

Human Factors Guidelines in Highway Design: Discussion paper for Brussels Meeting, june 8-9 2000

Wiel Janssen and Richard van der Horst
TNO Human Factors
Soesterberg, The Netherlands

1. Introduction

This paper has two parts. In the first we list a number of questions dealing with what it means when we try to incorporate 'human factors' into highway design guidelines. The second part focuses on the state of knowledge with respect to specific driver characteristics that could qualify for being incorporated. From this, recommendations for research to be undertaken next are derived.

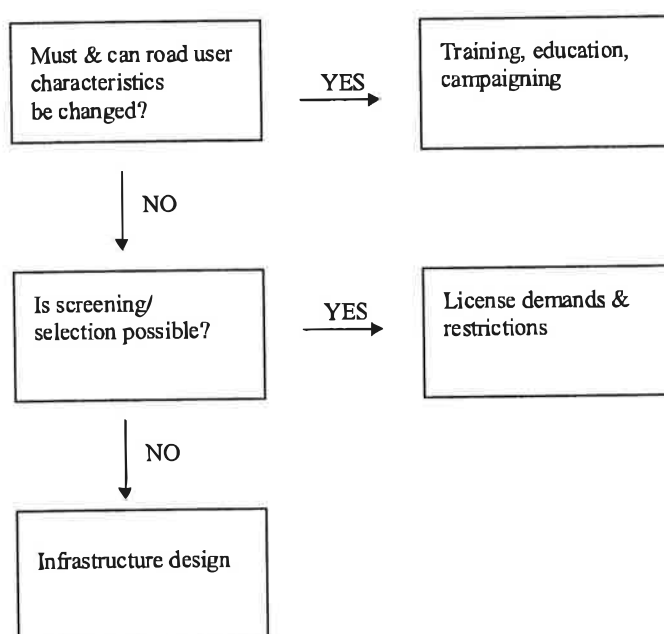
2. Basic questions

2.1 Accomodating different kinds of characteristics

The characteristics of people (i.e., road users) can, for the purpose of this discussion, be divided into three categories (see Fig.1):

- Those that can be changed by training and education.
- Those that cannot really be changed, and which can be subjected to selection procedures.
- Those that cannot really be changed, and to which the infrastructural design should be adapted.

Fig. 1



We are, of course, only considering characteristics that are relevant to taking part in traffic: that is, which have a demonstrated connection to behavior, future accident involvement, etc.

Deciding to which category a given characteristic belongs should, at least, take the following elements into account:

- Its importance, in terms of its effects on behavior and accident risk (i.e., the steepness of its dose-effect curve).
- Its distribution in the population.
- Its 'intrinsic' changeability.

2.2 Accomodating relevant driver chacteristics in highway design guidelines

It seems a straightforward matter to adapt the design to a relevant driver chacteristic. For example, if it were established that the 95th percentile of the distribution of standard deviations of lateral position is 25.0 cm at design speed it would be easy to calculate the minimum lane width that would make an involuntary lane exceedance almost impossible to occur.

A complicating factor to be mentioned here is the possibility of compensatory behavior from the driver's side. For example, if the lane width is extended to accommodate what theoretically is the 95th percentile some drivers may now start driving less carefully, thereby shifting the existing distribution of lateral position. It is difficult to foresee this type of effect and the ramifications it may have, and to anticipate on it.

2.3 Accomodating low or moderate correlations between relevant driver characteristics

A problem occurs when the design of an infrastructural object should be adapted to different relevant driver characteristics at the same time. If these characteristics are only weakly correlated within drivers – which is very often the case – the group that meets *all* cut-off criteria (like the 95th percentile) gets smaller with the addition of each next characteristic.

2.4 Accomodating future trends

It is difficult to predict how future driver populations will be composed. For this we are completely dependent on other sciences. Even those, however, will not be able to predict developments for more than a few basic demographic characteristics.

Other trends, particularly those that have to do with the introduction of new technology in the traffic system, will also affect driver behavior. In this area there is some level of agreement among experts about how things will proceed, and what the associated time perspectives are.

2.5 Defining what are the important driver characteristics

There may be two reasons why an individual characteristic is important.

