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DRIVING TASKS AND
NEW INFORMATION TECHNOLOGIES

SUMMARY

In the framework of the development and evaluation of new information technologies in vehicles, the driver maintains the central component of the traffic system. In this context, it will be most important to recognise and describe processes necessary for a safe and effective conduct of the driving task. In traffic research, however, systematic approaches to the analysis of the driving task are rare.

Therefore, the important approaches are shortly reviewed and evaluated with regard to certain criteria. At Last, they are summarised and assessed in a conclusive manner, including proposals for further research activities.

1. INTRODUCTION

In the framework of the development and evaluation of new information technologies in vehicles, the driver maintains the central component of the traffic system. Quite independently from what new developments are going to modify his task it will be most important to recognise and describe the processes necessary for a safe and effective conduct of the driving task - that means, to perform some kind of task analysis.

Therefore, task analysis is a concept of central importance to the design and evaluation of all components constituting a man—machine system (or driver—vehicle system). This (self—)evident f act has led to numerous theoretical approaches and methodological procedures for task analysis in work psychology and ergonomics. In traffic research, however, systematic approaches to the analysis of the driving task are rare. Especially today, where new technologies can be used to redesign the task of car driving, this shortcoming is quite regrettable. The aim of a study, we had done by order of DRIVE Central Office, was to analyse and evaluate existing studies and methods for driver task analysis to assist in recognising the gaps of knowledge that should be closed by further research. The main part of our report documents various approaches to driving task analysis. Obviously it is not possible to give a detailed presentation of all evaluated approaches. Therefore, each author/approach is shortly described in key—words; major concern will be put on evaluative aspects and possible conclusions.

2. DRIVING TASK ANALYSIS PROCEDURES

The order of presentation is according to a distinction introduced by HACKMAN (1970). He classified four types of task analyse is approaches:

1. Task -qua - task
2. Task as behaviour requirement
3. Task as behaviour description
4. Task as ability requirement

First, studies are listed that follow the "task-qua-task"
concept, i.e. focus on the objective task properties and the
physical nature of the task. Only two approaches could be
adjoined to this concept:

v.BENDA (1977):   classification system of traffic
                         situations
EICHENAUER et al
(1981):   road characteristics

Most of the reviewed approaches are associated with the second
concept: task as behaviour requirement. The question is raised,
which behaviours should be emitted, given the task. First,
procedures closely connected with the task—qua—task aspects are
described:

GALSTERER (1978):   measurement of task complexity of traffic
                         situations
FASTENNEIER
(1988, 1989):   taxonomies of traffic situations and task
                         complexity, combination with observation
                         methods.

Several approaches that have been developed for driver education
purposes are following:

McKNIGHT et al
(1970):   detailed behaviour requirement lists
BARRETT et al (1973): emergency situations for driver education
JENSCH et al (1978): prototypical situations for driver
                         education.

The chapter ends with approaches that structure the driving task
hierarchically or by means of production rules:

ALLEN et al (1971):   hierarchical modelling of the driving task
                      and derivation of driver information needs
SCHRAAGEN (1989):   normative task analysis for navigation in
                      unfamiliar cities
HALE/MICHON: driver behaviour as production rules
                      systems.

The third group of studies is connected with the description of
overt driver behaviour: what are drivers really doing when they
accomplish their task? Several studies (in an exemplary manner)
could be compiled in this descriptive category:

KLEBELSBERG (1970):   characteristics of driver behaviour and
                      driving style
TRANKLE (1980):   driver behaviour on motorways
QUENAULT (1969):   observation procedure for overt driver
                      behaviour

C.T.:   conflict and error counting methods.

We were not going to deal with the "task as ability requirement"
concept, because individual differences in driving ability are of
minor interest in the present context.

Each of the documented approaches is shortly evaluated in
relation to its utility for further driving task analysis work.

