# Route familiarity in road safety: a literature review and an identification proposal

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**Abstract.** Route familiarity can be an important safety-related variable, which is often neglected. A review of previous works highlighting the relationships between route familiarity and road safety in behavioural studies and engineering standards/frameworks has been conducted.

Theoretical frameworks supported by experimental results have revealed that driving behaviour can be affected by route familiarity. The latter may lead to distraction and self-confidence; and in turn to more dangerous behaviours after repeated journeys. From an economic perspective, the possible worsening of driving safety performance may be explained by trade-offs with mobility benefits.

Route familiarity is also considered in engineering practice. Road design guidelines assuming a “design driver” were suggested as implicitly preserving the safety of familiar/unfamiliar drivers. The mix of familiar and unfamiliar drivers in traffic flow is explicitly considered when computing the design traffic. The safety implications of these matters find only partial confirmation in previous studies focused on involvement in crashes. However, comparing those findings was difficult due to the high variability in measuring the route familiarity itself.

An attempt to harmonize the possible identifications of familiarity for future studies, based on previous findings, is proposed. The proposal considers two different scales used for measuring route familiarity: one based on travelling frequency, the other on distance from residence.

**Keywords:** route familiarity; road safety; driving behaviour; review; familiarity identification.

## 1. Introduction

Road safety is closely related to human factors, which play a crucial role in about 90 % of crashes (Treat et al., 1979; Singh, 2015). Among all driver-related crash variables, this article is specifically focused on drivers' route familiarity, and its multiple relationships with road safety.

"Route familiarity" can be defined as the specific drivers' familiarity with routes (see e.g. Yanko and Spalek, 2013) repeatedly travelled and thus, with the road elements they consist of. The adjective "familiar" is basically defined as: "*well-known from long or close association*" (Oxford University Press, 2016). Early studies associate the word "familiarity" with the frequency of having experienced a given stimulus in the past (see e.g. Mass, 1956; Lewis et al., 1967; Witherspoon and Allan, 1985). Hence, by applying these preliminary concepts, a route familiar driver is a driver who is travelling on a route well-known from long or close association, and the travelling on that specific route composed of different road elements has been the stimulus repeatedly experienced.

Drivers may also travel in different vehicles and under many personal, environmental, traffic conditions, with which they may be familiar or unfamiliar. All these factors could be influential: for example a driver can be suggested to be route familiar only at specific hours or in given conditions (Lotan, 1997). However, this article is specifically focused on the effects of drivers' familiarity/unfamiliarity with given routes, not considering in detail other familiarity aspects of the system human-vehicle-environment.

The route familiar condition can be easily associated to the recurrent driving task undertaken while going almost every day to the same work place (such as commuters), school, shop, etc.. Hence, route familiarity can be a very common condition for drivers worldwide. Some examples of the significant number of route familiar drivers in the traffic flow are reported as follows. About one third of the vehicle-miles travelled by American private vehicles are for commuting (AASHTO, 2013). More than 60 % of a surveyed Italian sample repeat a given trip at least 3 days a week and more than 60 %

of the average daily trips (average: 2000-2014) are made by car (ISFORT, 2014).

The topic of route familiarity is considered because of its influence on driving behaviour. However, by affecting driving behaviour, route familiarity can influence road and traffic behavioural-based safety aspects. These relationships between route familiarity, driving behaviour and road/traffic safety aspects have often only been implicitly considered in previous research and technical documents. However, the explanation of these relationships may be of interest for road safety researchers and practitioners, given their potential impact.

Moreover, while it is possible to provide a basic definition of route familiarity, and some exemplifications of familiar drivers such as commuters, it is rather hard to precisely categorize different levels of route familiarity. This means that finding a clear threshold for determining when an unfamiliar driver starts becoming familiar after a given frequency of travelling on the same route is difficult. This ambiguity is reflected in experimental research, as further discussed. The related major issue is the difficulty in comparing results from studies which have used different criteria for identifying the drivers' route familiarity and unfamiliarity.

Hence, thorough explanations of how route familiarity can be related to road safety aspects, and systematically identified dedicated studies are lacking. Given this, the article has a two-fold aim:

- Highlighting the relationships between route familiarity and road safety, through a detailed review of research studies and road and traffic engineering technical documents.
- Proposing a criterion for identifying route familiarity potentially useful for future studies, by attempting to harmonize previous criteria.

In the remainder of the paper, the possible influence of route familiarity on driving behaviour with implications for road safety, is described. The methods used for the review of research studies and technical documents are then presented. After that, the results from the review conducted are reported and discussed, revealing relationships between route familiarity and road safety. The proposal for a harmonized familiarity identification criterion, based on previous studies, is further presented. Finally, the main conclusions from the study are drawn.

## 2. Background

This background section has the aim of providing a theoretical basis for the subsequent review of research studies and technical documents, since several concepts presented here are further recalled. The influence of route familiarity on road safety is explored from different, but inter-related, perspectives.

### 2.1 Route familiarity and driving behaviour

Drivers' route familiarity has consequences for road safety because it affects the driving task itself.

The driving task is often defined as complex, organized in different hierarchical levels (Michon, 1985) and described through different levels of performance (Rasmussen, 1983). Moreover, driving tasks can both require attention, or being partly/totally automatic in given conditions (see also Reason, 1990; Embrey, 2005). By combining driving task levels and performances having the focus on familiarity (see Aasman and Michon, 1992; Hale et al., 1990), the following dichotomous relationship arises:

- Familiarity can be related to skill-based task automation, requiring less attention (such as in a commuting travel, while negotiating familiar road elements or operating short-term driving patterns). The switch to automation is possible in the case of familiarity with one or more factors of the road system (i.e. with the road, the vehicle, the environment). However, drivers familiar with these factors can also shift to rule-based behaviours (for example in unfamiliar cars, by applying well-known rules to other vehicles).

- Unfamiliarity can be related to the knowledge-based driving task consciousness, requiring attention to address the unknown situation (such as being a first-time driver, or while navigating in unfamiliar environments or operating unfamiliar manoeuvres, as skilled drivers).

This discrepancy between familiar and unfamiliar drivers in respect to the task automation implies the familiarization process leading unfamiliar drivers to become route familiar, which is then worth being analysed. The habituation process (Fig. 1) is described in the early dual-process theory (Groves and Thompson, 1970, revised by Rankin et al., 2009). People exposed to the same repeated stimulus over time, progressively decrease their response to that stimulus until an asymptotic value is reached. This habituation effect can last for short or long-term periods (even weeks: long-term habituation, see Rankin et al., 2009). However, in the case of a novel stimulus some responses can be recovered: in the so-called dishabituation effect. The response further decays, whether or not the stimulus is maintained.

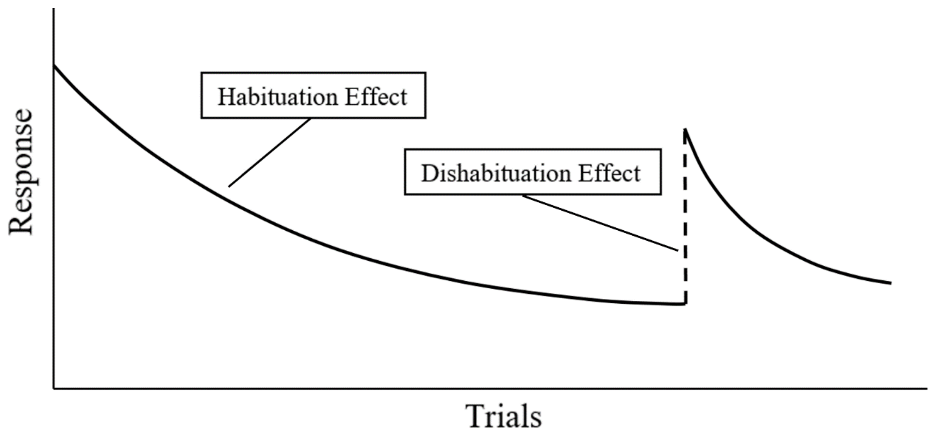


Figure 1. Habituation/Dishabituation effects (based on Groves and Thompson, 1970).

When driving on the same route in given boundary conditions is the repeated stimulus, then one should expect drivers to get progressively habituated to it. Thus, drivers' responses should asymptotically approach a low level (Fig. 1), at which the mental workload and the attention capacity can be greatly decreased, as explained through the Malleable Attentional Resources Theory (MART) (Young and Stanton, 2002, see also Mahalel and Szternfeld, 1986). However, in a low attention condition, the mind can be unconsciously occupied by non driving-related thoughts: "mind wandering" (see Yanko and Spalek, 2014). Moreover, the less demanding is the driving scenario, the more time may be spent driving with a wandering mind (Geden et al., 2017). Therefore, the acquired route familiarity can possibly foster drivers' distraction, through mind wandering.

