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Criteria for driver impairment

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Most traffic accidents can be attributed to driver impairment, e.g. inattention, fatigue, intoxication, etc. It is now technically feasible to monitor and diagnose driver behaviour with respect to impairment with the aid of a limited number of in-vehicle sensors. However, a valid framework for the evaluation of driver impairment is still lacking. To provide an acceptable definition of driver impairment, a method to assess absolute and relative criteria was proposed to fulfil the paradoxical goal of defining impaired driving which is consistent yet adaptable to interindividual differences.

1. Introduction

The professional area of traffic and transport suffers from an abundance of accidents and consequently the loss of time, insurance disbursements (liability), law suits with respect to healthcare (personnel fitness), regulation issues about working hours (driving time), and so on. The consequences of the performance of 'the driver' are central to this field. Every error, failure or lapse of attention may lead to a traffic accident.

It has been estimated that at least 90% of the causes of accidents can be traced to the driver (e.g. Smiley and Brookhuis 1987). Consequently, investigations of the causes of accidents have centred on driver-related variables. The likelihood of spontaneous errors, failures or slips may be related to the driver's energetic state, i.e. the psychophysiological status of the individual with respect to the background level of alertness, awareness, sobriety and physical health (Hockey *et al.* 1986). If the energetic state of the driver is inappropriate or insufficient to sustain a safe and accurate level of vehicular control, the driver is judged to be impaired.

The energetic state of the driver may be influenced by psychological factors such as boredom and physiological variables such as deactivation and muscular aches. Most driver impairment represents an amalgamation of psychological and physiological effects. For example, sleepiness may be characterized by physiological symptoms (e.g. eletroencephalogram [EEG] deactivation, heavy eyelids, yawning) in conjunction with subtle psychological changes such as attentional lapses, irritability

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and slow reactions to traffic stimuli. Similarly, an intoxicated driver cannot sustain safe and accurate vehicular control owing to psychophysiological impact of alcohol on the energetic state. This line of reasoning prompts two related questions: (1) How do we define and quantify an appropriate energetic state to guarantee driver safety? (2) How do we define unsafe levels of vehicular control?

There is broad, consensual agreement among transport professionals and the driving public alike about what constitutes unsafe or undesirable driving. It is common sense to pronounce that sleepy, intoxicated or sick drivers constitute a safety hazard to themselves and to other road users. However, there are theoretical problems surrounding the diagnosis of driver impairment beyond this anecdotal level. In the simplest case, the diagnosis of impairment due to alcohol intoxication is relatively straightforward. The amount of alcohol consumed may be measured by the blood alcohol concentration (BAC); this variable has an exponential relationship with accident likelihood (Borkenstein *et al.* 1974) and most countries have adopted a BAC level as a legal criterion based on this relationship. There is no equivalent index for other categories of driver impairment such as fatigue. This absence may simply be a conceptual limitation. The individual often spontaneously perceives and can report changes in energetic state from a purely phenomenological perspective. In the absence of an anchor scale (such as BAC in the case of alcohol or body temperature in the case of impairment due to a thermal stressor), the multidimensional character of driver impairment renders the concept susceptible to an undesirable level of indeterminacy. Ambiguity at the conceptual level inevitably creates practical problems of measurement and interpretation. This limitation is particularly striking when attempting to measure the impact of multivariate energetic states on a complex skill such as driving.

These problems set the background to the current analysis and discussion. There are practical reasons for devising a logical and consistent framework for the evaluation of driver behaviour. For example, it is now technically feasible to monitor and diagnose driver behaviour with respect to high accident likelihood (Brookhuis and Brown 1992) using a real-time sensor apparatus. However, the feasibility of an electronic device to evaluate such behaviour is dependent on a valid framework for the assessment of driver impairment (Fairclough *et al.* 1993, Brookhuis 1995a). In broader terms, a large number of research papers are published each year in the field of traffic psychology and a consensual framework to evaluate qualitative and quantitative aspects of driver impairment would aid comparisons between studies.

