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Highway Deceleration Lane Safety: Effects of Real-Time Coaching Programs on Driving Behavior

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Abstract: Real-time coaching programs are designed to give feedback on driving behavior to usage-based motor insurance users; they are often general purpose programs that aim to promote smooth driving. Here, we investigated the effect of different on-board real-time coaching programs on the driving behavior on highway deceleration lanes with a driving simulator experiment. The experiment was organized into two trials. The first was a baseline trial, in which participants drove without receiving any feedback; a cluster analysis was then performed to divide participants into two groups, based on their observed driving style. One month later, a second trial was carried out, with participants driving on the same path as the first trial, this time receiving contingent feedback related to their braking/acceleration behavior. Four feedback systems were tested; overall, there were eight experimental groups, depending on the clustered driving style (aggressive and defensive), feedback modality (visual and auditory), and feedback valence (positive and negative). Speed, deceleration, trajectory, and lateral control variables, collected before and onto the deceleration lane, were investigated with mixed ANOVAs, which showed that the real-time coaching programs significantly reduced speeds and maximum deceleration values, while improving lateral control. A change toward a safer exit strategy (i.e., entering the lane before starting to decelerate) was also observed in defensive drivers.

Keywords: highway safety; deceleration lane; exit ramp; real-time feedback; driving simulator; usage-based insurance; PHYD; driving behavior

1. Introduction

1.1. Safety of Highway Deleceration Lanes

Highway deceleration lanes and exit ramps are a relevant concern in road safety. Despite accounting for a negligible amount of total freeway mileages, they are significantly more risky than freeway mainline sections: in the United States, a National Cooperative Research Program (NCHRP) report showed an average rate of 0.68 crashes per million miles traveled by vehicles on deceleration lanes, 20% higher than that of freeway mainline sections near the exit ramp, and three times higher than that on acceleration lanes [1].

Despite this, there is a relatively small body of research on this topic, which dates back to the 1960s [2]. The vast majority of the studies focused on finding relationships between geometric/traffic features of the deceleration lanes and crash rates [3–6]. The main goal of these studies was to help practitioners to design safer infrastructures. The main geometric features that were shown to have an impact on deceleration lane safety are: deceleration lane length, deceleration lane type, and number of deceleration lanes. The conclusions from these studies were quite inconsistent; a recent meta-analysis [7] showed that, although significant risks associated with geometric features were observed in many studies, the

meta-estimates were not found to be significant, suggesting the need for further research on the topic.

A different approach was applied by Calvi et al. [8], who studied the impact of traffic volume on deceleration lane safety with a driving simulator study involving 30 participants. Contrary to previous crash-based studies, the focus switched to microscopic aspects of the phenomenon, i.e., the behavior of drivers on the deceleration lane; to evaluate safety, they considered vehicle speeds, deceleration, and trajectories. The results showed a significant effect of traffic volume on vehicle speed, deceleration rate, and trajectory, and highlighted some relevant issues, such as that drivers tended to decelerate before diverging, and that speeds in the deceleration lane were significantly higher than the design speed. Subsequently, the authors applied the same driving-simulator-based approach to investigate the effect of the deceleration lane type, comparing parallel and tapered designs [9], and observed significant differences in the speeds of diverging drivers, with greater interference with the through traffic on the tapered lane. Another study focused on evaluating the effects of the number of exit lanes [10]: the two-lane exit layout seemed to provide improved performance over the single-lane one by limiting the interference of the diverging drivers with the through traffic. Their driving simulator approach was later successfully validated by comparing speed and trajectory data collected both in the field and with a simulator experiment [11]. As in the majority of studies in the literature, their declared end goal was to provide guidance for safer infrastructure design.

A driver-behavior-focused approach was followed also by Lyu et al. [12], who carried out a naturalistic experiment involving 46 participants on a typical highway deceleration lane in Wuhan. As in [8], Lyu et al. studied drivers' speed, deceleration rate, and trajectories; in addition, they investigated vehicle lateral control during the diverging maneuver. The aim of the study was to investigate the effect of some sociodemographic characteristics (i.e., gender, occupation, experience) on drivers' behavior, showing several significant effects. In particular, male drivers showed earlier entries into the deceleration lane in comparison with female drivers; moreover, before entering the deceleration lane, experienced and professional drivers performed the last lane change as early as possible; in addition, the vehicles' speed while entering the exit ramp exceeded significantly the speed limit. Their approach introduced a crucial novelty to this line of research, switching the focus from infrastructural/traffic characteristics to drivers' characteristics.

From this analysis of the literature, it is possible to observe that only a small number of studies have investigated the safety of highway deceleration lanes by focusing on the driving behavior of road users. In addition, to the best of our knowledge, none of them investigated in-vehicle countermeasures aimed at improving the safety of exiting maneuvers in highways.

1.2. "Pay-How-You-Drive" Insurance Schemes

An emerging trend in the motor vehicle insurance sector is to offer usage-based insurance (UBI) schemes, in which drivers are charged premiums based on their vehicle usage instead of other potentially unfair attributes such as sociodemographic characteristics [13].

The two main UBI schemes are the so-called "Pay-As-You-Drive" (PAYD) and "Pay-How-You-Drive" (PHYD). The former charges premiums based on driver's mileage, the latter on driver's behavior on the road. In PHYD schemes, real-time kinematic data are collected with In-Vehicle Data Recorders and are used to assess drivers' performance in terms of safety [14].

PHYD schemes aim at providing several benefits for motor insurance providers, clients, and the general community [13]: (i) reducing road crashes; (ii) addressing the cross-subsidy issue, potentially resulting in reduced cost of insurance premiums; (iii) promoting fairer insurance costs, as users pay depending on their driving behavior, not on other attributes which may not necessarily reflect the chance of being involved in a crash; (iv) encouraging smoother driving styles, therefore reducing fuel consumption and giving additional monetary gain to the users and environmental benefits to the community.

The majority of PHYD schemes assume a correlation between harsh braking/accelerations and road safety [15–18]. Consequently, harsh driving is punished (e.g., incrementing premium prices), and smooth driving is reinforced (e.g., giving discounts on premiums). Positive effects on road safety have been observed [19,20], but research on such schemes' effectiveness is still limited [21,22].

Often, these systems are designed to provide a delayed "after-drive" feedback, which generally includes a report with more or less aggregate information about the safety performance [13,23,24]. A new trend in the motor insurance market consists in offering real-time coaching systems to provide feedback to users. Such systems are comparable to those proposed in the literature as educational tools to reduce speeding [25], to improve lateral control of the vehicle [26,27], and to eco-drive [28,29]. In one of the few studies dealing with a real-time feedback specifically designed for PHYD schemes, an improvement in safety performance was observed [30]. Moreover, it was demonstrated that these real-time systems have higher effectiveness compared to those giving "after-drive" feedback [31].

Ultimately, only few works investigated, in quantitative and microscopic terms, the safety benefits that can be provided by PHYD schemes. Moreover, there is a lack of research on the evaluation of real-time feedback systems specifically designed for PHYD schemes.

1.3. Aim of the Study

Recently, we investigated the effects of real-time coaching programs on driving behavior with a driving simulator study using different types of feedback, varying on the basis of the negative or positive feedback valence (valence can be defined as the subjective value attributed to a stimulus, such that stimuli with positive valence are supposed to attract individuals, whereas stimuli with a negative valence lead to avoidance behaviors (see the APA Dictionary of Psychology; https://dictionary.apa.org accessed on 13 July 2021)), as well as the sensory modality in which it was delivered. Participants underwent a two-trial experiment in which they drove on a path with both rural and urban roads, a highway, multiple intersections, and had several interactions with other motor vehicles and cyclists. After the first trial, which was a baseline run without any type of feedback, participants were divided into two clusters depending on the degree of "aggressiveness" in their driving style. During the second trial, which occurred after one month, they received real-time feedback based on their acceleration/deceleration behavior.

