Accident Analysis and Prevention 43 (2011) 101–111

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Supporting drivers in forming correct expectations about transitions between rural road categories

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ARTICLE INFO

Article history:
Received 1 October 2009
Received in revised form 15 July 2010
Accepted 29 July 2010

Keywords:
Road safety
Road design
Expectations
Information

ABSTRACT

In order to support drivers in forming the right expectations on the road, road categories are being made recognisable and predictable in the Netherlands. The present study investigated which of the selected road layouts can make rural road categories most recognisable for road users, especially in transitions from one road category to another. A second objective was to study whether explicit information could contribute to a better recognisability of transitions. The experiment was performed with a series of photographs showing sections of two road categories with an intersection in between. The road layout of road categories varied in markings and separation of driving direction (within-subjects factor). Informed and non-informed participants (between-subjects factor) had to indicate their expectations regarding speed limit and access restriction of each road section, before and after a transition. The results show that for transitions between distributor and through roads, the physicality of separation of driving direction is a better distinctive characteristic than the currently used edge marking. The green centre marking on through roads also enhances recognisability, but only with additional information. As far as transitions between distributor and access roads are concerned, the results demonstrate that this type of transitions is better recognised when no markings on access roads are present. Physical separation of driving directions on distributor roads also improves recognisability, although this layout is associated with higher speed limits. Providing explicit information has in general a positive effect on the reconisability of transitions. Implications are discussed in the light of potential safety effects.

1. Introduction

Having the right expectations about the road one is driving on is important for safe driving as expectations influence driving behaviour (e.g. speed) and help to anticipate events (e.g. van der Hulst et al., 1999). Experimental studies show that drivers can overlook objects when they do not expect them (e.g. Theeuwes, 1991; Theeuwes and Hagenzieker, 1993). According to Malaterre (1990) a substantial number of crashes (59%) are the result of inappropriate expectations. One way to support drivers in forming correct expectations is by making road layout predictable and recognisable. A recognisable road layout is assumed to support the correct expectations of drivers about what road type they are driving on, which road users they can encounter and what driving behaviour (e.g. driving speed) is expected of the driver. By means of evoking correct expectations, a recognisable road layout can make the traffic behaviour more predictable, prevent indecisive behaviour of road users, and allow them to act more on routine. As routine behaviour is related to less serious error types (Reason, 1990), a recognisable road layout can in the end prevent errors that could lead to crashes (e.g. Wegman et al., 2008).

The important role of a predictable and recognisable road environment forms the core of one of the principles of the Dutch road safety vision Sustainable Safety (Koornstra et al., 1992; Wegman et al., 2008): the principle of predictability. This principle builds on two other ones: the principle of functionality of roads and the principle of homogeneity of mass, speed and driving direction. Ideally, roads have only one function: a flow function or an exchange function (functionality); and their layout facilitates homogeneous use in speed, mass, and direction (homogeneity). Sustainable Safety distinguishes three road categories according to their function:

(1) *through roads (TR)*: high speeds, physical separation of driving directions, slow vulnerable road users are not allowed (access restrictions for mopeds, bicyclists, and agricultural vehicles),
(2) *distributor roads (DR)*: intermediate speeds on road sections and low speeds at intersections, physical separation of slow and vulnerable road users and fast traffic is preferred (access restriction at road sections for mopeds, bicyclists, and agricultural vehicles), and

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doi:10.1016/j.aap.2010.07.017

(3) *access roads (AR)*: the mixture of all traffic types requires low speeds, which is also enforced by the road layout.

1.1. Elaboration of Sustainable Safety principles in the Netherlands

An important issue of the Sustainable Safety vision is speed management in relation to road layout and access restrictions. In the Netherlands, two types of TRs can be found: (a) motorways with speed limits of 100 or 120 km/h and (b) regional TRs with a speed limit of 100 km/h. Rural DRs have a speed limit of 80 km/h, which is the rural default limit. A sustainably safe road design requires physical separation of driving directions and safe shoulders were speeds are 70 km/h or higher (Wegman et al., 2008). These requirements are not always met, especially for rural DRs and regional TRs. In practice, there are also many DRs in the Netherlands where agricultural traffic is allowed, due to lack of alternative route options. Rural ARs mostly have a speed limit of 60 km/h. A speed limit of 80 km/h is also common, particularly when separate bicycle paths are available. In fact, the speed limit of rural ARs is the result of a negotiation between the safety-minded who plead for 40 km/h due to the mixture of vulnerable and high-speed traffic, and the flow-minded who wanted to keep the 80 km/h limit situation.

Ideally, predictability is an integral characteristic of the functionality and homogeneity principles and can be found in a corresponding layout. As incorporating all three principles into understandable and uniform road layout turned out not to be that simple, a number of so-called 'Essential Recognisability Characteristics' (ERCs. CROW, 2004) were selected as a first structured attempt to make Dutch roads recognisable and predictable. These ERCs consist of road characteristics that are continuously visible to drivers and can provide them cues about the road type they are driving on. The ERCs mainly consist of variations in edge marking (e.g. broken and continuous) and the type of separation of driving directions (e.g. no separation, broken, continuous and/or coloured markings, physical separations) in unique combinations of patterns per road category. Table 1 presents a number of examples of rural road layouts with ERCs for the three road types.

