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Are car-following performance and pedestrian detection altered by anger?

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INTRODUCTION

Negative emotions while driving are problematic because they could cause a focus on internal thoughts rather than on the driving task, increasing the risk of accident (*e.g.* Galera et al., 2012; Lagarde et al., 2004). Epidemiologic studies showed that drivers going through a divorce or a separation have a higher risk to be involved in serious traffic accidents (Lagarde et al., 2004). The drivers from this experiment can be assumed to have experienced negative emotions as a consequence of their separation. They may also have been distracted by their thoughts, which is a potential factor increasing the risk of serious accident. Galera et al. (2012) studied a population of drivers admitted to emergencies due to a road accident, and those who reported to be highly distracted by their thoughts were more likely to be responsible for the accident. According to those studies, experiencing a negative emotion like anger while driving could increase the risk of accident because of the attentional disruptions provoked by negative emotions.

It is especially interesting to study anger, since it is a commonly experienced emotion behind the wheel. It should be noted that anger can arise from the driving context itself, but also from an anger-inducing event prior to the driving task (*e.g.* Jeon, Walker, & Yim, 2014). Therefore, anger could either be related or unrelated to the driving task and deteriorate the attention in both situations. For example, participants induced in an anger state are slower to localize the elements of a picture representing a driving environment (Jallais, Gabaude, and Paire-ficout, 2014). In this study, anger was induced by a mood induction procedure that was not related to the task or the driving context, and led to a deterioration of the response speed. Besides, simulator studies that induced anger by the driving task found a reduction of speed in the reaction to unexpected hazards (Stephens, Trawley, Madigan, & Groeger, 2013). They underlined that this longer time necessary to perform corrective actions could be due to a more superficial processing of unexpected events. In this experiment, angry participants had troubles to follow the movements of pedestrians when the visual contact was interrupted by another vehicle. Surprisingly, in spite of being slower to react to those hazards, angry drivers were as efficient as the other drivers to avoid the possible collisions.

Considering that anger is a negative and highly aroused emotion eliciting a strong approach behavioural response and an attentional focus on its source (Fox, Russo, Bowles, & Dutton, 2001; Harmon-Jones, Gable, & Price, 2013), we can question the angry driver's ability to detect the potential hazards in the presence of the source of their anger. They may focus on the source of anger at the expense of seeking potential hazards.

In addition to its effects on attention, anger can also affect the driving behavior. Several studies using retrospective surveys revealed that driving in an anger state can lead to aggressive behaviors or transgressions (*e.g.* Deffenbacher, Lynch, Oetting, & Swaim, 2002). Moreover, questionnaire studies have shown that aggressive forms of anger expression were related to crashes and crash related situations (Sullman, 2015). However, this kind of study is not designed to provide an objective observation of the drivers' behavior. Studies using the driving simulator confirmed that the driving style could be modified by anger (*e.g.* Abdu, Shinar, & Meiran, 2012). They concluded that angry drivers tend to adopt a riskier driving style (faster speed, inter-vehicular time reduction, traffic laws infractions) but surprisingly, this risky driving was not correlated with the number of collisions. Although no increase in the number of crashes were observed in the simulator studies, they often suggested that anger may lead to a faster speed and stronger accelerations (Mesken, Hagenzieker, Rothengatter, & de Waard, 2007; Roidl, Frehse, & Hoeger, 2014). For this reason, we suppose that anger may not directly impair the ability to avoid hazards, but it may interfere with the driver ability to control his speed, thereby indirectly affecting the crash hazard. To our knowledge, several studies have shown that anger may provoke maladaptive driving, but none of them clearly focused on the ability of angry drivers to adjust their speed to the actual situational traffic speed. In order to evaluate the effects of anger on the driving performance through the adaptation to the traffic speed variations, we need to use a task providing indicators of the driving performance on the basis of a realistic and standardized task suitable for driving simulators.