This possible relationship between route familiarity and distraction may be influential in road safety. In fact, distraction is a crucial causal factor for crashes (see e.g. Singh, 2015; Sandin, 2009; Staubach, 2009) and driving errors (Young and Salmon, 2012; based on a previous taxonomy by Stanton and Salmon, 2009). These findings are coherent with the "law of cognitive capacity" (Elvik, 2006): the more cognitive capacity is reduced (in this case through distraction), the more the accident rates increase. Rosenbloom et al. (2007) suggested a two-fold effect of familiarity: it can induce distraction by deteriorating the response to hazardous events, but also lead to overconfidence and risk underestimation (Thurman, 1986; Hamed, 2001). The overconfidence of familiar drivers could be explained by the optimism bias in perceiving accident risks, which increases with driving experience (DeJoy, 1989), and is potentially transferrable to the route familiarity case. Coherently, the perceived involvement of familiar drivers in accidents may be underestimated with respect to that of unfamiliar drivers compared to actual rates (Sticher, 2005). In addition, route familiarity is often mentioned among the self-perceived safest driving conditions (in responses from older drivers: Sullivan et al., 2011). This may also result in overconfidence.

Moreover, habituation can also be noted in the case of "behavioural adaptation" (to road changes): "*the collection of unintended behaviours that follows the introduction of changes to the road* *transport systems*" (Rudin-Brown and Jamson, 2013). Drivers' adaptation is troubling if road safety measures induce negative behavioural changes (e.g. speeding and less concentration in the case of lighting, Assum et al., 1999; or decreasing compliance to enforced speed limits over time, see Montella et al., 2015). Adaptation is possible only if drivers are repeatedly exposed to the countermeasure, then the measure is easily noticed (Elvik, 2004), likely to exclude cases in which it is aimed at reducing crash outcomes (e.g. restraint systems). Route familiar drivers may be particularly subject to adaptation, since they can repeatedly test the new condition (i.e. the safety countermeasure) and get used to it, following the usual habituation process and modifying their behaviour.

### 2.2 Economic aspects of route familiarity

The economic aspect focused on risk assessment can give a complementary perspective (see e.g. Colonna et al., 2016). A very simple equation for quantifying the risk R of an event is:

$$R = P \times I \qquad (1)$$

where: P = Probability of the event, I = Intensity of consequences. It can be measured in terms of losses (such as the cost to society of traffic accidents, see AASHTO, 2010).

Road safety measures can reduce the accident probability (e.g. in the case of lighting, Elvik et al., 2009). Drivers who perceive this improvement, could feel safer and modify their behaviour in order to reduce travel times (by driving faster), or mental workloads (by being less focused on driving, as in the case of lighting, Assum et al., 1999). However, these behavioural tendencies are associated with higher risks, able to partially/totally undermine the risk reduction. This phenomenon represents the downside of behavioural adaptation (previously associated with familiar drivers): so-called "risk compensation". It has been widely documented after introducing several safety measures (see van der

Horst, 2013; Vrolix, 2006; for recent example collections). Several frameworks have tried to conceptualize risk compensation through an economic approach (Peltzman, 1975; O'neill, 1977; Dulisse, 1997; Hedlund, 2000; Tarko, 2009; Noland, 2013). A common trait is that drivers, presumed to be rational, can make trade-offs between safety (i.e. accident risk) and other factors (i.e. mobility benefits), for the sake of increasing travel utility, assumed as the reference variable.

The formalisation of the perceived utility by Noland (2013) is given as follows:

$$U = f(P, T, C, A, R) \quad (2)$$

where P = Price, T = Travel Time (mobility-related variables); C = driver's Capability, A = in-vehicle activities, R = Risk (safety-related variables). Drivers seek the maximization of the utility U, by adjusting the variables through their performance.

Risk compensation can also be related to the route familiarization process (Intini et al., 2017a), as based on Eq. 2 (see Fig. 2). Drivers could accept more risky behaviours (e.g. speeding, hard braking), to obtain benefits such as decreased travel time (but with a possible fuel cost increase), to increase the perceived travel utility. The process is mainly governed through speed and steering performance.

Clearly, the economic perspective should be integrated with behavioural-based theories and not considered as an alternative to them. In fact, models based on rational users searching for utility maximization have been criticized (see e.g. Sen, 1977), and inconsistencies may arise from their application to driving performance. The latter may seem to be rationally determined through defined rules, while the relationships between speed, risk and travel time may be misperceived by drivers (Elvik, 2010). However, learning from experience and subjectivity (e.g. personal differences in perceived utility, see Dulisse, 1997) should also be taken into account. Moreover, drivers may have different target risk levels (Wilde, 1982), as risk perception is influenced by personal factors (Rundmo, 1996; Deery, 2000), emotions and feelings (Damasio, 1994, 2003; Slovic et al., 2004).

In fact, the development of driving behaviour is likely to come from trial-and-error stages (Rasmussen, 1983). For example, by continuously trying and learning from previous experience, the driver acquires information about the most suitable speed for a given condition, which becomes the "habitual" speed (Fuller, 2007). Moreover, the "rewarding" speed (allowing the driver to keep control and avoid collision while pursuing travelling goals) learned for a particular condition can be potentially transferred to similar situations without trial-and-error (Fuller, 2007). Hence, route familiar drivers, may feel comfortable in choosing higher speeds (or trade speed for lateral acceleration at curves, see Herrin and Neuhardt, 1974), which could be perceived as more rewarding, on road sections similar to familiar sections on which the trial-and-error speed determination stage has already occurred. This interpretation is coherent with the search for utility goals and the occurrence of trade-offs, independently from users' rationality.

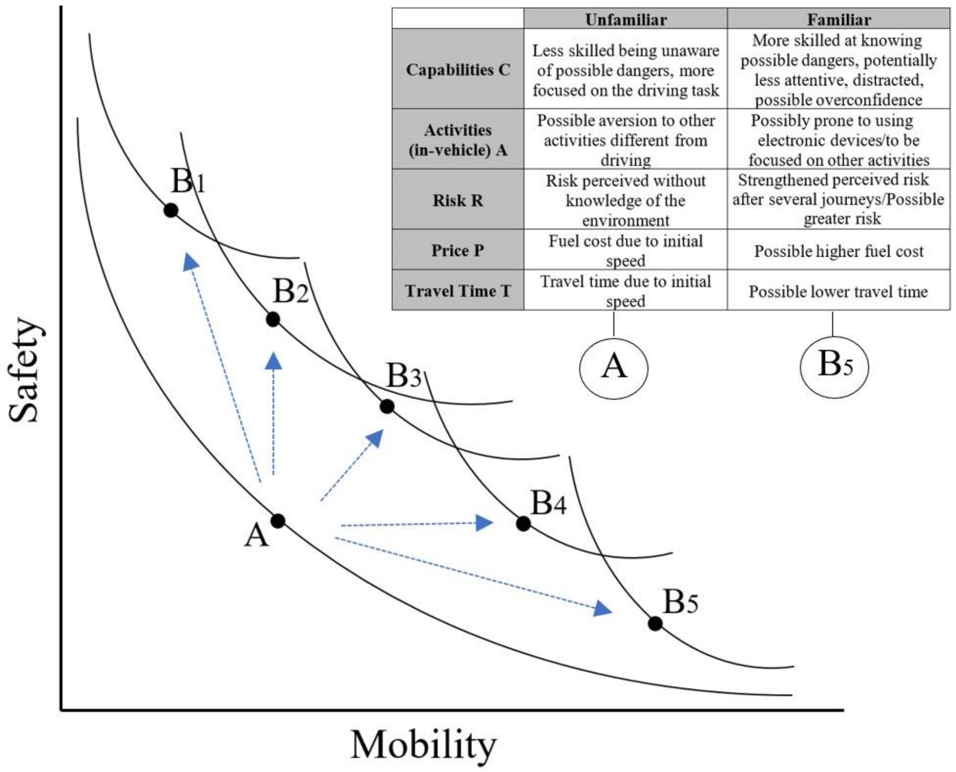


Figure 2. Trade-offs between safety and mobility (from the driver's state A on an indifference curve to different possible states B on other curves), with specific focus on familiarization processes (possibly from A to e.g. $B_5$, considering some of the explained theoretical expectations from the previous section); based on (Noland, 2013)

## 3. Methods used for the review

The methods used for the review of research studies and technical documents which have related route familiarity to road safety are shown in this section.

### *3.1 Review of research studies*

This part of the review was focused on highlighting the relationships between route familiarity and road safety based on research studies. Studies showing the influence of route familiarity on safety-related driver performances (i.e.: speed, lateral position, responses), perceptions (i.e.: of speed and enforcement, reaction times), and negative outcomes (accidents, violations) were considered.

Those studies were found in main scientific databases such as, but not limited to, "Google Scholar", "Science Direct", "Transport Research International Documentation-TRID", in different time intervals. The main keywords used for the searching process, also in combination with logical connectors, were "familiarity" and: "route", "road", "safety", "accident", "crash", "driving". Studies found in the literature were filtered by considering only those in which it was possible to directly associate the drivers' route familiarity to road safety-based aspects (such as performances, perceptions and negative outcomes). However, some studies were considered even if the inquiry into route familiarity was not their main objective. In these cases, the review was focused on the aspects which clearly suggested evidence of relationships between drivers' route familiarity and road safety.

