shift lever were thought to be best. Control feel and efforts were satisfactory.	combinations of main. transmission and splitter system which were not allowed, were often selected in heavy traffic by mistake due to driver loosing track of which combination was in use.	number of possible settings of trans. system and lack of a status display which is simple to read, causes improper use of controls in times of high driver loading.
d. Instrumentation	instrumentation was complete, fairly well laid out and incorporated many faulty condition or critical point warning devices.	all gauges did not have a common needle angle to allow fast checks of total system. Critical point warning devices operated when it was too late; gave no indication of trend.	number of gauges to be monitored was such that a common angle of needles would reduce time. Trend indicators would reduce visual search requirements and allow driver to plan ahead for actions required.
e. Small Controls		turn signals were non-cancelling. Headlight switch was poorly located for signaling (no momentary contact) Clearance light switch was poorly located for signaling (also no momentary contact).	All three switching systems could be redesigned to reduce amount of distraction their use entails. Also they could be positioned to reduce hand movement distance from steering wheel to minimum.

INTERVIEWS (CONT'D)

Topic	Positive Comments	Negative Comments	Inferences
f. Comfort		drivers complained of different discomfort areas on body - lower back most common; also seats didn't fit all drivers well. Poor ride over bumps, vibration of controls and high noise level were other frequent complaints.	range of seat and control adjustments were not always sufficient to accomodate drivers who were not of average build. Number of adjustments possible was small. Bouncing, vibration and noise may cause an increase in fatigue rate due to many factors.

1. Input

Visual search techniques which are highly developed with respect to rigorousness and optimization of repetition frequency are the driver's single most important information gathering behaviour. A sensitivity to all other relevant sensory inputs (particulary the vestibular) is not to be omitted, although it perhaps should not be called a behaviour.

2. Information Processing

a. Perception. Filtering and interpretation of all sensory inputs in such a way as to reduce noise and select safety-critical information will depend largely upon the driver's past experience and his use of situational cues,

b. Decision Making. Decisions are based on payoff matrices which must include safety-oriented (as opposed to goal-or time-oriented) payoff values, and accurate event probability estimation. Such probability estimations must be made using correct interpretations of existing situation and recall of similar past experiences.

c. Processing Rate Changes. A driver must make sudden changes in the content and rate of information processing to deal with unforseen changes in the driving environment. He must be accurate and make efficient use of processing time available from the moment that the environmental change is perceived.

d. Processing Sequence Control. Information processing must be scheduled and performed in a sequence which is the same as the sequence in which the driver's decisions and outputs will be required to maintain safe vehicle operation. Different ordering of the processing sequence by the driver reduces the time available to him for some critical processing (thereby reducing its accuracy) as well as that for his response and error correction.

3. Output

A driver must be sensitive to deviations from his subjective criteria of response adequacy. Presumably there is a limit beyond which he will consider himself to have made an inadequate response. Center-of-lane tracking is an example. The allowable deviations should not increase as the number of hours of continuous driving increases.

Much information is contained in the feedback the driver receives through vehicle controls, etc. His sensitivity to such secondary information as traction at road surface, side wind strength, and the vehicle's mechanical condition must not be allowed to diminish during extended driving missions.

Tasks of a "procedural sequence" nature (which have been well learned through frequent repetition) are usually completed after the driver's primary attention has shifted to some other task.

Though these tasks are rarely SCB+, their smooth, accurate completion minimizes driver distraction with respect to information processing and consequent short-term perturbations in SCB+ driver behaviour. In the event that the performance of "procedural sequence" tasks becomes more inaccurate as mission duration increases, the driver must divert more of his attention from SCB behaviour to the completion of such procedures.

IV. On-Going Activities and Future Programmed Activities

A. Continuation of Validation Task

The current effort will continue for several months in order to increase the sampling base of observational and interview data. Certain mission "scripts" need to be investigated further, especially non-freeway trips over two-lane highways and urban highway/street driving, for example.

B. Critical Review of "Fatigue" Measurement Techniques

A critical review and evaluation is being made of the relevance of the various kinds of techniques that have been applied to measure the cumulative effects of fatigue - or cumulative hours of driving on driver performance. This study is examining a wide variety of these kinds of measures, including physiological indices, and task performance, i.e., of tasks that are in some cases directly relevant to driving but in others definitely not. The objective is to identify the kinds of techniques and measures that will permit one to determine what happens to the performance of SCB's as a function of hours of continuous driving.

C. Truck Cab Dimensional Study

The second activity is a survey of the visual of envelope and interior dimensions of several of the most widely sold heavy highway truck cabs. It will determine specific physical dimensions - linear and angular - that will be required in a laboratory - based simulator if it is designed to: 1) represent the ranges of such dimensions among the actual vehicle cabs being compared, and 2) provide for adjustments to accomodate a reasonable range of personnel in terms various body dimensions, e.g., 5th to 95 percentile.

A. Laboratory Evaluation of Control-Display Configurations

In its next phase, the program will involve laboratory tasks designed to assess the effects of continous driving on the SCB's and to evaluate the effects of truck cab control and display design as well as work space configuration upon the operator's ability to maintain adequate SCB performance over extended driving periods. Consequently some task activity in this phase will be devoted to establishing and evaluating alternative control, display and workplace design concepts.

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