THE IMPACT OF ROUTE FAMILIARITY ON DRIVERS' SPEEDS, TRAJECTORIES AND RISK PERCEPTION

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ABSTRACT

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

This paper reports the results of an on-road test carried out on a two lane rural road in the District of Bari in Puglia Region (Italy) over six days of testing, in order to find relationships between route familiarity, speed and trajectories selection, and risk perception. The particular schedule used for the tests allows to consider the influence of familiarity on the behavior of the test drivers. In particular, data were analyzed by considering the influence of road geometry and human factors.

Speed choice seems to be affected by route familiarity: speed increases with the repetition of travels on the same route if the tests are scheduled in consecutive days. The speed increasing tendency is different according to the risk inclination of the different drivers and according to the different road geometric characteristics. The process of trajectory selection at curves is also influenced by route familiarity: the radius of curvature of the trajectories selected at curves increase with the repetition of travels on the same route, showing curve-cutting and encroachments. The radius increasing tendency is different according to the different geometric features of the curve sections. Furthermore, the particular experimental design (4 test repetitions in different speed driving conditions for each day of testing) allowed to consider also changes in risk perception over time based on speed measurements. As for what concerns the speed selection process, the comparison between the different speed driving conditions (free speed choice, driving at low speed, driving at medium speed, driving at high speed) showed some noticeable tendencies. On combining these results, the on-road test showed that route familiarity is clearly influential on the driving process. Since the experiment was carried out on a very low-volume road, some considerations about the practical impact of this phenomenon on the road design and safety-based maintenance are given. In fact, both speeding and curve-cutting tendencies related to route familiarity, are important safety issues to address, also considering that familiar users are more prone to inattentive driving.

1. INTRODUCTION

Driving behavior is universally accepted as a potential factor able to influence the occurrence of road accidents. However, driving behavior is not characterized by a universally accepted theory, because of the various factors involved in the process (Fuller, 2008). For example, the zero-risk model (Näätänen and Summala, 1974), the risk homeostasis theory (Wilde, 1982), the rule-based model (Michon, 1989), the risk allostasis theory (Fuller, 2008) and/or the risk monitor model (Vaa, 2013) could be taken into account. Speed choice is one of the main indicators of driver behavior and it is influenced in turn by many factors, among which risk perception is crucial (Tarko and Figueroa Medina, 2006). The way in which users perceive accident risk while they are driving is a topic currently studied, a perplexing topic due to the lack of consensus about measuring risk and users' risk misperceptions (Slovic et al., 1982). However, speed is not the only factor to be taken into account while considering road accidents. When considering the influence of road geometry, horizontal curves are in general road sections in which crash occurrence generally increases (Farmer and Lund, 2002). In fact, driving on curves requires combined control of both steering and speed, considering the limits of the vehicle/road interaction (skidding risk) (Campbell, 2012). Therefore, even though it can seem a simple skill-based driving task by considering the three levels of information processing proposed by Rasmussen (1986), driving errors in selecting the proper speed or in maintaining lane position can often occur and they represent a safety concern. However, although speeds at curve sections have been widely studied and related to predictor variables (Bonneson et al., 2009; Discetti et al., 2011), the role of lateral position and trajectories selected has not been as deeply investigated.

Furthermore, one influential feature in drivers' behavior can be identified in their familiarity with a route, determined by their habit of driving on it. In fact, there is some research about the relationships between route familiarity and driving performance. Yanko and Spalek (2013) e.g. carried out an experiment involving 20 drivers and a driving simulator. They found that route familiar users (users who had driven on the experimental route four times before the test) needed greater reaction times than route unfamiliar users (users who drove on the experimental route for the first time during the test) in order to respond to unexpected external stimuli simulated in the presented scenarios. The results obtained from the presented experiment are similar to what Martens and Fox (2007) suggest about route familiarity: it can lead to a greater distraction while driving, probably because familiarity could increase the effect of "mind wandering". Mind wandering occurs when the mind is occupied by thoughts not concerning the task being undertaken and so, responses to external stimuli are potentially slowed down. This interpretation is coherent with the MART theory presented by Young and Stanton (2002), which assumes that driving performance varies as a function of mental workload and that in low demand conditions (normal driving tasks) attention capacity is reduced. However, those studies are based on driving simulator experiences. Instead, in this study, route familiarity was inquired by considering data belonging to an on-road study. The investigation of speed behavior based on a real world setting has the advantage of producing data with the greatest validity in comparison with those obtained in a simulated scenario (see e.g. Godley et al., 2002). However, although familiarity is influential on driving behavior and it is considered in the road and traffic engineering guidelines (especially in the calculation of the equivalent traffic flow rate according to the Highway Capacity Manual, 2010), the matter is largely unexplored. There is a lack of experimental evidence determining the impact of route familiarity on accident rates and driving-related measurable variables (i.e. speed and steering).