Research studies were classified according to the main methodology employed, after having scanned the relevant articles selected for the review. Studies were then classified based on the recurrent methodologies used, explained as follows.

- Direct observations of driving behaviour ("OBS"), further divided according to the instruments used for the experimental research: driving simulators on recreated road scenarios (simulator-based studies: “OBS-SIM”) or instrumented vehicles on real roads (on-road studies: “OBS-ORS”).

- Crash database analyses (“CDA”), used to link accident counts, severities or related features to explanatory variables, or to make comparisons between different groups of accident data.
- Surveys (“SUR”), focused on specific questions directly asked to drivers and linked to their previous history of accidents or driving behaviour.
- Indirect observations of driving behaviour (“IND”) through analyses of telematic data from car insurance, used to link explanatory variables to actual behaviour and accidents recorded.

A further selection of articles was conducted for the first two categories of studies, the most numerous. The following “CDA” studies were not reviewed in detail: those in which detailed statistical analyses regarding drivers’ familiarity were not retrieved (e.g. Baldock, 2008; Mishra et al., 2010; Zheng et al., 2010; Sivak and Shoettle, 2010), those based on specific drivers, such as e.g. young or truck drivers (Chen et al., 2009; Knipling, 2009), and on interaction accidents with specific vehicles (e.g. Zhu and Srinivasan, 2011; Magazzù et al., 2006). The following “OBS” studies were not reviewed in detail: those which are mainly based on unfamiliarity with different road regulations rather than only different road environments (e.g. Thompson and Sabik, 2018; Huang et al., 2018), those in which drivers’ perception (e.g. visual perception of road signs) was related to familiarity, without (or only partial) reference to specific explanatory driving tasks or negative driving outcomes (e.g. Mourant and Rockwell, 1970; Johansson and Backlund, 1970; Beijer et al., 2004; Lehtonen et al., 2012; Babic et al., 2017). However, some of these studies were further referenced, where relevant.

This classification into categories of studies was carried out to allow consistent comparison and interpretation of different findings from studies which have used similar methodologies and variables. For the sake of consistent comparisons, the observed, measured or deduced variables considered by the authors of the studies were specifically reported for each of the reviewed studies.

Moreover, the criterion used for the identification of drivers' familiarity is a crucial methodological issue. In fact, this was found to vary greatly between the selected studies. Two main criteria based on different scales were used to identify drivers' familiarity:

- A frequency-based scale (i.e.: having previously driven a route from more than once a day to never).
- A distance-based scale (i.e.: from drivers close to home to foreigners).

On both scales, a driver can become route familiar due to repeated exposition. However, the first scale (frequency-based) directly identifies familiarity, by interviewing drivers about their travelling frequency on a given road or by inducing familiarity through repeated driving tests on the same route (and observing behaviours). The second scale (distance-based) indirectly identifies familiarity instead. Information concerning familiarity is typically deduced from specific variables in the database available (e.g. nationality, zip codes), without direct interviews/observations. Given that the main findings of the reviewed studies are evidently based on how drivers' familiarity was identified, the criterion used for the identification was also explicitly reported for each of the reviewed studies. This is useful for the further attempt at defining a harmonized criterion for identifying drivers' familiarity in future studies, as discussed later. However, the conditions of familiarity and unfamiliarity were not always explicitly defined in the reviewed studies. In these cases, the exact definitions were deduced from the methodological assumptions made. For example, in the case of experimental designs requiring several tests on the same drivers on given routes, the basic implicit unfamiliar condition deduced is being a "first time driver" of that route.

*3.2 Review of technical documents and related studies*

The second part of the review focuses on highlighting the relationships between route familiarity and road safety, based on technical documents from road and traffic engineering practice, namely standards, guidelines and technical reports. Hence, some technical documents which explicitly (or implicitly) consider the influence of drivers' route familiarity on road and traffic engineering applications and frameworks, potentially having implications for safety, were considered. The safety implications of the statements and arguments reported from the technical documents are further presented in the discussion section, by referring to studies from the scientific literature. They may also help to explain the recommendations/provisions from the technical documents selected.

# 4 Results from the review

The results from the review conducted are reported as follows, by dividing the presentation according to the two main subjects of the review methodology: 1) research studies, 2) technical documents.

*4.1 Results from the review of research studies*

The main findings from the review of research studies are summarized in the following Table 1. Since, as previously indicated, the type of study, the variables considered, and the specific criterion used for identifying drivers' familiarity are important for the further comparison of results and related discussion, they are explicitly reported in separate columns, alongside the main findings. In the column including information on the familiarity identification, the criteria used in the reviewed studies are reported in different types, depending on their coherence with the proposed harmonized criteria further presented in Table 3: **bold** if coherent, <u>underlined</u> if partially/potentially coherent. This aspect is discussed in Section 6.

As emerges from Table 1, the studies reviewed are from countries in Europe, North America, Asia and Oceania. It should be noted that studies conducted in the United Kingdom, Japan, Australia and New Zealand were in the presence of traffic driving on the left (right-hand drive vehicles). However, familiarity of drivers repeatedly subject to stimuli in the same environment may likely display its effects independently of left or right-hand traffic.

Survey-based studies are rare, potentially depending on the difficulty of collecting familiarity-related driving aspects (and/or associated to previous crashes) only from surveys. Surveys or questionnaires have proved to be a powerful complementary tool to reveal familiarity-related aspects of experimental tests (see e.g. Burdett et al., 2018a). Similarly, only one study based on the analysis of telematic data from car insurance was found.

Table 1. Research findings relating drivers' route familiarity to driving performances and negative outcomes.

| **Authors (Year) Country)** | **Type of study (CDA = Crash Database Analysis, OBS-ORS = On-Road Observations, OBS-SIM = Simulator-based Observations, SUR = Survey-based, IND = Indirect Observations)** | **Variables** | **Criterion used for identifying Familiarity (F = Familiar, U = Unfamiliar) Bold or underlined if, respectively, coherent or partially/potentially coherent with the criterion further proposed in this study** | **Main Findings** |
|---|---|---|---|---|
| Donaldson et al. (2006) (USA) | CDA | Crash variables<br>Severity | -distance-based-<br>F: environment of residence (urban/rural)<br>U: environment different than that of the residence | Even if rural residents were found to be over-involved in fatal rural road crashes[1], urban residents have the highest fatality risk in rural crashes compared to urban ones. |
| Wilks et al. (1999) (Australia) | CDA | Crash types | -distance-based-<br><u>F: country resident</u><br>**U: foreigner** | Over-representation of foreigners in angle, sideswipe and head-on crashes, over-representation of resident drivers in crashes with fixed-objects, pedestrians, parked vehicles and animals. |

| | | | | |
|---|---|---|---|---|
| Yannis et al. (2007) (Greece) | CDA | At fault driver<br>Crash variables | -distance-based-<br>F: country resident<br>**U: foreigner** | Foreign drivers are more likely to be at fault in crashes. The road elements associated to greater accident risks for them are junctions. Area types and lighting do not seem influential. |
| Yan et al. (USA) (2005) | CDA | At-fault driver<br>Crash dynamics (rear-end)<br>Crash variables | -distance-based-<br>Categorical scale variable for drivers' familiarity: from 1 for county residents to 4 for other country residents | Decreasing levels of familiarity (from county residents to foreigners) are associated to higher likelihoods of being involved in rear-end crashes at signaled intersections while both striking and being struck, as emerged from logistic regression models taking into account several variables. |
| Kim et al. (2012) (USA) | CDA | At-fault driver<br>Crash types | -distance-based-<br>F: country resident<br>**U: foreigner** | Foreign drivers are more likely to be involved in at-fault crashes. They are associated to accident causation due to improper manoeuvers or wrong way (based on logistic regression). |
| Yoh et al. (2017) (Japan) | CDA | Crash types<br>Crash variables<br>Traffic violation | -distance-based-<br>F: country resident<br>**U: foreigner** | Foreign drivers are more likely to commit traffic violations related to comprehension (e.g. of road signs) than resident drivers, who comparatively commit more violations related to speed (and priority to a lesser extent). |
| Harootunian et al. (2014a,b) (USA) | CDA | At-fault driver<br>Crash types<br>Crash variables | -distance-based-<br>F: state resident<br>U: out-of-state resident | Out-of-state drivers were found to be more likely to be at-fault, especially in single-vehicle crashes. Even with local differences, some crash factors are more associated to out-of-state drivers (e.g. curves, low lighting, wet pavements, etc.). |
| Burdett et al. (2017, 2018a) (New Zealand) | CDA | Crash variables | -distance-based-<br>continuous scale (distance from residence) | Drivers are more prone to crash close to home when considering both travel and crash data (higher percentage of crashes compared to total journeys in the same radius of 11 km from home). Close to home crashes are over-represented on low-speed urban roads, more associated to inattention (lapses) than violations. Low-speed urban accidents due to lapses of attention occur more at minor and mid-blocks than at major intersections. |
| Intini et al. (2017b, 2018) (Norway) | CDA | Crash types<br>Crash dynamics<br>Crash variables | -distance-based-<br>**F: ≤ 20 km from residence**<br>**U: ≥ 200 km from residence** | Familiar drivers are more involved in rear-end crashes (more being struck than striking), in crashes at low speed limit rural sections, at minor rural intersections and while commuting rather than working. Unfamiliar drivers are more likely to be found at sites with high seasonal traffic variations in summer, and in crashes involving heavy vehicles (based on statistical tests). After reconstruction of accidents at the micro-scale, crashes involving familiar drivers are mostly rear-end crashes (even if based on a small sample). |
| Rosenbloom et al. (2007) (Israel) | OBS-ORS | Traffic violation<br>Dangerous behaviours<br>Speeding tendency | -frequency-based-<br>F: familiar with the location<br>U: unfamiliar with the location | Drivers (female) perform more traffic violations (including speeding) and dangerous behaviours while traveling on roads in well-known familiar locations than in unfamiliar ones. |