As most of the work reviewed showed a lack of cognitive task
analysis, a chapter with an overview on psychological models of
the driver as an information processor was added. These concepts
try to describe and explain cognitive and motivational processes
involved in accomplishing the driving task. Internal
representations of critical situations, re-definitions of the
task, perceived risks, rules, knowledge, etc., are topics of
those driver models.

3. EVALUATION OF THE PRESENTED APPROACHES

This chapter summarises the information about the methods
presented in the previous chapter. It is organised into a matrix
giving some evaluation criteria as rows and the main task
analytic approaches as columns. The evaluations do not try to
evaluate the respective methods per se, but concentrate on their
usefulness for task analysis in real traffic. It follows a short
explanation of every criterion variable to further the
understanding of the table and some comments to avoid possible
misunderstandings.

3.1. Original purpose

What was the original aim that led to the development of the
methods? It can clearly be seen, that task analysis per se has
nearly never been the motive for the development of the
procedures. In most cases, the original purpose was either to
construct a tool for some kind of applied research (e.g. on
stress and strain, driver fatigue, information needs) or to
derive curricula for driver education.

Is the method derived from a model of the driving task or some
other theoretical framework or is it a more or less arbitrary
agglomeration of items? Some authors really modelled the traffic
system elements as a source of their gathering details of task
elements (e.g. McKNIGHT), others used theories of cognitive
psychology (e.g. HALE et al. explicitly relate to ANDERSON's
theory) or SCHRAAGEN on various theoretical approaches from
cognitive science; the kind of theoretical background is
indicated by a few words in the respective matrix cells. It may
surprise that the work of ALLEN et al. is scored "no theoretical
background", because these authors developed a brilliant
conception of the driving task. But the order of succession was
vice versa: They first collected their data and analysed the
driving task. The model of the driving task was developed later
on to structure the different subtasks they had found in the task
analysis.

3.2. Empirical evidence

This row characterises the approaches according to the kind of empirical evidence: was data gathered in field studies or from laboratory experiments? The result shows that many approaches have never been assessed by empirical means.

3.3. Degree of elaboration

This variable does not need to be explained in detail. We added it to the list because of the huge differences between the methods (the number of basic items or categories varies from 7 to 1700)

3.4. Extensiveness of training needed to apply the method

Some approaches can be applied quite easily with a minimum of training in the tools. Others, especially those techniques that rely on more than one human observer in field studies afford a lot of work in training observers, checking their inter—rater-reliability etc. Some methods could not be scaled on this dimension, because the main result of that work was something different from a method (see e.g. the approaches with driver education improvements on the mind).

3.5. Application utility

This variable tries to evaluate the scope of the approach: Some methods are clearly restricted in the application area (e.g. TRÄNKLE only collected items with regard to motorway driving), some methods are very general and can be used for many different kinds of work with no or only minor modifications.

What elements of the method can be of value for further research on traffic task analysis? Some of the reviewed approaches are very extensive and have undergone a lot of working steps that are not directly related to driver task analysis. We therefore specify that elements in this category that seem to be of more importance for further research on task analysis. If "none" is coded, our — of course subjective — opinion is that these studies are not suited as a base for further developments in task analysis. Please remember that this assessment has nothing to do with the overall value of these studies, but only refers to our specific perspective with regard to further driving task analysis utility.

3.6. Results useful for task analysis

This category is strongly related to the preceding one. It gives the main results of all approaches and some quantitative information for a better assessment of the scope of the approaches.

