

**REVIEW OF THE LITERATURE ON OBSTACLE AVOIDANCE MANEUVERS:
BRAKING VERSUS STEERING**

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**Report No. UMTRI-94-19
August 1994**

Technical Report Documentation Page

1. Report No. UMTRI-94-19		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Review of the literature on obstacle avoidance maneuvers: braking versus steering				5. Report Date August 1994	
				6. Performing Organization Code 304127	
7. Author(s) Lisa D. Adams				8. Performing Organization Report No. UMTRI-94-19	
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, MI 48109-2150 U.S.A				10. Work Unit No. (TR AIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address ITS Research Center of Excellence 2508 Patterson Place The University of Michigan 201 Aerospace Bldg. Ann Arbor, MI 48109-2140 U.S.A				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplementary Notes The ITS Research Center of Excellence is a program of collaborative efforts for the advancement and application of ITS technologies. The Center is supported through fees from industrial members as well as grants and contracts from local, state, and the U.S. DOT.					
16. Abstract This document reviews the literature on the control strategies drivers execute in emergency situations. Two possible strategies exist: braking to control speed and steering to control lateral position. Eleven items relevant to the topic of braking versus steering are summarized in tabular form. Abstracts or summaries of these studies are also contained in this document. In general, drivers are more likely to brake than to steer, while the optimal maneuver is more frequently steering alone, or steering combined with braking, rather than braking alone. Factors that may affect a driver's choice are discussed. Areas in which this research can be extended are also examined. Research on strategies concerning lateral and speed control can potentially be applied to IVHS technologies. By using insights about drivers' strengths and weaknesses in driving tasks, active control of the vehicle could assist drivers in choosing the optimal strategy.					
17. Key Words obstacle avoidance, accidents, braking, steering, driving, vehicle control				18. Distribution Statement Unlimited	
19. Security Classification (of this report) None		20. Security Classification (of this page) None		21. No. of Pages 21	22. Price

ACKNOWLEDGMENTS

Appreciation is extended to Michael Sivak and Michael Flannagan for their constructive comments throughout this research.

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INTRODUCTION

There are only two possible corrective actions a driver can take in response to many emergency situations: accelerating or braking to control speed, and steering to control lateral position. A review of the literature was conducted to determine what strategies of speed versus lateral control drivers use in emergency situations. Of additional interest was research on optimal strategies. The emergency situations under consideration included objects either moving into, or placed on, the path of the driver's vehicle.

The reviewed literature consisted of analyses of accident data, simulator studies, and field studies. Accident data provide information on maneuvers drivers attempted in failed situations. The accident information can be analyzed to see if a feasible maneuver existed that, if executed, would have prevented the accident. Simulator studies provide the driver with realistic accident situations without potential risk to the driver or vehicle. Such studies enable the researcher to repeat or modify the driver's maneuver under extreme or dangerous accident conditions and also to readily modify vehicle parameters. Finally, field studies place the driver in an actual accident situation by using dummy vehicles, targets, or people as the obstacles to avoid.

Research on strategies concerning lateral and speed control can potentially be applied to IVHS technologies. By using insights about drivers' strengths and weaknesses in driving tasks, IVHS may offer assistance in the areas where drivers do not perform well. Active control of the vehicle could assist drivers in choosing the optimal strategy.

TABULAR REVIEWS

This literature review covers eleven items relevant to the topic of braking versus steering. The review of four of these items is based on citations in secondary sources. Malaterre et al. (1987), Ferrandez et al. (1984), and Fleury et al. (1988) were described in Malaterre et al. (1988), and the data from Edwards and Malone (1982) were reported by Forbes (1994).

Six field or simulator studies were identified in the literature and are summarized in Table 1, which includes the type of vehicle used in the experiment, the emergency situation the vehicle encountered, the number of drivers, and the driver reaction to the emergency situation. The purpose of these studies was to determine the types of strategies drivers exhibit when an unexpected obstacle appears in their path. Obstacles included other moving vehicles, a pedestrian, a plastic barrel, a dummy car, and cones. Speed was monitored in all situations, but time and distance to collision were not always specifically stated. The experiments took place on either a test track or a simulated road. In one case the track was on a frozen lake (Rundkvist, 1973). Each of these investigations had a limited number of trials per driver because it was necessary to present drivers with unexpected situations, and that can be done only a limited number of times in an experimental session.

