DRIVER BEHAVIOR IN A THROTTLE OFF SITUATION

Alain Priez
Renault Research Department
Automobile Biomedical Department
Christophe Brigout
Claire Petit
Lionel Boulommier
AARISTE
France
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ABSTRACT

166 average drivers were asked to drive along a track at specified speed. The speed was increased at each lap. At 80 km/h one of the bends was sharpened without warning the driver. Three cars were used. They were identical except the handling : one was standard, one oversteering and the last understeering. None of the drivers knew there was several cars and each drived and saw only one car. Even if the drivers didn't know anything about the handling of the car, some differences already appeared in their driving behavior relying on the car dynamic characteristics, even at low speed (50 km/h).

Half of the drivers ran out of the road with the understeering car even if this was the car which gave them the highest confidence (but not necessary the best comfort as they generally felt the « steering wheel was heavy »). The two other cars gave close results and helped more than the two thirds of the drivers to keep on the road.

INTRODUCTION

Bends are probably the most difficult road parts to drive. Drivers often slow down when they reach a bend whereas they maintain their speed through other road events. Bends are also a frequent location for accidents all the more the severity increases (Table 1).

Table 1.
Location of road accidents involving at least one car versus severity (ref. LAB)

	Accidents	Injuries	Deaths
Curve	14 %	22 %	26 %
Straight	50 %	52 %	57 %
Crossing	36 %	26 %	17 %
Total	345 097	105 574	21 821

A quarter of the accidents involve only one car ; they correspond to half the fatal accidents. When considering only single car fatal accidents, crashes almost never occur at crossings but curves are over represented (Table 2).

Table 2.
Location of fatal single car accidents (ref. LAB : source fatal accidents in France in 1990 ; 13 unknown)

	Crossing	Straight	Curve
Deaths	1 %	39 %	59 %
2273	17	896	1347

Then, before considering sophisticated devices which help the driver to keep the control of his car in critical situations, it is important to study the links between the dynamic characteristics of the car and the driver behaviour, both in normal and critical driving situations.

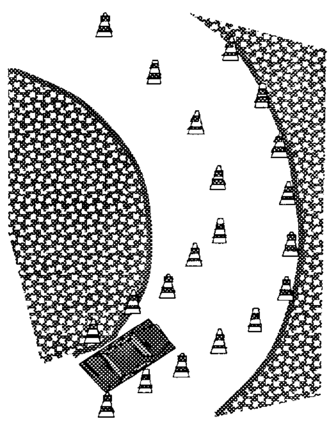
Protocol

166 average drivers were shared out among three homogeneous groups in terms of age, driving experience and ability to manage stressfull situations. Each group had to use a car with specific dynamic characteristics (neutral, oversteer or understeer). The test consisted of three laps of a private track ; the speed being increased for each lap (60 km/h, 70 km/h and 80km/h). The layout of the circuit was modified during the final lap without warning the driver, in order to tighten sharply a curve. This modification, appearing when the car was travelling at a speed of 80 km/h, was to bring about at least a removal of the foot from the accelerator pedal while on a bend.

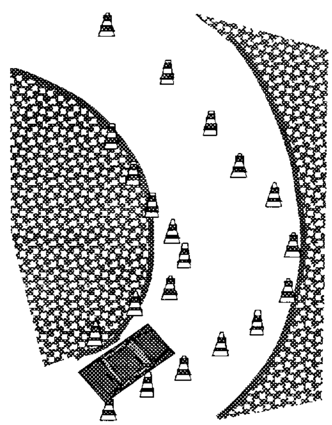
All the drivers volonteered ; they were working at Renault and none was a professionnal driver. Their ability to react to a stressfull situation has been evaluated within a psychometric test (Stroop test). They did not know the real aim of the study. They only had been told that the way they were driving in a curve will be studied. They were asked to drive on the right part of the road and to respect the required speed. A professional driver was sitting beside the driver in order to help him to follow the requirements and to ensure safety if the situation became too critical.

Three Renault 19 were used. They were identical except the handling : one was standard, one oversteer and the last one understeer. None of the drivers knew there was several cars and each drove and saw only one car (i.e. 54 drivers for the standard car ; 55 for the oversteer one and 53 for the understeer one).