Results presented in previous works showed a reduction in the occurrence of harsh braking/acceleration events in the second trial, especially for aggressive drivers [32], and an overall safer behavior when overtaking a cyclist [33]. In both cases, the feedback effectiveness did not depend on either its valence or modality.

In the present paper, we focused on analyzing a specific part of the trials: the maneuver of exiting the highway using the deceleration lane; in particular, we investigated whether the real-time coaching program had an impact on participants' behavior during such maneuvers.

It is worth noting that the coaching program was not specifically developed to address the behavior of drivers exiting the highway, but, more generally, to reduce the number of critical braking/acceleration events (see Section 2.1.4), which are considered as valid surrogates for dangerous driving [34]. Since the development of a specific real-time program to deal with each specific maneuver that drivers must perform on the road (e.g., overtaking a cyclist or exiting a highway) is not feasible, it is of great practical interest to assess whether a general purpose real-time coaching program can increase safety in different scenarios.

2. Methodology

2.1. Driving Simulator Experiment

2.1.1. Participants

For this experiment, we recruited 100 active drivers: 51 males and 49 females, with an age range of 20–33. The following selection criteria were considered: having normal or

corrected-to-normal vision, no previous experience with driving simulators, an average annual mileage of at least 1000 km, not less than 1 year of driving experience. We elected to focus on young-adult drivers because of their predisposition to choose UBI schemes [35] and since the literature indicates that they can significantly benefit from such schemes [36].

Participants were invited to perform two driving trials. Five of them suffered from simulator sickness and could not complete the first one; seventeen could not return for the second one; four did not complete the second trial. Hence, the final sample included 74 drivers (37 males and 37 females, age range 20–33; mean = 24, SD = 2.80). All participants received monetary compensation for completing the experiment and were naïve to its aim.

This study was conducted in compliance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) [37]. The experiment was approved by the Ethical Committee for the Psychological Research of the University of Padova (IRB N 3024 06/06/2019). At the beginning of the experiment, participants signed the informed consent.

2.1.2. Apparatus

The dynamic driving simulator at the Transportation Laboratory of the University of Padua was used for this experiment. This simulation system was described and validated in previous studies focused on testing in-vehicle applications [26,38–42] aimed at improving traffic safety. Thirty-one vehicle kinematic variables were collected by the simulator at a 50-Hz sampling frequency.

2.1.3. Experimental Design

The experimental conditions were administered on two different days. During the first day, after a short training session, participants were instructed to perform the first trial, driving as they would in the real world, following traffic sign indications toward the city of Padua. No feedback was delivered during this trial.

At the end of the first round of trials, two groups of participants with different driving styles (defensive vs. aggressive) were identified, by means of a cluster analysis. They were subsequently divided into 4 subgroups, balanced as to gender and driving style.

One month after their first trial, participants were administered the second trial, during which 4 different kinds of feedback (see Section 2.1.4) were delivered during the simulated driving task. Before the trial, participants were instructed on the basic functioning of the real-time coaching program.

2.1.4. Real-Time Coaching Program

The real-time coaching program was designed to give negative or positive feedback after, respectively, harsh or smooth driving events recorded during the experiment. The following definitions of harsh and smooth events were adopted:

- Harsh event: a timeframe longer than 1 s exceeding a deceleration threshold of −0.4 g or an acceleration threshold of 0.3 g.
- Smooth event: a timeframe longer than 1 s exceeding a minimum deceleration/acceleration threshold (±0.075 g) without exceeding the deceleration threshold of −0.4g or the acceleration threshold of 0.3 g.

These thresholds were chosen with a sensitivity analysis and were supported by findings of previous studies [34,43].

When a harsh or smooth driving event occurred during the second trial, one of the 4 different feedback was delivered, depending on the subgroup. Four feedback systems were therefore developed, varying on the basis of valence (negative or positive) and modality (auditory or visual). The 4 s visual or auditory signal was presented just after a harsh/smooth event was recorded.

As regards the auditory cues, two sounds were selected from the International Affective Digitized Sounds (IADS) database [44]. Sound #712 was selected as a negative feedback and #717 as a positive one. According to the normative 9-point rating scale for IADS sounds, the former had a low pleasantness (1.62), and the latter a high one (7.32).

As regards the visual cues, they both consisted of a bright circle on a dark background: a purple-colored circle indicated negative feedback, and a white-colored circle indicated positive feedback. The circle had a 3 cm diameter and was located within 13 degrees of the participant's visual field, simulating a device located in the upper part of the windscreen (Figure 1b).


(a)   (b)
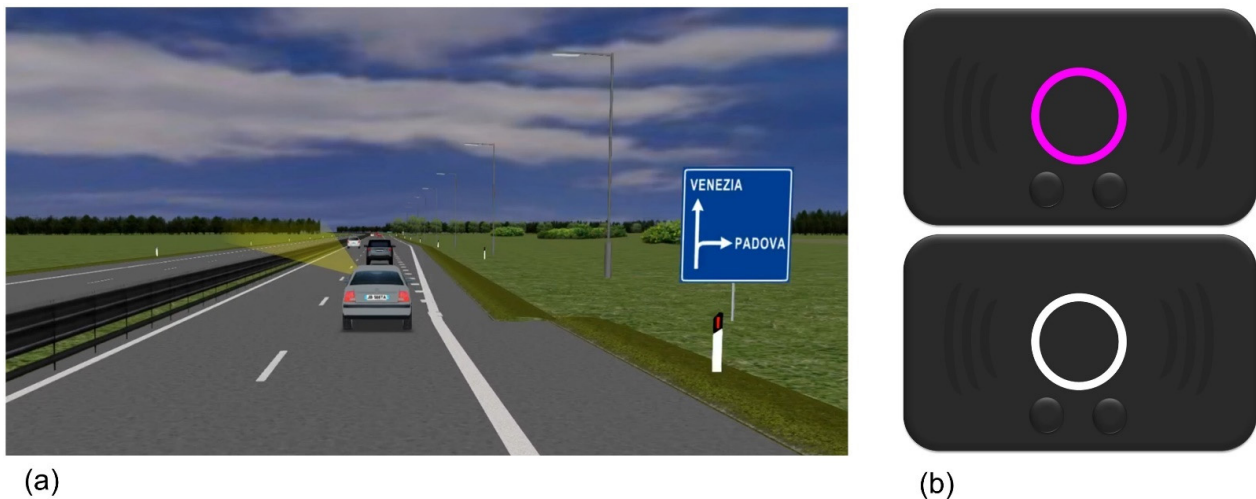
Figure 1. (**a**) 3D driving simulator scenario; (**b**) device showing visual negative (top) and positive (down) feedback.

The system consisting of a negative visual feedback was designed to closely resemble a real-time coaching device already available on the Italian motor insurance market. The other systems were designed to evaluate potential impacts on program effectiveness from changes in the feedback valence or modality.

2.1.5. Highway Scenario

Participants drove on a 11.5 km long route that included urban and rural roads, a highway section, and several types of intersections (priority, signalized, and roundabout). The duration of each session was about 15 min.