The approaches with an explicit relationship between the elements of the traffic environment and the typical tasks that have to be performed just there, seem to be of value for further activities to us (e.g. v.BENDA; GALSTERER; FASTENMEIER). The work of

McKNIGHT et al. is given a positive judgement for its extensiveness as a catalogue of tasks. Its completeness makes it well suited to be a source for more cognitive models. The conceptual framework of the ALLEN et al. studies is going to maintain its value in structuring tasks on different hierarchical levels. Also the postulated processing characteristics related to the model will be an accepted standard in the future. This evaluation is based more on the theoretical model of the driving task than on the task analysis procedure proposed by the authors. The hierarchical model has been of great heuristic value in the sense that it stimulated further work and gave central ideas that could be used or generalised by other researchers. This is an outstanding characteristic if this approach that put it apart from the others. SCHRAAGEN's normative task analysis is valuable because it applies to a subtask of driving that is severely underrepresented in task analysis until now: the navigation domain. The approach adopted by some authors (e.g. MICHON; HALE) to use production rules to describe the driving task seems to be interesting. But probably, its usefulness will be restricted to the guidance level of driving.

Table 1: Evaluation matrix

Criteria \ Approaches	von Benda (1977)	Eichenauer et al. (1981)	Galsterer (1978)	Fastenmeier (1988, 1989)	Mc Knight & Adams (1970)	Barrett et al. (1973)	Jenach et al. (1978)	Allen et al. (1971)	Schraagen (1989)	Hale et al. (199x)	Kleinsberg (1970)	Tränkle (1980)	Quenault (1969) Conflict Techniques
original purpose	scaling of dangerous traffic situations	description of optical input of drivers	research on stress and strain	derivation of driver's information needs	development of objectives and criteria for driver education	to identify situations for driver education	development of objectives and curricula for driver education	to derive driver information needs	normative task description	task analysis	description of driver behaviour	fatigue research	to identify types of drivers; safety measurement
theoretical background	significance of traffic situations in traffic system context	no theoretical background	significance of traffic situations in traffic system context	significance of traffic situations in traffic system context	based on traffic system components	no theoretical background	no theoretical background	no theoretical background	based on spatial knowledge representation approaches	models traffic behaviour as production rules	no theoretical background	no theoretical background	no theoretical background
empirical evidence	data gathered in lab. experiments	no empirical evidence	data from field studies	data from field studies	no empirical evidence	no empirical evidence	no empirical evidence	data from field studies	no empirical evidence	no empirical evidence	data from field studies	data from field studies	data from field studies
degree of elaboration	high	low	high	high	extremely high	low	high	high	medium	extremely high	low	medium	high
extensiveness of training needed to use the method	high	low	high	extremely high	./.	./.	./.	medium	./.	?	medium	low	medium
application utility	many applications possible	restricted to the description of road characteristics	many applications possible	many applications possible	data base for further research & to develop driver education program	restricted to driver education program development	restricted to driver education program development	many applications possible	restricted to navigation in unfamiliar cities	many applications possible	restricted to the description of driving styles	restricted to the assessment of individual differences in driver behaviour	many applications possible
when elements can be used as tools for further research on traffic task analysis?	classification system for traffic situations	none	behavioural requirements analysis procedure	combination of traffic taxonomies with observation methods	list of behaviour requirements	none	none	driver behaviour model; lists of driver information needs	normative task analysis	idea to describe driver behaviour as production rules	none	none	observation methods
results useful for task analysis	12 elements, 14 coding units, 9 categories to classify traffic situations; description of routes for 5 trip purposes	15 characteristics of driving situations	measurement of task complexity in 72 traffic situations	taxonomy about task complexity for 116 different traffic situations; catalogue of traffic situations for representative trip purposes	1700 behaviour requirements in 45 major tasks	8 critical driving manoeuvres	7 prototypical driving tests	10 tables of driver information needs; hierarchical description of driving task	normative task analysis (verbal description of items)	not yet finished	40 observed behaviours grouped to 7 driving style factors	4 clusters of driver behaviour variables	16 items for driver behaviour observation; 3 factors of conduct