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| Colonna et al. (2016b) (Italy) | OBS-ORS | Speed<br>Sight Distance<br>Speeding tendency | -frequency-based-<br>**F: having driven the test route 4 times in 4 subsequent days**<br>**U: first day driving** | Drivers more familiar with the route travel at higher speeds, especially those showing greater speeding tendency. The speed increases regardless of sight distances. Part of the speed increase was recovered after stimuli interrupted some drivers, and part was also maintained in the long-term. |
| Colonna et al. (2015, 2016c) (Italy) | OBS-ORS | Curve Trajectories<br>Speed self-perception | -frequency-based-<br>**F: having driven the test route 4 times in 4 subsequent days**<br>**U: first day driving** | Drivers who were more route familiar show emphasised curve cutting tendency, even if the trajectory radii are already higher than curve radii in the first test. They freely choose speeds similar to those perceived by themselves as high, rather than medium. The opposite tendency is noted in the first test. |
| Burdett et al. (2018b)(New Zealand) | OBS-ORS | Self-reported thoughts<br>Difficulty ratings | -frequency-based-<br>F: familiar with the location<br>U: unfamiliar with the location | Eleven female drivers observed during ten trips on their home-work routes reported mind wandering in 63 % of total cases (question asked by experimenters multiple times per trip). More attention was reported in the case of demanding tasks. |
| Young et al. (2017) (UK) | OBS-ORS | Eye fixation | -frequency-based-<br>**F: having driven 28 times over several weeks**<br>**U: first day driving** | Off-road dwell time generally increases with road familiarity and dwell time on safety-related aspects on the road ahead generally decreases with road familiarity (except in the open suburban scenario). These results are based on one professional driver who drove on five types of roads. |
| Wu and Xu (2018) (USA) | OBS-ORS[2] | In-vehicle activities<br>Speed<br>Deceleration distance | -frequency-based-<br>**F: intersection travelled > 52 times per year**<br>**U: intersection travelled only once a year** | Distracted driving activities and duration of these activities were found to be higher on familiar than on unfamiliar roads. Drivers were more likely to be speeding and decelerating at shorter distances from intersections on familiar roads. These results are based on naturalistic data of drivers crossing a high-risk intersection with different yearly frequencies. |
| Martens and Fox (2007) (Netherlands) | OBS-SIM | Glance duration<br>Response to Speed changes | -frequency-based-<br>**F: having driven 23 times in 5 subsequent days**<br>**U: first time driving** | Duration of glances at road signs decreases while drivers are becoming route familiar, while speed increases. Most drivers fail to notice a change of an intersection priority on the fifth test day. |
| Bertola et al. (2012) (USA) | OBS-SIM | Speed<br>Lateral Position | -frequency-based-<br>**F: having driven 7 times more than unfamiliar drivers**<br>U: having driven 7 times in the same day | Speeds and standard deviations of lateral position higher for familiar drivers than the group of "unfamiliar" drivers. |
| Charlton and Starkey (2013) (New Zealand) | OBS-SIM | Difficulty ratings<br>Detection tasks<br>Speed<br>Lateral position<br>Response to changes | -frequency-based-<br>**F: 20 journeys over 3 months**<br>**U: first time driving** | Difficulty ratings, items reported as unusual, speed and lateral position variance generally decreased, and average speeds increased, while becoming route familiar (and compared with a control group of unfamiliar drivers). Detection tasks were more successful for guidance-related items (markings or vehicles). These effects were generally lost when unfamiliar road scenarios were presented in the 8$^{th}$ test[3]. |
| Yanko and Spalek (2013, 2014) (Canada) | OBS-SIM | Reaction time<br>Peripheral response<br>Self-reported thoughts | -frequency-based-<br>**F: having driven 4 times in the same day**<br>**U: first time driving** | The group of familiar drivers show longer reaction times both for braking and for noting lateral obstacles, and shorter headways than the unfamiliar group. |

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| | | | | When controlling for the influence of mind wandering, drivers who reported mind wandering were found to show longer response times, higher speeds and shorter headways than drivers who reported being focused on the driving task. |
| Harms and Brookhuis (2016) (Netherlands) | OBS-SIM | Speed<br>Response to changes<br>Detection tasks | -frequency-based-<br>**F: having driven 18 times in 5 days**<br>**U: first time driving** | Most of drivers familiar with a simulated motorway section failed to respond to a road change (increased variable speed limit), the latter drivers showing average speeds higher than drivers who have noticed the change. Speed increased with familiarity and then stabilized. Verbal reports concerning events which caught drivers' attention decrease with familiarity, except for the specific task of detecting a truck, the score for which increases instead. |
| Martens (2017) (Netherlands) | OBS-SIM | Speed<br>Response to changes | -frequency-based-<br>**F: having driven 18 times in the same day**<br>**U: first time driving** | Most of drivers failed to respond to a road change (conversion of a road into a no-entry road), in both conditions of exactly the same road and of similar roads repeatedly travelled before the change. This result is based on drivers divided into different test scenarios, considering also the base no-change condition. A general auditory in-vehicle warning was found to reduce the failure to respond, while speeds increase over the consecutive drives tested in a short time period. |
| Baldock et al. (2005) (Australia) | SUR | Crash dynamics (Rear-end) | -frequency-based-<br>**F: daily travelling**<br>U: not applicable | Over-representation of drivers travelling daily on a road being struck on that road; in comparison with daily-frequency drivers striking (based on few interviews). |
| Liu and Ye (2011) (USA) | SUR | Crash types | -frequency-based-<br>F: at least monthly travelling<br>U: rarer than monthly travelling | Drivers travelling on familiar roadways are more likely to be involved in run-off road crashes (64 % of single-vehicle crashes of familiar drivers are run-off road, compared to 54 % of the unfamiliar ones). |
| Ryeng (2012) (Norway) | SUR | Enforcement perception | -frequency-based-<br>F: at least biannual travelling<br>**U: less than biannual travelling** | Drivers more familiar with the investigated sections make slightly better estimates on the actual enforcement on the sections with high enforcement levels. |
| Jin et al. (2018) (China/USA) | IND | Driver and vehicle variables<br>Telematic data (e.g. speed, acceleration, road familiarity) | -frequency-based-<br>Continuous scale, resulting in two predictor variables: percentage of roads travelled by 1-2 times or between 3 and 8 times in one month | Drivers who are more familiar with their driving routes are less likely to report accidents, as a result of logistic regression models. Familiarity is a significant factor for both high and low-risk drivers, based on latent class models. |

[1]see Blatt and Furman (1998), who found over-involvement of rural/small town residents and urban residents in rural and urban fatal road crashes, respectively.
[2]Naturalistic data were used in this study, it not being a typical experimentally designed on-road study.
[3]Results from a pilot study conducted with a similar study design were shown in Charlton and Starkey (2011).

### *4.2 Results from the review of technical documents*

The main aspects highlighted from the review of technical documents are summarized in the following Table 2.

In particular, the main retrieved statements/arguments documenting the consideration of the drivers' route familiarity in safety-related aspects of the road and traffic engineering practice, or which may be related to this relationship, are reported. Apart from this information, the table includes the following variables (reported in separate columns): information about the authors of the documents, reference area of the engineering practice (road or traffic), type of document (standards, guidelines, technical reports), type of reference to drivers' route familiarity (explicit or implicit).