After about 6.5 km from the start of the trial, drivers entered a two-lane highway. The lanes were 3.60 m wide and there was a 3.00 m wide hard shoulder on the right. After 2.6 km, drivers were required to perform an exit maneuver. The first traffic sign indicating the highway exit was located 1.2 km before the deceleration lane. The deceleration lane was 3.60 m wide and 300 m long, including a 100 m taper, with a parallel layout (Figures 1a and 2). The lane was followed by a smooth curve with a 500 m radius.
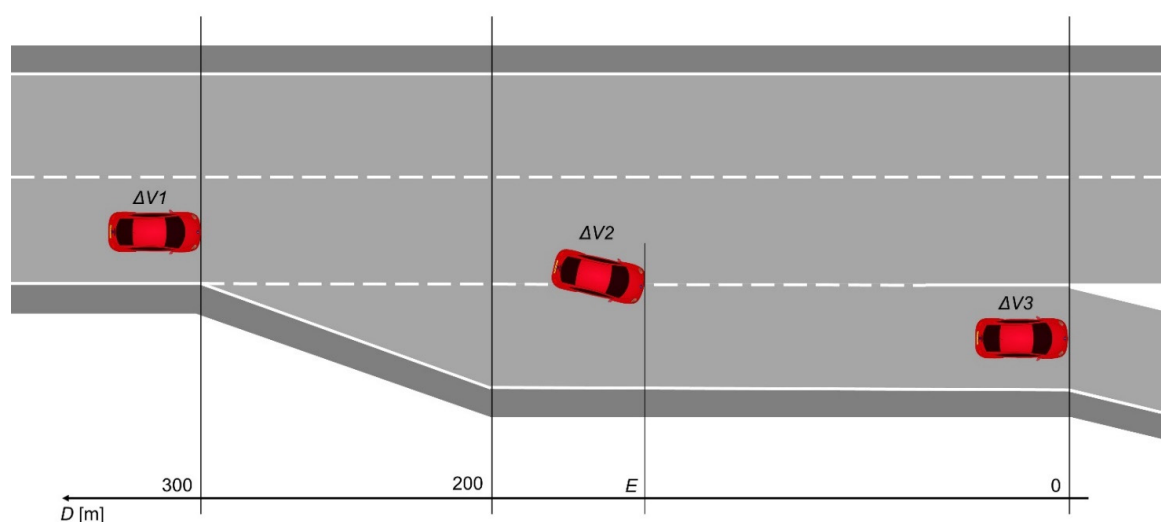
Figure 2. Speed/trajectory variables and geometric features of the deceleration lane.

The posted speed limit on the highway was 100 km/h, and there was about 1200 vehicles/lane/hour computer-controlled traffic. The speed of the computer-controlled vehicles was between 90 and 110 km/h.

2.2. Variables Analyzed

Several dependent variables were analyzed in this work. They can be classified into four broad categories: speed, deceleration, trajectory, and lateral control variables. The variables were chosen in line with the existing literature investigating driving behavior on deceleration lanes [8,12].

We considered the distance D to the end of the deceleration lane as a spatial reference. The deceleration lane was therefore located between $D = 300$ m and $D = 0$ m (Figure 2). A preliminary analysis showed, consistent with previous works, that some participants started decelerating before the beginning of the deceleration lane, but no participant started to decelerate earlier than $D = 500$ m.

Speed variables:

- *V_MEAN* [km/h]. The average speed on the highway, calculated from $D = 2300$ m to $D = 1300$ m, therefore, before the first traffic sign indicating the highway exit.
- $\Delta V1$ [km/h]. Speed change at the beginning of the deceleration lane, calculated as the difference between the speed at $D = 300$ m and *V_MEAN*.
- $\Delta V2$ [km/h]. Speed change when entering the deceleration lane, calculated as the difference between the speed recorded when the vehicle's center of gravity (COG) entered the deceleration lane and *V_MEAN*.
- $\Delta V3$ [km/h]. Speed change at the end of the deceleration lane, calculated as the difference between the speed at $D = 0$ m and *V_MEAN*.

Deceleration variables:

- *DEC_MEAN* [m/s^2]. Average deceleration between $D = 500$ m and $D = 0$ m.
- *DEC_MAX* [m/s^2]. Maximum deceleration between $D = 500$ m and $D = 0$ m.

Trajectory variables:

- *E* [m], "exit point", defined as the point in the space between $D = 300$ m and $D = 0$ m where the vehicle's COG enters the deceleration lane.
- *A* [m], "start-of-deceleration point", defined as the point in the space between $D = 500$ m and $D = 0$ m where the driver first fully raises the foot from the gas pedal (Note that, in principle, *A* is different from the point where the vehicle actually starts decreasing its speed; moreover, drivers can decelerate even without fully removing the foot from the gas pedal. *A* was defined in such way to avoid ambiguity in the definition of the deceleration phase, and to be consistent with previous literature [8]).

Lateral control variables:

- *LATACC* [m/s^2]. Average lateral acceleration between $D = 300$ m and $D = 0$ m.
- *SDSA* [degrees]. Standard deviation of steering angle between $D = 300$ m and $D = 0$ m.

2.3. Statistical Anlyses

A cluster analysis (see Section 3.2) was performed on data collected during the first round of trials; its objective was to equally distribute participants with different driving styles into the four feedback subgroups. In the analysis, the number of clusters was chosen according to Ward's method of hierarchical clustering with squared Euclidean distance measures, as in [45–47]; Z-scores were used to standardize grouping variables; K-means cluster analysis was then conducted to identify the clusters.

Mixed ANOVA models were applied to investigate the impact of the real-time coaching program on the exiting maneuver using data collected in both trials (Section 3.3). We considered one main factor (Trial), three between-participant factors (Driving style, Feedback valence, and Feedback modality), and their interactions. Each dependent variable (see Section 2.2) was investigated with a separate analysis. Effect size was quantified with $\eta_p{}^2$, which, as a rule of thumb, indicates a small effect if it is higher than 0.01, a medium

effect if it is higher than 0.06, and a large effect if it is higher than 0.14 [48]. Post hoc tests were carried out with Fisher's Least Significant Difference procedure.

IBM SPSS 22 statistical package was used for cluster analysis, whereas JASP 0.13.1 software [49,50] and MATLAB R2021a were used to perform the analyses reported in Section 3.3. Significance level was set at $\alpha = 0.05$.

3. Results

3.1. Descriptive Analysis

Table 1 presents descriptive statistics for the 74 participants who performed the exit maneuver from the highway in both trials. Mean values indicate a reduction in the average speed on the highway in Trial 2, and an even higher reduction in the other speed indexes in the deceleration lane. Mean and maximum decelerations tended to be lower (in absolute value) in Trial 2, whereas the exit and start-of-deceleration spots appeared to be farther away from the end of the deceleration lane. Average lateral acceleration and standard deviation of the steering angle were lower in Trial 2, suggesting higher lateral control of the vehicle. Except for some speed variables, standard deviations were lower in Trial 2, indicating more consistent behavior among the participants. It is worth noting that only data from 62 participants were available for the variable A in Trial 1 and 66 in Trial 2, since the other participants did not fully remove their foot from the gas pedal during the maneuver.

Table 1. Mean values and standard deviation (in parentheses) of dependent variables in Trial 1 and Trial 2.

Variable	Trial 1	Trial 2
V_MEAN [km/h]	92.33 (7.89)	87.59 (8.03)
$\Delta V1$ [km/h]	−1.40 (7.88)	−2.59 (7.59)
$\Delta V2$ [km/h]	−2.11 (8.01)	−4.84 (8.27)
$\Delta V3$ [km/h]	−14.29 (8.55)	−17.01 (9.42)
DEC_MEAN [m/s^2]	−0.46 (0.22)	−0.41 (0.16)
DEC_MAX [m/s^2]	−1.05 (0.34)	−0.95 (0.28)
E [m]	222.08 (43.93)	227.38 (33.33)
A [m]	189.16 (133.67)	211.64 (124.45)
$LATACC$ [m/s^2]	0.22 (0.07)	0.18 (0.06)
$SDSA$ [°]	4.04 (1.71)	3.45 (1.25)

It is also worth noting that, in absolute terms, the mean and maximum deceleration values were low compared to those of previous works on deceleration lanes (e.g., [8]). In the present experiment, the lane was not designed to necessarily induce harsh decelerations, and, indeed, it was relatively long and followed by a smooth curve (see Section 2.1.5).

