INFORMATION SOCIETY TECHNOLOGIES (IST) PROGRAMME

adaptive
integrated
driver-vehicle
interface

AIDE

IST-1-507674-IP

Risk trade-offs between driving behaviour and driver state

Deliverable No.		D2.3.2	
SubProject No.	SP2	SubProject Title	Evaluation and assessment methodology
Workpackage No.	WP2.3	Workpackage Title	Estimating the risk potential of integrated adaptive HMI
Activity No.	A2.3.2	Activity Title	Assessing the trade-off between behaviour and workload/driver state
Authors		W.H. Janssen, R.F.T. Brouwer (TNO), Y. Huang (LIU)	
Status		S	
File Name:		AIDE D2.3.2 v6.doc	
Project start date and duration		01 March 2004, 48 Months	

Revision chart and history table

Version	Date	Reason
1	30/11//2005	
2	16/12/2005	Additions/changes after internal talks of authors and collegial comments
3	06/01/2006	Additions/changes after peer Review
4	27/07/2006	Additions/changes after Audit
5	10/08/2006	Editorial revision after review by Project Coordinator
6	08/09/2008	Project Coordinator corrected Dissemination Level to PU.

Table of Contents

List of abbreviations and glossary

ADAS	Advanced Driver Assistance Systems. Systems that interact with the driver with the main purpose of supporting the driving task on the tracking and regulating levels.
AIDE	The Adaptive Integrated Driver-vehicle Interface targeted by the AIDE IP
Behavioural adaptation, compensation	The whole set of behaviour changes that are designed to ensure a balance in relations between the (human) organism and his/her surroundings, and at the same time the mechanisms and processes that underlie this phenomenon
Driver alertness	Capacity of driver to pay attention
Driver distraction	Attention given to a non-driving related activity
Driving performance	The degree to which the goals associated with the driving task are attained.
Driving task	All aspects involved in mastering a vehicle to achieve a certain goal (e.g. reach a destination), including tracking, regulating, monitoring and targeting.
HASTE	HMI and Safety of Traffic in Europe
IVIS	In-Vehicle Information System - Systems that interact with the driver with the main purpose to support tasks on the targeting and monitoring levels, or do not support driving at all.
Micro traffic simulation	Simulation model on the level of individual vehicles
OCM/T	Optimal Control Model/Theory
Risk	The product of the probability that something will happen and the severity of the consequences of the result; i.e. Risk = Probability of failure * Effect of failure

Risk, aggregate	Accident risk in the population (for 100% penetration rate, in case of a system that vehicles may be equipped with)
SP	Stated Preference
TLC	Time to Line Crossing
TTC	Time To Collision
Workload	The amount of information processing capacity that is used for (primary or secondary) task performance

Executive Summary

This Deliverable deals with the problem of how to get to an estimate of accident risk that incorporates both *driver state* (e.g., his momentary workload level or level of alertness) and his *driving performance* as expressed in commonly used parameters like speed and lane positioning accuracy. This issue should be resolved in some way in order to provide input to the final AIDE SP 2 evaluation methodology.

Three main sources of input were examined:

- The literature, preferably of an empirical nature. The conclusion here was that available results do not permit the derivation of trade-off expressions, because the underlying factors are not yet fully identified or their effects not sufficiently quantifiable.

- Modelling on the basis of Optimal Control Theory (OCT). This appears to permit the derivation of quantitative expressions relating (changes in) workload - as induced by secondary tasks – to accident risk.

- An SP study from the HASTE Project. A reanalysis of this expert-judgement-based study appeared to provide at least some quantitative results on driver state/driver behaviour trade-offs. These results can be turned into simple calculations that permit making risk estimates that incorporate both driver awareness and observable behavioural parameters.

- It is concluded that the application of these results, in the form of a few pragmatic rules, can form the basis for the specific component in the SP 2 methodology that takes driver state/driver behaviour trade-offs into account when estimating the overall risk effects of driver support systems.

1. Introduction

The general objective of AIDE SP2 is to develop a cost efficient and industrially applicable evaluation and assessment methodology for ADAS and IVIS.

There are three workpackages in this SP.

WP 2.1 performs a generic evaluation on methodology of behaviour and usability evaluation, and WP2.2 focuses on the (off-line) assessment methods and tools of driver workload and distraction.

The objective of WP 2.3 is to provide a methodology for assessing the accident risk (reduction) potential of advanced driver assistant systems (ADAS) and in-vehicle information systems (IVIS).

Risk assessment is, first of all, an important tool in the ‘formative’ phase, i.e., the development and evaluation of new products. In the development phase, risk assessment undertakes a systemic description of undesirable events and their potential consequences and provides a basis for prioritising between alternative solutions and actions.

In the evaluation phase, which is the issue here, risk assessment provides a basis for estimating risk effects and – possibly - deciding whether they are acceptable (Aven, 1992).