Table 2 summarizes five accident-data analyses in terms of the source of the accident data, number of accidents examined, and the driver reactions. Unless noted otherwise, the accidents are not specific to obstacle avoidance situations, but indicate what drivers do to avoid any type of accident situation.

The drivers' reactions to the emergency situation were classified by four maneuvers: braking only, steering only, combined braking and steering, and no action. Hatterick and Bathurst (1976) classified driver behavior in terms of 32 types of maneuvers. In order to summarize their data for this review, the 32 maneuvers were divided into five categories: braking, steering, combined braking and steering, no action, and other. Two sets of results are reported for this study in Table 2. The first set pertains to the data reported for all accident situations. The second set includes only accidents related to obstacle avoidance.

Table 1. Summary of Accident Avoidance Strategies From Field and Simulator Studies.

Author(s), date	Vehicle Type	Situation				Number of Drivers	Driver Reaction				Comments	
		Type of Obstacle	Time to Collision	Distance to Collision	Speed of Driver		Road Type	Brake Only	Steer Only	Brake and Steer		No Action
Lechner & Malaterre, 1991	Daimler-Benz Simulator	Vehicle stopped in path (Mercedes 990 SE Saloon Car)	2.0-2.8 s	35-85 m	90-100 km/hr	Intersection in open country with winding and straight roads	49	39%	12%	49%	--	<ul style="list-style-type: none"> • 39% of subjects attempted only braking, 67% began maneuvers by braking, and a total of 88% resorted to braking. • 20% of subjects were able to avoid collision: 60% by braking, 30% by lateral swerving, and 10% using both. • Fitting the simulator with ABS increased the success rate from 20% to 35%. • Using the maneuvers actually performed by the driver, the success rate increased to 47% when the obstacle was programmed to continue crossing the intersection. • A reduction in reaction time will allow previous failures to succeed for lateral maneuvers. This is not always true for braking maneuvers, however. • Overall, drivers prefer to brake when sufficient time is available; the shorter the time, the greater the tendency to swerve in front of obstacle's path. Drivers swerve behind the obstacle following braking when more time is available.
Malaterre et al., 1988	N/A	Vehicle in path (Renault van) whose speed was set for a collision course	--	--	90 km/hr	Intersection	--	--	--	--	<ul style="list-style-type: none"> • Subjects were asked to indicate what action they thought they would have taken during a conflict at an intersection and the reason for it. • Percentage of subjects choosing braking maneuver based on following factors: sufficient distance (15%), uncertainty about obstacle's movement (13%), poor visibility (29%), while other maneuvers (5%), and good visibility (17%), while other maneuvers (21%). 	
Malaterre et al., 1987	--	Cones 2.5 m apart	Less than 4.0 s	--	40-120 km/hr	Racing circuit	12	--	--	--	--	<ul style="list-style-type: none"> • Subjects were to indicate the final limit beyond which it would be too late to either brake or make a lateral movement to avoid an obstacle. • 32 measures of speed and time to collision for braking and swerving were obtained. • Subjects indicated that lateral movements could be executed nearer the obstacle than braking.
Rice & Dell'Amico, 1974	Chevelle	Plastic 20 gal barrel ejected from wooden structure	Arranged such that pure braking not adequate to avoid obstacle	30.5 m trip switch	90 km/hr (average)	Straight road (track)	34	INITIAL 70.5% FINAL 29.3%	INITIAL 23.5% FINAL 11.8%	INITIAL 3% FINAL 55.9%	INITIAL 3% FINAL 3%	<ul style="list-style-type: none"> • Percentages reflect the driver's initial control reaction and the final/second control reaction. • 33/34 drivers hit barrel. • Only successful driver was below average speed (44 mph).
Rundkvist, 1973	Volvo 144 or SAAB 99	Plastic foam dummy car emerged from hidden crossroad	--	A distance that would permit a very skilled driver to avoid the obstacle	70 km/hr	Oval track on frozen lake	55	11%	--	89%	--	<ul style="list-style-type: none"> • Each driver had 4 encounters, 2 with and 2 without ABS in vehicle. • 24 drivers had no familiarity driving on ice, 19 had some familiarity, 12 had good familiarity. • 6 who did not steer were female and had no familiarity with driving on ice.
Barrett et al., 1966	Simulator	Pedestrian dummy (165 cm tall)	--	Dummy released 23.3 m from shed	40 km/hr	Flat roads	11	91%	9%	--	--	6/10 drivers who braked hit the dummy. The other 5 drivers avoided the dummy.

