DRIVER PERCEPTION OF ROADWAY, TRAFFIC AND ENVIRONMENT: A BASIC HUMAN FACTOR TO BE CONSIDERED IN ROAD DESIGN STANDARDS

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ABSTRACT

More than 40 thousand people are killed and more than 3 million injured each year in road traffic accidents in both the United States and the European Union. In Europe 99 percent of fatal transportation accidents are road traffic related. More than 50 percent of all road crashes are attributed at least partly to late or missed perception of relevant information to avoid the accident. Safe driving requires adequate and efficient information gathering and processing from relevant sources within the road environment. A continuous input, in particular visual input, is essential for the orientation on the road. Orientation starts with the development of an internal representation of the road and ends with safe guidance and control of the vehicle. Perception is thereby the most important single basis for the drivers' decision making. Without knowledge about the actual traffic situation, organisation of appropriate and safe driving behaviour is not possible. Therefore, perception is a key issue in maintaining a high level of road safety. The design of a road should be in accordance to the perceptual capabilities of the driver. Changes in the design must be recognizable by the driver and transitions must be long enough to react appropriately. An extensive worldwide review of road design guidelines revealed that in most guidelines perception is underrepresented. The question of relevant information for driving tasks, optical guidance, perceptual illusions, reaction to combined signals as well as perception at night and under poor vision conditions are not adequately considered in the reviewed guidelines. Moreover, perceived road features may mislead drivers into making wrong decisions. Is it possible to construct roads in such a way that they are self-explaining in the sense that design features guide drivers to safe behaviour without further signs and signalling? This paper proposes recommendations with respect to perception for the consideration of human factors in the design of roads. Design recommendations were developed from the analysis of these factors which will be explained using an example. A methodology for integrating human factors into actual road design standards will be provided.

KEY WORDS

PERCEPTION / ROAD SAFETY / HUMAN FACTORS / TRAFFIC PSYCHOLOGY.

1. INTRODUCTION

Road engineers can specify the design characteristics of the roadway and the operational procedures. However, they cannot directly control the behaviour of the driver. For this reason, design and operational practices must be consistent with the perceptions, capabilities, and actions of the driver population. However, some reasons have made it difficult to achieve this. The driver's behaviour cannot simply be controlled by roadway geometry and traffic devices like the functioning of certain elements of a machine. They develop their own perceptions and motivations within the driving task and adapt their behaviour to optimise their performance according to their own criteria. Drivers are not passive elements when safety measures are introduced, although they often have been implicitly treated in this way. In practice, driver behaviour will often interact with design changes, reducing safety or other benefits. Thus, the ability of drivers to perceive, and their adaptations to perceived risks, interact with highway design features and operational characteristics to determine the actual safety of a road.

2. DRIVER PERCEPTION ISSUES IN ROAD DESIGN

To be effective, road safety policy must target the human, the vehicle and the infrastructure environment as well as the interaction between these elements, as shown in Figure 1. It reveals that around one quarter of the accidents originate from a combination of road and road user factors. Thus it appears that the interaction between road environment and the road user must be taken into consideration when developing guidelines and recommendations for safer roads, which, surprisingly, has been neglected for a long time (Hagenzieker, 2002).

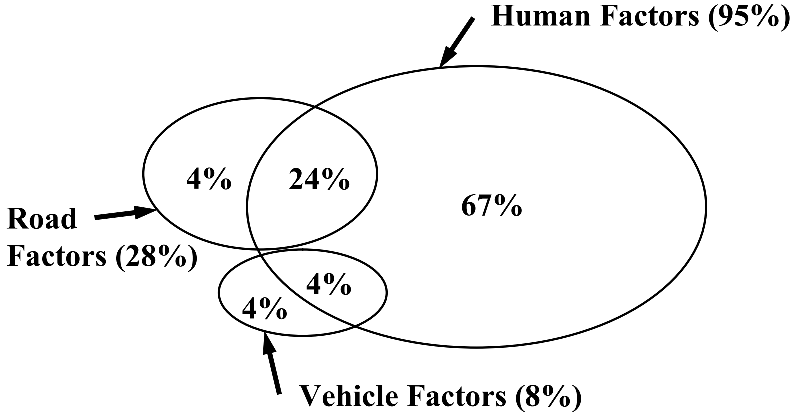

Figure 1 - Factors Contributing to Road Crashes (Austroads, 1994)

In fact, road safety is mostly treated implicitly in design guidelines and road users are always treated in this way (Dijkstra & Hakkert, 2002). However, one of the key safety principles in the sustainable road safety concept is predictability. This is directly related to the road user. The road network and road layout and design of individual roads must be clear and unambiguous. Drivers must be aware of the type of road they are on and they must immediately recognise a change in road type to adjust their behaviour appropriately.