The assumption of the evaluation methodology to be developed in SP2 is that the accident risk of a new product, i.e., an AIDE system, can be estimated in terms of an extrapolation of effects of possible changes in driving behaviour and/or driver condition like those measured in simulator and/or instrumented vehicle studies.

This report deals with one of the three tasks within WP 2.3, which comprises:

- Task 2.3.1, in which the functions describing the relation between driver behaviour parameters and risk level are identified.

- Task 2.3.2, which deals with assessing the trade-off between driving behaviour and driver state, i.e., the driver’s momentary workload and/or level of alertness.

- Task 2.3.3, which combines the various behavioural and driver state effects into a single overall risk assessment.

This Deliverable describes the results of Task 2.3.2. As there was no opportunity and no intention to perform empirical work, given the limited effort specified for this Task in the AIDE Workplan, the study had to be based on already available evidence from the literature and on theoretical considerations.

There are different ways in which the trade-off between driving behaviour and driver state can be interpreted. First, it may simply refer to the empirically observed interaction between the two, also indicated as behavoural adaptation or compensation. The trade-off here is seen as the influence of one (driving behaviour) upon the other (workload/driver state). For example, quite often drivers will adjust their driving behaviour to cope with increasing workload. In this case the trade-off is in the adjusted driving performance because of increasing workload: it is what drivers actually do.

In the present Report, however, the trade-off is considered with respect to risk measures per se. What this means may be illustrated by an elementary example.

Consider a driver who drives at 100 km/h while being fully alert. There is then a certain probability to get involved in an accident. When the driver drives at 80 and is still fully alert this probability will certainly be lower. However, if that same driver drives at 80 km/h but now is drowsy or distracted this probability may actually be very close to the former, 100 km/h, one. It is this trade-off that we are concerned with.

It is good to realise that, although theoretically there are limitless possible combinations of driver state and driver behaviour, in reality not all of them will exist. This is exactly because drivers, by adjusting their behaviour, are likely to compress the unrestricted universe of possibilities to a limited space. However, we need to distinguish what drivers *do* from the risk that is actually associated with a certain combination of driver state and behavioural parameters.

The risk that we are talking about here is based on risk considerations at the individual level. However if one 'averages' over all conditions and all drivers an estimate of these probabilities will be achieved, and this is to be equated to the accident risk in the population (that is, all the time assuming a penetration rate of 100% in case of a specific ADAS). So, when we talk about risk in this task we mean risk at this aggregated level.

Our approach has, thus, been as follows:

(1) We examined the literature on the availability of possible quantitative relations (i.e., trade offs) between driving behaviour and workload/driver state with regard to risk, in order to

(2) Derive a usable quantitative description of that trade-off.

2. Input from other AIDE activities

It is obvious that quantitative combined effects can only be made if we know the underlying elementary behaviour-risk functions. As mentioned, these have been provided in Task 2.3.1 (Jamson et al., 2005). We will in particular make use of the so-called Nilsson speed-risk functions, which are relatively well-developed.

Knowledge on the other half of the equation comes from theoretical notions outside AIDE as well as from empirical results generated in the AIDE SP 2 Work Package on ‘Workload estimation methodologies’; (WP 2.2; see Deliverable 2.2.1, Johansson et al, 2005, and the recent series of Deliverables from WP 2.2).

This Deliverable has also benefited from interactions with other AIDE SPs, in the form of Workshops dealing with the risk concept in different contexts. From these it has become clear that, while SP 2 must ultimately provide so-called ‘aggregate’ risk levels, this must of necessity start from the description and identification of possible risks at the ‘individual’ level. This risk is in terms of performance (behavioral) parameters.

Additionally, the terminology and conceptualisation of driver condition parameters has been tuned to that followed in SP 1.

3. Relations between driving behaviour and workload/driver state with respect to risk

Relations between driving behaviour parameters and risk have been collected and reported on the aggregated level in the Task 2.3.1 Deliverable (Jamson et al., 2005). These types of relations, of which some are quantitative and others qualitative, are almost ‘physical’ functions relating driving behaviour to risk, but they do not take momentary driver state or driver workload into account. In the present Task, however, we must elaborate on this and try to quantify the relation between driving behaviour, workload/driver state, and risk. To do so we need a vector that comprises driving behaviour related parameters (such as time-to-collision, speed, and time-to-line crossing) and workload/driver state, and that then comes up with a risk estimate. In doing so we need to be aware that ‘driver state’ itself can comprise a multitude of situations, so that we must be prepared to distinguish between, at least:

- ‘driver state’ per se, i.e., the driver’s momentary condition in terms of information processing and decision making capacities, as affected by, e.g., his level of alertness (or arousal), fatigue, sleepiness, level of alcohol or drugs intoxication, etc.

- driver state in terms of workload generated by the primary task of driving;

- driver state in terms of the workload generated by secondary tasks, such as being introduced by the actions of in-vehicle systems, whether of the IVIS or ADAS type;

- driver state in terms of momentary distraction, i.e., a non-functional (with respect to the driving task) redirection of attention towards an external element inside or outside the vehicle.

