

Towards a Structurally Safe Traffic System: The Development of Self-Explaining Roads

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1. INTRODUCTION

One of the major problems of road traffic is its level of unsafety. It is commonly estimated that over 90% of the traffic accidents are related to human error. Because better education, information and enforcement only have marginal effects on accident reduction, it is crucial that the road environment is adjusted to the human capacity limitation. The crucial question is how design principles can reduce the probability of an error when executing the traffic task. To obtain an error-free task execution, safety should be considered as a system property to be built into the road environment (e.g., Theeuwes, & Godthelp, 1993). Two design principles are crucial. Inherent safety refers to the reduction of potentially dangerous encounters. Self-Explaining Roads (SER) refers to roads which are designed in such a way that they elicit safe and adequate traffic behavior simply by their design.

2. CATEGORIZATION OF ROAD ENVIRONMENTS

The idea that road users categorize the traffic environment is based on the general notion that

people structure their world (see for a review Theeuwes, & Diks, 1995a). It is not the individual environments which are stored in memory but an abstract representation of an environment containing a basic set of typical properties. These prototypical representations develop through experience. In order to ensure unity in the way people structure their world, it is necessary that there is consistency both in the physical appearance of environments and the (traffic) behavior displayed in these (traffic) environments. When these conditions are met, it can be expected that prototypical representations of environments will develop and will be the same for everyone.

Riemersma (1988) investigated subjective road categorization as represented in the «heads» of road users. For the built-up area, the results indicate that the official objective criteria of road categorization as used in the design of road environment are only marginally present in the subjective categorization. In addition, the study shows that the estimated safe speed depends only on the effort it would require to keep the car on the road. The probability of the occurrence of meeting another road user (e.g., pedestrian) did not have an effect on the estimated safe speed.

Mazet and Dubois (1988) claim that categorization of road environments occurs on the basis of the behavior displayed in these environments. This implies that different categories of roads that generally require the same traffic behavior will subjectively be represented by the same pro-

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tototype. A residential area where everybody drives 80 km/h (although the speed limit is 50 km/h) and a city highway where the same speed is utilized will be categorized similarly.

Through experience with the traffic environment, road users will develop a prototypical representation with respect to the different types of roads. Categorization of road environments is based on these prototypical representations stored in memory. The categorization of a road environment activates a complete set of expectations where and when particular road users and particular road elements can be expected. As demonstrated by Theeuwes (1991a, 1991b, 1992) these expectations determine where road users look for potentially relevant other road users and determine the choice of speed road users would drive (Theeuwes, & Diks, 1995b).

Accident data confirm the notion that expectations do play a crucial role: a large portion of drivers (about 37 %) involved in automobile crashes do not act too late but do not act at all to avoid the collision (Sussman, Bishop, Madnick, & Walter, 1985). In addition, Malaterre (1986) claims that 59% of all accidents are the result of inappropriate expectations or interpretations of the environment. Note that accidents do not occur often, indicating that wrong expectations inducing errors in visual sampling (always looking at the wrong locations) and inadequate speed choices are typically not fed back to the driver. Given these considerations, it is clear that extremely dangerous situations may occur when the design of the traffic environment induces the wrong expectations among (a part) of the road users.

3. SELF-EXPLAINING ROADS: SOME RESULTS

Roads are self-explaining when the expectations that they elicit are in line with the behavior required on that road. In the Netherlands, the design of freeways and *woonerfs* are to some extent self-explaining and inherently safe. On the other hand, a very large extent of the Dutch roads – for example the 80 km/h 2- and 4 lane roads – are not designed according to the SER safety principles. These types of roads are not easily classified because they do not have any prototypical recognizable properties, nor do they

necessitate the traffic behavior required on these roads.

In order to settle around clear and understandable road categories, it is important to determine whether prototypical road categories exist and which road elements in the environment are the crucial for the activation of the prototype. For example, it is important to determine which road elements should be present in the environment (e.g., the markings, emergency lane) in order to let the road look like a motorway and not like another type of road. There should be clear and easy recognizable road categories for each type of road.

Recently, Theeuwes (1994; Theeuwes, & Diks, 1995b) investigated the characteristics of categorizing road environments. One experiment investigated the subjective categorization of roads outside the buildup area and how this categorization relates to the «official» road categories (Theeuwes, & Diks, 1995b). Subjects sorted photographs of existing roads, each picture belonging to one of four Dutch «official» categories. Multi-dimensional scaling and cluster analyses showed that subjects made, on average, 6 subjective categories. The «official» category «motorway» mapped well onto the subjective categorization. There was no relation between the subjective categories and the other official roads categories.