Figure 3 shows the trajectories of the individual vehicles' COG in both trials, showing that virtually all participants approached the exit from the right lane, and most of them entered the deceleration lane within its first third (i.e., within the taper), but with notable exceptions.
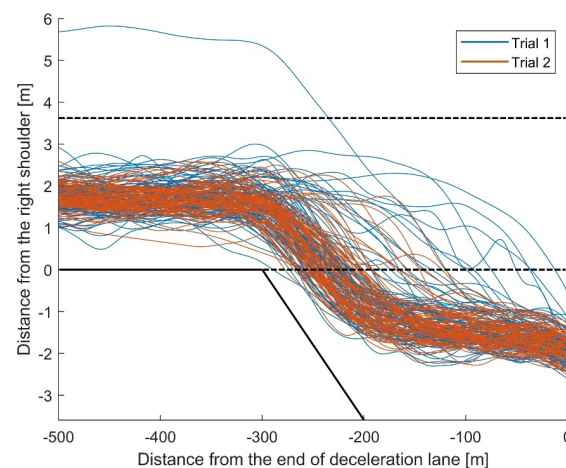
Figure 3. Individual vehicles' COG trajectories in each Trial.

3.2. Cluster Analysis: Identifying Driving Styles

A K-means clustering on 31 vehicle kinematic variables was applied to the 95 participants who completed Trial 1, separating them into two clusters. The details of this analysis are available in [32,33].

The first cluster included 49 participants who tended to have a smoother and safer driving style: e.g., they had fewer speed and acceleration peaks, and lower average speed; they were labeled as "defensive". The second cluster contained 46 drivers, with the opposite behavior, who were labeled as "aggressive".

As explained in Section 2.1.1, 21 participants dropped out of the experiment after Trial 1; 13 of them were defensive drivers, the remaining eight were aggressive drivers.

3.3. Mixed ANOVA: Evaluating the Effect of the Real-Time Coaching Program

Mixed ANOVAs were carried out to assess the effect of *Trial* (Main Factor), and the between-participant factors:

- Cluster—aggressive (N = 38) vs. defensive (N = 36)
- Feedback valence—negative (N = 35) vs. positive (N = 39)
- Feedback modality—visual (N = 41) vs. auditory (N = 33)

Besides their interactions, on the variables listed in Section 2.2.

3.3.1. Speed Variables

A significant effect of Trial on **V_MEAN** was observed, F (1.66) = 29.23, $p < 0.001$, $\eta_p^2 = 0.31$: participants reduced their average speed in Trial 2 by almost 5 km/h. Aggressive drivers had, on average, higher speed than defensive drivers in both trials, as the effect of Cluster was also significant, F (1.66) = 36.20, $p < 0.001$, $\eta_p^2 = 0.35$. Interaction was not significant, meaning that both clusters were affected in the same way by the main factor Trial (Figure 4a). Feedback valence and modality showed no significant effect.

Trial and Cluster had no significant effect on **ΔV1**, but their interaction was significant, F (1.66) = 6.87, $p = 0.011$, $\eta_p^2 = 0.09$. This can be observed in Figure 4b, where it is apparent that in Trial 2 defensive drivers, contrary to the aggressive ones, had a much higher speed reduction (about 4 km/h) at the beginning of the deceleration lane than in Trial 1. This was confirmed by post hoc tests, which showed a significant difference for defensive drivers, t (66) = 2.54, $p = 0.013$, contrary to the aggressive ones, $p = 0.246$.

As regards **ΔV2**, Trial had a significant effect, F (1.66) = 5.51, $p = 0.022$, $\eta_p^2 = 0.08$, as well as Cluster, F (1.66) = 6.65, $p = 0.012$, $\eta_p^2 = 0.09$, but not their interaction, with both aggressive and defensive drivers reducing their speed more when entering the deceleration lane in Trial 2 than in Trial 1, and with defensive drivers reducing their speed more than aggressive ones in both trials (Figure 4c).

A similar trend was observed at the end of the deceleration lane (variable **ΔV3**, Figure 4d) with significant effect of Trial, F (1.66) = 7.29, $p = 0.009$, $\eta_p^2 = 0.10$, and Cluster F (1.66) = 10.56, $p = 0.002$, $\eta_p^2 = 0.14$.

As in the case of *V_MEAN*, feedback valence and modality showed no significant effect on any of the three speed-change variables investigated.
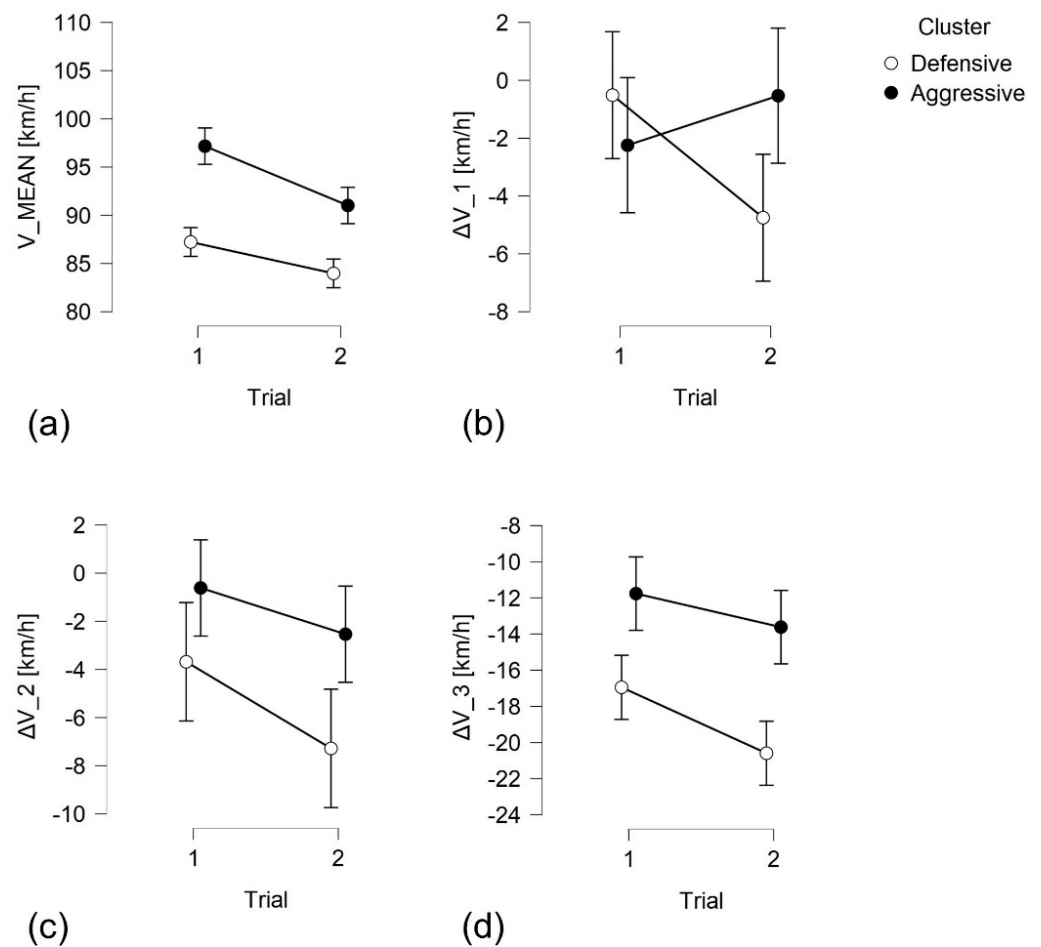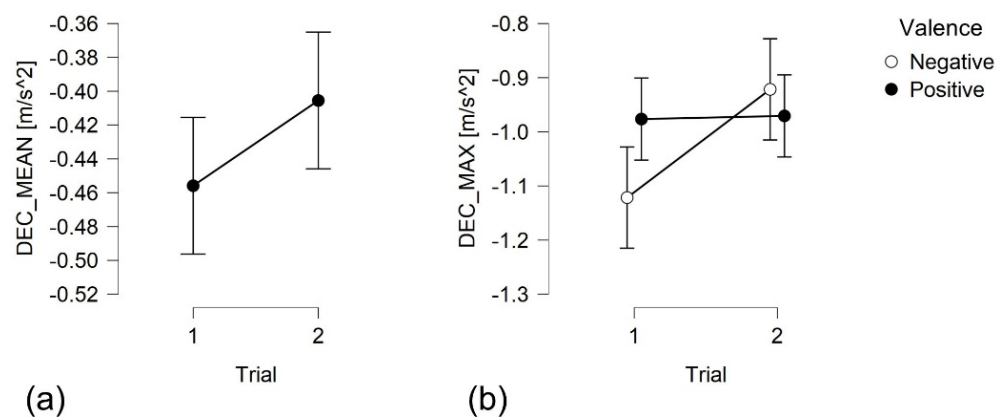
Figure 4. Mixed ANOVA results. Circles represent mean values, bars the 95% confidence intervals. Trial and Cluster effects on: (**a**) mean speed in the highway; (**b**) speed change at the beginning of the lane; (**c**) speed change at the exit point; (**d**) speed change at the end of the lane.