First, an increasing 'dose' of the characteristic may have an effect that rises at a fast rate, or the effect may already attain a level that is significant in an absolute sense at a relatively low dose. These may be reasons why the effect should be taken into account. The second reason is that the distribution of the characteristic in the population may be such that there is an overrepresentation in the critical tail of the distribution. For example, if high age were predictive of an increased accident involvement there would be more reason to worry if there were many people of high age than if there were only a handful. Thus, it is sheer numbers also that can make a characteristic important.

A somewhat provocative standpoint can be taken with respect to the level at which characteristics should be considered: is it really worthwhile to look into, e.g., drivers' personality characteristics as contributory factors, or is it enough to just measure behavior shown on the road as the basis for highway design?

2.6 Deciding on cut-off levels

When designing a consumer product it is unavoidable that a certain percentage of the population will have difficulties to use the product.

2.7 Deciding what are the appropriate output parameters

Finally, it should be agreed what it is we want to achieve. In road traffic, this could be:

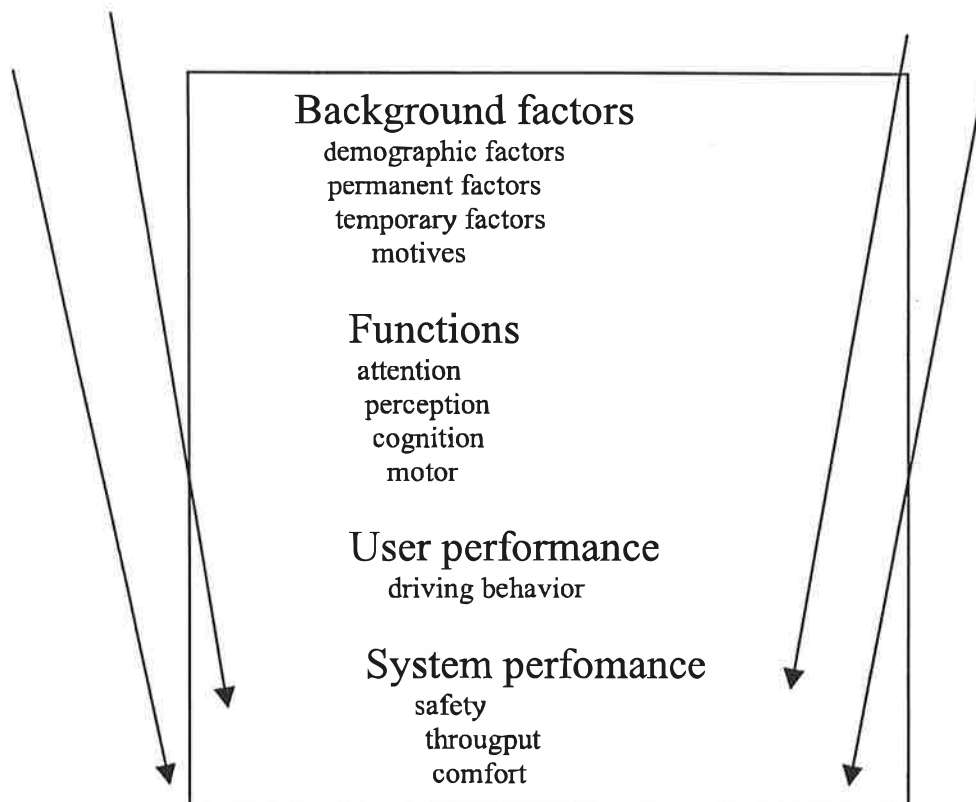
- Predictable and appropriate user behavior, in terms of speed, speed variability, lateral position keeping, car following, etc.
- Maximal driver comfort.
- Minimal accident risk.
- Maximal throughput.

3. An inventory of driver characteristics and their relation to system performance

On first sight, there hardly appear to exist individual characteristics that have *not* been considered for their connections with driving behavior or accident involvement. This sounds as if it should now be easy to draw an overall picture of this area. When we attempted to do so (Janssen, Lourens and Goebel, 1998; see also Stembord and In 't Veld, 1999) matters turned out to be somewhat more diffuse than expected.