Table 2. Summary of Accident Avoidance Strategies From Accident Data.

Author(s), date	Accident Data Source	Number of Accidents	Driver Reactions				Comments
			Brake Only	Steer Only	Brake & Steer	No Action	
Fleury et al., 1988	Accidents observed in situ (164 people)	82	--	--	--	--	A feasible maneuver was available 45% of the time. On main roads, a feasible maneuver is available in 50% of the cases where an obstacle is on the driver's near side and in 25% of the cases where an obstacle is on their off side. Drivers usually attempt a braking maneuver in these situations, and if a sideways movement is attempted, it is almost always in the same direction as the obstacle is moving.
Ferrandez et al., 1984	Accidents observed in situ (126 people)	72	21%	19%	24%	35%	The maneuvers executed were compared to the maneuvers that were theoretically feasible. The reasons for attempting an inappropriate maneuver were explored. 41 of the 72 accidents could have been avoided had a feasible maneuver been made. Of the feasible maneuvers possible, steering was feasible 76% of the time and braking 24%.
Edwards & Malone, 1982	National Accident Sampling System (NASS) data	4000	68%	5%	20%	--	Percentages reflect what drivers do to avoid collisions.
Hatterick & Bathurst, 1976	Institute for Research in Public Safety at Indiana University (IRPS) Files	265/488					<ul style="list-style-type: none"> Percentages reflect the driver's initial control reaction and the final control reaction. Data analyzed for only those situations where an evasive action could be taken (265 out of the 488 accidents). The percentages reflect a compilation of 32 maneuvers. The most frequent maneuver attempted was to steer straight only and brake with the intent to stop before the object. Maneuver with the highest average of success among all situations involved right steering (delayed or immediate) and non-braked deceleration in combination with braking. The least successful maneuvers were taking no action, accelerating straight ahead, and steering straight ahead while trying to reduce vehicle speed.
<i>All accident situations</i>	INITIAL		45.3%	8.7%	30.6%	6.4%	
	FINAL		38.5%	8.7%	37.4%	6.4%	
<i>Situations involving obstacle avoidance</i>	INITIAL		62.8%	2.3%	33.3%	0.8%	
	FINAL		52.7%	2.3%	43.4%	0.8%	
Limpert & Gamero, 1974	Multi-Disciplinary Accident Investigation (MDAD) cases	100	56%	7.5%	15%	--	<ul style="list-style-type: none"> Percentages reflect the maneuver used by the driver during the pre-crash phase of the accident to avoid the collision. A method was developed in which the vehicle response capability was evaluated in terms of what maneuver would have avoided the collision or significantly reduced collision speed. Developed by the University of Utah Crash Team.
	NHTSA sponsored Multidisciplinary Accident Investigation Team's data (University of Michigan Data File)	3000					

MAJOR FINDINGS

Driver Behavior

Anticipated Behavior

Malaterre et al. (1988) asked their subjects to indicate what maneuver they would have initiated during a conflict at an intersection. A videotape was used to show the subjects the situation prior to the conflict and then stopped at three distances from the obstacle. Slides were then used to show a van heading into the intersection on a collision course with the driver. Subjects' tendencies to steer were greater when their vehicle was at a shorter distance from the obstacle, when they had certainty about the obstacle's trajectory, and under conditions with good visibility.

Malaterre et al. (1987) asked their subjects to indicate when it would be too late either to brake or to make a lateral maneuver to avoid a stationary obstacle. Traveling at speeds of 40-120 km/hr and at varying time to collisions (all under four seconds), subjects reported that lateral maneuvers could be attempted closer to the obstacle than braking maneuvers.

