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Exploring the relationships between drivers' familiarity and two-lane rural road accidents. A multi-level study

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ABSTRACT

Previous research has suggested that drivers' route familiarity/unfamiliarity (using different definitions of familiarity), and the interactions between familiar and unfamiliar drivers, may affect both the driving performances and the likelihood of road crashes. The purpose of this study is to provide a contribution in the search for relationships between familiarity and crashes by: 1) introducing a measure of familiarity based on the distance from residence; 2) analyzing a traffic and accident dataset referred to rural two-lane sections of the Norwegian highways E6 and E39; 3) using a multi-level approach, based on different perspectives, from a macro analysis to more detailed levels.

In the macro analyses, the accident rates computed for different seasons and for different summer traffic variation rates (used as indicators of the share of familiar drivers in the flow) were performed. At the second level, a logistic regression model was used to explain the familiarity/unfamiliarity of drivers (based on their distance from residence), through variables retrieved from the database. In the last step, an in-depth analysis considering also accident types and dynamics was conducted.

In the macro analysis, no differences were found between accident rates in the different conditions. Whereas, as emerged from the detailed analyses, the factors: high traffic volume, low summer traffic variation, autumn/winter, minor intersections/driveways, speed limits < 80 km/h, travel purposes (commuting/not working) are associated to higher odds of having familiar drivers involved in crashes; while the factors: high traffic volume, high summer traffic variation, summer, head on/rear end-angle crashes, heavy vehicles involved, travel purposes (not commuting), young drivers involved are associated to higher odds of finding unfamiliar drivers involved. To a minor extent, some indications arise from the in-depth analyses about crash types and dynamics, especially for familiar drivers.

With regard to the definitions used in this article, the familiarity was confirmed as an influential factor on the accident risk, possibly due to distraction and dangerous behaviors, while the influence of being unfamiliar on the accident proneness has some unclarified aspects. However, crashes to unfamiliar drivers may cluster at sites showing high summer traffic variation and in summer months.

1. Introduction

The strong influence of driving behavior on road crashes has been recognized since decades. Human, vehicle, road, environment and traffic are the five categories of contributing factors to accidents occurring (see e. g. Colonna, 2002). Anyway, their relative incidence is completely disproportionate in favor of human factors (see e.g. Treat et al., 1979; Singh, 2015), which have to be considered by road engineers (see e.g. Campbell et al., 2016), and traffic safety researchers.

Singh (2015) estimated that the most frequent driver-related critical errors (more of 90% of the total) are the recognition errors, which account for 41% and are related to drivers' inattention, distraction and inadequate surveillance. This is confirmed by several other works which recognized driver distraction as a crucial causal factor in the crash occurring (e.g. Sandin, 2009; Staubach, 2009; Regan et al., 2008; Klauer et al., 2006; Young and Salmon, 2012). Moreover, this is coherent with the fourth law of accident causation proposed by Elvik (2006), the "law of cognitive capacity": the more the cognitive capacity approaches its limits, the greater is the increase in the accident rates. Therefore, as long as distraction and inattention affect negatively the

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cognitive capacity, accident rates can increase.

1.1. Familiar drivers and accident risk

The widely studied issue of driver distraction can be strongly linked to the drivers' route familiarity, which however is a topic less frequently considered. The route familiar drivers are road users who frequently travel on the same route, having perfect knowledge of the road environment and of all of its characteristics. This comes directly from the definition of the adjective *familiar*: well known from long or close association (*Oxford, 2016*), as long as no clear definition of "route familiar driver" was found in literature. In fact, previous research considered the concept of route familiarity in different ways: on a time-based scale (drivers categorized as familiar if the road was traveled at least once a week by Liu and Ye (2011); or once a month by Beijer et al. (2004), and Bertola et al. (2012); on a distance-based scale (town limits of the driver's residence were used as a boundary for defining familiarity e.g. by Rosenbloom et al. (2007) or on a more complex way, by considering that drivers can be familiar with a route only during specific times of the day or roadway conditions (Lotan, 1997).