The relevance of this distinction is simply that the functions relating these different states to accident risk may be of different natures. There is no reason why, e.g., the function relating driver alertness to risk is identical to the one relating secondary workload to risk.

3.1 Review of workload vs risk studies

There is no paucity of literature relating driver workload to environmental or in-vehicle conditions while driving per se. The rationale for being interested in workload is, after all, that there must be some effect of workload on accident risk. For example, Gaillard

(1993) says that workload assessment is important because the probability of the occurrence of errors is much higher when the operator is working at the margins of his capacity. Similarly, in a much quoted workload source like De Waard (1996) it says: ' If task demands are high in relation to the operator's capabilities, errors may occur, and in interaction with neglected classical human factors issues such as proper layout of instrumentation panels, these errors may become critical for safety.' (p. 11). Agreed. However, the question then becomes how this relationship actually looks, i.e., whether it can be quantified in some sense. Finally, this type of general statement appears to be common in the recent collection of theoretical formulations brought together by Macchi et al. (2005), which does not contain a single explicit quantitative statement relating driver workload/state to accident risk.

We then undertook to review the available papers from the literature that indicated that they *would* say something about this issue. As it turned out there were only a very limited number of them to begin with. The typical workload paper takes it for granted that workload is important, as noted above, and then moves on to workload measurement and interpretation issues etc. per se. But even the papers which announced that they would treat the issue did not quite do so, as will become apparent when we discuss them.

Hoyos (1988) describes in general terms the relation between mental load and risk in traffic behaviour. According to Hoyos "stress…is a lack of equilibrium between persons and their environment, which results from a discrepancy between demands and possible ways of dealing with situations. If there is a lack of balance between the activation level and the performance capacity of a driver, or if the demands which traffic makes on performance produce tensions, then there is the risk of an accident, in which the necessity to make decisions under time pressure and using limited mental capacity plays an important role" (p. 573).

Obviously, Hoyos describes workload and risk but does not tie them together. Later, he does refer to an experiment that shows that drivers compensate (speed decreased) for increasing workload (p. 579). However, the first relevant question for our task is not whether drivers compensate, but how we can tell whether the risk after compensation has increased, remained the same, or decreased.

Alm and Nilsson (1994,1995) tried to relate workload to risk as measured by car-following headway. They found that increased workload from a secondary task did not increase the headway. This conclusion followed from two driving simulator studies (Alm and Nilsson, 1994, 1995) on the effect of a mobile telephone task while driving. In the first study (Alm and Nilsson, 1994) a simple driving task was used where the subjects knew that only one event could occur, and also what to do when it occurred. In the second study (Alm and Nilsson, 1995) a more complex driving task was used, including interaction with other road users. More than one event could occur and more than one action was supposed to be performed in response to what happened in the traffic situation. The increased workload led to an increase in reaction time. One way to compensate for the increased reaction time is to increase headway. However, no evidence of compensation by increasing headway was found in their second study. Again, this study does not permit to distinguish sufficiently between what the actual relationships are and what drivers do.

A study by Jamson and Merat (2005) found that an increase in visual and cognitive secondary task load was associated with and partly compensated by driver performance: slower speed and short TTC. The findings are consistent with Alm and Nilsson (1995). In the study of Jamson and Merat drivers in a car-following situation were asked to perform either an auditory task (with three levels of difficulty) or a visual task (with three levels of difficulty) as a secondary task, comparing to driving as a primary task. The result of the study showed that driving speed reduced with increasing secondary task demand. Precisely, the mean speed dropped about 5 to 10 km/h (average speed was about 85 km/h) while the drivers had the highest level of auditory task and visual task respectively. However, the study of Jamson and Merat also showed that drivers became closer to colliding with the lead vehicle the more complex the secondary demand was. More precisely, the average minimum TTC dropped about 1.6 seconds and 1.4 seconds from about 8 seconds while drivers had the highest level of auditory task and visual task respectively. The reduction of TTC showed that drivers did not compensate enough for the increasing workload.

Interesting as these findings are, since they shed light on the compensatory processes by which drivers trade-off one parameter against an other, they still do not give us the needed risk effects in the way we are looking for.

Recarte and Nunes (2002) investigated the relation between attention and speed control. Their participants drove a stretch of 200 km under different conditions (free speed or restricted, information about the speed or not, normal driving performing a secondary task). The results showed that “when a second task was performed the speed increased independently of the speedometer availability under restricted speed but not in the free speed condition”. On basis of this result they argued that for each driver there is an optimum speed that minimises ‘resource consumption’. If they drive at this speed “[t]he control of this optimal speed is mostly automatic, and thus not affected by increased mental load imposed by several cognitive tasks” (p. 120). While this is, again, informative on the issue of what drivers actually *do* it does not provide the risk functions we are looking for.