The car-following task created by Brookhuis, De Waard, and Mulder (1994) represents a mainstream situation in which the driver has to follow and adjust his speed so as to match a lead vehicle's (LV) speed, thus maintaining a constant inter-vehicular distance. The speed curve of the experimental vehicle is defined beforehand, and the comparison between the two speed signals provides three indicators of driving performance: *Coherence* is the squared correlation between the two speed signals, thus giving an indication about the general respect of the LV speed curve. *Modulus* represents the amplification factor between the two speed curves. In other words, modulus provides the tendency of the participant to overshoot or undershoot the speed changes of the LV. *Phase shift / Delay* is the lag between the LV speed changes, and the participant reactions. It represents the mean amount of time required by the driver, after a change in the LV speed signal, to start adjusting his pace. It should also been noted that the car-following task has been used in different contexts and seems reliable to reveal the effects of multiple kinds of contexts on the driving performance.

Among the different uses of the car-following task, the effect of mental effort on car-following performance has been studied. Ranney, Harbluk, and Noy (2005) found that the car-following performance could be reduced by a high mental effort. In their experiment, interacting with an in-vehicle computer while completing the car-following task provoked an increase in the delay, indicating that the drivers were slower to react to the speed changes of the LV. When their mental effort increased, the drivers completing a dual task automatically extended their inter-vehicular distance in order to cope with the deterioration of delay. On the other hand, Ünal, de Waard, Epstude, and Steg (2013) showed that in a monotonous task, the mild arousal induced by music could improve the following performance. In their experiment, drivers had a better latency to speed changes when they listened to music in a monotonous and highly predictable environment. Consequently, we think that anger, by the high arousal it provokes, could impact the car-following performance, particularly in a high demanding situation like a double task. Moreover, we found no study using the car-following task to report an effect of anger on the driving performance.

The objective of this study is twofold. On one hand, we will investigate the effects of anger on a pedestrian detection task. As mentioned above, anger could cause a focus on its source (Fox, Russo, Bowles, & Dutton, 2001; Harmon-Jones, Gable, & Price, 2013). Thus, the angry participants should be less efficient to detect the pedestrians when a source of anger is present. On the other hand, we will search for an influence of anger on the driving performance, using a car-following task. Given that anger tends to promote a faster speed and more powerful accelerations (Roidl et al., 2014), we suppose that the angry drivers would have a reduced coherence and an increased modulus: A reduced coherence would point at a difficulty for the Anger group to reproduce the general speed curve of the LV. An increased modulus would indicate that the Anger group participants tend to overreact to the speed changes.

METHOD

Participants

Participants were recruited using an online preliminary questionnaire corresponding to the French adaptation of the Driving Anger Scale (DAS; Villieux & Delhomme, 2007).

Seventy-five drivers (24 to 45 years; M = 31, SD = 6) with normal vision and more than three years of driving experience completed the experiment and received a 60 Euros financial compensation. The 50 participants with the highest DAS scores were assigned to the Anger group and the others were assigned to the Control group. After removing 14 participants due to simulator sickness, a total of 61 participants (40 in Anger group; 21 in Control group) remained.

The research protocol was approved by the ethic committee of the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR).

Material

Mood induction (MIP) and measurement

Participants were induced either in anger or in a neutral mood according to their group. A 15 minute induction scenario was developed, based on the study of Stephens and Groeger (2011).

A timer present in the car was programmed to provide to the Anger group a negative feedback about the time that they took to finish the Induction drive. They were convinced to be slower than the average driver in order to increase the time pressure. In addition, they were impeded by an anger-inducing vehicle driving before them around 15km/h under the authorized speed. At some points of the scenario, anger inducing events (*e.g.* a vehicle horning at the participant) were displayed. The control group drove the same scenario with a positive feedback about their completion time, and the anger-inducing vehicle drove at the same speed as the participant, thus was not perceived as impeding. Finally, the anger inducing events were absent for the control group.

The MIP efficiency was measured using a modified version of the Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988) developed by Corson and Verrier (2007). The BMIS is a 16-item self-report questionnaire in which each adjective is rated on a 7-point scale. The 16 adjectives in this test correspond to 4 adjectives per emotion (*i.e.* anger, happiness, sadness and calmness) and provide a score for the valence and the arousal dimensions of the emotional state.

Car-following

The lead vehicle (LV) speed was shifting between .01 and .03 Hz with 20 km/h amplitude (70 to 90 km/h). Occasionally, the LV kept a 70 or 90km/h constant speed for 10 second. The driving performance was measured using the three car-following indicators (*i.e.* coherence, modulus, phase shift) and the inter-vehicular time.