Despite the existence of a large body of knowledge about human perception in psychology, driver perception is, in contrast to its importance, rarely addressed in road design standards. Design guidelines primarily use only a few human factor variables (reaction time, stopping sight distance, passing sight distance, expectancy and design consistency) which can implicitly be attributed to driver perception. No solution has been found to the problem of how to quantify the safety benefits of, for example a clear overview of the traffic situation along with a slight rise in operating speed which often occurs after introducing measurements intended to improve road safety. Drivers are highly adaptive to altering conditions – in a paradoxical way: subjectively perceived bad or even worse conditions lead to a tendency to behave more safely. However, subjectively perceived good conditions sometimes lead to an even stronger feeling of safety. In overcompensating the safety effects this will lead to more risky behaviour.

A potential hazard on the road influences driver behaviour and road safety through an internal and not necessarily conscious sequence of perceiving the hazard, determining subjective risk, responding to that perceived risk in the context of the driving task, and evaluating the appropriateness of the response. The part of this process the highway engineer can most directly address is the perception of the hazard. Therefore, this paper refers in the following mainly to the perception of the roadway and the road environment. Humans derive their internal representation of the outside world from both objective external perceived information

influenced by bottom up processes and subjective internal knowledge influenced by top down processes (Schlag & Heger, 2003). Moreover, the driver's visual perception is the only information source available for great distances. Expectancy makes an important contribution to visual search and visual selection processes. Drivers structure the road environment according to prototypical representations in spatial and temporal dimensions (Theeuwes & Hagenzieker, 1993). In addition to considerations relating to vehicle dynamics, consistency of road design elements is also important for expectancy issues (Lamm et al., 1999).
Human errors in visual perception are often caused by information deficits or false information. They can occur due to physical limitations e.g. limited sight distance. For example, if a driver cannot detect an obstacle on the road, he cannot be aware of its presence and logically an avoidance reaction will not be initiated. Perceptual errors are also caused through distorted perspective views, such as physically induced optical illusions. A common example for geometric properties of the roadway which leads to distorted visual perception is the superimposition of sag vertical curves and horizontal curves (Krebs, Lamm & Klöckner, 1981, Heger, 2001). These processes are data limited. Furthermore, while processing sensory information drivers may get both false sensations and false perceptions. False sensations sometimes occur when a receptor is in a fatigue state. Receptors, especially in peripheral regions of the retina, are also inhibited through mental workload. This effect, which is also known as "Tunnel Vision", reduces the Useful Field of View (Cohen, 1998). False perceptions can arise from the properties of the stimulus or of the person perceiving. In the famous Müller-Lyer-illusion, lines of equal length appear dissimilar on account of the orientation of the wings on the ends of the lines (see Figure 2).

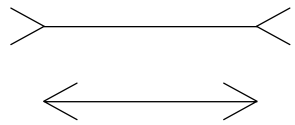

Figure 2 – The Müller Lyer Illusion

Drivers underestimate their own speed and the speed of other vehicles (Häkkinen, 1963). Distances longer than 50 m were overestimated (see Figure 3 and Figure 4). In combination these effects cause, for example, misperception of the available gap for overtaking.

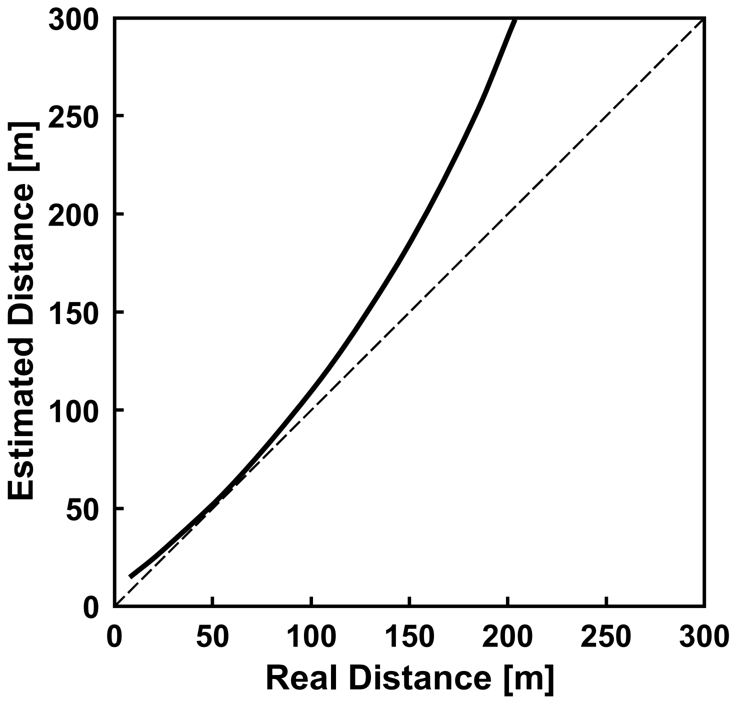

Figure 3 – Estimated and Real Distance of Approaching Vehicles (Schlag & Heger, 2003)

