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The influence of memory on driving behavior: How route familiarity is related to speed choice. An on-road study

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ABSTRACT

Differences in driving behavior due to the presence of users familiar (or unfamiliar) with the road are considered in the road and traffic engineering. However, although considered, the matter is largely unexplored: there is a lack of theoretical foundations and data on determining the impact of route familiarity on accident rates, speed choice and risk perception. On the other hand, some literature studies confirm that route familiarity is influential on driving behavior, encouraging research in this sense.

This paper reports the results of an on-road test carried out on a two lane rural road in the District of Bari in the Puglia Region (Italy) over six days of testing by following this time schedule: first four tests in four consecutive days, the fifth test in the ninth day after the first test and the sixth test in the twenty-sixth day after the first test. The main aim of the experiment was to find relationships between route familiarity and speed choice. In particular, speed data were analyzed by considering the influence of road geometry and human factors.

The main finding is that speed choice seems to be affected by route familiarity: speed increases with the repetition of travels on the same route. The particular schedule used for the tests allows to consider the influence of memory on the speed behavior of the test drivers. Moreover, some relationships between changes in speed over days, road geometry and drivers' attitudes were shown.

1. Introduction

Traffic safety policies can be implemented in different ways: enforcement, increasing user awareness, and engineering countermeasures. These policies should be defined by technicians and different experts: engineers, psychologists and economists in cooperation.

The engineering part of the matter involves interventions on existing roads in order to reduce the expected number of accidents (see for example AASHTO, 2010; Elvik and Vaa, 2004; Kononov and Allery, 2003). After sites of intervention have been identified, a countermeasure should be implemented. If the road infrastructure is recognized as the supposed or real main cause of accidents, the countermeasure should come from engineering.

However, apart from the method employed for choosing countermeasures, there is a lack of theoretical approaches able to take into account users' reactions to modifications in infrastructure. This phenomenon is not secondary because risk compensation is considered by different sources as a problem influential in safety (Taylor, 1964; Wilde, 1982), and in particular if the safety countermeasure is visible to drivers (Hedlund, 2000) (see van der Horst (2013) for a recent summary about experimental evidences of behavioral adaptation to countermeasures). If an engineering safety measure modifies user behavior, who acts pursuing the aim of minimizing travel disutility, which depends on several factors (O'Neill, 1977; Blomquist, 1986; Tarko, 2007), then the countermeasure could be useless or detrimental. In fact, in the case of adaptation, the possible increase in speed could lead to a mobility benefit (reduction in travel time) but also to a worsening of accident risk (Dulisse, 1997; Noland, 2013). Moreover, the relationship between speed and accident risk is well-known. It can be considered as a power function (Nilsson, 2004) or as an exponential function (especially for injury accidents (Elvik, 2014): the accident risk increases more if speed is higher.

Hence, in order to forecast the effectiveness of a countermeasure, it is necessary to consider driver behavior. However, driver behavior is not characterized by a universally accepted theory, because of the various factors involved in the process (Fuller, 2008). For example, the zero-risk model (Näätänen and Summala, 1974), the risk

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homeostasis theory (Wilde, 1982), the rule-based model (Michon, 1989), the risk allostasis theory (Fuller, 2008) and/or the risk monitor model (Vaa, 2013) could be taken into account.

Speed choice is one of the main indicators of driver behavior and it is influenced in turn by many factors, among which risk perception is crucial (Tarko and Figueroa Medina, 1980). The way in which users perceive accident risk while they are driving is a topic currently studied, a perplexing topic due to the lack of consensus about measuring risk and users' risk misperceptions (Slovic et al., 1982). One method to measure risk is cognitive heuristics: in uncertain conditions, decisions are not deterministic but they are influenced by experience acquired over time through empirical observations. This process is recognized as influential in risk perception and as closer to reality (Slovic, 1987; Hogarth, 1981), even if sometimes this method could lead to errors or imprecision (Sjöberg et al., 2004; Tversky and Kahneman, 1974). The heuristic approach is coherent with the process of speed selection (connected to the risk perception) which it is often based on users' misperception of risk and travel time (Elvik, 2010).