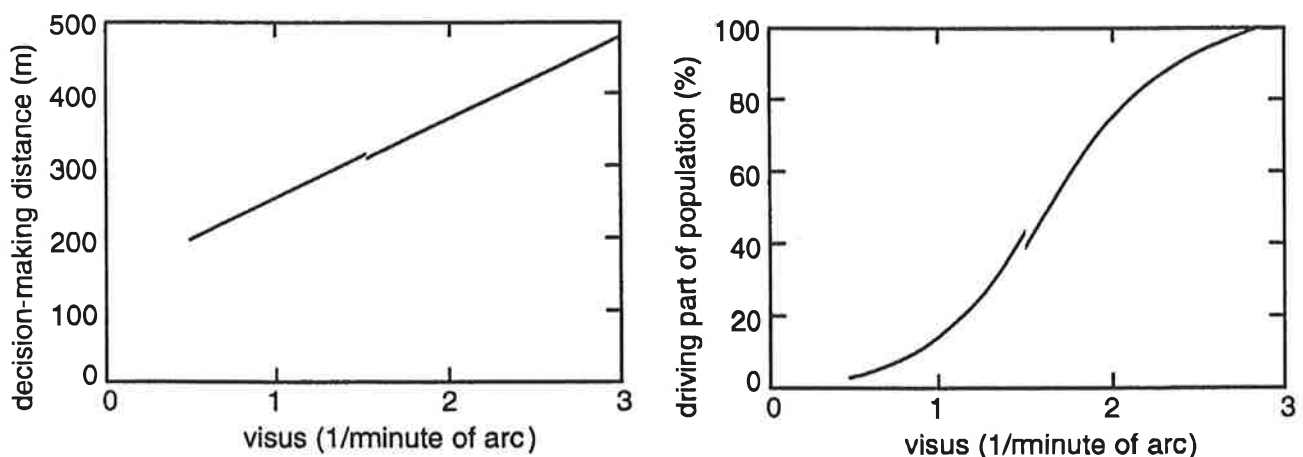
In order to structure the findings from the research literature we used a descriptive 'funnel' model, in which layer-by-layer various rubrics of human factors (and levels within them) were listed: see Fig. 2. The reasoning is that it is, first of all, the background factors of road users that determine how certain information-processing functions are performed. These in turn lead to certain behavior on the road, which finally results in certain system performance qualities (safety, throughput, comfort).

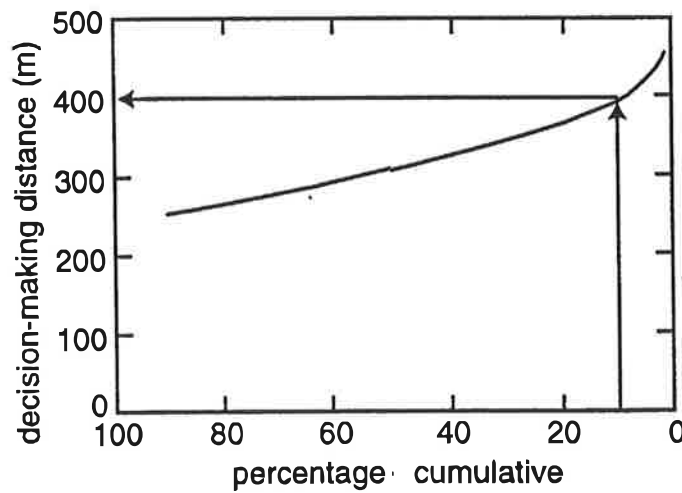
Fig. 2 Ordering of (categories of) characteristics in 'funnel' model



For all separate characteristics we looked for *dose-effect functions* as well as *population distributions* of the characteristic (for the Netherlands). The multiplication of these two curves results in a function relating the percentile of the distribution a given road user is at to the effect, i.e., the performance in terms of behavior, safety, etc. See Fig. 3 for an example. For many characteristics, however, this 'ideal' approach could not be followed because the required data appeared not to be available.

Fig. 3 Distance at which name on sign can positively be identified is a function of acuity. Distribution of acuity in driving population is known. The two functions together permit the assessment of the effect of different cut-offs (percentiles).





In this paper the results cannot be presented in detail. The following is an outline of what appeared to be the prominent patterns in the research literature. In this, we have restricted ourselves to the dose-effect functions, this being the essential first step in tying the evidence together.

3.1 Background characteristics and performance

- Demographic characteristics

	Effect on driving behavior?	Effect on accident involvement?
Gender	Yes	Yes
Age	?	Yes
Nationality	Yes	Yes
Driving experience	Yes	Yes
Socio-econ. Stratum	?	No
Annual mileage	?	Yes

Gender. Men drive significantly faster than women in some conditions (Hendrickx, 1991). Accident involvement is higher for men than women, in an absolute sense. However, this is reversed when mileage is taken into account ('Traffic Test', undated).
Age. There is an inverse-U relationship between age and accident involvement (Massie, 1995). However, this is moderated by experience (Maycock, 1997). No systematic study relating driving behavior to age could be traced.