Finally, Fuller, McHugh, and Pender (cited in Fuller, 2005) reported an experimental finding that showed a close relation between task difficulty – which is maybe to be equated to workload - and estimated risk. The investigators asked participants to rate video sequences of road segments travelled at different speeds. Participants had to rate each sequence on task difficulty, statistical risk of a collision, and their subjective experience of risk. The results showed that task difficulty increased with increasing speed, which also was found for risk experience. So, the results show that increasing speed led to a higher task difficulty, which in turn resulted in an increasing estimate of the risk on a collision.

The results of this study show that primary task workload – the workload that is associated with the driving task itself – is seen by subjects as following from the increasing difficulty in performing the driving task when speed goes up, which is in turn seen as equivalent to increasing risk. As such, they demonstrate that factors like risk, speed, and task performance have a coherent and consistent representation in drivers' minds. However, the results do not permit us to derive the functions we are looking for. They just tell us that primary task workload is apparently a covariate of speed and the risk associated with it, but not what happens to risk when a secondary task is added or the driver becomes more or less alert.

Based on the results of this literature review – where we considered only those papers that stated they would treat the subject of relating driver workload to accident risk - we must conclude that there is no reported reasonably empirically underpinned quantitative trade-off relation between driving behaviour and workload/driver state.

Apparently, we are moving into uncharted territory.

3.2 More on the workload-risk trade-off function

Since the empirical literature did not provide us with a quantitative relationship of the type we were looking for we turned to other sources, in particular to available theoretical workload models that would permit us to link workload to risk.

As a mind-setting exercise a plausible conceptualisation of the functions relating behaviour, workload, and risk is presented in the graph below. This graph incorporates:

- the assumed 'physical', and known, relationships between a parameter (in this case: speed) and accident risk

- an assumed implicit effect of primary task workload, i.e., of the load associated with driving itself, that is monotonic with the behavioural parameter itself. Thus, we assume that primary task load goes up monotonically with speed, and is therefore included in the inherent risk associated with the speed parameter, so that it needs not be shown separately in this plot (cf. the Fuller et al. results)

- the assumed effect of workload – as generated by having to perform secondary tasks in the vehicle - on these functions, in the sense that the 'physical' functions are assumed to become steeper the higher driver workload is

- the adaptation by the driver to his own (secondary) workload by reducing speed, which is assumed not necessarily to be a perfect process. However, as stated repeatedly before, it is not this compensation effect by itself that interests us, but it is nevertheless of relevance because it puts restrictions on the space of states that will actually be observed to exist.

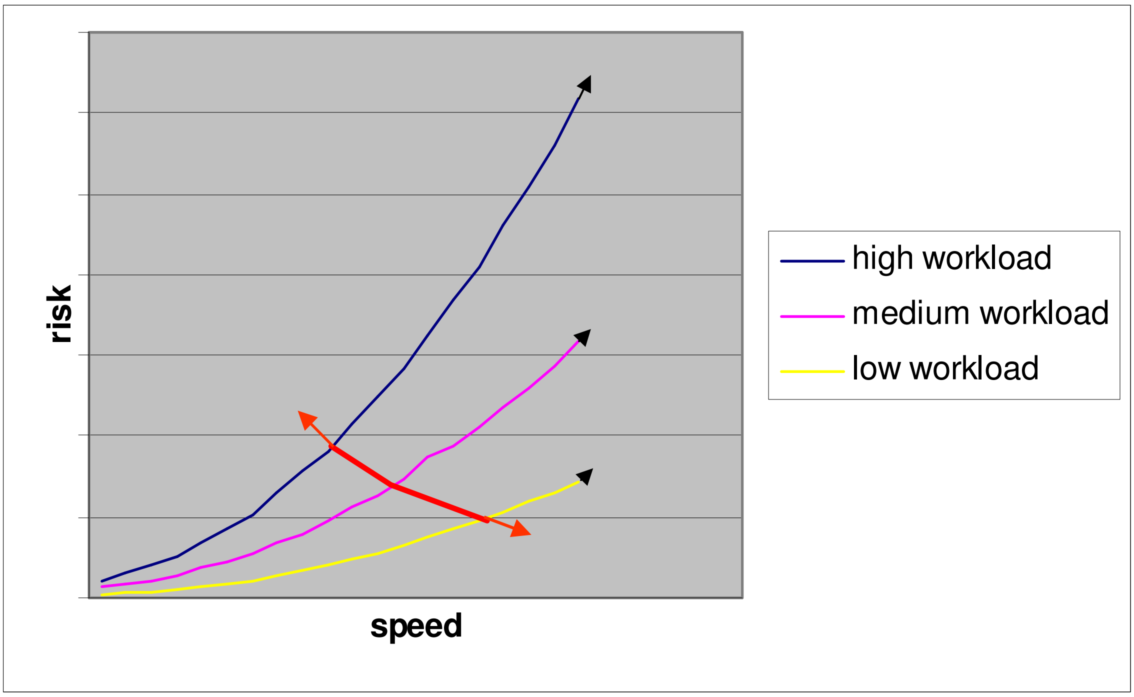

Figure 1. Conceptualisation of possible relationships between behavioural parameter (speed), level of secondary task workload, and driver's adaptive (compensatory) behaviour - shown here as a shift corresponding to the red arrows. Curves are assumed to follow the Nilsson equations. Drivers shift from one curve to the other when workload level changes, which is associated with speed adaptations.