The track was a winding road. It was marked out with cones to force the drivers to stay on the right part of the road. The critical situation consisted of sharpening one of the bends from a radius of 50 m to 25 m (Figure 1).



A: normal driving



B : critical situation

Figure 1. Test site

Sensors gave informations about the car dynamic forces and the actions of the driver. Physiological measures were also performed to evaluate his emotional response and his mental load.

Normal Driving

All the driving before the critical situation was considered as normal driving. Then, it is possible to look at the influence of the type of vehicle (St : standard ; Ov : oversteer ; Ud : understeer) on the observance of the requierements and on the dynamic forces due to the driving signature of the subjects.

The observance of the driving speed for each lap is the first indicator about normal driving (Figure 2) :

- all the drivers easily acceded the required speed,
- understeer car users drove faster (+ 5 km/h) than the others. This difference is statistically significant.

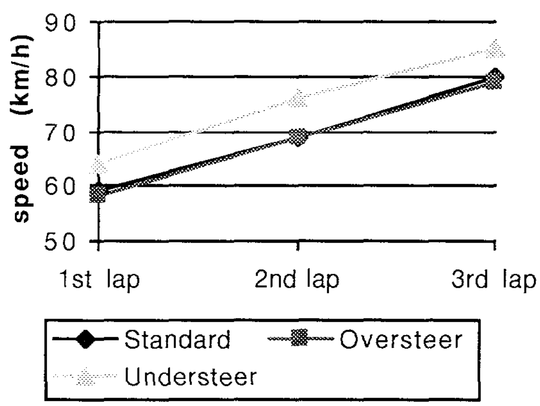


Figure 2. Respect of the required speed versus the type of car used.

Longitudinal dynamic forces were rather smooth. Lateral forces were more sizeable but remained in accordance with a normal driving on a trunk road (Table 3). As a mean value has no significance, only the 95 th and 99 th percentile are given (i.e. 95 % of the driving time, the lateral acceleration was below 0.4 g).

Table 3.
Dynamic forces in normal driving
(γ_t : lateral acceleration)

	acceleration (g)	deceleration (g)	γ_t (g)	yaw speed (°/s)
99th perc.	0.15	- 0.2	0.5	20
95th perc.	0.09	-0.12	0.4	14

These values are similar to previous studies (Lechner, 1993). 95 th percentile is relevant to the limits of comfortable driving where as 99th percentile corresponds to the limits the driver voluntary reaches.

The three cars can be significantly separated ($p<0.05$) when considering the lateral forces (Table 4).

Table 4.
Lateral acceleration and yaw speed versus the type of car during normal driving
(St : standard ; Ov : oversteer ; Ud : understeer)

	St	Ov	Ud
99th perc. γ_t	0.6 g	0.5 g	0.5 g
95th perc. γ_t	0.5 g	0.4 g	0.4 g
99th perc. yaw speed	24 °/s	18 °/s	18 °/s
95th perc. yaw speed	17 °/s	12 °/s	13 °/s

Significantly higher lateral forces for the standard car may be surprising. It can come from a bias of the study : all the drivers were working for Renault and perhaps they were more used to the feeling of the standard car than to the others. However, the understeer car gave a better safety feeling (a better feeling of control ?) than the others, that was testified by the higher driving speed.

Critical situation

Most of the drivers were really impressed by the sharpening of the curve as the high increase of their heart rate testified even if some of the drivers did not understand what had happened. The physiological response indicates that the driver adapted their steering manoeuvre rather than changing their strategy.

64 % of the drivers were able to pass the sharpended curve without any problem. The mean speed at the entrance of the curve was 74 km/h and the mean slowdown was 19 km/h to reach 55 km/h at the entrance of the narrow curve (Figure 3).

10 % of the drivers negociated the bend on its external part and they had more difficulties to pass the modified part with a failure ratio of 75 % versus 33 % for those who were driving on the inner part. This observation is linked neither to a particular car nor to the speed.