ITS America and the Commission of the European Union launched ambitious programmes in the field of road transport telematics (information and telecommunication systems) to improve the conditions with respect to road safety, transport efficiency and environmental quality. The programmes sought to create favourable conditions for the development of integrated road transport environments through collaborative efforts in information technology and telecommunications applied to road transport. It seems likely that this comprehensive concept reduces political objections to the introduction of many safety measures that include constraints on individual drivers' freedom. Any measure that marginally constrains individual road user behaviour in order to improve safety is more acceptable if it can be shown incidentally also to reduce traffic congestion and air pollution. Certain projects within this programme aim to detect and avoid inadequate vehicle control under conditions where the driver's cognitive, perceptual and motor abilities may become impaired (i.e. accident risk is increased). This could be realized by instant detection of driver impairment followed by the presentation of a warning to the driver (and, if necessary, other drivers in the immediate vicinity) and, again if necessary, terminating with autonomous vehicle control to ensure safe control of the vehicle.

2. Techniques to define driver impairment

The first step towards a definition of driver impairment is finding a means of distinguishing between 'normative' and 'impaired' categories of behaviour. One way is to induce impairment in a systematic and controlled fashion, therefore allowing the study of the continuum from normative to impaired driving. However, this categorization is a contentious procedure as several alternative approaches are possible. Impaired driving by definition implies that the driver is not fit to drive, as we have seen. This may be represented by psychophysiological changes that could be used as a classification index to define levels of driver alertness.

For example, EEG data may be used to index impending sleepiness while carrying out tasks like driving, independently from behavioural measures (Brookhuis *et al*. 1986, Torsvall and Akerstedt 1987, Akerstedt *et al*. 1991, Lal and Craig 2001). It is possible to collect concurrent data from driving behaviour and some well-defined psychophysiological measures and use the latter to categorize the former (Brookhuis 1995b). Among those are also heart rate and heart rate variability for effort and (mental) workload (Mulder 1986, Mulder 1992), facial muscles' activity for effort and emotional load (Van Boxtel and Jessurun 1993), and blink rate, eyelid position and activity for sleepiness (Dingus *et al*. 1987, Stern *et al*. 1994).

The importance of psychophysiological indicators for driver impairment lies in their independence from driver behaviour per se. Psychophysiological variables represent the covert 'costs' associated with overt behaviour (Eysenck and Calvo 1992, Meijman 1997) and hence are indirect indicators of performance impairment.

A number of methods can be used to judge driving impairment based on behaviour; first, letting subjects drive under adverse conditions; second, using accident precursors; and third, using expert observation ratings.

2.1. *Driving under adverse circumstances*

One technique is to manipulate the driving situation in such a (controlled) way that it artificially induces impaired driving. The resulting data are then judged to be representative of impaired driving by definition and may be suitable as a benchmark measure for comparison.

One straightforward method for inducing impaired driving is to have the driver consume an illegal amount of alcohol and complete a journey in actual traffic. The detrimental effects of blood alcohol on driving performance and traffic accidents are well documented as demonstrated (Louwerens *et al*. 1987, Brookhuis 1998). The data collected during this test ride may be used to benchmark impaired relative to normative driving for this particular driver.

Similarly, it may be possible to ask drivers to complete a driving task under conditions where they are impaired by depriving them of their perceptual senses. This technique involves an assessment of primary vehicle control under conditions where areas of the driver's visual field are occluded (Godthelp *et al*. 1984). When driver vision is totally occluded for a while, the effects of 'eyes off the road' time on lane keeping ability may be measured.

Finally, high levels of fatigue could also serve as such according to Brown (1994, 1997) who proposed to define fatigue in terms of the consequences of sustained performance or sleep deprivation.

2.2. *Use of critical incidents ('accident precursors') as markers to define impairment*
The goal of this technique is to expose the driver to a sufficiently high level of an external stressor that the driver is unable to sustain safe performance, i.e. drifts off-road or collides with another vehicle. Extreme forms of the imposed attentional impairments as introduced by De Waard *et al.* (1998) are feasible ways to induce stress in this sense. They had subjects drive while distracted from the road by an extremely demanding visual search task.

There is some logic in reasoning that drivers are impaired if they are unable to avoid collisions or keep the vehicle on the road. Therefore, one may use the critical incident as a marker and analyse the period of activity before this incident via regression analysis (Bekiaris *et al.* 1997, Brookhuis *et al.* 1997, De Waard *et al.* 2001). These techniques may ascertain which variable(s) are the strongest predictors of the critical incident.