In order to get to a plausible parameterisation of the hypothesised functions depicted in Fig. 1 the modelling results by Wewerinke and Hogema (2003) were found to be the primary candidate.

The Wewerinke and Hogema modelling is based on Optimal Control Theory as developed by Kleinman, Baron & Levison, 1970 (see Jürgensohn, 2005, for a recent review of control models in driving) and as further elaborated by Wewerinke (1989) to include a model for workload that has been shown to correlate well with a variety of workload measures.

Although the authors did not actually consider the present issue it is possible to make use of their results for our purposes. This is demonstrated in the Figure below.

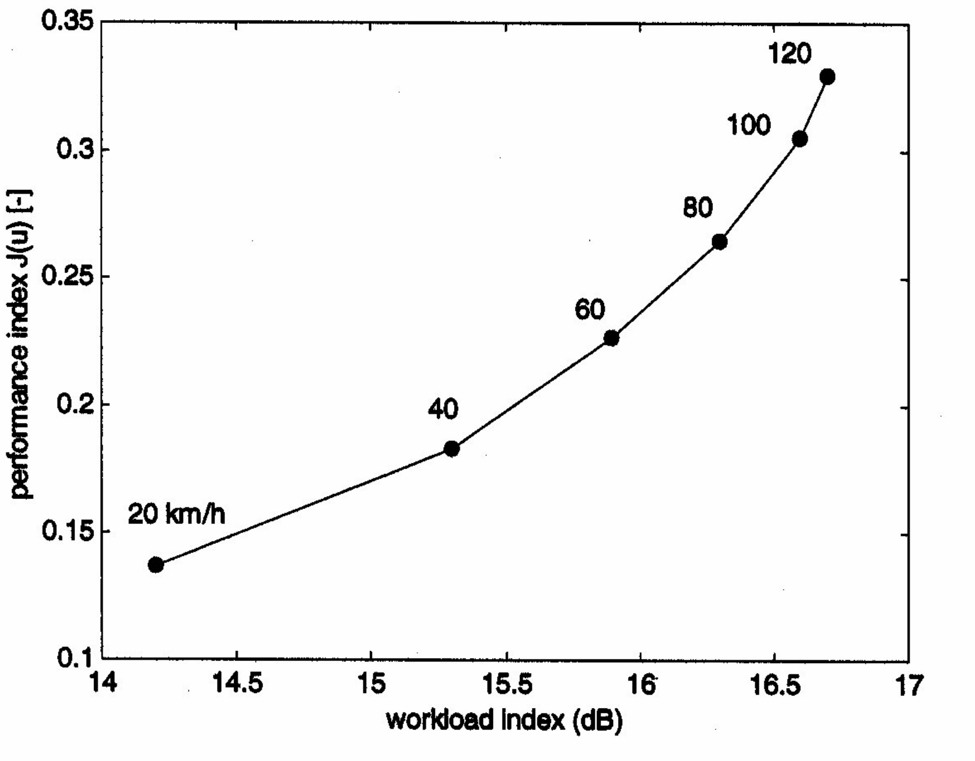

Figure 2 Relation between workload and performance index (for lane keeping), modelled according to Optimal Control Theory by Wewerinke and Hogema (2003).

The figure contains driving speed, the workload associated with the different speed levels, and a so-called 'performance index' which can be equated to a risk level.[1]

It is apparent from these model results that workload – which, in OCM, is straightforwardly equated to the mental effort that drivers have to exert – shows a fairly shallow increase with increasing speed. However, what is more important here is its relation to risk, i.e., the performance index. If we consider the workload level of driving at low speed as baseline, then it becomes apparent that risk about doubles at medium workload levels, and triples at the highest workload levels (NB: workload levels in Figure 2 are in dB, i.e. logarithmic, scale).

If these approximate values are now combined with the Nilsson speed-risk functions we find the expressions for the three different-coloured curves in Fig. 1 showing those functions for different levels of secondary task workload. They are functions in v raised to a power of between 3-5, depending on what type of accident is being considered (Jamson et al., 2005), and preceded by a coefficient that is either α, 2α,

[1] Although, in the case that Wewerinke and Hogema considered, it was not accident risk itself but a well-established *proxy* for risk, i.e., the probability of the vehicle getting out of the lane; see the Jamson et al. (2005) Deliverable for further discussion of this parameter.

or 3α, where the value of α can either be left unspecified for comparative purposes or calibrated on the basis of accident statistics. This is the result we were looking for.

Although it is clear that:

- The parameters that Wewerinke and Hogema were considering cannot strictly be equated to the ones that we are considering (i.e., their risk estimate was only a proxy, their workload was not specifically modelled as caused by a secondary task, etc.); and:

- Their results were based on modelling only (although much of that modelling had been shown to be valid in other studies); and:

- Their procedure leaves unspecified what the metric for workload is

we feel that their results can serve to support the proposal of a rule-of-thumb for the AIDE risk evaluation methodology.