Table 2. Main road safety-based statements/arguments in some road and traffic engineering technical documents which may be explicitly or implicitly related to drivers' route familiarity.

| **Author (Year) (Country)** | **Engineering Area** | **Type of document** | **Reference** | **Relevant statements/arguments[1]** |
|---|---|---|---|---|
| Milliken et al. (1998) (USA) | Road | Technical Report | Explicit | "*The designer should assume that motorists are driving on a roadway for the first time and that they have no familiarity with its features*" |
| Wooldridge et al. (2003) (USA); MdE/SETRA (1994) (France); MIT (2001) (Italy); FGSV (2008) (Germany); Lamm et al. (1999) (Germany) | Road | Standards/ Guidelines/ Technical Report | Implicit | *Road design consistency*. It is defined as the "*conformance of a highway's geometric and operational features with driver expectancy*" (Wooldridge et al., 2003). Elements of the road alignment and their associated speeds should be harmonized and not greatly different from the previous ones, in order to possibly avoid surprises (e.g. sudden sharp curves after long tangents; subsequent radii). |
| MdE/SITRA (1994) (France); MIT (2001) (Italy); CSIR (2000) (South Africa); MdE/SETRA (1994) (France); FGSV (2008) (Germany) | Road | Standards/ Guidelines | Implicit | *Element lengths*. Maximum and minimum lengths may be set for tangents based on speeds, to avoid: drivers' misperceptions and inappropriate trajectories (for short tangents between curves), speeding, distraction, and/or fatigue (for long tangents). Minimum curve lengths may be required to avoid misperceptions, incorrect trajectories. |
| Lamm et al. (1999) (USA); MIT (2001) (Italy) | Road | Standards/ Guidelines | Implicit | *Friction*. An appropriate level of road friction is required in calculations of road design parameters. |
| MIT (2011) (Italy); Krammes and Garnham (1998) (USA); Fitzpatrick et al. (2003) (USA); Milliken et al. (1998) (USA); AASHTO (2001) (USA); ITE (2016) (USA); Donnell et al. (2009) (USA); Lamm et al. (1999) (Germany); DTMR (2013) (Australia) | Road/Traffic | Standards/ Guidelines/ Technical Report | Implicit | *Speeds*. The relationships between design, operating and posted speeds should be controlled. Operating speeds (usually measured through the $85^{th}$ percentile speed) should not be substantially different from design speeds, considered as safe for ideal design drivers on each road element. The posted speed should generally be coherent with the $85^{th}$ percentile speed. |
| TRB (2016) (USA) | Traffic | Guidelines | Explicit | In the case of a significant presence of unfamiliar drivers in the traffic flow, both design capacity and free flow speeds may be reduced through appropriate factors accounting for the different |

| | | | | |
|---|---|---|---|---|
| | | | | composition of the driver population. The greater the number of unfamiliar drivers there are in the flow, the more free flow speed and capacity may be reduced, with respect to the “all familiar drivers/regular commuters” condition. |

[1]Relevant statements are summarized according to some recurrent topics from the different considered sources, while each of them may contain only part of the summary.

Possible relationships between route familiarity and safety-based concepts in road/traffic engineering practices are reported in Table 2. Most of the statements/arguments reported for the road design aspects are generally valid in several countries. Hence, examples of standards, guidelines and technical reports which cover them, mainly from North America and Europe are provided.

Explicit references to the drivers’ route familiarity were found in documents belonging to both the road and traffic engineering practice. However, most of the possible relationships between the aspects highlighted in Table 2 and the influence of route familiarity in road safety are only implicit. Hence, they are highlighted and discussed in the next section.

## 5 Discussion

The findings presented in both Table 1 and Table 2 are discussed in this section. The discussion is structured according to the two aims of this study: the explanation of the relationships between drivers’ route familiarity and road safety, and the attempt at identifying route familiarity by means of the frequency and distance-based criteria. The further proposal for identifying drivers’ route familiarity is mainly based on the discussion of identification criteria used in previous studies.

### *5.1 Discussion on the relationships between route familiarity and road safety*

The discussion is divided according to the two main categories of documents reviewed: research studies and technical documents. In both cases, the relationships between route familiarity and road safety are explicitly explained, since these are often only implied in the findings highlighted from the review conducted.

#### *5.1.1. Discussion based on research findings*

Research findings reveal some important safety-based aspects related to route familiarity, which were consistently found in the documents reviewed: the proneness of familiar drivers to be less focused on the driving task, their propensity for aggressive driving performances, and the increased likelihood of unfamiliar drivers to be at fault in crashes. Those three aspects are discussed in detail as follows:

- Familiar drivers may be less focused on driving tasks, as emerges from studies in which driving behaviour was directly observed (on-road/simulator-based). The decreased attention was associated to mind wandering (Yanko and Spalek, 2014; Burdett et al., 2018a); distracted driving activities (Wu and Xu, 2018); both actual and potential impairment in reacting to environmental inputs, such as increase in dwell times (Young et al., 2017) and reaction times (Yanko and Spalek, 2013), decrease in duration of glances at road signs (Martens and Fox, 2007). This tendency is explainable through several psychological frameworks, which associate familiar driving to automatic processes (Rasmussen, 1983; Reason, 1990; Embrey, 2005, Charlton and Starkey, 2013. 2018). The familiarization process may lead drivers towards a habituated state, due to the repeated application of the same stimulus (Groves and Thompson, 1970; Rankin et al., 2009), leading to reduced mental workload and attention (Young and Stanton, 2002). The gradual process leading to habituation is documented in studies that monitored key variables during the familiarization process. For example, Charlton and Starkey (2013) found that difficulty ratings associated to each drive and items reported as unusual (see also Harms and Brookhuis, 2016) decreased with route familiarity. Moreover, the acquired familiar drivers' reduced attention was related to failure to respond to changes, such as to road signs (Martens and Fox, 2007), or variable speed limits (Harms and Brookhuis, 2016). In addition, the relationship between familiarity and possible over-involvement in distracted driving activities (Wu and Xu, 2018) is another safety concern, since distraction was consistently related to errors (Young and Salmon, 2012) and crashes (Sandin, 2009; Staubach, 2009). On the other hand, familiar drivers may still focus on demanding tasks (Burdett et al., 2018a) for which "automated" driving may not be adopted, or on specific guidance-related tasks/items, such as detecting vehicles (Charlton and Starkey, 2013, Harms and Brookhuis, 2016). Charlton and Starkey (2013) explain this through two layers present in familiar drivers: one level of inattention blindness due to the automatic process and one level of awareness of some momentary tasks necessary for driving. Another important aspect was suggested by Martens (2017): the effects of familiarity (leading to failure in responding to changes) were noted on roads similar to those on which the familiarization process occurred, but not being strictly limited to them.

- Familiar drivers may be more prone to more dangerous driving performances, as another side of the familiarization process. Speeding tendencies (Rosenbloom et al., 2007; Colonna et al., 2016b; Wu and Xu, 2018); traffic violations (Rosenbloom et al., 2007); increase in curve cutting behaviours or higher standard deviations of lateral positions than unfamiliar drivers (Colonna et al., 2016c;  Bertola et al., 2012); decelerating at shorter distances from the target point (Wu and Xu, 2018); underestimation of their speeds (Colonna et al., 2015) were all phenomena associated to familiar drivers in studies focused on direct behavioural observations. Moreover, independently of the type of study (i.e. on-road or simulated driving) and the number and interval of test repetitions, speed was consistently found to increase over time with acquired familiarity (Martens and Fox, 2007; Charlton and Starkey, 2013; Harms and Brookhuis, 2016; Colonna et al., 2016b; Martens, 2017). Speeds were found to stabilize after an initial growth in the first test repetitions in at least two studies (Harms and Brookhuis, 2016; Colonna et al., 2016b, even if in the latter study, there were pauses between subsequent tests). The phenomenon of speed increase and further stabilization at a constant value can be equated to the habituation process (Groves and Thompson, 1970; Rankin et al., 2009), which can occur by driving the same route several times. In this case, speed increase does not necessarily mean increasing tendency for speeding: i.e. the increased familiar speed may still be lower than the speed limit. However, higher speeds are associated to higher crash likelihood (Elvik, 2013; Nilsson, 2004). Hence, the familiar speed increase may be related (Intini et al., 2017a) to typical trade-offs (Noland, 2013) between safety (more risks) and mobility (shorter travel time), for the sake of higher utility. Similarly, curve cutting tendencies may also lead to a decrease in travel times but a risk increase. Moreover, familiar drivers were also associated to inattention blindness, distraction, mind-wandering and task automation. These tendencies may seem diametrically opposed to the previously highlighted more dangerous behaviours, but they are connected however. In at least three studies reviewed (Charlton and Starkey, 2013, Yanko and Spalek, 2014; Harms and Brookhuis, 2016), the increase in speed occurred in parallel with a documented decrease in attention capacity. Findings from Yanko and Spalek (2014) demonstrated that drivers were more prone to higher speeds and shorter heading distances when subjected to mind wandering than when driving focused. They suggest that being less aware of the environment; drivers may also be less concerned with applying safety margins while driving. In parallel, the increased speed may result from the familiarization process after subsequent refinements (Harms and Brookhuis, 2016), in a trial-and-error fashion (Fuller, 2007), when the attention capacity is still greater than in the case of mind wandering. It should be noted that drivers are generally more prone to crash close to home (Burdett et al., 2017) or in the same rural/urban environment as their residence (Blatt and Furman, 1998; even if Donaldson et al., 2006, point out that urban residents have higher fatality rates in rural compared to urban crashes). Part of these results may also be interpreted in light of the familiar tendency towards more dangerous behaviours. However, data exploration by Burdett et al. (2018b) revealed that most close-to-home crashes (clustering at low-speed urban roads) were more associated to lapses of attention than violations. Based on this, distraction may be more influential than dangerous behaviours on crashes. However, further evidence is needed for this crucial deduction.