3.3.2. Deceleration Variables

The main factor Trial was not significant on **DEC_MEAN**, F (1.66) = 2.75, p = 0.102, η_p^2 = 0.04, although a tendency of participants to reduce (in absolute value) their mean deceleration in Trial 2 can be observed in Figure 5a. No significant effect was reported for any of the between-participant factors.
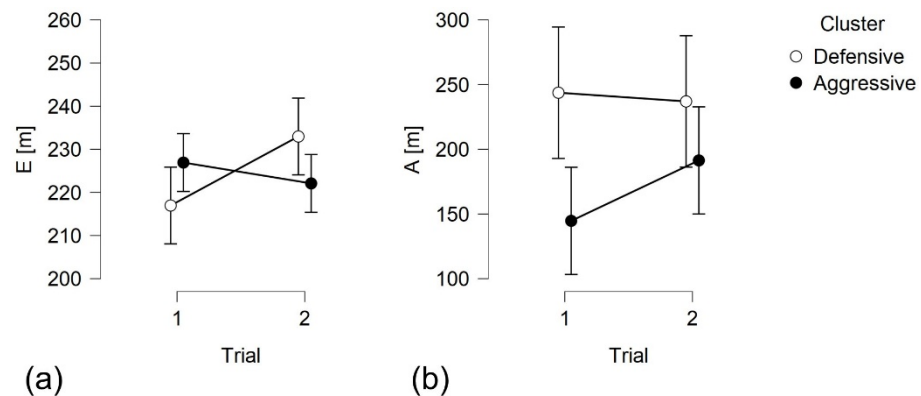

Figure 5. Mixed ANOVA results. Circles represent mean values, bars the 95% confidence intervals. (**a**) Trial effect on mean deceleration; (**b**) Trial and Feedback valence effects on maximum deceleration.

A more evident and significant effect of Trial was found when analyzing **DEC_MAX**, F (1.66) = 5.18, p = 0.026, η_p^2 = 0.07: participants reduced, on average, their maximum deceleration from -1.05 m/s^2 to -0.95 m/s^2 (Figure 5b). A significant interaction between Trial and Feedback valence was also observed, F (1.66) = 5.04, p = 0.028, η_p^2 = 0.07, and it showed that the participants who received a negative feedback were able to significantly reduce their maximum deceleration, as confirmed by the post hoc test, t (66) -3.07, p = 0.003, contrary to those who received the positive feedback, p = 0.827.

No significant effect was reported for any of the between-participant factors, nor for any other interaction.

3.3.3. Trajectory Variables

No significant main factor effect was found for variable **E**: on average, drivers tended to enter the deceleration lane at around the same point in both trials. However, an interesting interaction Trial*Cluster was found significant, F (1.66) = 6.45, p = 0.013, η_p^2 = 0.09. As can be observed in Figure 6a, defensive drivers tended to enter the lane significantly earlier in Trial 2, the post hoc tests resulting significant, t (66) = 2.77, p = 0.007. In absolute terms, they entered the lane about 16 m earlier in Trial 2. Conversely, aggressive drivers did not significantly change their behavior, t (66) = 0.83, p = 0.411.
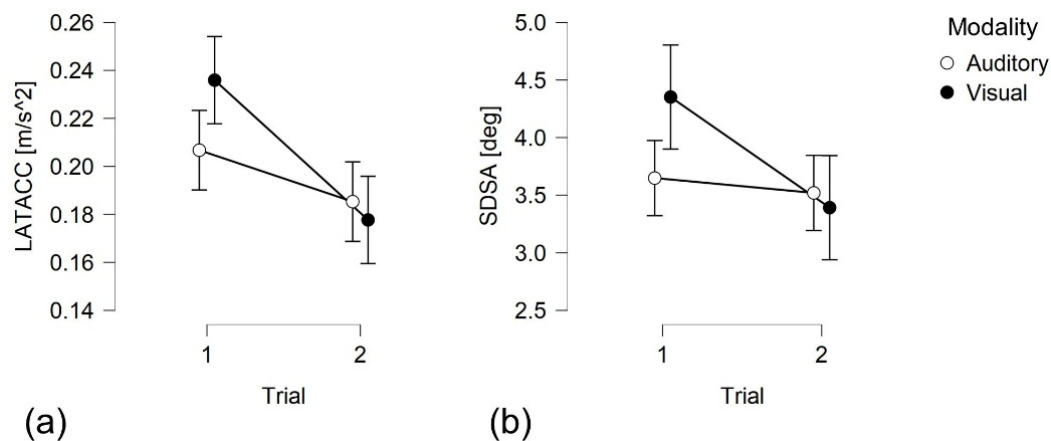

(a)   (b)

Figure 6. Mixed ANOVA results. Circles represent mean values, bars the 95% confidence intervals. Trial and Cluster effects on: (**a**) exit point E; (**b**) start-of-deceleration point A.

As regards the variable **A**, Trial was found not significant, and neither was its interaction with Cluster. Factor Cluster, however, was itself significant, F (1.47) = 7.34, p = 0.009, η_p^2 = 0.14., with defensive drivers raising the foot from the gas pedal much earlier (about 70 m on average) than the aggressive ones in both trials (Figure 6b). The analysis of this variable was performed on the 55 participants who released the gas pedal in both trials; the others kept the foot on the pedal for the whole maneuver in one or both trials, as mentioned in Section 3.1.

3.3.4. Lateral Control Variables

Trial had a significant effect on **LATACC**, F (1.66) = 19.37, $p < 0.001$, η_p^2 = 0.23 with a relevant reduction of mean lateral acceleration in the second trial. There was also a significant interaction between Trial and Feedback modality, F (1.66) = 4.54, p = 0.037, η_p^2 = 0.06, with the visual feedback seemingly more effective than the auditory one (Figure 7a). Indeed, post hoc tests showed that the visual feedback group significantly reduced their *LATACC* values in Trial 2, t (66) = 4.93, $p < 0.001$, whereas the auditory feedback group did not, p = 0.134.

Figure 7. Mixed ANOVA results. Circles represent mean values, bars the 95% confidence intervals. Trial and Feedback modality effects on: (**a**) mean lateral acceleration (LATACC); (**b**) standard deviation of steering angle (SDSA).

Similar results were coherently found when analyzing **SDSA**, with significant effects of Trial, $F (1.66) = 7.25$, $p = 0.009$, $\eta_p^2 = 0.10$, and interaction Trial*Feedback modality, $F (1.66) = 4.24$, $p = 0.043$, $\eta_p^2 = 0.06$ (Figure 7b). Again, the visual feedback group was able to improve lateral control, $t (66) = 3.58$, $p < 0.001$, whereas the auditory feedback group did not, $p = 0.673$; however, in this case, post hoc tests also showed a significant difference between the two feedback groups in the first trial, $t (66) = 2.10$, $p = 0.040$, suggesting that the effect could be explained, at least in part, by the random difference in behavior of the two groups during the baseline trial.

4. Discussion

In this paper, we examined the impact of real-time coaching programs on drivers' behavior in highway deceleration lanes, and whether their driving style or the way in which the feedback was presented had any effect on the program's effectiveness. The next paragraphs discuss the findings from our driving simulator experiment.