Nationality. There are bits of evidence suggesting that nationals driving in other than their own countries experience more than their share in accident involvement, and that this is related to the quality of their driving behavior (Dostal & Dostal, 1996: data for Germany).

Driving experience. This variable has already been mentioned under 'Gender', as it interacts with that variable. Experience also affects the quality of driving behavior (e.g., Kuiken & Groeger, 1991).

Socio-economic stratum. The results on this variable are inconsistent and conflicting (e.g., Zlatoper, 1991; Keeler, 1994; Chipman, 1995; Abdallah et al., 1997).

Annual mileage. The final word on the relation of this variable with accident involvement could well have been said by Maycock (1997): although a high annual mileage increases risk simply through exposure, those who drive more have a lower accident involvement

per mile driven. Thus, the resulting curve is negatively accelerating. It has not been traced in what way this originates from driving behavior (Kuiken & Groeger, 1991).

- Permanent characteristics

	Effect on driving behavior?	Effect on accident involvement?
Intelligence	?	No
Field-dependence	Yes	No
Attitudes	?	No
Life-style	?	Yes
Sensation seeking	Yes	Yes
Handicaps	Yes	Yes
Anthropometric variables	No	No

Intelligence. There is no evidence that intelligence is related to road accident involvement, except perhaps at the very low end of the scale (Elvik, 1989).

Field-dependence. This is the aptitude to resist interfering contextual information when looking for a certain visual pattern. It is tested by means of the so-called 'Embedded Figures Test'. While research has shown that there may be some effects on driving behavior, there appears to be no relationship with accident involvement (e.g., McKenna, 1986; Quimby & Watts, 1981).

Attitudes. A review by Assum (1997) concludes that attitudes are not reflected in relative accident involvement, when due corrections (for age and annual mileage) are applied. We found no reported research on the effects of attitudes on driving behavior.

Life-style. Tillman and Hobbs in 1949 wrote: 'A man drives as he lives.' Judging from recent research there may be more than a grain of truth in this after all. Gregersen and Berg (1994) related certain 'life-styles' of young Swedish driver subjects – composite profiles of everyday activities and interests – to their accident involvement. There appeared to be 4 'high risk' and 2 'low risk' life-styles, the latter being almost exclusively practised by women. The paper did not report on actual driving behavior.

Sensation seeking. This is an individual's inclination to indulge in new, complex and intense experiences, including the willingness to run the associated physical, social, legal and financial risks (Zuckerman, 1994). Modest correlations with several driving behavior parameters have been found (speeding, close following: Jonah, 1997; Heino, 1996), as well as with accident involvement (Jonah, 1997).

Handicaps. Cardiac and vascular diseases, diabetes, epilepsy, Alzheimer's disease, and migraine are all long-lasting conditions that have been shown to be associated with disproportionate accident involvement (the degree depending on the specific ailment). Most of this evidence has been summarized by Elvik (1989). For none of these conditions is there research that deals with effects on driving behavior. For (some types of) brain disorders and for Parkinsonism there is evidence of negative effects on driving behavior, but there are no reports on accident risk.

Anthropometric variables. There is not much to mention with respect to this category. Presumably, driving an automobile has become so easy in a strictly physical sense, and

cabins are so well-designed, that there cannot be much differentiation with respect to driving behavior or accident risk.

- Temporary characteristics

	Effect on driving behavior?	Effect on accident involvement?
Alcohol	Yes	Yes
Cannabis	Yes	No
Diazepam	Yes	No
Fatigue	Yes	Yes
Stress	?	Yes
Time-of-day	Yes	Yes

Alcohol. The behavioral as well as the consequent accident involvement effects of alcohol intake appear to be sufficiently documented by now (e.g., Stark, 1987).

Cannabis. Moskowitz (1986) concludes that there is probably no effect of cannabis intake on the ensuing accident risk. Some aspects of driving behavior seem to suffer, while others may even get better (Smiley, 1986; Robbe, 1994).

Diazepam. The state of affairs seems to be much the same as for cannabis (O'Hanlon et al., 1982).