2.3. *Use of expert observation ratings of driving*
In some countries in Europe individuals who reach a certain age are required to subject themselves to examination by trained driving instructors, the case of the renewed elderly drivers' licensing. These professionals make an assessment of the individual's capability to drive safely based on their expert examination concerning driving patterns. Formalization of expert observation may be used to develop a categorization for safe versus impaired driving.

A related example is the use of observation of drivers' facial activity in order to index fatigue (e.g. Wierwille and Ellsworth 1994). In this example, a system of scoring facial symptoms of fatigue is designed and observers are trained to score behavioural symptoms of impairment directly from videotape.

These techniques are practical, plausible and feasible, but all have limitations. In the case driving under adverse circumstances, there is an implicit assumption that all categories of driver impairment are equivalent. Hence, impairment due to alcohol is treated as interchangeable with other variables such as sleepiness. Whilst some researchers have emphasized the convergence of impairment variables on simple, laboratory tasks (Dawson *et al.* 1998), comparisons between different types of driver impairment have indicated key differences as well as similarities (Fairclough and Graham 1999). This approach may also produce highly variable and paradoxical results due to individual differences representing the motivations/capabilities of individuals to resist the influence of impairment. For example, Fairclough and Graham (1999) found that the performance of a group who were partially sleep deprived (e.g. 2–3 h of sleep) was equivalent and in some instances slightly superior to a control group. The advantage of using alcohol in driving under adverse circumstances lies in its propaganda strength as a categorization system based on legal and well-accepted criteria. The use of visual occlusion is a rarely used but valid attempt to measure decrements in lane-keeping performance by effectively 'blinding' the driver to normal visual feedback. This method is suitable for the measurement of drivers' lane-keeping abilities, but is very specific to this aspect of driving impairment and the ecological validity of this approach is limited.

The technique described in 'critical incidents' provides a direct link between either behavioural or vehicle input measures and examples of impaired driving. Whereas ethical considerations dictate that the techniques described in driving under adverse circumstances are usually applied under strict precautions such dual controls, closed circuit or simulator investigations, the critical incidents' method must always be applied in a driving simulator. This may raise the usual questions about the perception of risk and drivers' motivation to avoid accidents under artificial conditions (De Waard *et al.* 1999a, b, Farber 1999). A second problem with the 'critical incidents' method is the absence of a valid rationale when one has to decide what size of time window is appropriate to define the period before a critical incident, e.g. small windows of about 1 min or larger windows of say 10 min or more.

The 'expert ratings' method is highly descriptive and provides a subjective analogue to the 'critical incidents' method, i.e. assessment of safe driving is based around those behaviours deemed to be critical to accident causation. The second approach of impairment observation takes the emphasis from primary task measures to overt indicators of energetic state that do not necessarily directly reflect the quality of driver performance. The advantage of these measures is an assumption of increased sensitivity, indicating stages of reduced alertness that occur before full-blown sleepiness, e.g. yawning. The weakness of expert ratings is that it represents an indirect index of driver impairment.

All three approaches have advantages and disadvantages. The problem with investigating the consequences of impairment is that it is a very generalized technique that may often prove inconclusive, i.e. changes due to impairment may not have a strong association with driving safety. Those approaches concerned with antecedents of safety have the advantage of increased specificity, but are difficult to define and operationalize for the purposes of research. A fundamental problem underlies all three methods which is concerned with the definition of driver impairment.

3. Absolute and relative criteria

An adequate representation of driver behaviour is fundamental for the categorization of impairment and the development of criteria to define the division, or 'red line' between the normative and impaired examples of the primary task. These criteria may be formulated in either absolute or relative terms. The former relates to absolute values of behavioural measures, valid for the driving population under all circumstances; the latter relates to baselined values representing intra-individual variability.

Commonly, impaired driving is defined as a statistically significant increase or decrease of a particular measure of driving. For example, in studies of in-vehicle displays, a significant increase of vehicle lateral deviation would be assessed as an impairment effect resulting from attention distraction. In fatigue research, a significant decrease of steering reversal rate may be interpreted as impairment as the driver reduces the fidelity of steering control. This is a natural method for the categorization of impaired driving in an experimental setting since most experiments contain control conditions or control subjects.