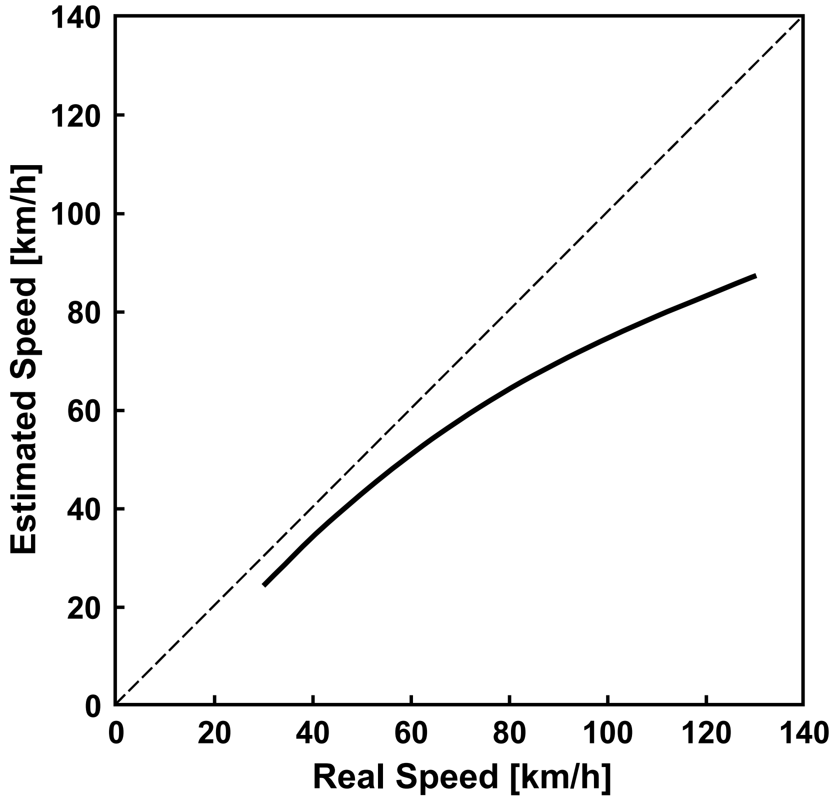

Figure 4 – Estimated and Real Speed of Approaching Vehicles (Schlag & Heger, 2003)

Another discrepancy between objective reality and the perception of drivers is the Speed Adaptation Effect, which arises from the immediate past experience. In particular, travelling for prolonged periods at high speeds leads to the erroneous perception that slow speeds appear considerably slower than they objectively are. In cases where speedometers are rarely used, selected speeds can be up to 35 percent higher than under normal conditions (Fuller & Santos, 2002).

Most design standards address road design issues which are basically spatial in nature, through separated horizontal and vertical alignment and cross-sectional considerations. This is not the view of the driver when acquiring information about the roadway and traffic. It is also of particular interest that drivers do not perceive in a static way, e.g. picture viewing, they perceive during self movement. This means, that every fixation on the road to acquire relevant information has been made from a different viewpoint. In rapidly changing environments, different perspective views must be cognitively evaluated before they can be used within decision making. Until now these issues are not properly addressed in road design standards.

3. RECOMMENDATIONS

Most road design standards have a long tradition. Their structure and content is based primarily on manual design processes which encompassed the major task of the design engineer in the past. This implies avoidance of complicated calculations and complex considerations. In the past this was a major factor for the exclusion of many human factor variables from the road design process. But now nearly every road design is made using computer aided road design software. Even in developing countries personal computers are more and more in common use. For a further improvement in road safety it is time to overcome these limitations to create effective user centred recommendations, guidelines and standards taking into account the full complexity of the road system as far as necessary. Only one example will be outlined here.

Referring to the considerations about quantification of safety benefits made in section 2 it is very easy to evaluate the physical perspective effect of geometric properties on drivers' visual perception of the road by modelling the roadway in a software package, which is usually already done in general design. A visualisation of the road and the driver in movement gives the road design engineer the opportunity to evaluate qualitatively. Detailed information about quantitative evaluation procedures can be obtained in Heger, 2001. It has been found that a radius of a curve which was perceived twice as large as it really was revealed considerably higher accident values in this location than similar curves without this effect. We recommend that modern standards must provide a procedure to evaluate these effects.
Furthermore, the speed adaptation effect has implications for the management of drivers' speed on exits from high speed roads such as the German Autobahn or similar freeways. The likelihood is that drivers will approach the first off – motorway bends and junctions at higher speeds than they imagine. Guidelines should provide flexible solutions for smooth transitions to be effective in road safety.
For road management purposes video recording and surveying of the road network is more and more in common use. Through this, it is very easy to check whether traffic signs and other safety related information are placed inside the borders of the driver's Useful Field of View (Cohen, 1998). Furthermore, it should be ensured that mental workload levels do not fall below or exceed median levels (Heger, 1998).
To meet expectancy requirements recommendations, guidelines and standards of road design should provide clearly recognisable road types. Therefore, within categorisation of roads, we prefer the concept of self explaining roads: a road environment where road users know how to behave simply by its design, and with a type of road in line with road users' expectations. This knowledge gives guidance to a clearly understandable and recognisable road categorisation with a limited number of categories according to their function by making them homogenous within and maximally different among categories. All these recommendations, which cannot be fully explained here, should be integrated in an international Human Factors Guideline for further improvement of road safety.

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