4. SYNTHESIS AND CRITIQUE OF THE FIELD

In the proceeding chapter the various task analysis procedures had been compared and comprehensively assessed by means of some criteria. In this chapter we try to proceed in assessing the task analysis approaches in a conclusive manner. First, this will be done by means of a matrix: the rows of this matrix represent the hierarchical structure of the driving task according to the hierarchical three-level model of the driving task. This approach has been chosen because it is the model that both has been proven to be heuristically fruitful and which is acknowledged by many scientific disciplines dealing with traffic safety problems. Nevertheless, it has to be added that a hierarchical modelling of the driving task should not be overestimated so far as it still is more a conceptual framework for the description than for the explanation of driving tasks and driver behaviour. The rows of the matrix are distinguished as follows:

- Navigation 1 (pre-trip phase)
- Navigation 2 (direction-finding)
— Guidance
- Control

The columns of the matrix include various components of drivers' information—processing. They are structured according to well—known models of human information—processing, differentiating into components such as perception, cognition and action:

Perception: sensing and identifying
Cognition: interpreting and judging
Action: executing control

One cell of this matrix remains "empty": per definitionem cognitive processes can not be analysed on the control level where highly over-learned automatised skills dominate behaviour.

By means of this matrix we try to present a conclusive overview in order to demonstrate
— the topics the various task analyses have dealt with
- which aspects of the driving task are sufficiently compiled
— on which topics research is scarce.

The names of the authors which represent a specific driving task analysis approach are categorised according to the rows and columns of the following matrix.

Table 2: Taxonomy of driving task analysis approaches

Perception:	Cognition:		Action:
sensing & identifying	interpreting & judging	decision-making	executing control
McKnight et al	McKnight	McKnight	McKnight
N1 Allen et al	Allen	Allen	Allen
Schraagen	Schraagen	Schraagen	Schraagen
Hale/Michon	Hale/Michon	Hale/Michon	Hale/Michon
McKnight et al	McKnight	McKnight	McKnight
N2 Allen et al	Allen	Allen	Allen
Schraagen	Schraagen	Schraagen	Schraagen
Hale/Michon	Hale/Michon	Hale/Michon	Hale/Michon
v.Benda	v.Benda		v.Benda Barrett
Galsterer	Galsterer	Galsterer	Galsterer Tränkle
Fastenmeier	Fastenmeier	Fastenmeier	Fastenmeier C.T.
G McKnight	McKnight	McKnight	McKnight Quenault
(Jensch)	(Jensch)		Jensch Eichenauer
Allen	Allen	Allen	Allen Klebelsberg
Hale/Michon	Hale/Michon	Hale/Michon	Hale/Michon
Galsterer			Barrett McKnight
Fastenme ier			Klebelsberg C.T.
C McKnight			Tränkle Hale/Michon
Allen			Quenault Jensch
Hale/Michon			Galsterer Allen
			Fastenmeier

Abbreviations:
N1= Navigation Level; N2= Navigation Levet2; G= Guidance level; C= Control level.

Regarding this matrix for its own one could have the impression
that the approaches listed above seem to have dealt sufficiently
with all relevant aspects of driving task analysis. So far, this
matrix reveals a blurred image of the subject. This is, because
many attempts are both of restricted value for the purpose of a
systematic task analysis — as evaluated above in each case — and
include in some cases just singular aspects of the driving task.

For instance, the task analysis procedures by HALE/MICHON and
JENSCH et al are put in parenthesis. This is on account of the
fact that JENSCH' et al approach was to derive curricula for
driver education purposes; their crucial point is clearly in
investigating the "overt behaviour" of drivers and their actions,
respectively. Perceptual and cognitive processes in driver
behaviour are to some extent taken into consideration — this is
the reason why JENSCH is listed in the matrix - however, these
processes are dealt with in a rather peripheral, arbitrary and
abstract manner, i.e. there is no systematic inquiry of
perceptual and cognitive processes at all.

The disadvantage of the production rules' idea (see HALE and MICHON) is - apart from objections mentioned in chapter 2 - that it is, so far, a more or less theoretical approach. Taking for granted that it is indeed an universal approach, all processes that are represented by the cells of the matrix could be thoroughly analysed by means of this technique. However, as far as we know, there is still a discussion how it could be applied to real traffic; thus, it still seems to be a work that needs to be done.