The brief summary about previous studies investigating the relationships between familiarity and the driving process shown above, clearly indicates that driver behavior can be affected by familiarity (phenomena such as inattention, mind wandering, low mental workload demand, greater reaction times needed were both theoretically postulated and experimentally observed). However, on considering also that route familiarity has been related to more traffic violations, more dangerous behaviors and speeding by Rosenbloom et al. (2007), the matter is perplexed: route familiarity seems to be characterized by a twofold nature. That is, can familiarity be able to both induce inattention and affect driving performances? In this paper, the investigation about the relationships between route familiarity and driving behavior is based on measured data belonging to an on-road experiment. In particular, driver behavior was observed in terms of both speed and trajectories chosen. Measures were repeated over days in order to simulate the process of acquiring familiarity with a given route. Moreover, different driving test conditions were planned for the aim of measuring indirectly also changes in subjective risk perception over time based on obtained data.

2. METHODS

2.1. On-road experiment

The experiment was carried out on a two-lane rural road (SP31, situated in the municipality of Cassano delle Murge, district of Bari, Italy).

As both road and environmental characteristics can affect the results of the experiment, an isolated road and with very low traffic volume (ADT < 400) was chosen for the experiment in order to ensure free flow characteristics during tests. In fact, in general, free flow and low traffic volume conditions are necessary to perform similar experiments involving measurements of speeds and lateral position. In particular, the road segment involved (shown in Fig. 1) consisted of three tangents (T1, T2, T3) and three curves (C1, C2, C3), for a total length of 2 km. On this stretch, the posted speed limit is 50 km/h.

In order to minimize confounding factors, users were selected by considering that the sample of drivers should be at least age-homogeneous, with similar driving experience and exposure, and unfamiliar with the test road. For this reason, participants were recruited among students of the Technical University of Bari using advertisements requesting volunteers. Information about the sample of drivers were obtained by submitting them to a questionnaire. Drivers at least 22 years old, holding a driving license for a minimum of 3 years, who declared to have at least 10 km experience (on average) per week on rural roads, who had the use of their own car for the driving test, and who had never travelled on the chosen route before were selected as users. All these exclusions were made in order to meet the following general principle: the "unfamiliar with the road" condition must not be confused with the "inexperienced driver" condition, since changes in speed and trajectories due to familiarity were also investigated. Therefore, the definitive test sample consisted of 20 drivers, characterized by: age: 24.45 ± 1.10 years old, 16 males and 4 females, years licensed: 5.75 ± 1.25 years.

2.2. Test schedule

The drivers were asked to drive their car equipped with GPS on the chosen road. The driving test consisted of four return journeys on the same route and for each journey users had to abide by the following instructions about driving (henceforth referred as to driving conditions):

- lap 1 (outward/return journey): users had to drive normally, so they were free to choose their speed;
- lap 2 (outward/return journey): users had to drive selecting the speed considered low by themselves;
- lap 3 (outward/return journey): users had to drive selecting the speed considered medium by themselves;
- lap 4 (outward/return journey): users had to drive selecting the speed considered high by themselves.

Each of the 20 drivers repeated that driving test pattern six times on six different days distributed according to the schedule shown in Fig. 1. The first four tests were scheduled on four consecutive days (1st, 2nd, 3rd and 4th days of testing). The other two tests were carried out on the ninth day after the first test (5th day of testing) and the twenty-sixth day after the first test (6th day of testing).

This chronological repetition of driving tests over days was chosen in order to test if speeds and trajectories selected can change with the acquired road familiarity in the short term and in the long term after interrupting the continuity of driving tests (Colonna et al., 2016). It should be specified that it is hard to exactly define the number of travel repetitions on the same road with a given frequency, necessary for considering a driver as familiar with the road. However, for what concerns the familiarity in the short term, four repetitions in four consecutive days were considered as an effective procedure to simulate behavioral changes over time due to route familiarity, based on the experimental plan used in a similar study (Martens and Fox, 2008).

Instead, the pattern of four tests chosen for each day was selected in order to verify the effect of a change in driving styles on the evolution of speed and trajectories (Reymond et al., 2001).

test ID	1	2	3	4						5																	6
day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Figure 1: The study site and timing pattern of the tests for each user.

All the tests were carried out in good weather and light conditions. Users drove alone without any conditioning due to the presence of experimenters in the car with them during all tests, in order to avoid alteration of the results. Furthermore, in cases in which bad weather conditions or car following situations were reported by the drivers, those tests were rejected from the analysis. Data belonging to one of the twenty drivers were discharged from all the further analyses due to the large amount of missing data (more than 40 % of the total).

2.3. Data collection and analysis

Driver behavior was observed in terms of speed and positioning. The GPS system recorded the position and speed of the vehicle with a frequency of 1Hz. Data were obtained by using the technique of differential GPS positioning, a dynamic method, through the use of two receivers. The first receiver was employed as fixed station. The second receiver, the mobile station, consisted of an on-board rover antenna and a receiver which had the task of recording data on the position of the antenna with respect to the fixed point (baseline) on a mobile device (USB) connected to the car battery. This technique leads to an average location accuracy to within 10 cm and an average speed accuracy to within 1 km/h.