It has to be noted that drivers (can) rely on far more than the defined ERCs, such as road width and surface, curvature, and road environment characteristics (e.g. Davidse et al., 2004; Goldenbeld and Van Schagen, 2007; Kaptein et al., 1998; van Schagen et al., 1999; Weller et al., 2008) when recognising a road category. Furthermore, recognition of categories is enhanced when (1) the differences between categories are sufficiently large and (2) the variation within each category is small (Kaptein and Claessens, 1998; Theeuwes and Godthelp, 1995). Given the current variation within the layout of road categories in the Netherlands, and the relative small distinction in ERCs between the layouts of the different categories, it is not surprising that some road categories are not correctly recognised, i.e. the expectations of road users regarding speed limits, manoeuvres and road user types allowed on the road are not always correct (e.g. Aarts and Davidse, 2007).

1.2. Enhancing recognisability

A recognisable and predictable road layout as a prerequisite for predictable road user behaviour is related to the internationally more familiar concept of 'self-explaining roads' (SER). The concept is used for a layout that does not need any additional explanation or learning process to know what it means and what to expect. The predictability principle is more specifically meant to support drivers in their expectations about speed, manoeuvres and vehicle types allowed. In both concepts a question remains whether it is really possible to give clear information to road users via road layout. It has been suggested that roads can be made at least partly 'self-explaining' at low cost through speed colour coding (Campagne, 2005). Such a way of coding may enhance the distinctiveness of road types, but the meaning of each colour in terms of speed limit, manoeuvres and vehicle types allowed remains abstract and does not necessarily fit the expectations elicited by the total appearance and affordance of the road (e.g. Gibson, 1986; Goldenbeld and Van Schagen, 2007; Weller et al., 2008).

From a holistic safety perspective, however, SER should ideally meet psychological as well as physical requirements. Whereas colour coding may be sufficient for the first one, it is certainly not enough for the second one: colour-coded roads do not, for instance, prevent drivers from colliding at high speeds. Taking both psychological and physical safety requirements into account, only a few road types in the Netherlands turn out to be self-explaining. Theeuwes (1994) found that motorways, equipped with emergency lanes, safety barriers and gantries were nearly always and very quickly correctly recognised by drivers. Aarts and Davidse (2007) found similar results when rural roads were equipped with a safety barrier: participants associated safety barriers with motorways and thus with high speed limits. Low speed zones, on their turn, may easily be recognised as such, provided that they are characterized by a credible low-speed design by a narrow and curved road, with uneven surface, and a built-up area near to the road (e.g. Martens et al., 1997). For other road categories, recognisability or self-explainingness is not so obvious in the sense that drivers do not always classify them in the same way as intended by the road authority. A study by Weller et al. (2008) for instance, found that the subjective impression of road users about road pictures had either to do with a kind of monotony, comfort, or demand. These classifications were, for instance, influenced by horizontal alignment, road width and surface quality, presence or absence of a centre line and sight distance.

In the Netherlands, the enhancement of predictability has, until now, mainly been dealt with by implementing ERCs leaving other important characteristics more or less intact. The effects of this intermediate step in the Sustainable Safety approach have been evaluated in a rural roads photo-classification study of Aarts and Davidse (2007). The results showed that DRs and TRs were often mixed up. It has been concluded that the edge marking, which is used for the distinction between these road types, may not have a relevant meaning to road users. Another finding was that roads with a physical separation of driving directions (particularly those with a safety barrier) were often classified as roads where higher speed limits applied. Apparently, road users pay more attention to the separation of driving direction than to the edge marking. This seems logical as the former layout characteristic provides road users with information that is relevant for possible behavioural choices (i.e. overtaking), whereas the latter does not. Finally, ARs were better recognised as low speed roads when equipped with non-compulsory red cycle lanes or when no markings were present at all. This finding is in line with some previous studies where red cycle lanes were found to be a self-explaining layout characteristic (Kaptein and Theeuwes, 1996). Based on the evaluation study of Aarts and Davidse (2007) it can be concluded that many road layouts in the Netherlands are not yet well recognisable and predictable for road users.

Not all layout variants have been evaluated so far. However, based on indications from previous studies, it can be expected that some of the layout characteristics can be helpful in forming the right expectations. First, the green centre line marking (see Table 1 variants 3 and 4) may turn out to be of benefit for recognisability of through roads. On the one hand, psychological research shows that the perception of colour takes place directly, i.e. it does not need cognitive interpretation (Kolb and Whishaw, 2003). It has been suggested that SER may be partly realised at low cost through speed colour coding (Campagne, 2005). On the other hand, the meaning