Regarding each level of the driving task in detail, the following comments have to be made: The control level seems to be the only field of research that has been studied extensively. This holds true both for the approaches, presented in this report, and for the linear control models concentrating in modelling within one task, e.g. steering and cornering skills.

As far as the "middle ground" is concerned (guidance level) many useful results are available at present although a systematic linking of larger driver—vehicle interface design features to expected task behaviour is surprisingly lacking (compare HALE et al 1990). Furthermore, a remarkable f act is that many approaches on the guidance level concentrate on the "action" side of driving. Only few procedures take adequate notice of underlying processes such as perception, cognition, anticipation, etc. According to these basic topics only the research done by ALLEN et al and FASTENMEIER turns out to be useful; McKNIGHT's approach is of restricted value in this context and although the production rules' idea is based on an explicit theory from cognitive psychology experience is still lacking with this approach.

The main shortcomings of task analysis procedures seem to exist on the navigation level: HALE/MICHON are listed rather for theoretical than for practical reasons. SCHRAAGEN's attempt is by its nature normative in its approach and restricted to driving in unfamiliar areas; it has to be validated by an empirical or experimental study. Although McKNIGHT et al extensively analysed many relevant driving task components, the number of items concerning navigation tasks is strictly limited; thus, the usefulness of this approach for the navigation tasks has to be questioned. The same holds true for ALLEN et al: they also use very few items for the analysis of what they call macro-performance tasks. Especially as far as the implementation of electronical in—car navigation systems is concerned task analysis should concentrate more on cognitive styles and cognitive mapping of drivers and related topics. The importance of these processes for both evaluating navigation systems and establishing design criteria has been summarised recently in DRIVE-reports (e.g. VAN WINSUN et al 1990; GSTALTER & FASTENMEIER 1991).

What we should also bear in mind is the following: the discussion in this report about various driving task analyses made evident that a relevant number of these approaches ranges back to the early 1970's. So far, the question arises if research done in 1970 can be transferred to road traffic problems in the 1990's

without any reservation especially under the premise of introducing new technologies in vehicles. In our opinion this has to be taken into consideration as far as the results of these analyses are concerned: in any case, the "older" procedures are in need to be updated. Less detriment has to be made for the task analysis techniques themselves.

Another shortcoming of task analysis relates in general to that kinds of approaches which appear to have remained closely to their origins, i.e. task analysis for driver training purposes. Their "atomistic" view indeed seems to be useful for the purpose of deriving detailed and elaborate curricula for driver training and driver education by extensively analysing all kinds of task components. However, the value of these procedures has to be questioned as far as the design of new driver—vehicle interfaces is concerned.

Another remarkable f act is, in general, a lack of a precise description, definition and integration of environmental objectives, i.e. explicitly situational variables such as traffic and driving situations. Thus, with the exception of FASTENMEIER who integrated the task—qua—task and the behaviour—requirement approaches by v.BENDA and GALSTERER, in most task analysis procedures

— situational variables aren't clearly defined or are just "mentioned" in general
— situational variables usually aren't varied systematically.

This seems so much the more a surprising statement as already twenty years ago task analysis research claimed the urgent need of a taxonomy of situations in order to describe and control the interactions between driver and situational characteristics (e.g. HACKMAN 1970; FREDERIKSEN 1972; MAREK & STEN 1977; recently HOYOS & KASTNER 1986).

Summarising the discussion about the task—as—behaviour—description approaches it shows up that they are of limited value for general task analysis purposes. They concentrate both on car—handling and drivers' overt behaviour without regard to underlying cognitive processes.

The most promising procedures are comprised in the task—as—behaviour—requirement approach, especially when they are linked with task—qua—task aspects. However, a systematic error—modelling should be added to these approaches, i.e. they also should consider tasks which arise when the driver—vehicle—road system is operating abnormally (or single components of this system, respectively).