For the purpose of this paper, data collection was limited to speeds and lateral positions belonging to curves 1 and 3 of the test road. Curve 2 was excluded from the analysis due to the detected absence of spiral transition curves that would have made the comparison with the other curves unreliable. Geometric data on curves 1 and 3 obtained through the reconstruction based on survey data are reported in Table 1.
Three cross-sections were defined along both curve 1 and curve 3, corresponding namely to: the intersection of the tangent and approach spiral (PC), the midpoint of the circular curve (PI), the

intersection of the departure spiral and tangent (PT) (see Table 1). Lateral positioning (distance along the cross section between the right edge of the carriageway and the geometric centerline of the vehicle) and speed data obtained from the data collection were assigned to each cross-section so identified.

Table 1: Geometric data of the two curves considered[1]

	Curve 1	**Curve 3**
Right/left curve	Left	Left
Cross section ID - Intersection of tangent and approach spiral	1	4
Cross section ID – Midpoint of the circular curve	2	5
Cross section ID - Intersection of departure spiral and tangent	3	6
Radius of curvature (m)	46.80	93.20
Curve length (m)	32.19	23.50
Curve widening (m)	0.88	0.76
Approach spiral length (m)	19.20	20.19
Departure spiral length (m)	28.83	40.45
Carriageway width – Intersection of tangent and approach spiral (m)	5.38	5.55
Carriageway width – Midpoint of the circular curve (m) (Carriageway width without widening (m))	6.26 (5.38)	6.35 (5.59)
Carriageway width – Intersection of departure spiral and tangent (m)	5.30	5.59
Longitudinal slope (m/m)	< 0.03	< 0.03
Cross slope (m/m)	0.02	0.01

[1]All geometric variables are referred to the two curves travelled on the outward journey.

For the purpose of analyzing changes in the trajectories at curves with the acquired road familiarity, the radius of curvature of the trajectories selected by drivers was chosen as the variable to be inquired. The three points representing the position of vehicles' geometric centerline along the considered cross sections at curve entrance, midpoint and exit were fitted with curves for both the two curves and for both the two directions of travel. The fitting process was repeated for each driver, each day of testing and each test driving condition. The process of curve fitting by using three points can be anyway only a rough estimate of the real trajectory chosen by the drivers. However, for the aim of this study, the radius of curvature of the trajectory computed in correspondence with the circular curve was employed as a convenient measurement representative of the trajectory; allowing the comparison between different drivers, days and sections. A more detailed analysis of the deviation of the real trajectories from the fitted curves can be considered for further studies. Mean values of the computed radii for the sample of drivers on each day of testing and in each test driving condition are shown in Table 2.

Statistical analyses were performed in order to test whether the days of testing (henceforth referred to as the variable "time") can affect the radius of curvature and the speed in the different test conditions. Given that the radii and speed data distributions are normal and homoscedastic, data were compared by parametric tests. To evaluate the presence of an overall effect, the mixed ANOVA test was performed, while Bonferroni post-hoc tests were carried out to isolate where the differences are. In detail, it was tested whether there is a difference in mean radius of curvature over time, with the 6 days of testing, the 4 test driving conditions and the 4 road sections (two curves travelled both in the outward and return journeys) as fixed effects, and the 19 drivers, as random effects. The same process was repeated for the variable speed. The mixed ANOVA was chosen because the individual process of selecting speed and trajectories can be influenced by human factors. Drivers' individual characteristics can be considered as a peculiar factor affecting all responses from the same subject. Thus, in this way, the different measures of speed and radius can be modelled as inter-dependent rather than independent.

3. RESULTS

In this section, findings about trajectories and speed at the two considered curves are reported. Mean data of speed and radius of curvature are presented in Table 2 for each driving condition, each road section inquired (in each direction of travel: both outward and return) and each day of testing.

Table 2: Mean and standard deviation (in brackets) of speed (a) and radius of curve trajectories (b) data of the sample of drivers in the different test conditions, days of testing and road sections (O = Outward, R = Return)