Pedestrian detection

In the detection task, pedestrians were positioned at 60cm at the left or the right side of the road. They were always placed behind voluminous objects like houses, trees or bus shelters in order to be visible from a 3 second distance approximately. The pedestrian detection performance was measured using the response times and the distance of detection

Apparatus

The experiment took place in the Laboratory for Road Operations, Perception, Simulators and Simulations (LEPSiS) fixed-base car driving simulator at IFSTTAR. This simulator was composed of a Peugeot 308 surrounded by 8 screens (220 cm high × 165cm wide) providing around 280° horizontal and 40° vertical field of view. The five screens placed in the front of the vehicle provided the forward view and the three others screens placed at the rear and the right side of the vehicle allowed the participant to see the driving environment through the right and central rear mirrors. A 22” screen placed on the left side of the vehicle allowed the participant to see the environment through the left rear mirror.

Procedure

After completing the informed consent form, participants drove the Training session in order to familiarize themselves with the driving simulator, the car-following task, and the pedestrian detection task. Afterwards, they completed a first experimental scenario (Experimental 1). This scenario consisted of the car-following task in which they were instructed to follow and replicate the vehicle speed of the car in front of them (Brookhuis et al., 1994). In addition to the car-following task, participants had to detect all the pedestrians placed along the road. Those pedestrians could either be placed alone (Pedestrian), at the opposite side of a neutral vehicle (Pedestrian-Neutral), or at the opposite side of the anger-inducing vehicle present in the Induction scenario (Pedestrian-Anger). A total of 12 pedestrians were presented, but the participants were not informed about this number.

After the Experimental 1 scenario, participants drove the induction drive according to their group. They were instructed to finish the track as fast as possible while respecting the traffic laws.

Finally, they completed the second experimental scenario (Experimental 2) in which they had to complete the double task situation performed in the Experimental 1 scenario one more time.

RESULTS

Mood induction

The Anger group was composed of the participants with the highest DAS scores in order to maximize the effects of anger induction. Nevertheless, the mood induction led to a high variability of effects between the participants. Therefore, we decided to continue the analysis only for those participants in the Anger group who reported an increase in the arousal and the anger ratings (Mean anger ratings = 2.06, Mean arousal ratings = 4.36) and with the participants in the Control group who did not report more anger or arousal after the induction (Mean anger ratings = 1.16, Mean arousal ratings = 3.92).

The following analyses were carried out with the 35 participants who were successfully induced, and who did not suffer from simulator sickness. The Anger group was composed of 18 participants (*M* = 29 years, *SD* = 7; 8 females), and 17 participants formed the Control group (*M* = 33 years, *SD* = 6; 5 females).

Car-following performance

A shift score was calculated for each indicator of the driving performance in order to report the differences in driving performance induced by the induction scenario. Shifts scores were obtained by subtracting the Experimental 1 scores from the Experimental 2 scores (*e.g.* coherence shift = Experimental 2 coherence – Experimental 1 coherence). Then, four one-way ANOVAs were carried out to test the effect of the Group (Anger/Control) on the four driving performance indicators (Coherence shift, Modulus shift, Delay shift and inter-vehicular time shift).

These analyses revealed an effect of the Group on the Delay shift $F(1, 33) = 4.66$, $\eta^2 = 0.124$, $p = < .05$. The Control group had a greater Delay shift than the Anger group, showing that they reacted faster to the speed changes of the lead vehicle in the second experimental drive. No significant effect of the Group was found concerning the Coherence shift ($F(1, 33) < 1$, *n.s.*), the Modulus shift ($F(1, 33) < 1$, *n.s.*), and the TIV shift ($F(1, 32) = 1.81$, $\eta^2 = 0.052$, $p = .19$).