- Unfamiliar drivers were found to be more likely to be at fault when involved in crashes. Improper manoeuvres, wrong way (Kim et al., 2012) or junction-related crashes (Yannis et al., 2007) were specifically related to foreigners, typically unfamiliar with foreign roads. Similarly, out-of-state (Vermont, USA) drivers (Harootunian et al., 2014), were found to be over-involved in at-fault crashes, especially for single-vehicle accidents and in winter. Unfamiliar drivers may suffer from orientating in foreign environments (see also Leviäkangs, 1998), possibly resulting in improper manoeuvres leading to crashes. In Yoh et al. (2017), foreign drivers in Japan were associated to more violations related to comprehension (e.g. of road signs) than residents. If the foreign environment has unfamiliar way of traffic (e.g. left-hand), this may be an additional factor (see e.g. Thompson and Sabik, 2018; Malhotra et al., 2018), such as while interpreting results from Wilks et al. (1999), related to accidents to foreign drivers in Australia. These findings are coherent with common sense expectations, but unfamiliar drivers could have similar problems only in some environments. Yannis et al. (2007) found e.g. that foreign drivers are over-exposed to at-fault crashes especially at junctions (see also Wilks et al., 1999 for angle crashes and Yan et al., 2005, for rear-end crashes at signaled intersections), which may be demanding road elements, leading unfamiliar drivers to errors. Foreigners were also found to be over-represented in angle, sideswipe, head-on crashes (Wilks et al., 1999), and unfamiliarity may then have been a contributory factor. An inverse relationship between familiarity and accident reporting was found by Jin et al. (2018) as well, even it is hardly comparable with previously cited results.

Whereas, when it comes to the involvement of familiar and unfamiliar drivers in specific types of crashes, it is hard to find common traits among the reviewed studies. Familiar and unfamiliar drivers were associated to different crash types (Wilks et al., 1999; Baldock et al., 2005; Liu and Ye, 2011; Yan et al., 2005; Intini et al., 2017b, 2018). However, the design of these studies and the familiarity identification criteria were different. It is worth noting that at least two studies (Baldock et al., 2005; Intini et al., 2018) revealed an over-involvement of familiar drivers in rear-end accidents, (being struck more than striking). The over-involvement of familiar drivers in rear-end accidents may be explainable through their possible greater tendency to shorter headways (see e.g. Yanko and Spalek, 2013), or to brake at shorter distances from the target point (i.e. an intersection in: Wu and Xu, 2018). Conversely, Yan et al. (2005) related rear-end accidents to unfamiliarity in case of signalized intersections. Other similarities concern the lower tendency of unfamiliar drivers to run-off accidents with respect to familiar drivers (Liu and Ye, 2011, Intini et al., 2018). However, these studies differ in the familiarity scales adopted. Hence, investigation into relationships between route familiarity and crash types should be surely deepened.

#### *5.1.2 Discussion based on the review of technical documents*

As a result of the review of technical documents (see Table 2), some important safety-based aspects emerge in considering the influence of route familiarity. However, except for some specific cases (e.g. Milliken et al., 1998; TRB, 2010), the influence of route familiarity in engineering standards, guidelines and reports is not explicitly stated. Hence, these possible relationships are suggested in this section, especially from the road engineering side, through using findings from relevant research studies.

As emerges from Table 2, several road geometric design rules are essentially driver-based and some of them may be associated to route familiarity. The road layout should ideally induce safe behaviours through its own features by meeting drivers' expectations: the concept of "self-explaining road" (Theeuwes and Godthelp, 1995; see Charlton et al., 2010; Mackie et al., 2013; for some applications). Following from this, road design consistency (see Wooldridge et al., 2003) is a strictly user-based crucial safety aspect (Gibreel et al., 1999; Ng and Sayed, 2004; Dell'Acqua et al., 2013), considered in several road design standards and guidelines. The requirements of road design guidelines, ensuring that the road geometry should be consistent and not surprising for design drivers, imply assuming that they are road unfamiliar, as explicitly stated by Milliken et al. (1998). This is clearly understandable, since a familiar driver might know the pitfalls of a road layout very well due to long previous association (except for rapid changes in boundary conditions). On the other hand, unfamiliar drivers can be surprised by demanding and not self-explaining layouts (such as sharp curves after a sequence of smooth curves) possibly leading to improper manoeuvres with crash outcomes (Kim et al., 2012). This may imply that drivers' familiarity could prevent accidents on particularly non self-explaining road sections. Familiar drivers may be able to keep road geometric elements in their memory even after long periods (Colonna et al., 2016b) and provide higher perceived risk ratings in some instances of demanding road curves (Kanellaidis et al., 2000). Moreover, they may be particularly attentive to guidance-related items (Charlton and Starkey, 2018), and form specific mental schemes of different road types and associated speeds (Charlton and Starkey, 2017a,b). However, the greater road knowledge with respect to unfamiliar drivers may be compensated by other behavioural tendencies previously discussed, such as mind wandering (Yanko and Spalek, 2013) distracted driving and more dangerous behaviours (e.g. Wu and Xu, 2018). Liu and Ye (2011) found that familiar drivers were more prone than unfamiliar drivers to run-off-road crashes, of which a large share usually occurs at curves. With no additional information about road layouts and other boundary conditions at which crashes occurred, it is difficult to state whether being familiar was a preventive or contributory crash factor. Moreover, familiar drivers were more associated to crashes on roads (Burdett et al., 2017) and environments (Blatt and Furman, 1998; Ryan et al., 1992; Lu et al., 2000) they are likely to know best.

Some road design standards/guidelines set minimum tangent and curve lengths to prevent steering errors. This is referred to a design driver, assumed to be unfamiliar, the most exposed to misperceptions due to ignorance of the road. Conversely, setting maximum tangent lengths could help prevent monotony, fatigue (Lamm et al., 1999), and distraction. Both familiar and unfamiliar drivers could benefit from this setting. However, since familiarity is related to both speeding and distraction, preventing high speeds and/or possible distraction by limiting tangents could be specifically helpful for them. Design guidelines usually impede excessive acceleration/braking between subsequent elements, based on design speeds (see e.g. MIT, 2001). High speed differences (e.g. between a tangent and the sharp curve ahead) could be specific issues for unfamiliar drivers who cannot expect the required speed change. They could suddenly brake or not match the appropriate curve speed. The same remark is valid for intersections or driveways (i.e. unexpected or poorly visible). The latter suggestion is supported by the over-involvement of foreign drivers in angle (Wilks et al., 1999, mostly related to intersections) and junction crashes (Yannis et al., 2007).

Features of road elements are internationally designed based on design speeds. However, if operating speeds are significantly higher than design and posted speeds, this could be a safety concern (Fitzpatrick et al., 2003). Considering the driving behaviour, the speed is determined through trial-and-error based on experience (Rasmussen, 1983), and familiar drivers may travel at their subjective maximum “safe” speed. This speed can be higher than speed limits because of trade-offs between risks (e.g. perceived crash and speed ticket risks, Tarko, 2009) and mobility benefits (Noland, 2013). Conversely, unfamiliar drivers could still not have a clear perception of road risks, by not travelling at the optimum safe perceived speed. This means that consistency criteria for design, operating and posted speeds can be considered as mainly focused on increasing familiar drivers’ safety. They are indeed related to speeding and crashes at more familiar locations (Rosenbloom et al., 2007; Blatt and Furman, 1998).

Concerning friction, drivers normally notice skidding when it is happening (Colonna et al., 2016d, 2018b), potentially being a problem regardless of familiarity. However, on one hand, familiar drivers may have knowledge of specific road sites where the road usually become slippery; on the other hand, skidding could occur to unfamiliar drivers because of speed errors while approaching unexpected curves. The previously determined safe speed of familiar drivers may prevent skidding, except when boundary conditions suddenly change and they do not react accordingly. This latter suggestion is related to the higher proneness of familiar drivers to run-off crashes than those classified as unfamiliar (Liu and Ye, 2011).