a) Variable: SPEED

Test Condition	Road Section	Day of Testing					
		1	**2**	**3**	**4**	**5**	**6**
Low Speed	**C1 (O)**	48.6 (4.4)	50.1 (5.7)	50.9 (3.5)	53.3 (6.3)	51.8 (5.2)	51.5 (4.6)
	C3 (O)	57.1 (7.0)	56.4 (6.0)	59.1 (7.7)	59.8 (7.7)	57.7 (7.9)	59.1 (7.8)
	C1 (R)	50.9 (5.5)	49.9 (5.8)	50.9 (5.9)	51.4 (6.7)	51.1 (6.9)	51.5 (5.7)
	C3 (R)	60.6 (6.9)	59.9 (6.9)	61.3 (7.3)	62.5 (8.6)	63.6 (10.3)	61.3 (7.9)
Medium Speed	**C1 (O)**	54.7 (3.7)	55.9 (5.2)	56.6 (3.5)	57.7 (6.0)	58.1 (4.2)	56.3 (5.1)
	C3 (O)	72.3 (5.2)	72.3 (5.8)	74.4 (6.3)	73.9 (7.0)	74.4 (6.9)	75.1 (6.9)
	C1 (R)	56.5 (4.9)	56.8 (4.8)	58.6 (3.0)	59.3 (5.6)	58.8 (4.6)	59.1 (4.6)
	C3 (R)	76.6 (5.6)	77.4 (6.1)	79.9 (7.4)	78.7 (9.6)	80.4 (8.9)	81.8 (8.2)
High Speed	**C1 (O)**	56.4 (5.1)	57.5 (6.4)	60.9 (5.1)	61.0 (6.6)	61.4 (4.4)	61.2 (6.1)
	C3 (O)	79.3 (9.5)	80.3 (6.6)	85.1 (6.8)	80.1 (11.2)	85.9 (6.8)	83.3 (11.8)
	C1 (R)	60.9 (6.5)	62.5 (4.8)	64.0 (5.1)	62.6 (6.2)	63.9 (6.0)	66.8 (7.9)
	C3 (R)	85.4 (9.0)	89.1 (8.6)	90.5 (7.3)	93.4 (13.8)	94.9 (7.5)	95.6 (10.2)
Free Speed	**C1 (O)**	55.5 (7.9)	53.0 (5.2)	56.3 (5.5)	58.2 (4.9)	58.2 (4.8)	55.9 (4.7)
	C3 (O)	72.3 (6.5)	73.9 (7.9)	79.8 (9.3)	80.3 (11.4)	81.6 (9.0)	78.3 (7.0)
	C1 (R)	57.1 (4.8)	59.4 (3.5)	59.7 (6.0)	60.6 (5.8)	62.6 (5.0)	61.6 (6.0)
	C3 (R)	76.6 (8.6)	81.4 (9.8)	84.2 (10.6)	84.4 (13.5)	87.2 (10.0)	88.3 (9.2)
Average	**C1 (O)**	53.8 (6.2)	54.1 (6.2)	56.2 (5.7)	57.5 (6.5)	57.4 (5.7)	56.3 (6.1)
	C3 (O)	70.4 (10.8)	70.7 (11.0)	74.6 (12.3)	73.4 (12.5)	74.9 (13.2)	73.9 (12.4)
	C1 (R)	56.4 (6.4)	57.2 (6.6)	58.3 (6.9)	58.4 (7.3)	59.1 (7.5)	59.6 (7.2)
	C3 (R)	74.8 (11.7)	76.9 (13.3)	79.0 (13.6)	79.8 (16.0)	81.5 (14.8)	81.7 (14.4)

Note: The speed of each road section Ci (X) represents the average value computed on the three cross sections considered for each curve and each direction of travel (Intersection of tangent and spiral, midpoint of the curve and intersection of spiral and tangent).

b) Variable: RADIUS OF THE CURVE TRAJECTORY

Low Speed	**C1 (O)**	68.1 (1.1)	67.9 (1.0)	67.9 (0.9)	68.4 (1.1)	67.8 (1.1)	68.4 (1.0)
	C3 (O)	155.0 (5.9)	153.5 (5.5)	153.8 (4.6)	158.3 (7.5)	152.0 (6.0)	151.7 (5.0)
	C1 (R)	58.9 (1.2)	59.0 (1.2)	58.8 (1.2)	59.5 (1.4)	59.0 (1.6)	59.1 (1.4)
	C3 (R)	122.1 (5.1)	119.7 (5.2)	122.5 (4.9)	124.5 (7.0)	127.6 (7.6)	125.1 (6.2)
Medium Speed	**C1 (O)**	68.5 (1.2)	68.9 (1.3)	68.4 (1.3)	69.1 (1.9)	68.3 (1.2)	68.4 (1.5)
	C3 (O)	159.0 (5.2)	160.7(10.7)	158.7 (5.2)	159.8 (6.4)	159.6 (7.0)	160.2 (9.0)
	C1 (R)	58.9 (1.5)	59.4 (1.3)	60.1 (1.5)	59.6 (1.5)	59.7 (1.3)	59.5 (1.5)
	C3 (R)	124.0 (5.5)	125.6 (6.6)	126.7 (6.1)	128.7 (6.5)	129.6 (8.1)	128.8 (4.9)
High Speed	**C1 (O)**	68.4 (1.6)	68.3 (1.2)	68.9 (1.5)	68.5 (1.1)	68.1 (1.3)	68.9 (1.4)
	C3 (O)	159.6 (7.1)	159.4 (7.0)	161.0 (5.5)	162.4 (4.7)	160.3 (6.9)	161.3 (5.5)
	C1 (R)	59.9 (1.5)	59.7 (1.4)	60.3 (1.2)	60.3 (1.2)	59.5 (1.3)	60.1 (0.8)
	C3 (R)	125.0 (5.2)	125.5 (4.7)	127.3 (6.3)	132.0 (5.1)	129.9 (4.3)	131.3 (6.3)
Free Speed	**C1 (O)**	68.0 (0.9)	67.9 (0.8)	67.7 (1.3)	68.8 (1.4)	68.1 (1.4)	68.5 (1.5)
	C3 (O)	157.4 (6.4)	156.2 (5.9)	155.9 (5.8)	159.7 (7.7)	158.9 (7.5)	155.6 (3.3)
	C1 (R)	60.3 (1.2)	59.4 (1.4)	60.2 (1.1)	59.3 (1.9)	60.2 (1.6)	60.4 (1.3)
	C3 (R)	124.4 (4.2)	119.8(21.4)	120.7(20.9)	124.2(23.8)	125.5(25.6)	121.7(26.1)
Average	**C1 (O)**	68.3 (1.2)	68.2 (1.1)	68.2 (1.3)	68.7 (1.4)	68.1 (1.2)	68.6 (1.3)
	C3 (O)	157.8 (6.3)	157.6 (8.0)	157.2 (5.8)	160.0 (6.7)	157.7 (7.4)	157.3 (7.1)
	C1 (R)	59.5 (1.4)	59.4 (1.3)	59.8 (1.4)	59.7 (1.5)	59.6 (1.5)	59.7 (1.4)
	C3 (R)	123.9 (11.9)	122.7(11.9)	124.2(11.9)	127.2(13.1)	128.0(14.3)	126.7(13.9)