The inclusion of a control condition allows the experimenter to assess the *relative* impact of an independent variable on individual driving behaviour. Because impaired driving in this case is always compared with a control or a baseline condition, the only criterion of significant change is dictated by statistical testing. This categorization may be contrasted with those measures that form *absolute* criteria to define impaired driving in general. For example, following a vehicle at a 0.1 s time headway is unsafe and therefore impaired for everybody as the minimum reaction time in a laboratory environment is at least approximately 0.2 s. In other words, absolute criteria are those fixed values that define the absolute red line of demarcation for impaired driver behaviour (Brookhuis 1995a).

There is a degree of interdependence between relative and absolute criteria. The position of 'normal' or 'baseline' driving is crucial in determining the relationship between both criteria. For example, imagine a 'cautious' driver who usually follows at 2 s time headway contrasted with a 'risky' driver who has a normal following headway of less than 1 s. Obviously, the difference between baseline and impaired driving is much smaller in absolute terms for the risky driver than for the cautious driver. In other words, the risky driver leaves a much smaller range for impairment (which may be termed an impairment margin). The width of the impairment margin describes the degree of differentiation between impaired driving and normal driving. In turn, this separation also defines the degree of overlap between the two distributions. The amount of overlap is important as it describes (1) the discriminative properties of the categorization and (2) the potential for false alarms versus undetected impairment when designing assessment criteria around these data. The power of the technique is dependent on these phenomena. An illustrative example will clarify the interdependence of the two types of criteria and the notion of impairment margin.

Suppose the aim is to discriminate drink driving from normal, sober driving by a simple, easily derived driving parameter: the amount of weaving, measured as the standard deviation of lateral position (SDLP). Alcoholic intoxication has the inherent advantage of possessing a benchmark, i.e. the relationship between BAC and accident likelihood (Borkenstein *et al.* 1964). Based on this relationship, in some countries the legal limit of BAC is 0.5 promille, in others it is still 0.8 promille. From the data of Louwerens *et al.* (1987), average SDLPs with these BACs are known values. In the three examples in figure 1, (a) describes (hypothetical) distributions of measured weaving of one particular driver in sober and drunk condition (0.8 promille), giving good separation with a small overlap. The driver in the example is called Mr Average because his SDLPs at 0.8 and 0.5 promille match the average 'population' values as reported by Louwerens *et al.* (1987). Figure 1(b) describes the same driver who is now only marginally drunk (0.5 promille) showing a considerably smaller separation and larger overlap between distributions. In figure 1(c) population values of 0.0 and 0.8 promille are depicted, with wider (because population) distributions, showing that the overlap zone is even further increased, whereas the separation between the two distributions is the same as in figure 1(a).

Thus, the problem is clear; if Mr Average with 0.8 promille is to be caught at all costs, occasionally the in-vehicle detection device, with (relative) criterion set at about 21 to 22 cm SDLP, will give false alarms in about 10% of all cases. If false alarms have to be avoided completely, the detection criterion must be set at about 24 cm SDLP, while drunk Mr Average will then slip through in about 30% of the cases. At 0.5 promille things are much worse, avoiding false alarms by setting the criterion at 24 cm means that Mr Average, now marginally drunk, will slip through in at least 60% of all cases. For the population, the (absolute) criterion must be set at least at 26 cm SDLP, still 'allowing' 60% of really drunk driving. If false alarms are not avoided, drivers generally would never accept such a device, and it will be difficult if not impossible to make this type of in-vehicle detection device compulsory. The individual Mr Average, however, could be forced to drive with a detection device through court judgement after conviction for drunk driving.