This states that, if a secondary task induces extra workload compared to baseline, the risk *doubles* from that alone if the workload changes from 'low' to 'medium', and it *triples* if the workload changes from 'low' to 'high'.

3.3 The risk effects of driver awareness vs behavioral parameters

Whereas the previous sections have considered 'workload' as a contributory factor to accident risk there is more to 'driver state' than workload, as we have argued before. While it has been well documented in this respect that states like fatigue, drowsiness, alcohol intoxication etc. are reflected in accident risk we still have to consider less dramatic factors that are more likely to be involved in the everyday interaction between a driver and an (AIDE) in-vehicle support system.

Within the European project HASTE a Stated Preference (SP) study among experts was performed that yields at least some results of a quantitative nature on the topic that interests us here, since it involved a so-called 'driver awareness' dimension (Batley, 2005; see the Task 2.3.1 Deliverable for a more elaborate description of the design and execution of the study: Jamson et al., 2005). The internal HASTE document by Batley et al. forms the basis for the further analysis given in the following.

In the SP study 81 experts, recruited by the researchers on the basis of an a priori list of candidates, rated a series of multidimensional driving situations in terms of the accident risk involved with each of them. (In fact, only ordinal – rank order – judgements were requested from the subjects, from which the underlying risk scales were then derived by logit model estimates). All situations presented to the experts were defined in terms of a combination of:

- Speed (where the levels were: at the speed limit, 5, 10, 20, or 50 % over the limit, or 5, 10, 20, and 50% below the limit).
- Variation in lane position (low, medium, or high).
- Speed variability (low, medium, or high).
- Headway (0.5, 1, 2, 4 or 10 s).
- Driver awareness (poor, fair, good, or excellent).

Because the latter dimension was included – a driver state parameter, however vaguely defined – this would permit a comparison of the risk levels associated with this particular parameter with those of the specific behavioural parameters: which is the type of result we are looking for, realising that it is only the 'driver awareness' state, and not primary or secondary task workload, that the SP study asked to assess.

The raw results of this study, as presented in the HASTE internal paper by Batley et al. (2005), have been reworked for the present purpose. That is, the results given there for the individual dimensions in terms of coefficients of logistic regression functions have been re-analysed so as to correspond to common percentage scales of increases and decreases in risks for the different dimensions and their combinations, relative to a baseline.

The figure below summarises the results of this analysis, expressed as percentages increase in risk for a given level of a dimension compared to its baseline level (which was always the safest level for that dimension – e.g., driving with a 'low' lateral position variability was the baseline for that dimension).

No differential effects were – somewhat surprisingly – found for 'speed variability'.

A further major result of the study was, however, that no interactions were found, which means that effects for combinations of dimensions are simply to be regarded as additive.

What this implies, for example, is that we can see that when driver awareness drops from ‘excellent’ to ‘good’, risk is estimated to increase by 63%. This can, however, be counteracted in many ways, such as reducing one’s driving speed from ‘limit + 10%’ to the limit itself (risk reduction of a little over 50%). Thus, what these graphs permit is to derive by how much one needs to compensate on a given dimension in order to nullify a change in risk on another one. And, of course, the risk effects of moving back and forth on a single dimension, such as awareness, can by themselves be estimated.