Mean trajectories (considering all users, all test conditions and all days) obtained by fitting points representing mean position of vehicles' geometric centerline along the considered cross sections for both the two curves and for both the two directions of travel are graphically depicted in Figure 2. As can be seen in Fig. 2, on average, drivers tend to cut left-hand curves in the outward journey showing encroachments on the inside lane. This is more evident in curve 1, where the radius of curvature is shorter. However, encroachments can also be noted in curve 3, even if their percentages are smaller. Furthermore, drivers also tend to cut right-hand curves in the return journey when the radius is small. Instead, at curve 3, the mean trajectories of vehicles are almost always near to the lane centerline.

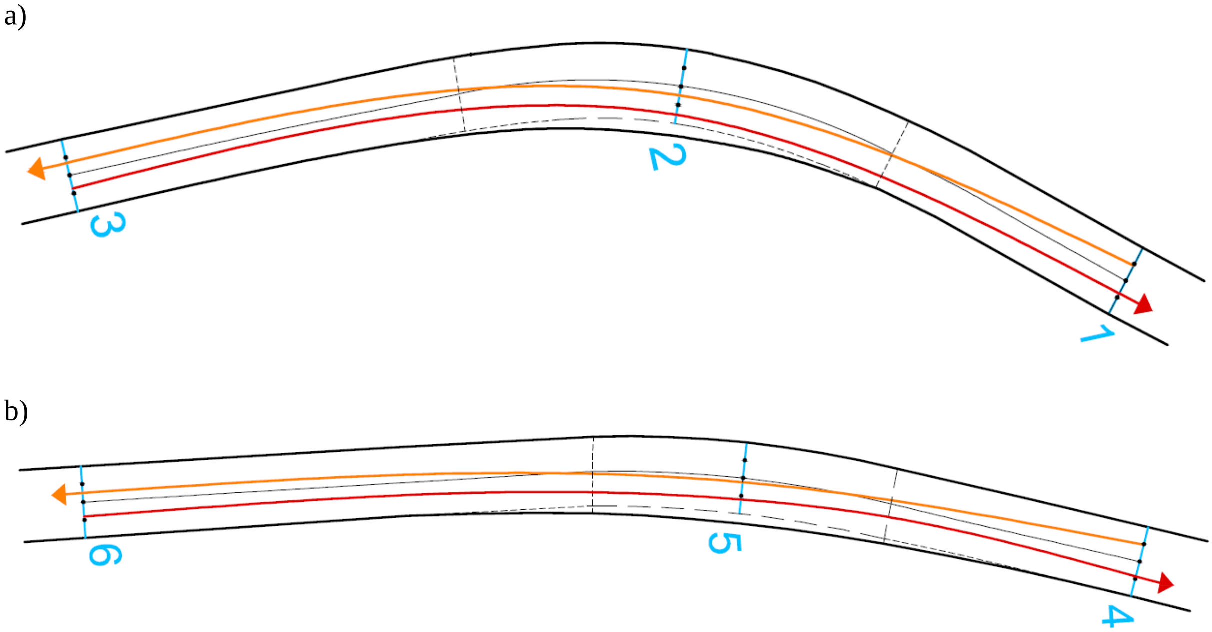
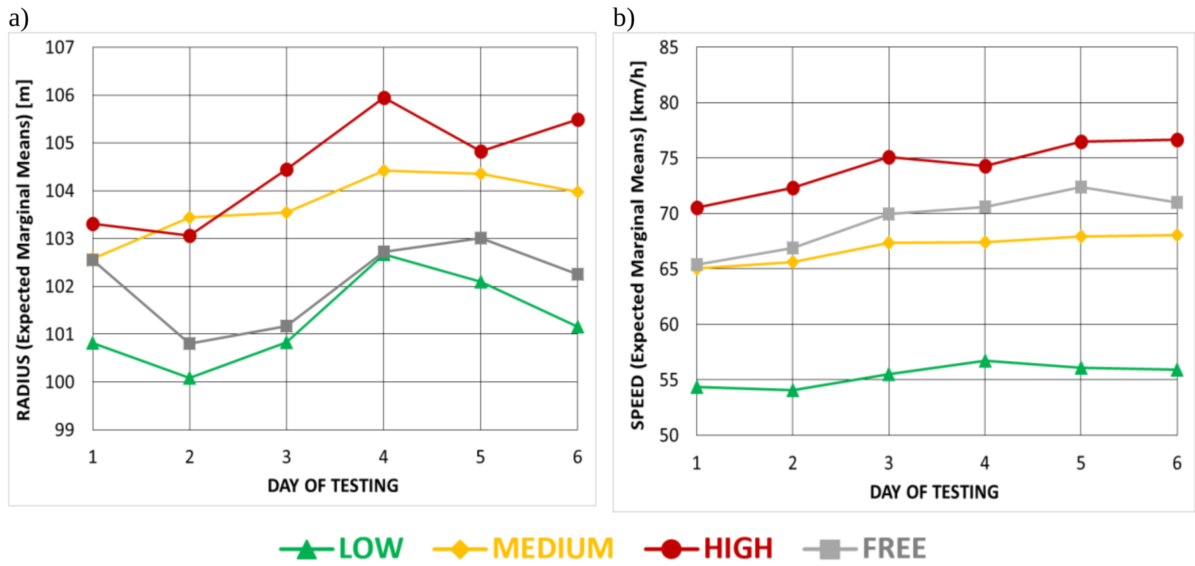