In another experiment (Theeuwes, 1994) Reaction Time was used to determine the ease with which roads could be categorized. The idea was that a road which looks very much like the prototype stored in memory can be quickly categorized, while categorizing a road unlike the prototype will take longer. In this experiment pictures of existing roads outside the built-up area were used. In order to determine the effect of the presence of particular road elements on road categorization, particular road elements (e.g. markings, guard rails, traffic lights, etc.) were systematically taken out or inserted into the picture. The results indicated that road users do have a strong prototypical representation of a motorways. Road users do not have a prototype of a 4-lane 80 km/h road. The results are in line with the idea that a prototypical representation of a particular type of road can only develop through experience with a road environment that homogeneous and physically differs from other types of road environment. In the Netherlands there is not

much coherence in the physical appearance of 4-lane 80 km/h through roads. In addition, there is not much consistency in the behavior displayed on these types of roads. For example, 4-lane 80 km/h through roads often contain road elements which make them appear like a motorway (for example, due to the presence of elements like a guard rail), in other cases they look more like a road for all traffic (for example, due to the presence of alleys). Because there is not a strong prototype for these type of roads, it is likely that road users do not know how to behave and what to expect on these type of roads. Not knowing how to behave and what to expect might very well be the reason for the fact that in the Netherlands about 6 times as many people get killed (per kilometer driven) on 80 km/h roads than on motorways.

4. DESIGN CRITERIA

Theeuwes and Godthelp (1993) identified some criteria which will increase the self-explaining character of roads. When developing the «road of the future» one should start with a few easy recognizable and distinguishable road categories. These types of roads should be designed in such a way that high speed differences and directional differences are not possible. Four categories can be distinguished: freeways, highways connecting larger regions, rural roads connecting residential and shopping areas, and woonerfs, i.e., roads going from door to door.

For these four categories, self-explaining roads should fulfill the following tentative criteria:

- Unique road elements (homogeneous within one category and different from all other categories).

- Unique behavior for a specific category (homogeneous within one category and different from all other categories).

- Unique behavior should be linked to unique road elements (e.g., woonerfs: obstacles-slow driving; freeway: smooth concrete-fast driving)

- The lay-out of crossings, road sections and curves should be linked uniquely with the particular road category (e.g., a crossing on a high-

way should physically and behaviorally be completely different from crossing on a rural road).

- One should choose road categories with are behaviorally relevant.

- The same road category should connect a section which psychologically is interpreted as a single unit (e.g., a road connecting two cities).

- There should be no fast transitions going from one road category to the next.

- When there is a transition in road category, the change should be marked clearly (e.g., rumble strips)

- When teaching the different road categories, one should not only teach the name but also the behavior required for that type of road.

- Category-defining properties should be also visible at night.

- The road design should expel speed differences and differences in direction of movement.

- Road elements, marking and signing should fulfil the standard visibility criteria.

- Traffic control systems should be uniquely linked to specific categories (e.g., on freeways, systems that regulate traffic flow and on rural road, systems that restrict driving speed).

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ABSTRACT

This paper discusses the concept of a structurally safe traffic system. The design of many roads and their typical appearance reflect the way these roads developed through history. Because the road design is not considered as a system property optimally adapted to human capabilities and limitations, there is by no means a structurally safe traffic system. The crucial question is how potential errors occurring in traffic can be reduced by revising and redesigning the lay-out of the road environment. As a means to this end, the so called «Self-Explaining Road» (SER) has been deve-

loped, a road environment which elicits safe and adequate traffic behavior simply by its design. The present paper discusses the basic ideas underlying Self-Explaining Roads, and some empirical data regarding road categorization. Criteria for road design which will increase the Self-Explaining character of roads are identified.

RESUMO

Neste artigo é analisado o conceito de sistema rodoviário com segurança estrutural. O design de muitas estradas e a respectiva aparência típica reflectem a forma como elas foram sendo desenvolvidas ao longo da história. Pelo facto de o design de estradas não ser considerado como uma característica do sistema que deve ser adaptado às capacidades e limitações humanas, não existe em rigor um sistema rodoviário com segurança estrutural. A questão crucial reside em saber como é que os erros potenciais dos condutores podem ser reduzidos através da revisão e de um novo design do ambiente rodoviário. Para atingir esta finalidade tem sido desenvolvida a chamada «Self-Explaining Road» (SER), isto é um meio viário que promove a segurança e comportamentos de condução adequados simplesmente devido ao seu design. Neste artigo são analisadas as ideias básicas subjacentes às «Self-Explaining Roads» e alguns dados empíricos sobre a categorização de estradas. São identificados critérios de design que aumentarão as características desejadas nas estradas.