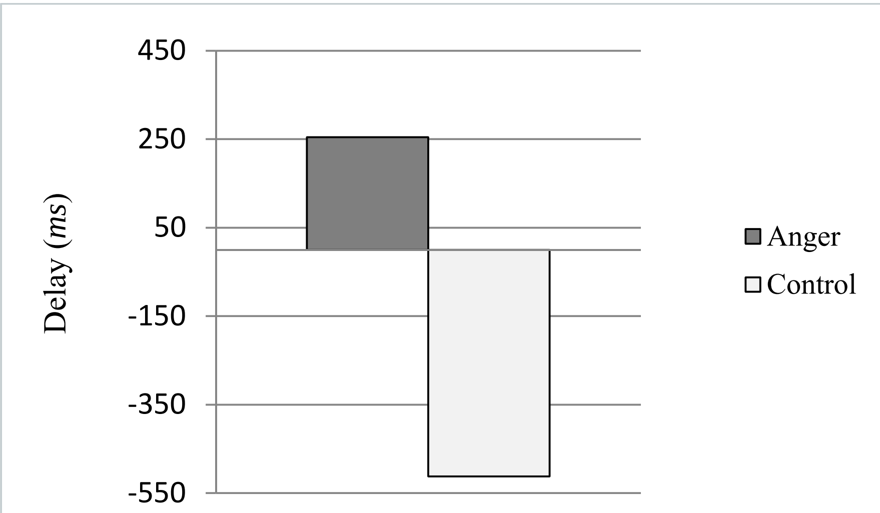

Figure 1: Delay shift (Experimental 2 delay - Experimental 1 delay) for each induction Group (Anger/Control)

Pedestrian detection performance

Due to a technical issue, the detection data for one participant from the Control group was not exploitable. Consequently, the following analyses were performed for the 34 remaining participants.

In order to avoid the predictability of the targets, the pedestrian detection task was not the same in both experimental scenarios letting the comparison between them impossible. Thus, separate analyses for both scenarios were conducted.

Response Time

For each Experimental scenario (Experimental 1/Experimental 2) an ANOVA was carried out with the Group (Anger/Control) as a between subject factor and pedestrian condition (Pedestrian/Pedestrian Neutral/Pedestrian Anger).

The first analysis was carried out with the mean response times (RT) of the Experimental 1 scenario as a dependent variable, and revealed a main effect of the pedestrian condition ($F(2, 64) = 4.61 \eta^2 = 0.126$, $p < .05$,) and no significant effect of the Group ($F(1, 32) < 1$, *n.s.*). Planned comparisons showed that the mean RT of the pedestrian-neutral ($M = 1460$ *ms*) was shorter than the mean RT of the pedestrian-anger ($M = 1735$ *ms*), $F(1, 32) = 4.50$, $\eta^2 = 0.123$, $p < .05$, and tended to be shorter than the mean RT of the pedestrian ($M = 1593$), $F(1, 32) = 3.69$, $\eta^2 = 0.004$, $p = .06$. The difference between the mean RT of the pedestrian-anger and the pedestrian was not significant ($F(1, 32) < 1$, *n.s.*).

The second analysis was carried out with the mean RT of the Experimental 2 scenario as a dependent variable. This analysis revealed no significant effect of the Group ($F(1, 32) = 2.39$, $\eta^2 = 0.001$, *n.s.*), and no significant effect of the pedestrian condition ($F(2, 64) < 1$, *n.s.*).

Distance of detection

The same analyses performed for the RT were carried out for the distance of detection. The first analysis with the mean distance of detection of the Experimental 1 scenario as a dependent variable revealed a main effect of the pedestrian condition $F(2, 64) = 9.78$, $\eta^2 = 0.234$, $p < .001$. However, no significant effect were found concerning the group ($F(1, 32) < 1$, *n.s.*). Planned comparisons showed that the mean distance of detection of the pedestrian-neutral ($M = 49$ *m*) was longer than the mean RT of the pedestrian ($M = 39$ *m*), $F(1, 32) = 5.66$, $\eta^2 = 0.150$, $p < .05$. Other planned comparisons were not significant ($F(1, 32) < 1$, *n.s.*).

The second analysis was carried out with the mean distance of detection of the Experimental 2 scenario as a dependent variable (Figure 2). This analysis revealed no significant effect of the Group ($F(1, 32) = 1.77$, $\eta^2 = 0.002$, *n.s.*), and no significant effect of the pedestrian condition ($F(2, 64) < 1$, *n.s.*). Planned comparisons showed a significant difference in the mean distance of detection between the Anger and the Control group when the pedestrian was placed alone ($F(1, 32) = 5.99$, $\eta^2 = 0.158$, $p < .05$). However, this difference was not significant for the Pedestrian Neutral condition ($F(1, 32) < 1$, *n.s.*), and the Pedestrian Anger condition ($F(1, 32) < 1$, *n.s.*).