Indeed, this lack of both the error—modelling and a comprehensive driver errors' taxonomy applies to task analysis research in general. Such a taxonomy neither exists in relation

- to driving performance in general
— to single parameters of drivers' information—processing.

Of course, this doesn't claim that research has neglected driver errors so far: what is missing is a systematic approach! Many attempts of error classification have been made in fact especially in work sites (e.g. LEPLAT & RASMUSSEN 1982; REASON 1985; etc.) but a transmission of approaches from work psychology and related topics to road traffic is still missing.

Most error counting methods in road traffic stem from a Conflict Technique background, because it is proposed that the same types of errors are also causes of traffic conflicts. One attempt of systematically counting errors by in—car observation has been presented by RISSER & BRANDSTÄTTER (1985). Modified versions of this method by other authors have been applied for various purposes: evaluation of an in—car navigation system (GSTALTER 1991) and analysis of driver information deficiencies (FASTENMEIER 1991).

An approach to overcome some of the deficiencies, mentioned above, could be indeed a combination of error counting methods with behaviour requirement approaches which explicitly take regard of situational variables. In this context, one basic assumption is the concept of a safety—continuum. If one considers traffic safety to be a variable varying between correct behaviour (i.e. behaviour according to a defined standard) and traffic conflicts and/or — in a further step — accidents, then errors in the behaviour of road users should be found somewhere in between those two extremes. Within the following succession: standard behaviour — errors in driving behaviour — traffic conflicts — accidents, the frequency of events is decreasing, the dangerousness of events increasing. For instance, the probability of two traffic participants to be involved in a traffic conflict is limited to a certain degree; on the other hand, a conflict will only possibly lead to a collision. So, when trying to identify types of behaviour which lead to traffic conflicts or to accidents one would expect an accident to have been preceded by dangerous or erroneous behaviour. Thus, one will have to distinguish between different types of errors, i.e. considering both the legality and the degree of danger coincident to any certain behaviour as two very important aspects. Those aspects of traffic safety reducing behaviour should be analysed together with their relationship to traffic conflicts, accidents and behavioural requirements. In this context, a number of questions have to be answered:

— how to determine the logical and numerical relationship between errors and conflicts?
— how to define the term "error" itself? how to observe and record the difference between errors, slips, mistakes, faulty actions and traffic violations?
— how to proceed in developing a taxonomy of driver errors which is closely related to traffic situations: take a driving task analysis from the behaviour requirement approach and define errors as deviations of "ideal" and required behaviour?

Both the process of task analysis and the development of a task analysis methodology can be very time—consuming. According to this statement there are two main strategies for further research

in general, being dependent on cost—benefit considerations: first, all task analysis procedures which have been evaluated as appropriate tool for further applications could be adopted for all problems arising under the premise of developing and implementing new driver—vehicle interface design features. There is indeed a pool of procedures which can cope with problems such as changing driving tasks due to the introduction of RTI—systems, changes in task allocation, etc.

Nevertheless, one could argue that there is a need of a task analysis methodology to be developed fundamentally for road traffic purposes. Especially as far as the drivers' cognitive processes are concerned, this report made evident that very few approaches take adequate notice of this basic topic. Thus, one possible proceeding is to take a model of human information—processing as a conceptual framework and/or tool of analysis both in order to exactly defining all steps and phases of information—processing and by regarding all components of the driver—vehicle—environment system to finally derive the tasks that have to be accomplished by the driver.

Another aspect should be mentioned at last: So far, driving task analyses of course had been confined to "driving" itself. But as far as future conceptualisations such as co-operative road infrastructure management are concerned, new and other aspects of the driving task will become important. Supposing that such concepts will be realised in the near future it should be obvious that the existing characteristics of the driving task will change. In this case adequate task analysis procedures are still lacking.

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