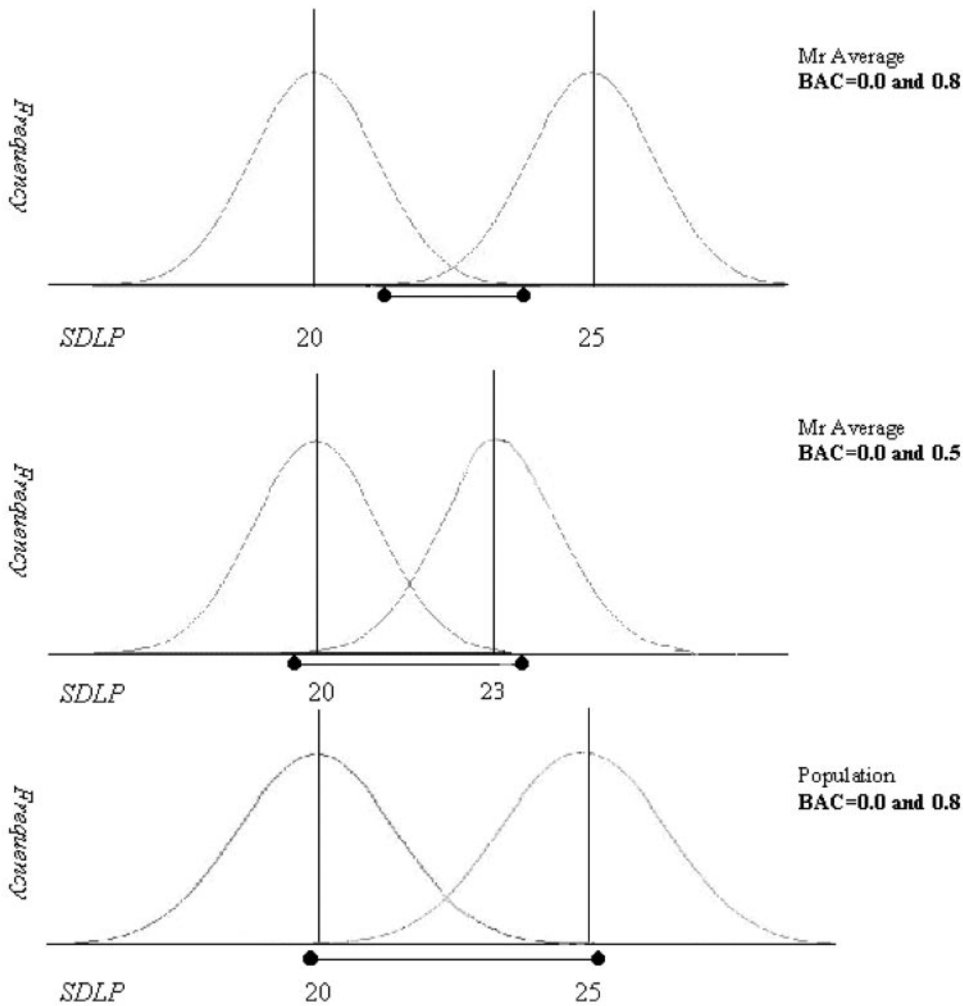

Figure 1. Distribution of weaving for (a, top) one driver, sober and under the influence of 0.8 alcohol, (b, middle) the same driver, sober and under the influence of 0.5 alcohol, and (c, bottom) the population values for sober and 0.8.

4. Categories of driving impairment

There can be little argument that certain categories of accidents (e.g. where the driver loses control of the vehicle and leaves the road) constitute impairment of driving skills; however, impaired driving per se does not inevitably lead to an accident. For example, an intoxicated driver weaving between two lanes benefits from either the absence of vehicles in the adjacent lane or the avoidance reactions of other road users. At the level of vehicle control, accidents where the driver bears the sole responsibility may result from either:

- loss of lateral vehicle control (e.g. lane weaving);
- inappropriate use of lateral vehicle control (e.g. swerving into adjacent lane);

- inappropriate use of longitudinal vehicle control (e.g. speeding, close following);
- concurrent occurrence of the second and third points (e.g. at overtaking); and
- concurrent occurrence of the first and third points (e.g. skidding).

Taking a conceptual step back from traffic accidents, one could define impaired driving as those driver errors which may function as antecedents to actual accidents, as in critical incidents/accident precursors. Harvey *et al.* (1975) defined driver error as 'any action or lack of action by drivers that would require them or other road users to implement a correction in order to make the situation safe again'. Harvey *et al.* performed a roadside observation study of driver errors. Their eight most frequent errors and the categories of vehicle control associated with each are listed below. The five categories of vehicle control described above cannot exist in a vacuum. Therefore, an attempt has been made to provide a series of referents in the driving environment to provide a context to the category of vehicle control.

This subset of driver errors may be used at a behavioural level to describe impaired driver performance. However, to measure these errors, driving behaviour must be decomposed and operationalized into quantitative data. This translation shifts the definition of impaired driving from a behavioural level to a dependent variable or sensor level. In table 2, vehicle measures have been substituted for the appropriate category of vehicle control.