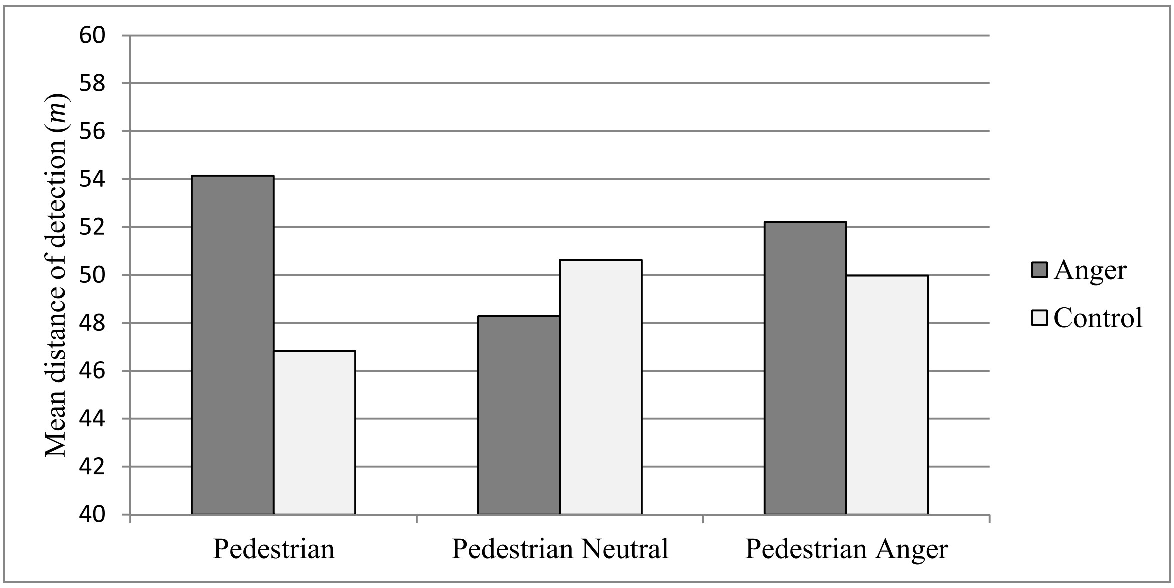

Figure 2: Mean distance of detection for the Experimental 2 scenario according to the Induction group (Control/Anger), and the Pedestrian condition (Pedestrian/Pedestrian Neutral/Pedestrian Anger)

DISCUSSION

In this research, participants were induced in anger using a driving scenario so as to study its influence on driving performance and pedestrian detection.

As suggested by Stephens et al. (2013), we decided to recruit our participants according to their trait-anger while driving. Despite that, the anger ratings were not homogeneous for the participants induced in anger. The MIP seemed to be efficient to increase the anger valence and the arousal for 18 participants, but the remaining participants did not report a significant increase in the ratings for both dimensions concurrently. When debriefing with the rest of the Anger group participants who did not experience anger, some mentioned that they could not get angry because of the lack of realism of the driving simulator. Some participants even admitted that they did not take the timer into account because they knew that they were too slow to finish under the suggested time. These results could mean that in a situation where there is no chance of success, some of the drivers with a high trait-anger used efficient coping strategies to avoid the apparition of anger. However, this interpretation would not be consistent with the fact that trait-anger is negatively correlated with the adaptive/constructive behavior (Deffenbacher, Lynch, Oetting, & Yingling, 2001). Future researches may try to combine classical anger induction procedures and the anger-evoking scenarios in order to report a more powerful induction.

However, with the objective of studying the influence of an anger-state evoked by the driving situation, we decided to select only the participants who reported a noteworthy induction. Our two groups composed in this way were significantly different in the valence and the arousal ratings, thus we were able to perform the statistical analyses.