Fatigue. It is difficult to single out the effect of fatigue from that of other factors, notably time-of-day. An effort by Folkard (1997) to do so resulted in a function of accident risk against time-on-duty that has a local maximum at about 2 to 4 hrs, with a further increase in risk appearing after approximately 12 hrs. A behavioral study by Riemersma et al. (1977) also demonstrated the development of negative effects after 2 to 4hrs of driving.

Stress. Much of the epidemiological research in this area is weak, because of its retrospective nature and its reliance on self-reports. What other research there is, however, suggests that there is a significant relationship between life stress and accident risk (McMurray, 1970). There appears to be no systematic research on the effects of stress (levels) on actual driving behaviour.

Time-of-day. According to Folkard (1997) accident involvement has primary peaks at 3 am and 3 pm, which are probably related to circadian rhythms. Secondary peaks are at 2 am, 2 pm, and 9 pm. In a simulator study by Lenne et al. (1997) Ss' speed choice as a function of time-of-day showed a surprising resemblance to the Folkard cycle.

- Motives.

There are some isolated findings which show an effect of certain motivational factors on behavior and/or accident risk. It appears to be particularly well-established that high-risk driving is associated with being in a company or lease vehicle (e.g., Rajalin, 1994).

3.2 Information-processing functions and performance

- Attention.

	Effect on driving behavior?	Effect on accident involvement?
Divided attention	?	Yes
Attention shifts	?	Yes

Divided attention. The capacity for sequential or parallel monitoring of several relevant objects can be expressed as a 'Useful Field of View' (Ball et al., 1993). This has been shown to correlate with accident involvement for drivers aged over 55.

Attention shifts. The capacity to shift attention swiftly to the next relevant object is regarded by some as an essential element of driving ability. It can be measured by laboratory tests, such as the dichotic listening task (DLT; Gopher & Kahneman, 1971). Modest correlations between these tests and accident involvement have been reported (Kahnemann et al., 1973; Mihal and Barrett, 1976; Aviolo et al., 1981, 1985). However, this type of test, consisting in monitoring whether certain sounds are presented in one ear or the other, may not really pinpoint the attention shifts that are most prominent in traffic. The shifts in traffic may be more of a mixture of active inspection of the environment and attention being passively, and involuntarily, drawn by conspicuous objects.

- Perception

	Effect on driving behavior?	Effect on accident involvement?
Vision	Yes	No
Audition	?	?
Motion perception	?	?

Vision. There is now reasonable agreement that elementary visual parameters, like static acuity, are not predictive of future accident involvement (Burg, 1967, 1968; Hills and Burg, 1978). Compensation, in the sense of not (being allowed to) taking part in traffic may be of influence here. 'Higher-order' characteristics are more properly regarded as aspects of attention (see the previous paragraph).

There are relations with driving-related parameters, however, like identification and readability distances of signs.

Audition. We found no literature on the effects of auditory characteristics on driving behavior or accident involvement.

Motion perception. The same is true for this aspect. For example, we have not been able to locate research dealing with an individual's susceptibility to motion sickness, or other vestibular characteristics, as a factor that might affect his driving capabilities.

- Cognition

	Effect on driving behavior?	Effect on accident involvement?
Knowledge	?	No
Risk perception	?	Yes

Decision making	?	Yes
-----------------	---	-----

Knowledge. Elvik's (1989) review summarizes the literature by concluding that no relationship has been shown to exist between road user's knowledge of traffic rules and their accident involvement.

Risk perception. There is some evidence showing that drivers who are slow in recognizing imminent dangers will be overinvolved in road accidents (Quimby & Watts, 1981).

Decision making. The relevant aspect appears to be the general *thoroughness* with which people make decisions on their everyday issues. Scores on the self-rated Decision Making Questionnaire (DMQ), which cover this characteristic, are reflected in road accident involvement, according to West et al., 1992 and Parker et al., 1995).

For all three cognitive characteristics considered there does not appear to be research relating the characteristic to actual driving behavior.

- Motor functions

	Effect on driving behavior?	Effect on accident involvement?
Reaction time	?	No

The issue here boils down to whether someone's quickness of responding to relevant stimuli is related to the quality of his driving performance and/or his future accident involvement. An early review by Goldstein (1962) concludes that this is hardly the case ($r = .17$, maximum, over several studies). Compensation, possibly in the form of acting more carelessly when one knows that one is quick in replying, may play a role (cf. the overrepresentation of young male drivers in road accidents).