Anyway, a typical example of route familiar user is a driver repeating almost daily his/her travel from home to work, which is also a frequent driving condition (about a third of the vehicle miles traveled related to private vehicles are for commuting according to: AASHTO, 2013). In this case, if no other unexpected events arise and if the user is enough experienced with the driving process itself (excluding novice and very-low mileage drivers), then the driving process is in the "habituation" stage (Colonna et al., 2016a). This is a low-energy consumption state of the driver in which the response to external stimuli is reduced, coherently with Malleable Attentional Resource Theory (MART) by Young and Stanton (2002), the dual-process theory (Rankin et al., 2009) and the external and internal risk model (Colonna and Berloco, 2011). In fact, driving on a familiar route is mostly an automatic process, in which skill-based tasks are unconscious (Rasmussen, 1986). Therefore, route familiarity can lead to distraction and inattention by favoring mind wandering: the mind is occupied by thoughts not concerning the driving task and consequentially, responses to external stimuli are potentially slowed down. Thus, route familiarity can be involved in the same problems related to accident proneness discussed above while considering distraction. This theoretical and logical assumption is supported by some research. Yanko and Spalek (2013) found that route familiar users (who had driven on the simulated route four times before the test) needed greater reaction times than the unfamiliar (who drove only once) in order to respond to unexpected external stimuli introduced in the scenarios. These results are similar to what found by Martens and Fox (2007) from another driving simulator study. In this case, priority road signs were modified in the last driving test, after some test repetitions. Only 2 out of 12 drivers noticed a change in signs, indicating possible inattention for familiar drivers.

Therefore, route familiarity can cause inattention. Anyway, this is not the only measurable output of a familiarization process. Familiarity with a given road environment can be a synonymous of more self-confidence and more risk-taking behaviors especially for more aggressive drivers (Colonna et al., 2015). Rosenbloom et al. (2007) observed the driving behavior of a sample of female drivers in both familiar and unfamiliar locations. They found that drivers performed more traffic violations, dangerous behaviors and speeding while driving in more familiar locations. The same tendency of speed increasing for familiar drivers was found by Colonna et al. (2016a) from an on-road test. They also highlighted that this tendency is roughly independent from road geometry, being more related to the drivers' attitude to risk (even if a similar experiment conducted by Intini, 2014; but on a different road environment, with a smaller sample and a different measuring apparatus, did not reveal the same speed increase over days). A driving simulator study conducted by Bertola et al. (2012) revealed that drivers who acquired familiarity with the test route increased their speed and mean standard deviation of lateral position. Moreover, a study by Colonna et al. (2016b) revealed that familiar drivers are more prone to curve-cutting behavior and encroachments, highlighting also the role of drivers' attention at horizontal curves (Charlton, 2007), where concurrent friction issues may arise (Colonna et al., 2016c). Therefore, familiar drivers may try to maximize their mobility benefits in terms of reduction of travel time, but this leads to an increase of the accident risk due to the speed increase and to more dangerous behaviors (Noland, 2013; Nilsson, 2004; Intini et al., 2016).

These findings show that the drive-related measurable parameters speed and lateral position can change with the acquired route familiarity towards a less safe scenario. Considering again the US statistics by Singh (2015), the second most frequent driver-related critical errors related to crashes are the decision errors (speeding, false assumptions of others' actions, illegal manoeuvers and misjudgment of gap and others' speeds) accounting for the 33% of the total driver-related accidents. Therefore, familiarity can be involved also in this other group of errors.

1.2. Unfamiliar drivers and accident risk

Based on the previous section, route unfamiliar drivers may seem safer than route familiar drivers. This is because it is expected that unfamiliar drivers should be in the road "studying" phase, where the attentional capacity is almost entirely devoted to the acquisition of the information related to the road environment. Therefore, they should be less inclined to distraction and less prone to speeding and risk-taking behaviors because the road is not well known. However, some other features should be taken into account. In the road design guidelines, it is commonly followed this good practice principle: road design should be thought for users who are driving on a roadway for the first time and who have no familiarity with its features (Milliken et al., 1998). This need is also coherent with the concept of the self-explaining roads (Theeuwes and Godthelp, 1995; Charlton et al., 2010; Mackie et al., 2013). A sudden sharp curve after a long straight section of road is unexpected and dangerous for all drivers, because the reality (the unexpected curve) does not match the expectations built up during the previous long stretch of straight road. However, the curve is truly unexpected only for the unfamiliar drivers who never/rarely traveled on that road and it could lead to errors in speed and steering. This could easily explain why also route unfamiliar drivers can show road safety weaknesses.

Moreover, the Highway Capacity Manual (TRB, 2000) suggests to take into account the vehicular composition of traffic flow with regard to route familiarity by the introduction of a coefficient (driver population factor) in the calculation of the equivalent flow rate Vp for multilane highways/freeways:

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

where: Vp = 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, variable between 0.85 (strong presence of recreational users such as tourists in the traffic flow) and 1 (flow mainly composed of regular users such as commuters).

This means that other conditions being equal, in the context of uninterrupted flows, a decrease in fp due to the presence of unfamiliar drivers corresponds to a worsening in the level of service (an increase in the Vp and the equivalent density, a decrease in the average speed). Moreover, while the average speed may be reduced, unfamiliar drivers, less confident with the route, may select speeds lower than familiar drivers (see e.g. Colonna et al., 2016a): the speed variance can increase. This effect can be related to an increase in the accident risk (Garber and Gadiraju, 1989).