By applying the cognitive heuristic concept to driver behavior, it is possible to identify one influential feature in drivers' behavior: the familiarity with a route (on which this paper is focused) determined by the habit of driving on it, while acquiring experience and information. There is some research about the relationships between route familiarity and driving performances. Yanko and Spalek (2013) e.g. carried out an experiment involving 20 drivers and a driving simulator. They found that route familiar users (users who had driven on the experimental route four times before the test) needed greater reaction times than route unfamiliar users (users who drove on the experimental route for the first time during the test) in order to respond to unexpected external stimuli simulated in the presented scenarios. The results obtained from the presented experiment are similar to what Martens and Fox (Martens and Fox, 2007) suggest about route familiarity: it can lead to a greater distraction while driving, probably because familiarity could increase the effect of "mind wandering". Mind wandering occurs when the mind is occupied by thoughts not concerning the task being undertaken and so, responses to external stimuli are potentially slowed down. This interpretation is coherent with the MART theory presented by Young and Stanton (2002), which assumes that driving performance varies as a function of mental workload and that in low demand conditions (normal driving tasks) attention capacity is reduced. The matter of risk underestimation related to route familiarity was considered also by Rosenbloom et al. (2007), who observed the driving behavior of a sample of female drivers in both familiar and unfamiliar locations. They found that drivers performed more traffic violations, more dangerous behaviors and speeding while driving in more familiar locations, confirming that risk perception could change with the acquired route familiarity.

From an engineering point of view, the matter of familiarity is considered in the traffic flow theory and in the road design guidelines.

In fact, within the framework of the level of service (LOS) calculation for highways and freeways, the Highway Capacity Manual (2000) suggests the following formula in order to calculate the equivalent flow rate (higher equivalent flow rates correspond to lower LOS), taking into account vehicular composition of traffic flow:

$$V_p = \frac{V}{\mathrm{PHF} * N * f_{\mathrm{HV}} * f_p} \quad (1)$$

where

V_p = 15-min passenger-car equivalent flow rate (pcphpl).
V = hourly volume (pc/hr).
PHF = Peak Hour Factor.
N = number of lanes in one direction.
f_{HV} = heavy-vehicle adjustment factor.
fp = driver population adjustment factor.

The introduction of the f_p factor in the equivalent flow rate (V_p) calculation makes it possible to implicitly consider users as divided into two categories according to their familiarity with a route:

- Users familiar with the route: in general all those who drive on a given route almost daily (regular users), such as commuters.
- Users not familiar with the route: all those who infrequently drive on the route, such as tourists or other non-habitual (recreational) drivers.

HCM 2010 considers $f_p = 1$ in the case of traffic mainly consisting of regular users and a value between 0.85 and 1 for traffic with a more or less significant component of recreational users. This means that other conditions being equal, a decrease in f_p down to a minimum of 0.85, corresponds to an increase in the V_p of up to about the 20% more than the value calculated for f_p equal to 1. In the context of uninterrupted flows, an increase in the V_p (equivalent traffic flow rate) is related to an increase in the car density (equivalent passenger cars/km) and consequently this leads to worsening in the level of service of the road. Therefore, according to this method, the presence of recreational users leads to an evident deterioration in the LOS of the road.

Considering that differences between users familiar and unfamiliar with a given route are influential on flow rate, it could be assumed that accident rates should also be different between the two categories of users. In fact, it is commonly accepted that route familiarity is a factor influencing speed choice and trade-offs between travel time and safety (see e.g. Milliken et al., 1998). However, accident rates have not been largely related to familiarity in literature studies. Instead, this relationship would conduct to noticeable results, as can be verified by considering e.g. Blatt and Furman (1998), who found that people are most likely to be involved in crashes on roads on which they traveled most frequently (among the considered sample, most of the rural residents involved in fatal crashes were traveling on rural roads while urban residents were primarily involved in urban accidents).

Moreover, a good practice for road designers should be the consideration that users are driving on a roadway for the first time and that they have no familiarity with its features (Milliken et al., 1998).

So, even if theoretically assumed as an influential factor in the road and traffic engineering, the impact of route familiarity on driving behavior and traffic safety was not adequately studied by measuring, for example, accident rates for different compositions of traffic flow (tourist/commuters), by understanding the process responsible for making an unfamiliar user familiar with a given route and/or by estimating possible variations in speed choice based on on-road experiments.

As explained, the crux of the problem in dividing the familiar drivers from the unfamiliar ones is represented by the habit connected to a given route. From a merely psychological point of view, the effect of habituation has been explained by various theories, such as the early study by Groves and Thompson (1970). They supposed the existence of two parallel and interacting processes in the central nervous system: the habituation process and the sensitization process. Both processes handle external inputs and generate behavioral outputs: the response to an external stimulus depends on which process is prevailing. In the habituation process, the response decreases with the repetition of the same stimuli over time until it reaches an asymptotic constant value (habituation effect). When the stimulus is withheld after response decrement, the response recovers at least partially over the observation time.