4.1. Effect of Real-Time Coaching Program on Drivers' Behavior (Factor Trial)

The results presented in Section 3 showed that the presence of the real-time coaching program had a significant effect on participants' driving behavior, influencing their speed, deceleration, trajectory, and lateral control.

Drivers tended, in general, to behave more cautiously in Trial 2. This was confirmed by the fact that the average speed in the highway section decreased, on average, by almost 5 km/h. The fact that the driver's "base" speed was lower in Trial 2 implied that the speeds in the deceleration lane were also lower in that trial. For this reason, instead of investigating in absolute terms the speeds at the beginning, entry point, and end of the deceleration lane, we chose to investigate the speed-changes at those points. This allowed us to isolate the further reduction in speed that was directly caused by the real-time coaching program. This effect was significant at the entry point ($\Delta V2$) and at the end ($\Delta V3$) of the lane; in terms of safety, these two variables are of particular interest, as one of the main issues of deceleration lanes is that drivers tend to exceed the design speeds used to determine the length of the lane and the radius of the ramp curve [8,51,52]. As regards the speed change at the beginning of the lane ($\Delta V1$), the effect of the feedback appeared evident only for the defensive drivers; this is further discussed in Section 4.2.

Since the feedback system is directly linked to drivers' acceleration/braking, it is not surprising that participants decelerated more smoothly in Trial 2. In particular, the improvement was more evident in the maximum deceleration values than in the mean values, coherent with what was observed in the rest of the simulation path, where participants significantly reduced the number of elevated gravitational-force events [32]. Note that this reduction in the deceleration values of Trial 2 was observed despite an increase in the

speed reduction, meaning that drivers decelerated with less intensity but for a longer time, i.e., in a smoother way. Smoother driving is of course desirable from a safety point of view; harsh decelerations, conversely, are dangerous because they can increase the potential for loss of vehicle control and reduce the time available for other road users to respond to the driver's behavior [34]. In addition, it is also worth noting that this significant reduction was observed despite the maximum deceleration value being relatively low, even in Trial 1, because of the geometric characteristics of the deceleration lane (see Section 2.1.5). Further research can investigate how program effectiveness on deceleration variables is influenced by lane geometry.

The program had a much more limited impact on vehicles' trajectories, as it was not found significant, except for an interaction with the factor Cluster on variable E, which is discussed in Section 4.2. Therefore, on average, drivers tended to start decelerating and entering the deceleration lane at the same points in both trials. However, by analyzing individual vehicle trajectories (see Figure 3), it was possible to observe that in Trial 2 the behavior was much more consistent among the participants and that there were fewer outliers: in Trial 1 seven of seventy-four drivers entered the deceleration lane with $E < 100$ m, whereas in Trial 2 all of them did it with $E > 100$ m.

One of the most important effects of the program involved lateral control, which significantly improved in Trial 2, considering both *LATACC* and *SDSA*. To some extent, this can be observed in qualitative terms in Figure 3, where the trajectories in Trial 2 showed generally fewer oscillations. This, again, represents a further positive effect on road safety.

4.2. Effect of Driving Style on Program Effectiveness (Factor Cluster)

A significant effect of participants' driving style was observed on speed and trajectory variables. Previous studies showed that the same real-time coaching program was more effective for aggressive drivers, mainly because there is more space for improvement [32,33].

As regards speed variables, however, the improvement was similar for both driver categories (except in the case of $\Delta V1$), meaning, on the one hand, that all users can benefit from it, and, on the other hand, that aggressive drivers are unable to reach defensive drivers' performance.

The analysis of trajectory variables deserves a more in-depth discussion, as the defensive drivers' behavior is not the optimal one in terms of safety. As can be seen in Figure 6a, in Trial 1, defensive drivers tended to start their deceleration earlier than aggressive drivers, while entering the deceleration lane at about the same spot. This implies that the majority of defensive drivers adopted a potentially dangerous (and also operationally disruptive—see [53]) exit strategy, which consisted in starting the deceleration before entering the deceleration lane. Such behavior was observed also in [8]. Twenty-three out of 36 defensive drivers (63.8%) were characterized by this behavior; conversely, only 12 out of 38 aggressive drivers adopted it (31.6%).

By entering the deceleration lane earlier in Trial 2, some defensive drivers switched exit strategy, reducing to 18 (i.e., 50%) the number of defensive drivers decelerating before entering the deceleration lane.

This change in exit strategy was likely linked to the decrease in approaching speed, with defensive drivers reaching the beginning of the deceleration lane (see the analysis of variable $\Delta V1$ in Section 3.3.1) with a significantly lower speed in Trial 2, allowing them to perform the exiting maneuver comfortably, even without starting the deceleration beforehand. This did not happen to aggressive drivers (see Figure 4b), who, consequently, did not significantly modify their trajectory in Trial 2.

4.3. Effect of Feedback Modality and Variance on Program Effectiveness

It has been suggested in the literature that multimodal feedbacks are more effective than either visual or auditory feedbacks, whereas, considering the two modes separately, results are not conclusive [54–56]. For this reason, Feedback Modality variable was included in the experimental design. The results of the present study did not show significant

differences between auditory and visual modalities, with the notable exception of lateral control, where the visual feedback produced an improvement in performance and the auditory did not. However, as mentioned in Section 3.3.4 and as can be observed in Figure 7, this may have been caused by a random difference in the two groups in Trial 1, combined with a ceiling effect, which prevented the participants in the auditory feedback group to improve their performance in the second trial.

Feedback valence (positive or negative) did not show any significant effect on most of the dependent variables, as observed in previous studies on this driving simulator experiment [32,33]. This is in contrast with the findings of Harbeck et al. [57], who suggested that rewards have greater impact on behavioral changes, especially for young drivers. It is however possible that in the present study there was a ceiling effect, caused by the attributes of the feedback sounds: their symbolic meaning may have amplified their effect, disguising differences in their impacts. For one variable, *DEC_MAX*, a significant interaction between Feedback valence and Trial was found, as only participants who received a negative feedback were able to improve their performance in Trial 2. However, as in the case of the feedback modality effect on lateral control discussed above, this may be explained, at least in part, by a random difference in the two groups in Trial 1 (Figure 5b). Further research is required to confirm these findings.

5. Conclusions

This work investigated the impact of a motor insurance real-time coaching program on drivers' behavior on highway deceleration lanes. Data were collected with a driving simulator experiment, and the analyses involved several kinematic variables.

The main result from the present work is that the tested real-time coaching programs were able to significantly improve the safety of the exit maneuver from the highway, with participants reducing their speed both approaching and using the deceleration lane, decelerating more smoothly and with higher lateral control. This also allowed some drivers, characterized by a "defensive" driving style, to modify their exit strategy by entering the deceleration lane before starting the deceleration, instead of doing the opposite (which is both a safety and an operational issue). Finally, no significant effect of feedback modality and valence was observed on most of the investigated variables.

These results have a potentially relevant practical interest because they suggest that it is possible to improve driving behavior with a very simple general purpose feedback system that depends only on a fixed acceleration/deceleration threshold. They also suggest that developing real-time coaching systems, primarily aimed at increasing the smoothness of driving style, could also produce additional benefits in specific and seemingly unrelated situations, as also shown in previous works [33].

There are some limitations that will be addressed in future research in order to generalize the conclusions and the practical implications of the present work. The main one is that only one exit maneuver per trial was performed, and this limited in some ways the investigation of a variety of features that can potentially modulate the feedback effect, such as geometric and traffic features; in particular, the deceleration lane was designed in a "safe" way, since it was relatively long, and it was followed by a smooth curve. In the future, it will be interesting to investigate the program's effectiveness on deceleration lanes that require a higher speed reduction.

The kinematic realism of the simulator was validated in several scenarios mentioned in Section 2.1.2. However, a specific analysis of the realism of vehicle deceleration in the case specifically studied here could be of interest.

In addition, the participants were a homogeneous group of young Italian drivers; it will be interesting to investigate the relationship between sociodemographic characteristics and the real-time coaching program's effectiveness on deceleration lanes.