3.3 Behavioral characteristics and system performance

In this category, certain aspects of driving behavior per se are considered for their capacity of predicting accident involvement.

	Effect on accident involvement?
Driver type	Yes
Violations/driver record	Yes
Behavioral parameters	Yes

- Typologies.

A typology of drivers would exist when a limited number of *patterns* in relevant parameters were found, and a procedure to assign each and every driver to one and only one of the patterns. Several driver typologies have been developed over the years, including those of Quenault (1966, 1967a,b, 1968 a,b) and Risser et al. (1983). Despite some methodological drawbacks in some of these studies (e.g., no control for exposure) it

is probably fair to say that driver type has been demonstrated to be related to accident involvement.

- Violations/driver record.

Several papers (Mercer, 1989; Peck, 1993; Rajalin, 1994) demonstrate that driver records, in combination with exposure data, are predictive of accident involvement. It also appears that self-rated violation data are good enough to replace the 'objective' data in the driver record (Reason et al., 1990; Parker et al., 1995).

- Driving behavior.

It is a central question of traffic safety science what the quantitative functions are relating behavioral parameters (speed, speed variability, lateral position keeping, headways, TTCs, TLCs, etc.) to accident risk (probability and severity, both of single-vehicle and multi-vehicle accidents). Only little exists in the sense of well-developed theoretical frameworks (for speed and speed variability, by Nilsson, Koornstra, and Salusjaervi).

3.4 Conclusions

It may not be too apparent from the compressed descriptions given here, but the field is rather bewildering for the sheer number of characteristics investigated and for its heterogeneity in methodologies, statistical treatments, completeness and type of dose-effect functions obtained, etc.

Nevertheless, it is clear that a number of useful effects exist and are waiting to be applied. On the other hand, the investigation of several variables that may be very relevant has hardly started. Among the latter should be counted:

- (1) Life-style, i.e., composite profiles as interrelated patterns of rather mundane characteristics that are more descriptive of an individual than simple unidimensional variables.
- (2) Attentional characteristics. Of the information-processing functions, attention – the stage preceding the actual processing by the senses – appears to be of central relevance. This pertains, on the one hand, to the 'Useful Field of View', and on the other to the capacity to shift attention from one object to another.
- (3) Decision-making characteristics. Individuals differ in the way in which they reach decisions. If the situation is risky, the perception of the risk and the thoroughness with which the decision is taken appear to be of prime importance.
- (4) Driving behavior parameters. If safety is a desired outcome of the highway design process it should be known what the accident risks associated with certain driving behaviors are. This can only be the case if quantitative relationships are developed that link behavioral parameters to the ensuing accident probability and/or severity.

4. Priorities for a research agenda

The four identified issues qualify for being proposed as forming the research agenda for this group.

The research should result in the following:

- (1) Dose-effect functions for the relevant characteristics. Care should be taken:
 - that the methodologies applied for the separate issues are identical

- that complete functions are produced, rather than incomplete or dichotomous ones
- that the estimates of effects are in standardized form, so that they can be compared across the different characteristics.

(2) Population distributions for the relevant characteristics. While this half of the story has not been discussed in this paper it is sure that they are woefully lacking or incomplete for most of the relevant characteristics. Yet they are absolutely required in order to assess what the ultimate effects of design guidelines will be.

5. References

- Abdallah, I.M., Raeside, R., Barker, D. & McGuigan, D.R.D. (1997). An investigation into the relationships between area social characteristics and road accident casualties. *Accident Analysis & Prevention*, 29, 583-593.
- Assum, T. (1997). Attitudes and road accident risk. *Accident Analysis and Prevention*, 29, 153-159.
- Aviolo, B.J., Alexander, R.A., Barrett, G.V. & Sterns, H.L. (1981). Designing a measure of visual selective attention to assess individual differences in information processing. *Applied Psychological Measurement*, 5, 29-42.
- Aviolo, B.J., Kroeck, K.G. & Penek, P.E. (1985). Individual differences in information-processing ability as a predictor of motor vehicle accidents. *Human Factors*, 27, 577-587.
- Ball, K., Owsley, C., Sloane, M.E., Roenker, D.L. & Bruni, J.R (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology & Visual Science*, 34, 3110-3123.
- Burg, A. (1967). The relationship between vision test scores and driving record: general findings. Rept. 67-24, Los Angeles, Dept. of Engineering, University of California.
- Burg, A. (1968). Vision test scores and driving record: additional findings. Report 68-27, Los Angeles, Dept. of Engineering, University of California.
- Chipman, M.L. (1995). The role of exposure, experience and demerit point levels in the risk of collision. *Accident Analysis and Prevention*, 14, 465-483.
- Dostal, G. & Dostal, A.W. (1996). Verkehrssicherheitsprobleme infolge von Zuwanderung. Bergisch Gladbach: BAST, Heft M66.
- Elvik, R. (1989). Human factors contributing to road accidents. Etterstad: Institute of Transport Economics, Working Paper O-1481.