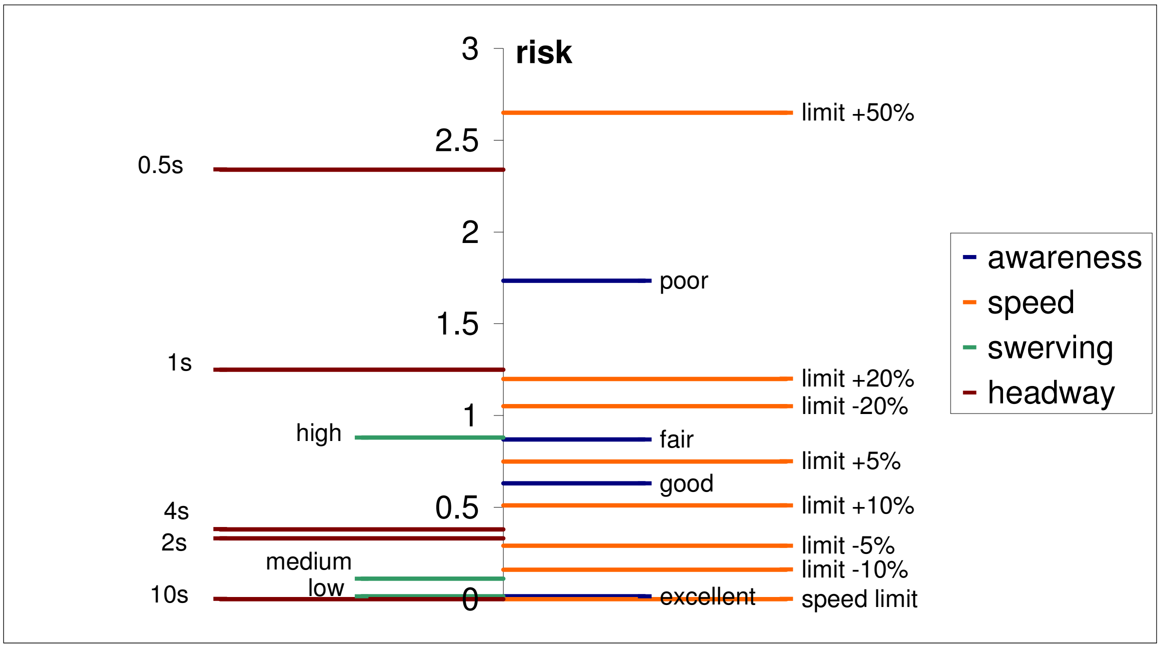

Figure 3 Risk effects, relative to arbitrary baseline, for different driving performance and driver state parameters, as estimated by HASTE SP study. Examples: when speed is increased from baseline (i.e., at speed limit) to 20% over speed limit risk will increase by about 125%; when awareness drops from baseline (i.e., ‘excellent’) to ‘poor’ risk will increase by about 175%; etc. Effects of separate parameters are independent.

Of course, criticisms can be raised in connection with SP studies in general and with this one in particular, such as the validity even of expert judgements, and the definitions of dimensions and levels (what exactly is a ‘high’ lateral position variation?; are the dimensions really independent ones in the statistical sense?; is a given percentage over the speed limit independent of the absolute level of the speed limit itself, as far as risk is considered?; etc). Nevertheless, this type of study is not uncommon, and its material is what we have and what we must work with at present.

On the basis of these results rules of thumb with respect to the trade-off between ‘driver awareness’ and behavioural parameters may therefore be derived, from Figure 3, that look as follows:

- When driver awareness drops from ‘excellent’ to ‘poor’ risk will increase by about a factor of 2.

- This is about equivalent to:

(1) a speed increase (expressed as a percentage over the speed limit) of about 30 %.

(2) a decrease in headway from about 2 to about 0,5 s; or

(3) a combination of the two, or a combination involving lateral position stability as well.

Obviously, all the (combined) effects can also work the other way around, i.e., if one wants to increase one’s speed to 30% over the limit this would require awareness to go up from ‘good’ to ‘excellent’ so as to maintain the same level of risk.

4. Discussion and conclusion

4.1 What have we got ?

We started this Report by noting that there are already (semi)-quantitative expressions around that relate certain driving performance parameters to (aggregate) accident risk. We then asked ourselves whether similar expressions could be found, or derived, relating driver state (e.g., momentary workload, level of alertness) to accident risk, only to conclude that the literature has apparently produced not much more than general statements saying that higher workload must lead to more risk. We then tried to fill the gap by resorting to two available, more indirect sources of material, one of them the results from applying a well-developed control model (OCM), the other a re-analysis of a study from a EU Project that apparently had also realised that there was a paucity of results in these respects (the HASTE SP-study). Both of these are respectable studies by themselves. The only thing is that they were not designed with the specific AIDE requirements in mind, so that there remains the question of to what extent the results they provide are applicable for our purposes.

To this the following can be said:

(1) These results are applied and turned into proposed rules-of-thumb, i.e., in case of secondary workload, as yielding factors by which the accident risks resulting from the accompanying behaviour-risk functions should be modified (e.g., doubled, halved,...). Thus, to stay on the safe side they are not applied to two decimals accuracy.

(2) There is, admittedly, an issue of what – e.g. – ‘excellent’ or ‘poor’ driver awareness is, in an operational sense. Some further specification of these categories is required and is foreseen as part of the development of the final methodology: see 4.2.

(3) Since the implications of the results of these two studies for the AIDE SP2 methodology are far-ranging there is undoubtedly a need for further testing and validation. There are two ways in which this can be done: (a) By behavioural studies, most likely in a driving simulator, that vary driver workload or level of alertness and establish what happens to risk (or a close proxy of risk) (b) By simulation that includes the effects of driver state, through its effects on certain behavioural parameters, on estimates of accident risk. For example, driver state might be reflected in response time to discrete events like a lead vehicle suddenly braking, with a consequent effect on TTCs etc. (see the relevant Chapter in Jamson et al., 2005). Both types of check will be done in SP 2 as part of the final steps leading to the specification of the AIDE Methodology.

4.2 Application to AIDE SP 2 methodology

With all their limitations, the OCM modelling study and the HASTE SP material are the best – and all - we have at present to work with for estimating accident risk in conditions that involve driver state/workload considerations.

With respect to *workload induced by a secondary task* the proposal is summarised in the speed-risk functions of Figure 1. An unresolved point here is what workload metric should be used to apply the proposed rule-of-thumb. However, the rule is not so fine-grained that this would possibly matter very much, as long as we agree in which category a particular level of workload belongs (i.e., low, medium, or high). This will be done as one remaining activity in WP 2.3 before the final methodology is specified.