Figure 2: Reconstruction of mean trajectories at curve 1 (a) and curve 3 (b).

However, the main aim of this paper is to discuss changes in speed and selected trajectories over the days of testing due to acquired road familiarity. The main findings from the data analysis, where the influence of both the four different test conditions (chosen as an indicator of risk perception) and the six days of testing was taken into account, are reported as follows. Changes in speed and trajectory (in terms of radius of curvature) over the days of testing, considering both the different test conditions and the road sections, are summarized in Figure 3.



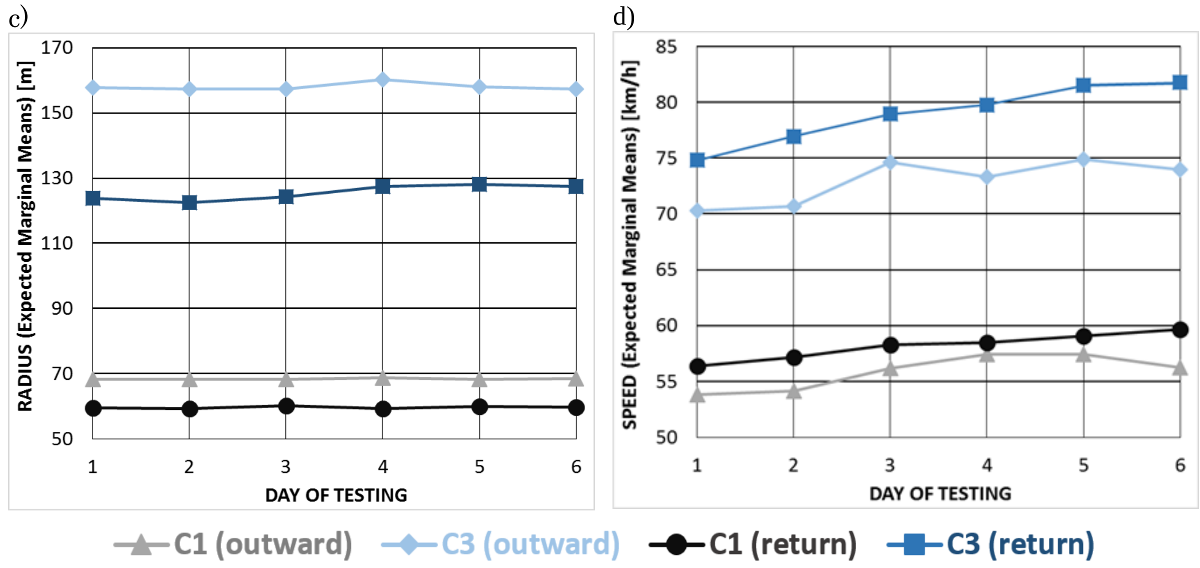


Figure 3: Changes in speed (a, c) and trajectory (b, d) over time by considering both the different test conditions and the road sections inquired.
Note: The graphs show a truncated y-axis as long as relative small differences between radii and speeds are illustrated.

The estimated values of radius of curvature and speed were plotted against the days of testing and are shown in Figure 3, by separating the trend for the different driving test conditions and for the different road curve sections (for both outward and return journeys). All statistical analyses were performed using SPSS software. Results from the statistical analyses are summarized in Table 3.