Folkard, S. (1997). Black times: temporal determinants of transport safety. *Accident Analysis and Prevention*, 9, 417-430.

Goldstein, L.G. (1962). Human variables in traffic accidents: A digest of research and selected bibliography. Washington, DC: National Academy of Sciences, National Research Council.

Gopher, D. & Kahneman, D. (1971). Individual differences in attention and the prediction of flight criteria. *Perceptual and Motor Skills*, 33, 1335-1342.

Gregersen, N.P. & Berg, H.Y. (1994). Lifestyle and accidents among young drivers. *Accident Analysis and Prevention*, 26, 297-303.

Heino, A. (1996). Risk taking in car driving: perceptions, individual differences and effect of safety incentives. Ph.D. Thesis, University of Groningen.

Hendrickx, L.C.W.P. (1991). How versus how often; the role of scenario information and frequency information in risk judgment and risky decision making. Ph.D. Thesis, University of Groningen.

Hills, B.L. & Burg, A. (1978). Reanalysis of California driver-vision data: general findings. *Transportation Research Record*, 625, 47-50.

Janssen, W.H., Lourens, P.F. & Goebel, M. (1998). Road user characteristics and their relation to behaviour and safety (in Dutch). TNO Human Factors, Rept. No. TM-98-C042.

Jonah, B. (1997). Sensation seeking and risky driving: A review and synthesis of the literature. *Accident Analysis and Prevention*, 29, 651-666.

Kahneman, D., Ben-Ishai, R. & Lotan, M. (1973). Relation of a test of attention to road accidents. *Journal of Applied Psychology*, 58, 113-115.

Keeler, T. (1994). Highway safety, economic behavior, and driving environment. *The American Economic Review*, 84, 684-693.

Koornstra, M. (1990). Analysis of the safety effects of changes in driving speeds: a mathematical-theoretical analysis (in Dutch). Leidschendam: SWOV.

Kuiken, M.J. & Groeger, J.A. (1991). Report on feedback requirements and performance differences of drivers. Groningen: Traffic Research Centre.

Lenne, M., Triggs, T.J. & Redman, J.F. (1997). Time of day variations in driving performance. *Accident Analysis and Prevention*, 29, 431-437.

- Massie, D.L., Campbell, K.L. & Williams, A.F. (1995). Traffic accident involvement rates by age and gender. *Accident Analysis and Prevention*, 27, 73-87.
- Maycock, G. (1997). Accident liability – the human perspective. In T. Rothengatter & E. Carbonell Vaya (Eds.), *Traffic and Transport Psychology: Theory and Application*. Amsterdam: Pergamon, 65-76.
- McKenna, F.P., Duncan, J. & Brown, I. (1986). Cognitive abilities and safety on the road: A re-examination of individual differences in dichotic listening and search for embedded figures. *Ergonomics*, 29, 649-663.
- McMurray, L. (1970). Emotional stress and driving performance: The effect of divorce. *Behavioural Research in Highway Safety*, 1, 100-114.
- Mercer, G.W. (1989). Traffic accidents and convictions: group totals versus rate per kilometer driven. *Risk Analysis*, 9, 71-77.
- Mihal, W.C. & Barrett, G.V. (1976). Individual differences in perceptual information processing and their relation to automobile accident involvement. *Journal of Applied Psychology*, 61, 229-233.
- Moskowitz, H. (1986). Personal communication in Smiley & Brookhuis, 1987.
- Nilsson, G. (1984). Speeds, accident rates and personal injury consequences for different road types. Linköping: VTI, Rept. VTI-227.
- O'Hanlon, J.F., Haak, T., Blaauw, G.J. & Riemersma, J.B.J. (1982)). Diazepam impairs lateral position control in highway driving. *Science*, 217, 79.
- Parker, D., West, R., Stradling, S. & Manstead, A.S.R. (1995). Behavioral characteristics and involvement in different types of traffic accident. *Accident Analysis and prevention*, 27, 571-581.
- Peck, R.C. (1993). The identification of multiple accident correlates in high risk drivers with specific emphasis on the role of age, experience and prior traffic violation frequency. *Paper presented at Symposium on 'Behavioral factors that determine accident rates', Santa Monica, CA*.
- Quenault, S.W. (1966). Some methods of obtaining information on driver behaviour. Crowthorne, UK: Road Research Laboratory, RRL Report 25.
- Quenault, S.W. (1967a). Driver behaviour – safe and unsafe drivers. Crowthorne, UK: Road Research Laboratory, RRL Report 70.
- Quenault, S.W. (1967b). The driving behaviour of certain professional drivers. Crowthorne, UK: Road Research Laboratory, RRL Report 93.