A significant presence of unfamiliar (recreational) drivers in the traffic flow is deemed to possibly reduce both the free flow speed and the capacity of multi-lane highways and freeways (TRB, 2016). This is coherent with the expectations for unfamiliar drivers: they may select lower speeds than familiar drivers (possibly leading to an average speed decrease but a speed variance increase) and can be less prone to close car-following through longer headways (hypothesis reported e.g. by Seeherman and Skabardonis, 2013, who however highlight that further research is needed) than familiar drivers, leading to capacity reduction. The presence of various traffic components (i.e. familiar and unfamiliar drivers) in the flow may be implicitly influential on safety, as well as capacity. In fact, they may show different behaviours in terms of speed, lateral position, acceleration, braking, etc., as previously discussed. A mix of familiar and unfamiliar drivers was associated to a higher speed variance, which in turn could be related to a higher accident risk (Garber and Gadirau, 1988). Moreover, a higher variance of gaps (unfamiliar drivers may select greater gaps) between vehicles could induce following drivers to overtake, leading to more potential conflicts. This in turn could possibly lead to more accidents at different road sites (Fazio et al., 1993; Dijkstra et al., 2010; Lu et al., 2011). However, the possible factors involved are various and they are interdependent. For example, an average flow speed reduction could instead result in a crash reduction (Nilsson, 2004; Elvik, 2013). Nevertheless, the interaction between familiar and unfamiliar drivers may represent a safety concern, as indicated above. However, this topic has scarcely been addressed. Some previous findings (Baldock et al., 2005; Intini et al., 2017b, 2018) reveal an over-involvement of familiar drivers in accidents in which interactions with other vehicles occurred. However, no significant specific interactions between familiar and unfamiliar drivers were noted by analysing a sample of two-lane rural road crashes (Intini et al., 2018). Hence, further specific studies are needed, especially for multi-lane roads, where interactions are greater.

### *5.2 Discussion of the criteria used for identifying drivers' familiarity*

The criteria used for identifying drivers' familiarity in the studies reviewed were classified into frequency-based and distance-based criteria.

In "OBS" studies (direct observations), the behaviour of familiar drivers is necessarily compared with unfamiliar drivers' behaviour, or the possible changes during/after the familiarization process are observed. This is addressed in four basic ways:

1) by comparing the condition of acquired familiarity with the initial unfamiliarity condition for the same drivers (e.g. in Colonna et al., 2016b; Young et al., 2017; Martens and Fox, 2007) or by observing the behaviour of drivers who have become familiar in the tests (e.g. in response to changes, see Martens and Fox, 2007; Harms and Brookhuis, 2016);

2) by comparing drivers who acquired familiarity after test repetitions with drivers who only drove once or less than familiar (e.g. in Bertola et al., 2012; Yanko and Spalek, 2013; Charlton and Starkey, 2013);

3) by comparing drivers already familiar with a given condition (e.g. given locations, as in Rosenbloom et al., 2007; Wu and Xu, 2018) with the same drivers in unfamiliar conditions (e.g. Rosenbloom et al., 2007); or

4) with drivers unfamiliar with the same condition (e.g. Wu and Xu, 2018).

Moreover, in the first two cases of the above-reported list, the number of repetitions to observe potential behavioural changes varies from four tests in a day (Yanko and Spalek, 2013) to 20 times over 3 months (Charlton and Starkey, 2013) or 28 times over several weeks (Young et al., 2017). However, some changes in the same drivers or differences with a control group of unfamiliar drivers (e.g. on their first drive) were observed regardless of the number of repetitions, even if related to different measures (i.e. speed, position, eye fixations, response to changes, etc.).

Survey-based studies (Baldock et al., 2005; Liu and Ye, 2011; Ryeng, 2012) also use a frequency-based scale and relate it with crash-related and other variables. Interviewed drivers were asked about their familiarity with the road on which crashes occurred or to which the other variables investigated are referred (i.e. enforcement in Ryeng, 2012). Choosing a frequency-based scale may be explained by the preference for a direct measure, since interviews were possible. However, the studies reviewed have set different minimum traveling frequencies for identifying familiarity of drivers from daily (Baldock et al., 2005), to at least monthly (Liu and Ye, 2011) or even at least biannually (Ryeng, 2012).

Moreover, in one instance (Jin et al., 2018), telematic data from car insurance were used to reveal relationships between accidents and predictor variables, including route familiarity. In this case, route travel repetitions are directly measurable. Hence, frequency scales may be the best choice as well.

Whereas, most crash databases lack information concerning the frequency of travelling on the road on which the accident occurred, this being usually limited to the travel purpose only. However, more frequently collected information concerns nationalities and zip codes of drivers involved in accidents (in Zhu and Srinivasan, 2011, frequency-based variables were also available, derived from a nationwide data collection project). Hence, for these studies, the distance-based scale is a necessary choice. The studies were conducted by comparing accidents to drivers beyond and within given distances from home (the first deemed as "unfamiliar", the second deemed as "familiar"). In this regard, there are three main strategies:

1) comparing variables (i.e. likelihood, severity, type, characteristics, location) associated to accidents which occurred involving foreign drivers with those related to resident drivers (e.g. in Wilks et al., 1999; Yannis et al., 2007; Kim et al., 2012);

2) using urban boundaries to compare crash-related variables (i.e. involvement of urban residents in urban versus rural accidents and vice versa, as in Donaldson, 2006);

3) using the absolute distance in kilometers from their residence as a variable for relating crash likelihood and features to familiarity (based on travel surveys, Burdett et al., 2017; or on zip codes, Intini et al., 2018).

It is worth noting that some findings relating crash-related variables to familiarity were highlighted in the reviewed studies regardless of the specific measures considered (i.e. foreign vs residents, rural vs urban residents, far from home vs close to home drivers). Hence, it is evident that, even if a frequency-based scale was deemed to be directly related to familiarity (because it was self-reported by drivers, measured or controlled through repeated tests in controlled environments), a certain arbitrariness still remains. In fact, the number of tests required or the minimum traveling frequency on a given road to acquire a familiar condition, are hard to define and they actually vary among the reviewed studies indeed. The same is valid for distance-based measures, indirectly derived from a database.

## 6. Proposal for a harmonized method for identifying familiarity

Defining standards for identifying a driver's route familiarity is rather complex. Several measures and different criteria for identifying the drivers' route familiarity have been used in research studies, depending on the type of study design and the specific methodology. The main issue is that the identification of familiarity should be based on personal subjective features, since drivers may experience different familiarization processes (see Li et al., 2018) or provide different answers about the relationships between travelling frequency and self-reported familiarity (see Baldock et al., 2008). Hence, predefined limits dividing familiarity and unfamiliarity conditions (familiarization as a binary process) should be avoided. Setting universal thresholds beyond which considering a driver as familiar (or unfamiliar), is most likely to be affected by biases.

However, for research purposes, some measurable indicators able to reveal the relationships between familiarity and safety-related variables have to be considered. Moreover, a standardized procedure that may at least ensure the comparability between results from different studies (otherwise impaired) should be the optimum goal, even if potentially affected by biases due to the implicit uncertainties discussed. In this sense, a criterion for the identification of drivers' familiarity, which attempts to harmonize the methodologies used in previous studies and theoretical frameworks, is suggested here. The specific identification criteria are shown in Table 3 for both frequency and distance-based scales. For the reasons explained above, they should not be intended as strict deterministic boundaries, but rather as a possible rational harmonized basis deriving from previous studies, an alternative to *a-priori* values and potentially useful for future research. The coherence of methodologies used in previous studies with the identification criterion proposed here is documented in Table 1. Most previous studies are entirely or partially coherent with this proposal.

Table 3. Proposed frequency and distance-based identification criteria for drivers' route familiarity.

| Scale | Familiarity | Unfamiliarity |
|---|---|---|
| **Frequency -based** | • Survey-based: Frequency ≥ Weekly<br>• Observational studies (on-road/simulator-based): Test repetitions ≥ 4 | • Survey-based: Frequency ≤ Yearly<br>• Observational studies: First time driving (excluding practice) |

| | | |
|---|---|---|
| **Distance-based** | Distance from residence ≤ locally calibrated average commuting trip distance | Distance from residence ≥ locally calibrated minimum long-trip distance (foreigners considered as unfamiliar) |

For the reasons previously explained, different types of studies may necessarily rely on different scales. Hence, the criterion (frequency or distance-based) to be fulfilled depends on the study designs and methodologies used. If both measures are available, frequency-based scales should be preferred since they are self-reported or controlled in repeated tests on the same experimental layouts.

The reasons for assuming those measures are outlined as follows.