Furthermore, it will be worth testing alternative feedback modalities (e.g., tactile) or combinations of modalities, as well as long-term effects on driving behavior.

Finally, on a more general note, further research on real-time coaching programs can investigate reducing misperception of braking capabilities [58,59] and compare the monetary incentives involved in such programs (which include both private and societal benefits, see Section 1.2) with the potential willingness-to-pay to avoid the so-called "time saving bias", as shown by Tscharaktschiew [60].

References

1. Torbic, D.J.; Hutton, J.M.; Bokenkroger, C.D.; Harwood, D.W.; Gilmore, D.K.; Knoshaug, M.M.; Ronchetto, J.J.; Brewer, M.A.; Fitzpatrick, K.; Chrysler, S.T.; et al. *NCHRP Report 730: Design Guidance for Freeway Mainline Ramp Terminals*; National Cooperative Highway Research Program, Transportation Research Board: Washington, DC, USA, 2012; ISBN 9780309258548.
2. Lundy, R.A. The effect of ramp type and geometry on accidents. *Highw. Res. Rec.* **1967**, *163*, 80–119.
3. McCartt, A.T.; Northrup, V.S.; Retting, R.A. Types and characteristics of ramp-related motor vehicle crashes on urban interstate roadways in Northern Virginia. *J. Saf. Res.* **2004**, *35*, 107–114. [CrossRef]
4. Lord, D.; Bonneson, J.A. Calibration of predictive models for estimating safety of ramp design configurations. *Transp. Res. Rec.* **2005**, *1908*, 88–95. [CrossRef]
5. Bared, J.; Giering, G.L.; Warren, D.L. Safety evaluation of acceleration and deceleration lane lengths. *ITE J.* **1999**, *69*, 50–54.
6. Chen, H.; Zhou, H.; Lin, P.-S. Freeway deceleration lane lengths effects on traffic safety and operation. *Saf. Sci.* **2014**, *64*, 39–49. [CrossRef]
7. Papadimitriou, E.; Theofilatos, A. Meta-analysis of crash-risk factors in freeway entrance and exit areas. *J. Transp. Eng. Part A Syst.* **2017**, *143*, 04017050. [CrossRef]
8. Calvi, A.; Benedetto, A.; De Blasiis, M. A driving simulator study of driver performance on deceleration lanes. *Accid. Anal. Prev.* **2012**, *45*, 195–203. [CrossRef]
9. Calvi, A.; Bella, F.; D'Amico, F. Diverging driver performance along deceleration lanes: Driving simulator study. *Transp. Res. Rec. J. Transp. Res. Board* **2015**, *2518*, 95–103. [CrossRef]
10. Calvi, A.; Bella, F.; D'Amico, F. Evaluating the effects of the number of exit lanes on the diverging driver performance. *J. Transp. Saf. Secur.* **2016**, *10*, 105–123. [CrossRef]
11. Calvi, A.; D'Amico, F.; Ferrante, C.; Bianchini Ciampoli, L. A driving simulator validation study for evaluating the driving performance on deceleration and acceleration lanes. *Adv. Transp. Stud.* **2020**, *50*, 67–80. [CrossRef]
12. Lyu, N.; Cao, Y.; Wu, C.; Xu, J.; Xie, L. The effect of gender, occupation and experience on behavior while driving on a freeway deceleration lane based on field operational test data. *Accid. Anal. Prev.* **2018**, *121*, 82–93. [CrossRef]
13. Tselentis, D.I.; Yannis, G.; Vlahogianni, E.I. Innovative motor insurance schemes: A review of current practices and emerging challenges. *Accid. Anal. Prev.* **2017**, *98*, 139–148. [CrossRef] [PubMed]
14. Carfora, M.F.; Martinelli, F.; Mercaldo, F.; Nardone, V.; Orlando, A.; Santone, A.; Vaglini, G. A "Pay-How-You-Drive" car insurance approach through cluster analysis. *Soft Comput.* **2019**, *23*, 2863–2875. [CrossRef]

15. Mendels, O.; Bertental, G.; Kamara, T. Unsupervised Driver Safety Estimation at Scale, a Collaboration with Pointer Telocation. Available online: https://devblogs.microsoft.com/cse/2018/07/30/unsupervised-driver-safety-estimation-at-scale/ (accessed on 13 August 2021).

16. Handel, P.; Skog, I.; Wahlstrom, J.; Bonawiede, F.; Welch, R.; Ohlsson, J.; Ohlsson, M. Insurance telematics: Opportunities and challenges with the smartphone solution. *IEEE Intell. Transp. Syst. Mag.* **2014**, *6*, 57–70. [CrossRef]

17. Boquete, L.; Rodríguez-Ascariz, J.M.; Barea, R.; Cantos, J.; Miguel-Jiménez, J.M.; Ortega, S. Data Acquisition, analysis and transmission platform for a pay-as-you-drive system. *Sensors* **2010**, *10*, 5395–5408. [CrossRef]

18. Hu, X.; Zhu, X.; Ma, Y.; Chiu, Y.; Tang, Q. Advancing usage-based insurance—A contextual driving risk modelling and analysis approach. *IET Intell. Transp. Syst.* **2019**, *13*, 453–460. [CrossRef]

19. Shi, X.; Wong, Y.D.; Li, M.Z.-F.; Palanisamy, C.; Chai, C. A feature learning approach based on XGBoost for driving assessment and risk prediction. *Accid. Anal. Prev.* **2019**, *129*, 170–179. [CrossRef] [PubMed]

20. Soleymanian, M.; Weinberg, C.B.; Zhu, T. Sensor data and behavioral tracking: Does usage-based auto insurance benefit drivers? *Mark. Sci.* **2019**, *38*, 21–43. [CrossRef]

21. Ryder, B.; Dahlinger, A.; Gahr, B.; Zundritsch, P.; Wortmann, F.; Fleisch, E. Spatial prediction of traffic accidents with critical driving events—Insights from a nationwide field study. *Transp. Res. Part A Policy Pract.* **2019**, *124*, 611–626. [CrossRef]

22. Winlaw, M.; Steiner, S.H.; Mackay, R.J.; Hilal, A.R. Using telematics data to find risky driver behaviour. *Accid. Anal. Prev.* **2019**, *131*, 131–136. [CrossRef] [PubMed]

23. Toledo, G.; Shiftan, Y. Can feedback from in-vehicle data recorders improve driver behavior and reduce fuel consumption? *Transp. Res. Part A Policy Pract.* **2016**, *94*, 194–204. [CrossRef]

24. Toledo, T.; Musicant, O.; Lotan, T. In-vehicle data recorders for monitoring and feedback on drivers' behavior. *Transp. Res. Part C Emerg. Technol.* **2008**, *16*, 320–331. [CrossRef]

25. Reagan, I.J.; Bliss, J.P.; Van Houten, R.; Hilton, B.W. The effects of external motivation and real-time automated feedback on speeding behavior in a naturalistic setting. *Hum. Factors J. Hum. Factors Ergon. Soc.* **2013**, *55*, 218–230. [CrossRef]

26. Biondi, F.N.; Rossi, R.; Gastaldi, M.; Orsini, F.; Mulatti, C. Precision teaching to improve drivers' lane maintenance. *J. Saf. Res.* **2020**, *72*, 225–229. [CrossRef] [PubMed]

27. Pappalardo, G.; Cafiso, S.; Di Graziano, A.; Severino, A. decision tree method to analyze the performance of lane support systems. *Sustainability* **2021**, *13*, 846. [CrossRef]

28. Hibberd, D.; Jamson, A.; Jamson, S. The design of an in-vehicle assistance system to support eco-driving. *Transp. Res. Part C Emerg. Technol.* **2015**, *58*, 732–748. [CrossRef]

29. Huang, Y.; Ng, E.C.; Zhou, J.L.; Surawski, N.; Chan, E.F.; Hong, G. Eco-driving technology for sustainable road transport: A review. *Renew. Sustain. Energy Rev.* **2018**, *93*, 596–609. [CrossRef]