Quenault, S.W. (1968a). Driver behaviour – safe and unsafe drivers. II. Crowthorne, UK: Road Research Laboratory, RRL Report 146.

Quenault, S.W. (1968b). Dissociation and driver behaviour. Crowthorne, UK: Road Research Laboratory, RRL Report 212.

Quimby, A.R. & Watts, G.R. (1981). Human factors and driving performance. Crowthorne, UK: Transport and Road Research Laboratory, Report LR 1104.

Rajalin, S. (1994). The connection between risky driving and involvement in fatal accidents. *Accident Analysis and Prevention*, 26, 555-562.

Reason, J.T., Manstead, A.S.R., Stradling, S.G., Baxter, J.S. & Campbell, K. (1990). Errors and violations on the road: a real distinction? *Ergonomics*, 33, 1315-1332.

Riemersma, J.B.J., Sanders, A.F., Wildervanck, C. & Gaillard, A.W.K. (1977). Performance decrement during prolonged night driving. In Mackie, R.R. (Ed.), *Vigilance. Theory, Operational Performance, and Physiological Correlates*. New York, Plenum, 41-58.

Risser, R., Schmidt, L., Brandstaetter, C.H., Bukasa, B. & Wenninger, U. (1983). Verkehrspsychologischer Testverfahren und Kriterien des Fahrverhaltens. Wien: Kuratorium fuer Verkehrssicherheit, 1983-06.

Robbe, H.J. (1994). Effects of cannabis on driving behaviour. Ph.D. Thesis, University of Leiden.

Salusjaervi, M. (1990). Finland. In G. Nilsson (Ed.), *Speed and safety: research results from the Nordic countries*. Linköping: VTI.

Smiley, A., Noy, I. & Tostowaryk, W. (1986). The effect of marijuana alone and in combination with alcohol on driving performance. In P.C. Noordzij & R. Roszbach (Eds.), *Alcohol, Drugs and Traffic Safety*. Amsterdam: Elsevier.

Smiley, A. & Brookhuis, K.A. (1987). Alcohol, drugs and traffic safety. In J.A. Rothengatter & R.A. de Bruin (Eds.), *Road Users and Traffic Safety*. Assen/Maastricht: Van Gorcum, 83-104.

Stark, D.C. (1987). The risk of fatal accidents to drinking drivers and pedestrians. In J.A. Rothengatter & R.A. de Bruin (Eds.), *Road User Behaviour: Theory and Research*. Assen/Maastricht: Van Gorcum, 387-395.

Stembord, H. & in 't Veld, R. (1999). Vehicle and driver characteristics: vital components in road design. *Transportation Research Record*, in press.

Tillman, W.A. & Hobbs, G.E. (1949). The accident prone automobile driver: A study of the psychiatric and social background. *American Journal of Psychiatry*, 106, 321-331.

'Traffic Test' (undated). PROV – enquetes.

West, R., Elander, J. & French, D. (1992). Decision making personality and driving style as correlates of individual crash risk. Crowthorne, UK: Transport and Road Research Laboratory, TRRL Contractors Report 309.

Zlatoper, T.J. (1991). Determinants of motor vehicle deaths in the United States: A cross-sectional analysis. *Accident Analysis and Prevention*, 23, 431-436.

Zuckerman, M. (1994). Behavioural Expressions and Biosocial Bases of Sensation Seeking. Cambridge: University of Cambridge Press.