Initially, we expected the anger induction to cause a reduction in coherence and an increase of the modulus because the angry drivers tend to drive at a higher speed and with higher accelerations (Roidl et al., 2014). Our hypotheses were not supported. A possible explanation is that the anger induced may have not reach a sufficient level to provoke the behavioral modifications observed in the literature (*e.g.* Abdu et al., 2012; Mesken et al., 2007; Roidl et al., 2014)

However, an interesting effect of the induction on the delay was found. It appears that the Control group had a shorter delay in the Experimental 2 compared to the Experimental 1 scenario. In other words, they were faster to react to the speed changes of the lead vehicle (LV). This improvement in the following performance could reveal a benefit from the training represented by the Experimental 1 scenario. However, the Anger group did not follow the same pattern of results. Their delay was similar when the first and the second experimental scenario are compared. This may indicate that the Anger group participants could be less attentive to the speed changes of the LV compared to the Control group. According to the literature about the influence of emotions on the attention (*e.g.* Fox et al., 2001; Harmon-Jones et al., 2013), this effect could be a consequence of the distraction evoked by anger. This lack of improvement for the Anger group participants could also reveal that angry drivers prioritized the pedestrian detection task at the expense of the car-following performance. The results obtained for the detection task could help to decide the most probable interpretation. If the Anger group detected the pedestrians slower and from a shorter distance than the Control group, we may explain their car-following performance by a distraction provoked by anger. On the contrary, if the Anger group detected the pedestrians faster and from a longer distance, we would conclude that they may have prioritized the detection task.

Concerning the pedestrian detection task, we assumed that in the presence of the source of anger, the Anger group participants would have a focus on the anger-inducing vehicle. We predicted that the angry participants would have detected the pedestrians in the Pedestrian-Anger condition in a slower time and from a shorter distance compared to the Control group. Our hypotheses were not supported. Moreover, no significant effects were revealed by the analyses carried out on the response times whereas an effect was found concerning the distance of detection. The analyses performed on the distance of detection for the various pedestrian conditions did not provide any evidence of a distraction induced by the anger-inducing vehicle. Contrary to our hypotheses, both groups reported similar distances of detections in the Pedestrian-Neutral and the Pedestrian-Anger conditions, indicating that the type of vehicle had no incidence on the detection performance. A first possible explanation is that the participants did not assume that the vehicle, in the Pedestrian Anger condition, was the same as in the Induction scenario. The fact that the Experimental scenarios and the Induction scenarios were split by the mood check may have indicated to the participants that the three scenarios were not related. Consequently, they may not have associated the Anger vehicle in the Experimental scenarios as the source of their anger. Another possible explanation is that in those two conditions the vehicle may have represented a cue inciting the drivers to search for the targets. Therefore, both groups could have been in a high state of preparation to detect the pedestrians facing a vehicle.

Finally, we noticed that the detection distance was affected by the anger induction only when pedestrians were placed alone. Even though they were initially comparable, the Anger group had a significantly longer distance of detection than the Control group in the second experimental scenario. According to the hypothesis mentioned above, this enhanced detection for pedestrians presented alone could indicate that the Anger group participants focused uppermost on the detection task rather than the car-following. When the pedestrian was alone, the attentional resources that were not invested in the car-following task could have been exploited to seek the pedestrians. One possible explanation is that anger seems to promote heuristic processing (*see* Angie, Connelly, Waples, & Kligyte, 2011 for a meta-analysis). Thus, the Anger group could take more time to notice that the lead vehicle modified its pace because the speed change may have to be more important to be noticed. Stephens et al. (2013) studied the effect of anger on the detection of unexpected hazards. They concluded that angry drivers are slower to break or avoid a pedestrian jaywalking when the vision was disrupted. In our experiment, we only assessed the detection performance, but this task does not require a further processing about the risky dimension of the situation. Indeed, drivers experiencing anger may detect the pedestrians from a longer distance while being slower to consider them as a potential hazard. Future studies could confirm this hypothesis by requiring the participants to detect the pedestrians as fast as they can, and to brake only if they consider it as hazardous.

CONCLUSION

The study presented here provided new elements helping to understand the relationship between anger, driving performance, and pedestrian detection. Our experiment placed the drivers in an environment requiring to follow traffic speed changes of a lead car while being cautious about pedestrians. It seems that drivers experiencing anger tended to detect the pedestrians from a longer distance when the pedestrians were presented alone. This result could indicate that the Anger group was more concentrated on the pedestrian detection at the detriment of the reactivity to the speed changes of the lead vehicle. Future studies could be designed so as to reveal a possible prioritization of the pedestrian detection to the expense of the adaptation to the traffic speed variations.

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