Table 3: Summary of the results of the two mixed one-way ANOVAs performed for both measurements of speed and radius of the trajectory

Measure	Effect	Test	p[1]
Speed	Time	F(5,80.018) = 7.829	**< 0.001**
	Test Condition	F(3,48.003) = 89.351	**< 0.001**
	Road Section	F(3,48.006) = 493.348	**< 0.001**
	Driver	F(16,100.169) = 2.904	**0.001**
	Time x Test Condition	F(15,1380) = 2.924	**< 0.001**
	Time x Road Section	F(15,1380) = 2.368	**0.002**
	Test Condition x Road Section	F(9,1380) = 88.534	**< 0.001**
	Driver x Time	F(80,1380) = 5.147	**< 0.001**
	Driver x Test Condition	F(48,1380) = 13.392	**< 0.001**
	Driver x Road Section	F(48,1380) = 4.822	**< 0.001**
Radius of the Trajectory	Time	F(5,105.041) = 3.832	**0.003**
	Test Condition	F(3,55.749) = 4.464	**0.007**
	Road Section	F(3,55.636) = 3834.152	**< 0.001**
	Driver	F(18,90.222) = 1.166	0.306
	Time x Test Condition	F(15,1094) = 0.363	0.987
	Time x Road Section	F(15,1094) = 2.806	**< 0.001**
	Test Condition x Road Section	F(9,1094) = 6.860	**< 0.001**
	Driver x Time	F(73,1094) = 1.027	0.419
	Driver x Test Condition	F(54,1094) = 5.288	**< 0.001**
	Driver x Road Section	F(54,1094) = 5.940	**< 0.001**

[1]*Boldface indicates statistically significant values with 5 % level of significance.*

A significant effect of time on radius of curvature at the $p < 0.05$ level was found [F (5, 105.041) = 3.832, p = 0.003]. A Bonferroni post-hoc test showed that the most remarkable differences lie between the second day and all other days of testing. Nevertheless, there was no statistically significant interaction between driving test conditions and time on radius, [F(15,1094) = 0.363, p = 0.987]. Thus, even if globally radius of curvature is affected by time and test conditions, the way in which drivers modify the radius of their curve trajectories over days seems to be not influenced by the different driving test conditions. Instead, there is a statistically significant interaction between time and curve road sections on radius, [F(15, 1094) = 2.806, p < 0.001]. Therefore, drivers modify their curve trajectories over days but, this process varies according to the geometry of the curve section.

A significant effect of time on speed at the p <0.05 level was found [F (5, 80.018) = 7.829, p < 0.001]. A Bonferroni post-hoc test showed that the most remarkable differences lie between the first days of testing (1st and 2nd) and the latter days of testing (3rd, 4th, 5th and 6th). Instead, no significant differences can be noted between the latter days (4th, 5th and 6th). There was a statistically significant interaction between driving test conditions and time on speed, [F(15,1380) = 2.924, p < 0.001]. Thus, the way in which drivers modify the speed over days seems to be influenced by the different driving test conditions. Moreover, there is a statistically significant interaction between time and curve road sections on speed, [F(15, 1380) = 2.368, p = 0.002]. Therefore, drivers modify their speed over days but, this process varies according to the geometry of the curve section.

4. DISCUSSION

In this section, results obtained from the data analysis will be discussed by focusing on the changes in speed and trajectories at the inquired curves with the acquired route familiarity.

As can be seen in Fig. 3 and Table 2, the radius of curvature of the trajectories chosen by the drivers at curves increases over days. This happens even if the radius of trajectories at curves was already considerably higher than the radius of curvature of the curve itself on the first day of testing. In particular, there is a clear increasing tendency while going from the second to the fourth day of testing, showing that road familiarity can influence the process of curve driving. The increasing tendency over the first four consecutive days is similar to what can be noted for speeds by looking at Fig. 3 and Table 2. On the fifth and the sixth days, more distant in time than the others, the value of radius decreased again. Therefore, in the long term, the memory of drivers fails to recall the last trajectory chosen. This result is different from that found for speeds, which remain roughly constant in the long term, even if driving tests are interrupted for some days. This is confirmed by the statistical analyses performed. The highlighted tendency could mean that drivers can feel more confident in cutting curves with the acquired road familiarity by choosing higher radii of their curve trajectories. Furthermore, the observed reduction of radii values in the fifth and the sixth days, more distant in time than the others, indicates that drivers fail to maintain the greater curve cutting tendency (in respect to the first travel) if they are not constantly exposed to the road. On the other hand, in the same days of testing, they can maintain higher speeds than the speeds measured on the first travel. Therefore, it seems that, generally speaking, the curve cutting tendency can be more demanding than the high speeding behavior at curves.

The different test driving conditions have an influence on how people change their speeds over time. In fact, the increase in speed over the first four days is higher in both the high speed and free speed test conditions than in the other two test conditions. Apart from speed variations over days, it can be noted that speed in the free speed test condition is always included between speeds in the medium and high test conditions. Moreover, changes in speed over days get the speed in the free test condition much closer to the high test condition, while in the first day of testing it was very close to the speed in the medium speed test condition. From the point of view of risk perception, this can be seen as an underestimation of risk while becoming familiar with the road, since when users were free to choose speed, they chose speed closer to the speeds considered high by themselves while more familiar. Instead, the increasing tendency of the radius over days can be noted in all test driving conditions. This can be explained by the fact that drivers were focused on the task of choosing speed by abiding by the instructions and so, choosing trajectories was an unconscious task to accomplish. Therefore, the familiarization process in terms of trajectories seems to be independent of different driving styles even if, higher speeds can be actually related to higher values of the radius of the chosen trajectories. This is confirmed by the results from a Pearson product-moment correlation. In fact, there is a strong, positive correlation between speed and radius of curvature of the trajectories selected, which is statistically significant ($r^2 = 0.613$, n = 1243, $p < 0.001$).