30. Dijksterhuis, C.; Lewis-Evans, B.; Jelijs, L.H.; Tucha, O.; de Waard, D.; Brookhuis, K. In-car usage-based insurance feedback strategies. A comparative driving simulator study. *Ergonomics* **2016**, *59*, 1158–1170. [CrossRef] [PubMed]

31. Dijksterhuis, C.; Lewis-Evans, B.; Jelijs, B.; de Waard, D.; Brookhuis, K.; Tucha, O. The impact of immediate or delayed feedback on driving behaviour in a simulated Pay-As-You-Drive system. *Accid. Anal. Prev.* **2015**, *75*, 93–104. [CrossRef] [PubMed]

32. Rossi, R.; Tagliabue, M.; Gastaldi, M.; De Cet, G.; Freuli, F.; Orsini, F.; Di Stasi, L.L.; Vidotto, G. Reducing elevated gravitational-force events through visual feedback: A simulator study. *Transp. Res. Procedia* **2021**, *52*, 115–122. [CrossRef]

33. Rossi, R.; Orsini, F.; Tagliabue, M.; Di Stasi, L.L.; De Cet, G.; Gastaldi, M. Evaluating the impact of real-time coaching programs on drivers overtaking cyclists. *Transp. Res. Part F Traffic Psychol. Behav.* **2021**, *78*, 74–90. [CrossRef]

34. Simons-Morton, B.G.; Zhang, Z.; Jackson, J.C.; Albert, P.S. Do elevated gravitational-force events while driving predict crashes and near crashes? *Am. J. Epidemiol.* **2012**, *175*, 1075–1079. [CrossRef] [PubMed]

35. Tselentis, D.; Theofilatos, A.; Yannis, G.; Konstantinopoulos, M. Public opinion on usage-based motor insurance schemes: A stated preference approach. *Travel Behav. Soc.* **2018**, *11*, 111–118. [CrossRef]

36. Bolderdijk, J.; Knockaert, J.; Steg, E.; Verhoef, E. Effects of Pay-As-You-Drive vehicle insurance on young drivers' speed choice: Results of a dutch field experiment. *Accid. Anal. Prev.* **2011**, *43*, 1181–1186. [CrossRef]

37. World Medical Association. World Medical Association declaration of helsinki: Ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*, 2191–2194. [CrossRef] [PubMed]

38. Rossi, R.; Gastaldi, M.; Meneguzzer, C. Headway distribution effect on gap-acceptance behavior at roundabouts: Driving simulator experiments in a case study. *Adv. Transp. Stud.* **2018**, *46*, 97–110. [CrossRef]

39. Rossi, R.; Meneguzzer, C.; Orsini, F.; Gastaldi, M. Gap-acceptance behavior at roundabouts: Validation of a driving simulator environment using field observations. *Transp. Res. Procedia* **2020**, *47*, 27–34. [CrossRef]

40. Orsini, F.; Gecchele, G.; Gastaldi, M.; Rossi, R. Collision prediction in roundabouts: A comparative study of extreme value theory approaches. *Transp. A Transp. Sci.* **2019**, *15*, 556–572. [CrossRef]

41. Gastaldi, M.; Orsini, F.; Gecchele, G.; Rossi, R. Safety analysis of unsignalized intersections: A bivariate extreme value approach. *Transp. Lett.* **2021**, *13*, 209–218. [CrossRef]

42. Rossi, R.; Gastaldi, M.; Gecchele, G.; Biondi, F.; Mulatti, C. Traffic-calming measures affecting perceived speed in approaching bends. *Transp. Res. Rec. J. Transp. Res. Board* **2014**, *2434*, 35–43. [CrossRef]

43. Wåhlberg, A.A. Changes in driver celeration behaviour over time: Do drivers learn from collisions? *Transp. Res. Part F Traffic Psychol. Behav.* **2012**, *15*, 471–479. [CrossRef]

44. Bradley, M.M.; Lang, P. *Affective Norms for English Words (ANEW): Stimuli, Instruction Manual and Affective Ratings*; Technical Report No., C-1; NIMH: Gainesville, FL, USA; The Center for Research in Psychophysiology: Gainesville, FL, USA, January 1999.
45. Gianfranchi, E.; Tagliabue, M.; Spoto, A.; Vidotto, G. Sensation Seeking, non-contextual decision making, and driving abilities as measured through a moped simulator. *Front. Psychol.* **2017**, *8*, 2126. [CrossRef]
46. Gianfranchi, E.; Tagliabue, M.; Vidotto, G. Personality traits and beliefs about peers' on-road behaviors as predictors of adolescents' moped-riding profiles. *Front. Psychol.* **2018**, *9*, 2483. [CrossRef] [PubMed]
47. Gianfranchi, E.; Spoto, A.; Tagliabue, M. Risk profiles in novice road users: Relation between moped riding simulator performance, on-road aberrant behaviors and dangerous driving. *Transp. Res. Part F Traffic Psychol. Behav.* **2017**, *49*, 132–144. [CrossRef]
48. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: New York, NY, USA, 1988; ISBN 0805802835.
49. Team JASP. *Computer Software, Version 0.13.1*; JASP: Amsterdam, The Netherlands, 2020.
50. Love, J.; Selker, R.; Marsman, M.; Jamil, T.; Dropmann, D.; Verhagen, J.; Ly, A.; Gronau, Q.F.; Smíra, M.; Epskamp, S.; et al. JASP: Graphical statistical software for common statistical designs. *J. Stat. Softw.* **2019**, *88*, 1–17. [CrossRef]
51. El-Basha, R.H.S.; Hassan, Y.; Sayed, T.A. Modeling freeway diverging behavior on deceleration lanes. *Transp. Res. Rec. J. Transp. Res. Board* **2007**, *2012*, 30–37. [CrossRef]
52. Fukutome, I.; Moskowitz, K. Traffic behavior and off-ramp design. *Highw. Res. Rec.* **1963**, *21*, 17–31.
53. Van Beinum, A.; Farah, H.; Wegman, F.; Hoogendoorn, S. Driving behaviour at motorway ramps and weaving segments based on empirical trajectory data. *Transp. Res. Part C Emerg. Technol.* **2018**, *92*, 426–441. [CrossRef]
54. Adell, E.; Vaárhelyi, A.; Alonso, M.; Plaza, J. Developing human–machine interaction components for a driver assistance system for safe speed and safe distance. *IET Intell. Transp. Syst.* **2008**, *2*, 1–14. [CrossRef]
55. Cabral, J.P.; Remijn, G.B. Auditory icons: Design and physical characteristics. *Appl. Ergon.* **2019**, *78*, 224–239. [CrossRef]
56. Cao, Y.; Mahr, A.; Castronovo, S.; Theune, M.; Stahl, C.; Müller, C.A. Local danger warnings for drivers: The effect of modality and level of assistance on driver reaction. In Proceedings of the International Conference on Intelligent User Interfaces, Hong Kong, China, 7–10 February 2010; pp. 239–248.
57. Harbeck, E.; Glendon, A.I.; Hine, T.J. Reward versus punishment: Reinforcement sensitivity theory, young novice drivers' perceived risk, and risky driving. *Transp. Res. Part F Traffic Psychol. Behav.* **2017**, *47*, 13–22. [CrossRef]
58. Svenson, O.; Eriksson, G.; Gonzalez, N. Braking from different speeds: Judgments of collision speed if a car does not stop in time. *Accid. Anal. Prev.* **2011**, *45*, 487–492. [CrossRef] [PubMed]
59. Svenson, O. Biased judgments of the effects of speed change on travel time, fuel consumption and braking: Individual differences in the use of simplifying rules producing the same biases. *Transp. Res. Part F Traffic Psychol. Behav.* **2021**, *78*, 398–409. [CrossRef]
60. Tscharaktschiew, S. The private (unnoticed) welfare cost of highway speeding behavior from time saving misperceptions. *Econ. Transp.* **2016**, *7–8*, 24–37. [CrossRef]