For the frequency-based definition:

- Commuters (almost daily-frequent drivers) were previously used as a typical example of familiar drivers. However, drivers can be familiar with a route even if they do not strictly travel it daily. Some behavioural changes were actually observed after a number between four and five subsequent travelling days (Martens and Fox, 2007; Colonna et al., 2016b; Harms and Brookhuis, 2016). However, these studies differ in their experimental designs: in some of them (Martens and Fox, 2007; Harms and Brookhuis, 2016) there were more drives per day. However, evidence of significant changes was noted even for 4 test repetitions in the same day (Yanko and Spalek, 2013). Hence, this is the minimum number of test repetitions proposed for future studies. Clearly, the more test repetitions there are, the more the simulated familiar condition is likely to be reliable. However, a huge number of repetitions may not be necessary, since driving parameters seem to become stable after several drives (see Harms and Brookhuis, 2016). Coherently, Li et al. (2018) estimated that the steady time (time to get a steady memory of road scenes observed on seven drives over subsequent days, based on memory scores) is 7.6 days, through experimental data modelling. Hence, more than 7 test repetitions over different days could be redundant when observing behavioural changes due to familiarity. However, some drivers were found to fail in repeating the same driving performance (speeds and trajectories) if they interrupt the route driving for about one week (Colonna et al., 2016b,c). This is coherent with the possibility of a response recovery after stimuli interruption (Groves and Thompson, 1970; Charlton and Starkey, 2013). Hence, in survey-based studies (self-reported familiarity related to extended time periods), the familiar threshold should be at least weekly-based, to have a higher likelihood of keeping enough road memories. All the reviewed studies are coherent with this identification proposal, except for survey-based studies by Liu and Ye (2011) and Ryeng (2012), which set a very low threshold frequency, monthly and bi-annually respectively. Studies by Rosenbloom et al. (2007) and Burdett et al. (2018a) are formally not coherent with this proposal, but no identification was needed in their studies indeed, since they directly asked drivers to travel on familiar roads.

- A driver who has never previously travelled on a given road is surely unfamiliar with it. However, there are several frequency measures included between the familiar definition (weekly), and the zero frequency (e.g. monthly, yearly), representing shades of familiarity/unfamiliarity. Possible long-term memory of previous habitual levels can be expected (Rankin et al., 2009). This has indeed been observed in drivers after almost one month (Colonna et al., 2016b). However, those memory effects are likely to be largely unconscious. In fact, Charlton and Starkey (2018) found that drivers have a generally poor recall accuracy of specific features and events which occur during familiar road driving, even a short time after the drive. Nevertheless, considering monthly drivers as unfamiliar could be unrealistic. A yearly frequency can be suggested as a minimum threshold for defining unfamiliar drivers (see also Ryeng, 2012). All the reviewed studies are coherent with this identification proposal, except for the survey-based study by Liu and Ye (2011), which considered drivers travelling more rarely than monthly as unfamiliar (even if this largely includes the yearly frequency); and the simulator-based study by Bertola et al. (2012), who considered drivers who travelled only seven times on the simulated route as unfamiliar.

Whereas, for the distance-based definition:

- On average, drivers can be reasonably assumed to spend most of their annual mileage on roads near their residence (typically home-work routes), being familiar with them. Hence, a possible definition is based on the drivers' average commuting distance, varying according to private transport patterns of different countries. This distance measure has the advantage of being flexible and less strict than fixed thresholds such as town limits (Rosenbloom et al., 2007). On average, commuting distances are around 20 km. In North-America, Litman (2003) set to 15 miles (approximately 24 km) the average home-work trip distances. In countries with lower usage of private transport, such as Norway, average car commuting journeys are 15.8 km (Hjorthol et al., 2014). In New Zealand (Burdett et al., 2017), the mean distance travelled from home is about 39 km, but the median of 11 km is significantly lower, thus being coherent with previous results. These commuting trip distances are coherent with the possible estimate of 1 hour/person/day needed for mobility (Colonna, 2009). Significant differences were noted even between in-county and out-of-county (Yan et al., 2005), or between in-state and out-of-state residents (Harootunian et al., 2014a,b) in the United States, coherently suggesting that the "familiarity" distance should be close enough to the residence. Most of the reviewed studies are not explicitly coherent with this distance-based identification proposal for familiar drivers. In fact, most of them were aimed at comparing foreigners with residents. The latter were generally not explicitly defined as "familiar", but compared with foreigners. However, considering all resident drivers as familiar can lead to biased results in familiarity-based studies since there could be several resident drivers unfamiliar with locations far from their residence but in the same country. A different identification strategy is proposed here.

- On average, drivers are unfamiliar with roads very far from their residence. Previous studies mainly considered discrepancies between country residents and foreigners (e.g. Yannis et al., 2007). However, even residents may be unfamiliar with state roads far from their residence. Hence, the distinguishing condition could be that long trips are rarer than commuting trips and for them, other modes can be chosen. For this reason, the unfamiliarity distance-based threshold can be set according to the average distance above which other means of transport are typically preferred to the car (e.g. planes), locally derivable. In Intini et al., 2017b, 2018, this distance was set to 200 km, based on Norwegian estimates (Hjorthol et al., 2014; Thrane, 2015). This rule could be potentially violated by professional drivers of long-distance buses/trucks, controllable by introducing variables accounting for heavy vehicles. Moreover, based on previous studies, independently of distance, foreign drivers should be considered as unfamiliar, because of their ignorance of foreign road environments (especially if coming from far away areas, see Yannis et al., 2007), a condition associated to at-fault crashes (Kim et al., 2012), ratings of difficulty of the foreign environment (Thompson and Sabik, 2018) and mistakes associated to different road regulations (Huang et al., 2018). Clearly, there could be cases in which foreign drivers may be familiar with routes in other countries, but this is hardly predictable from a crash database, while most studies using distance-based scales rely on them. Hence, some necessary simplifications are needed for identifying familiarity using this distance scale. Most of the reviewed studies are potentially or fully coherent with this identification proposal, except for Donaldson et al. (2006), who compared urban versus rural residents. In fact, urban resident drivers may be unfamiliar with other urban scenarios in the same country as may rural residents in a similar way. Whereas, Yan et al. (2005) used a four levels categorical scale from county resident to foreigner.

Only one “IND” (indirect drivers’ observation) study was found, providing an insufficient basis for linking Table 3 to such studies. However, these studies may potentially rely on the same frequency-based criterion proposed for “SUR” studies, even if Jin et al. (2018) used a continuous scale rather than familiarity thresholds.

Values included between those thresholds (frequencies between weekly and yearly and distances between average commuting and long trips) can be considered as representing “transition” drivers, classifiable neither as familiar nor as unfamiliar with a reasonable margin of error. Excluding transition drivers while analysing the relationships between familiarity and driving performances/accidents may result in discarding great amounts of data. In a recent study (Intini et al., 2018), about 50 % of drivers involved in rural segment accidents could be defined neither as familiar nor as unfamiliar based on the criteria in Table 3. Hence, large databases would be needed when conducting studies based on the distance scale, for considering only the extreme cases of familiar and unfamiliar drivers. On the other hand, excluding drivers belonging to the intermediate transition distances, may result in a far greater chance of reliable comparisons between actual familiar and unfamiliar drivers. Finally, it is worth noting that familiarity has also been measured on a continuous scale (see Charlton and Starkey, 2017a). This is a sort of directly self-reported frequency-based scale of familiarity, but transformed into a rating scale, without explicit reference to the frequency of travelling on the road.

## 7. Conclusions

This article was mainly conceived with two aims: 1) a detailed review of research findings and engineering aspects relating drivers’ route familiarity with road safety-based issues, 2) the proposal for an identification criterion, useful for future studies on the topic, which may use different methods.

As a result of the review conducted, the common traits that emerged from research findings and technical documents, which found confirmation in the existing theoretical background, are reported as follows:

- Driver behaviour can be affected by route familiarity. The familiarity driving condition could be a highly automated task, potentially linked to inattention and over-confidence. Higher levels of confidence can also lead to more dangerous behaviours (e.g. speeding) while selecting the subjective safe behaviour during repeated journeys. This possible reduction in safety can be justifiable for trade-offs with mobility benefits (i.e. travel time), which may compensate for the positive effect of increased road knowledge.

- Road and traffic engineering practice currently considers familiarity to some extent, with potential links to safety issues. Assumptions for design drivers have been suggested to implicitly preserve the safety of both unfamiliar (e.g. through road consistency) and familiar drivers (e.g. through geometric requirements). The mix of familiar and unfamiliar drivers in traffic has been associated to possible safety-based remarks. However, the highlighted safety implications only partially match results from studies focused on crashes involving familiar/unfamiliar drivers. Nevertheless, comparing these findings was difficult due to the high variability in identifying familiarity, and all the additional contributing factors.

The relationships between route familiarity and road safety are often implicit, especially in technical documents. Hence, the review also specifically focused on highlighting those possible hidden relationships, to enlarge the knowledge of researchers and practitioners on this topic. In fact, there are several engineering road-safety based aspects in which drivers' route familiarity should be considered, based on the main findings from the review. For example, it should be taken into account in the assessment of safety countermeasures (by considering familiarization of drivers with them) or while planning safety interventions/new designs for routes mostly travelled by unfamiliar drivers (e.g. tourists).

Moreover, since there is currently no standard method for identifying drivers' route familiarity in different types of studies, an attempt was made to present a harmonized proposal, which is mainly based on previous findings and is potentially useful for future studies. Both frequency and distance-based scales have been considered for research purposes according to the study design. The proposed criterion can allow greater comparability between future studies on this topic.

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