These measures are the building blocks used to define and characterize 'impaired driving' at the sensor level. However, these measures merely describe the pattern of vehicle control in operation at any given time. They do not tell us if driving behaviour may be categorized as impaired or not. For this, we need both the absolute and relative criterias demonstrated earlier.

5. Criteria for impaired driving based on previous studies of impairment

It is proposed that qualitative categories of driver impairment are to be translated into both relative and absolute criteria with respect to the quantifiable measures of driving behaviour. It is proposed that absolute criteria are defined by those instances of driving behaviour deemed to be unsafe in general. These criteria may be defined in a qualitative fashion, e.g. driver running off-road, or in a quantitative manner, e.g. SDLP of the vehicle surpassing a trigger level of 26 cm as in the alcohol case. For the purpose of a first attempt to define impaired driving, initial focus should be on the detection of impairment within a motorway-driving scenario (Fairclough *et al.* 1993). Although motorways are relatively safe, and for that reason not very interesting, their characteristics are constrained and thus represent a simple scenario for the current discussion. The focus will be on the detection of three categories of impaired behaviour: following too closely, straddling lanes and driving more than the speed limit.

A preliminary list of impairment criteria was proposed by Brookhuis (1995a). He characterized criteria in terms of absolute levels (i.e. the cut-off point which defines impaired driving) and relative change (i.e. the relative change which indicates a significant change in individual driver performance). The criteria proposed below are based on work on the effects of illegal levels of alcohol intoxication, visual occlusion, driver inattention and prolonged journey time on driving behaviour. The tables of criteria will thus be constructed for either the group of average drivers or each individual driver.

Table 1. Driver errors and vehicle control.

Error	Vehicle Control
Following too closely	inappropriate longitudinal control relative to the lead vehicle
Overtaking in the face of oncoming traffic	inappropriate lateral/longitudinal control relative to the manoeuvre and the vehicle in the adjacent lane
Overtaking at a junction	inappropriate lateral/longitudinal control relative to the location
Following too closely and overtaking vehicle	inappropriate lateral/longitudinal control relative to the lead vehicle and the manoeuvre performed by the lead vehicle
Changing lanes abruptly	inappropriate lateral control relative to the lane width
Straddling lanes	loss of lateral control relative to the lane width
Driving too fast for the circumstances	inappropriate longitudinal control relative to the legal limit/traffic density

Source: Harvey *et al*. (1975).

Table 2. Driver errors and vehicle measures.

Error	Vehicle measures
Following too closely	time headway to the lead vehicle time-to-collision (TTC) to the lead vehicle
Overtaking in the face of oncoming traffic	speed lateral position of the vehicle time headway to the vehicle in the adjacent lane TTC to vehicle in the adjacent lane
Overtaking at a junction	speed lateral position of the vehicle TTC to the 'give-way' line
Following too closely an overtaking vehicle	speed lateral position of the vehicle time headway to the lead vehicle time-to-collision (TTC) to the lead vehicle
Changing lanes abruptly	steering wheel activity speed lateral position of the vehicle time-to-line crossing
Straddling lanes	steering wheel activity lateral position of the vehicle time-to-line crossing
Driving too fast for the circumstances	speed

- Following too closely: characterized as 'tailgating' where the vehicle's temporal separation from a lead vehicle is assessed.
- Straddle lanes: characterized by an increase of the lateral deviation of the vehicle. This pattern of weaving may occur both within the lane and increase in magnitude between lanes.
- Driving too fast: characterized by the driver breaking the legal speed limit.

Table 3. Definition criteria for following too closely, straddling lanes and driving too fast.

	Absolute change	Relative change
Following too close:		
Time headway to lead vehicle (TTC)	<0.7 s	-0.3 s
Straddle lanes:		
Steering SD	$>1.5°$	$+0.5°$
Lateral deviation (SD) of the vehicle	>0.25 m	$+0.04$ m
Minimum time-to-line crossing (TLC) right lane	<1.3 s	-0.3 s
Minimum time-to-line crossing (TLC) left lane	<1.7 s	-0.2 s
Median TLC (right lane)	<3.1 s	-0.7 s
Median TLC (left lane)	<4.0 s	-1.4 s
Driving too fast:		
Vehicle speed	limit + 10%	+/− 20%

Table 4. Lane-keeping criteria based on visual occlusion.