Nevertheless, the road familiarization process is more evident in less demanding geometric environments (higher radius of curvature). In fact, the increasing tendency in the radius of the trajectory chosen is more evident in curve 3 than in curve 1 (Fig. 2). The very small value of radius of curvature of curve 1 mainly prevents a high increasing tendency in the radius of the trajectories chosen over days. This is confirmed by the statistical analysis performed. Geometric characteristics of curves are also influential on speed increasing over time. In fact, the increase in speed over time is considerably higher at curve 3 than at curve 1, since it has a greater radius of curvature and so, it allows more degrees of freedom in the speed choice process.

Thus, both the driving performance measures considered for the experimental test, that are speed and radius of the curve trajectories, seem to be affected by the increased road familiarity. In particular, an increase in both speeds and radii chosen by the drivers was noted. On considering what expected from previous experimental studies and behavioral theories, these highlighted phenomena seem to confirm that the familiarization process implies a dual connotation. In fact, the reduction of attention capacity and mental workload is parallel to the increase of unsafe behaviors such as speeding and curve cutting tendency. However, from the perspective of drivers, this could be necessarily not related to a conscious more risk-taking behavior, as the greater knowledge of the road could lead to choose speeds and trajectories still acceptable by the drivers, even if unsafe for an unfamiliar driver. This dual connotation of familiarity needs to be further investigated for the aim of understanding how these two processes (getting more inattentive and modifying driving performances) are independent, p artially or totally inter-related. One possible explanation could be that, when all the information about the road are completely acquired and the familiarization process is complete, drivers are habituated to a given level of driving performance, which remains constant over time. In this phase, it could be normal to observe a reduction in the attention capacity, as long as all the information are already acquired by the road users and the driving performance is adapted to that particular environment. Instead, in the familiarization stage, in which the driver is learning the information about the road layout, changes in driving performances (speeds and trajectories) could take place in respect to the first travel. The problem is that it is difficult to state when the familiarization process ends and in which part it is conscious. Moreover, the matter is perplexed by the fact that not all drivers behave in the same way and are equally prone to modify their driving performances: i.e. more risky drivers could accept more unsafe behaviors than the prudent drivers once become familiar. The possible explanation given in this paragraph is coherent with the habituation theory and its application to the driver behavior (Groves and Thompson, 1970, Rankin et al., 2009, Colonna et al., 2016) but it should be verified by further studies.

5. CONCLUSIONS

The field experiment carried out has provided important elements concerning the evolution of speed choice, trajectories' selection and risk perception with increased familiarity with two curves belonging to a given route. In particular, with regard to the influence of acquired road familiarity, these results have been highlighted:

- Both speeds and radii of curvature of the trajectories selected by drivers progressively increase in the early four consecutive days of testing;
- The increase in both speeds and radii is greater in sections in which the road geometric characteristics are less demanding;
- The different test conditions related to different speed behaviors were influential only on speed changes, showing that users are more prone to underestimate risk related to speed while familiarity is acquired;
- In the long term period (5th and 6th days of testing) the values of radius of curvature of the trajectories selected decrease again, while speeds remain settled on a similar value; showing that

in this case maintaining a curve-cutting behavior was more demanding than the high speeding at curves.

These results point out that, while in the road design stage, great attention is devoted to the unfamiliar drivers, also the matter of familiar drivers should be stressed in respect to road safety. In fact, it is normal to consider that the sequence of road elements should always meet the expectations of a user driving for the first time on a given road. However, on the other hand, it should be considered that behavior of drivers got familiar with the road could be totally different from an ideal behavior, especially on very low-volume roads where less constraints are present for drivers. This implies, as a consequence, that among other things, the necessity for efficient traffic speed control measures arises.

Moreover, general results about encroachments and cutting behavior at curves on low-volume roads can address practitioners in the design and safety-based maintenance decisions for very low-volume local two-lane highways. In the design stage, it should be known that curve trajectories selected by drivers could be totally different from the lane centerline paths. So, designers should pay attention to the combination of radius of curvature, sight distance and carriageway enlargements in order to prevent head-on collisions. In safety-based maintenance, the use of centerline and shoulder rumble strips, advanced warning signs, perceptual measures and/or delineation treatments could help drivers in the choice of speed and lateral position at curves.

Finally, researchers should know, while planning on-road and driver simulator experiments, that measures of speed and lateral position can vary over test repetitions. Therefore, in order to get more correct estimates, planning at least some repetitions of the same test or considering results from similar studies should be taken into account.

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