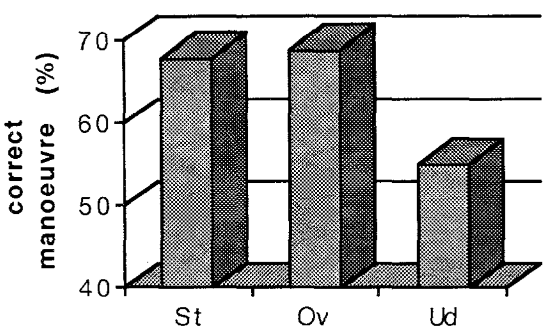


Figure 3. Distribution of the drivers who passed the critical curve versus the type of car (St : standard ; Ov : oversteer ; Ud : understeer)

From this point, the studied population will be separated into two groups : those who passed the curve called "correct" and those who did not called "uncorrect".

Speed is a good criterion to discriminate the quality of the manoeuvre. Wide angle steering was not enough to catch up the correct trajectory. The weak, but significant, differences between the dynamics forces within correct or uncorrect manoeuvres show that the drivers were close to their limits (Table 5).

These values show the importance of the transient event in comparison with the values obtained during normal driving.

Table 5. Dynamic forces whether the driver passed or not versus the type of car (St : standard ; Ov : oversteer ; Ud : understeer)

Speed (km/h)	St	Ov	Ud
correct	50	51	51
uncorrect	64	64	62

γ_t (g)	St	Ov	Ud
correct	0.8	0.8	0.8
uncorrect	1	0.9	0.9

yaw speed (°/s)	St	Ov	Ud
correct	31	32	31
uncorrect	35	37	30

Driving speeds remain homogeneous whatever the car used. They are contained between 31 and 64 km/h when drivers passed the sharpened curve and between 52 and 74 km/h when they did not. 64 km/h appears to be a limit above none could pass.

If the studied population is restrained to those who passed the curve at speed that overlaps (52 to 64 km/h), all the cars keep almost the same success ratio than for the global population (Figure 4). The size of the group with the understeer car becomes 50 % larger than the other groups : (Standard : N = 24 ; Oversteer : N = 20 ; Understeer : N = 30).

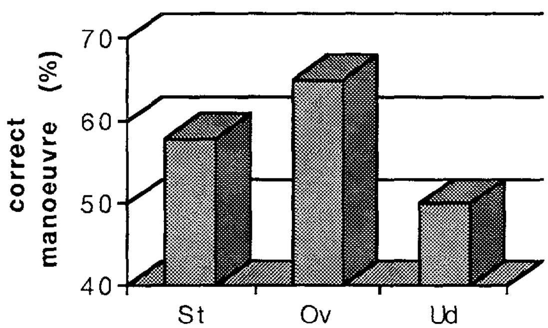


Figure 4. Distribution of the drivers who passed the critical curve versus the type of car (52 km/h < driving speed < 64 km/h) (St : standard ; Ov : oversteer ; Ud : understeer)

Referring to the restrained population, the mean speed was 59 km/h for the St and the Ov car and 57 km/h for the Ud car. Lateral dynamic forces became closer between correct and uncorrect manoeuvre but still remained significantly differents (Table 6).

Table 6.

Lateral dynamic forces whether the driver passed or not versus the type of car (52 km/h < driving speed < 64 km/h)

(St : standard ; Ov : oversteer ; Ud : understeer)

γ_t (g)	St	Ov	Ud
correct	0.95	0.91	0.92
uncorrect	1	0.9	0.94

yaw speed (°/s)	St	Ov	Ud
correct	32	35	33
uncorrect	35	33	32

Lateral forces were similar for the three cars. The main difference came from the steering manoeuvre required, which was much more important for the Ud car. Inter-vehicles comparisons do not show any difference versus the manoeuvres, however the steering angle was larger when the driver did not pass the sharpened curve. Actually, the time the driver steered is of prime importance. If the car was on the outer part of its lane, or if the driver was surprised, any delay was harmfull to the driver especially with the Ud car. The other point is the way the driver held his steering wheel : none of the drivers who were holding their steering wheel with one hand tried to use his second hand, and none succeeded to pass the critical point.

CONCLUSION

Drivers with the understeer car drove faster than the others (+ 5km/h). At the sharpened point, this difference was not significant any more.

Critical situation induced an increase of 0.4g of lateral acceleration and 14 °/s of yaw speed relatively to the values for comfortable driving.

Paradoxicaly, if the understeer car gave a better feeling for normal driving, drivers had more difficulties than with the other cars, in the critical situation.

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REFERENCES

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