Measure	Speed (km/h)	Absolute criteria
SDLP	>50	0.25
SD steer	at 60	1.7°
	$>80-120$	1.5°
Median TLC	60	6.0 s
	80	5.7 s
	100	5.0 s
	120	4.2 s
15% TLC	60	3.8 s
	80	3.5 s
	100	3.1 s
	120	2.9 s
Minimum TLC at different speeds		1.1 s

Note there is a good deal of commonality between the measures which comprise each behavioural category. The definition of these values should allow a tentative specification of impairment criteria.

Godthelp (1988) carried out several studies of lane keeping under conditions of complete visual occlusion. He found that time-to-line-crossing (TLC) measures varied as a function of speed. In this case, all measures refer to lane straddling, e.g. the ability to stay in a lane. During this experiment subjects had to neglect path errors until the moment the vehicle heading could still be comfortably corrected to prevent crossing of the (motorway) lane boundary. These data are translated into criteria in table 4.

6. Integration

Separate measures have been discussed until now such as SDLP, TTC, TLC, speed measures and steering wheel measures. Each measure has its value in determining driver impairment. However, an integrated diagnosis, or in other words a classification based on an integration of the flow of information by measures from a whole lot of vehicle sensors, would potentially be much more powerful (De Waard and Brookhuis 1991, Fairclough *et al.* 1993, Brookhuis 1995a). In one of the EU projects (SAVE; Bekiaris *et al.* 1997, Brookhuis *et al.* 1997), the processing of the impairment-sensitive sensor data has been realized through an Integrated Monitoring Unit. This device is divided into three functional units: the vehicle sensors from which instantaneous driving data are collected, an advanced diagnosis or classification subsystem that analyses and interprets these data, and the storage/retrieval device used as a template of normal (normative) driving. The diagnosis or classification subsystem consists of a series of processing algorithms in sequence, centred around a Neural Network. The sequence consists of preprocessing by a suitable form of principal component analysis, processing by an artificial neural net (using a Barycentric Correction Procedure Sequential Learning Algorithm), after which a final diagnosis is performed with the aid of fuzzy logic (De Waard *et al.* 2001). A series of validation experiments have been carried out to test and tune the system. Alcohol intoxication, serious fatigue and inattention have been subjected to classification procedures. It turned out that a correct diagnosis of at least 90% could be attained in case of impairment, but only for individual drivers based on their idiosyncratic, normative template. The reference to relative criteria appeared to be feasible for the conceptualization of a driver impairment-monitoring device.

7. Conclusion

Several alternative schemes to approach monitoring impaired driving have been discussed, notably comparing performance with the decrement produced by illegal levels of alcohol intoxication and visual occlusion. It is clear, in principle, that driving after too much alcohol or when blindfolded can only impair vehicle handling. However, these impairment manipulations are not equivalent and may produce specific effects that are not generalizable to fatigue or illness, for example. Nevertheless, the advantage of the manipulation of alcohol is that most countries have prescribed a legal limit for driving while intoxicated. Therefore, the drunk-driving case could have an exemplary function as both an impairment category in its own right and as the nearest standard available for a legal definition of driver impairment.

The use of a multidimensional approach (i.e. using psychophysiology, observation and direct measurement of driver performance for the assessment of impaired driving behaviour) has some advantages in terms of improved sensitivity and validity. The problems of sensitivity have been discussed with reference to absolute and relative criteria. It has been argued that both criteria are necessary to fulfil the paradoxical goal of providing a definition of impaired driving that is consistently adaptable to interindividual differences. However, within the current context, it is essential that overt driving performance functions as an anchor point for all other measures. The development of criteria to define driver impairment is necessary in order to:

- define the validity of other indicators from different domains of measurement; and
- identify the magnitude of performance decrement to provide contextual information to a warning device.

Finally, a method has been proposed and discussed here to index driver impairment. The approach described presents a decomposition of driving performance into operationalized measures of driver behaviour with the aim of monitoring its safety. This analysis represents the first step towards the development of realistic criteria for determining impaired driving. The crucial aspect of criteria development concerns the definition of the magnitude of change and those boundaries of driver impairment that separate safety-critical changes from non-safety-critical changes. Areas such as age, experience, medical history and circumstantial factors have been neglected. However, this is only the beginning and a potentially important step which, with the help of experts in the field, will hopefully lead to valid, integrated driver monitoring systems.

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