With respect to *driver awareness w*hat the material summarised in Figure 3 requires in order to be applied is an indication of the driver's state of awareness, i.e., whether the driver's awareness is judged to move up or down into a different category as the result of an experimental treatment, like the provision of an AIDE support system. If there is agreement on this, which may be based on actual measurement of driver state by whatever means, the resulting estimated effect on risk follows. This may then be added (or subtracted) to whatever driver behavioural effects are found at the same time, from which an overall estimate on accident risk then follows. It is one remaining activity in WP 2.3, before specifying the final methodology, to establish such operational agreement.

In summary, the proposal is as follows:

(1) To transform the level of workload added by a task to baseline workload into a risk estimate:

- double the risk if that workload is at a medium level; and

- triple the risk if that workload is high

(2) To transform a change in a driver's level of awareness into a risk estimate:

- double the risk if awareness drops from 'excellent ' to 'poor'; and

- apply the factors as shown in Figure 3 for other changes in awareness, e.g. ,from 'fair' to 'poor' or from 'excellent' to 'good'.

(3) The effects as specified in (1) and (2) are then to be added or subtracted from the effects associated with the purely behavioural changes that are observed.

5. Contribution to SP 2 and overall AIDE objectives

The pragmatic rules-of-thumb proposed here complete the picture of how to estimate the effects on accident risk of changes in driving behaviour as well as in the driver's state that could result from the introduction of in-vehicle support systems like the AIDE system. As such, it is a contribution to the AIDE SP 2 evaluation methodology per se and an input of work yet to be performed in Task 2.3.3 (which is to design a procedure to remove spurious correlations that may exist between the single behavioural parameters as well as driver state parameters, so as to get to the 'purest' possible estimate of risk effects).

References

Alm, H. & Nilsson, L. (1994). Change in driver behaviour as a function of handsfree mobile telephones. *Accident Analysis and Prevention*, *26*, 441 – 451.

Alm, H. & Nilsson, L. (1995). The effects of a mobile telephone task on driver behaviour in a car following situation. *Accident Analysis and Prevention*, *27(5)*, 707 – 715.

Aven, T. (1992). *Reliability and risk analysis*, London: Elsevier.

Batley, R. (2005). Results of HASTE SP model. Unpublished memo, University of Leeds.

De Waard, D. (1996). The Measurement of Driver's Mental Workload. PhD Thesis, Groningen University.

Fuller, R. (2005). Towards a general theory of driver behaviour. *Accident Analysis and Prevention, 37,* 461 – 472.

Gaillard, A.W.K. (1993). Comparing the concepts of mental load and stress. *Ergonomics, 36(9), 991-1005*

Hoyos, C.G. (1988). Mental load and risk in traffic behaviour. *Ergonomics, 31 (4),* 571 – 584.

Jamson, H. & Merat, N. (2005). Surrogate in-vehicle information systems and driver behaviour: effect of visual and cognitive load in simulated rural driving, *Transportation Research*, *Part F (8)*, 79 – 96.

Jamson, S. et al. (2005). AIDE Deliverable D 2.3.1 (in press).

Johansson, E., Engström, J., Cherri, C., Nodari, E, Toffetti, A., Schindhelm, R. and Gelau, C. (2004). Review of existing techniques and metrics for IVIS and ADAS assessment. AIDE Deliverable 2.2.1.

Jürgensohn, Th. (2005). Control theory models of the driver. In Macchi, L., Re, C. & Cacciabue, P.C. (Eds.) Proceedings of the International Workshop on Modelling Driver Behaviour in Automotive Environments. Ispra, Italy, May 2005, 37-42

Kleinman, D.L., Baron, S. & Levison, W.H. (1970). An optimal control model of human response. Part 1: Theory and validation. *Automatica, vol.6.*

Macchi, L., Re, C. & Cacciabue, P.C. (Eds.) Proceedings of the International Workshop on Modelling Driver Behaviour in Automotive Environments. Ispra, Italy, May 2005.

Nilsson, G. (1984). *Speeds, accident rates and personal injury consequences for different road types.* (Report VTI-277). Linköping: Väg- och Trafikinstitutet (VTI).

Recarte, M.A., & Nunes, L. (2002). Mental load and loss of control over speed in real driving. Towards a theory of attentional speed control. *Transportation Research, Part F (5)*, 111 – 122.

Svensson, Å. (1998). *A method for analysing the traffic process in a safety perspective*. Doctoral Dissertation, University of Lund, Lund, Sweden.

Wewerinke, P.H. (1989). *Models of the human observer and controller of a dynamic system.* Ph.D. Thesis, Twente University, Enschede.

Wewerinke, P. & Hogema, J. (2003). Modelling driver behaviour in combined longitudinal and lateral control. Report TM-03-D001, TNO Human Factors, Soesterberg.