Observed Behavior

Two methods of reporting driver responses were used in the literature: several studies reported the drivers' initial responses to emergency situations, and others reported the drivers' responses throughout the maneuvers. In general, the initial response a driver makes is to brake. Lechner and Malaterre (1991) and Rice and Dell'Amico (1974) found that 67% and 70.5% of drivers begin their maneuvers by braking. Hatterick and Bathurst's (1976) accident study found that 62.8% of drivers, in situations where an evasive action is feasible, begin their maneuvers by braking. The drivers' responses throughout the maneuvers generally involve braking, most often accompanied with steering, as shown in Figure 1. Steering, alone, was the maneuver least attempted in all studies.

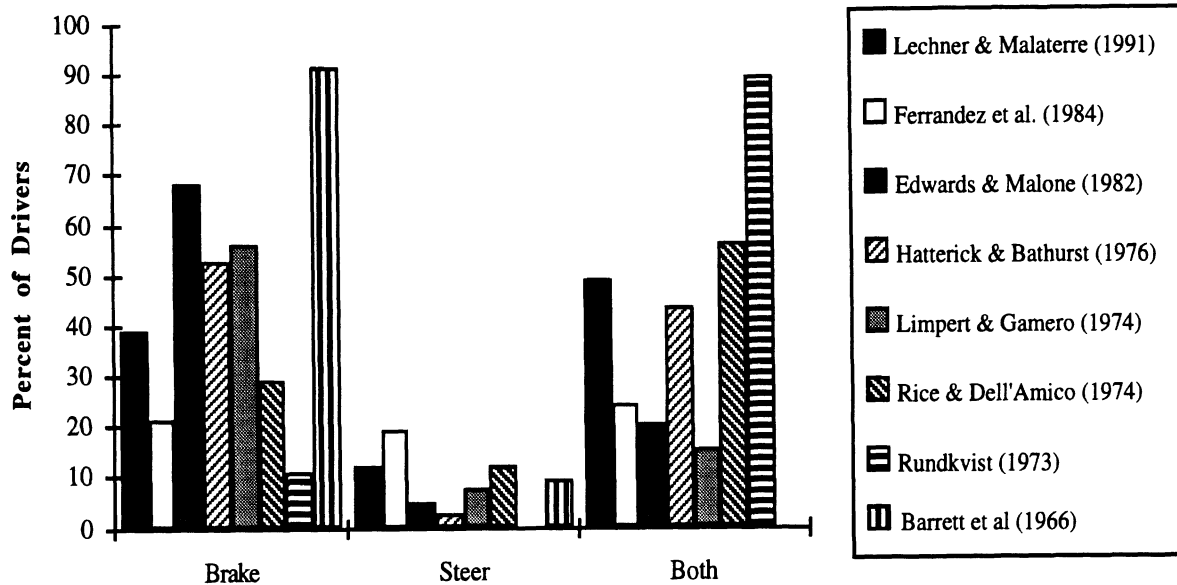


Figure 1. Drivers' response to accident situations throughout the maneuver.

Lechner and Malaterre (1991) used the Daimler-Benz simulator to examine the behavior of subjects when another vehicle passed in front of them at a right angle in an intersection at varying times and distances to collision. They found that subjects braked when sufficient time was available before hitting the obstacle, and that subjects swerved in the same direction as the obstacle was moving when time to collision decreased.

Rice and Dell'Amico (1974) designed their study such that pure braking was not adequate to avoid a plastic barrel that was ejected from an inconspicuous wooden structure on a straight road track. At a speed of 90 km/hr, 33 out of 34 drivers hit the barrel. Most maneuvers involved braking alone (29%) or braking and steering (56%).

Barrett et al. (1966) used an unprogrammed, TV-projected image in a fixed-base simulator to examine driver behavior during an emergency. Ten out of the 11 subjects braked, while one steered. Of those who braked, only four were able to avoid a pedestrian dummy that was released from a shed 23.3 m from their vehicle. The one subject who steered avoided the pedestrian.

Based on accident data, Fleury et al. (1988) reported that drivers usually attempt a braking maneuver in obstacle-avoidance accidents, and, if a lateral maneuver is attempted, it is almost always in the same direction as the obstacle is moving.

Rundkvist's results do not exhibit the same pattern as the other experimental studies. This may be because the oval track used in the study was a frozen lake. A plastic foam dummy car emerged from a hidden crossroad four times. During two of the four encounters, the vehicle was equipped with an antilock braking system (ABS). In this study, 89% of the drivers executed a combined braking and steering maneuver, and the remaining 11% executed only a braking maneuver. Forty-four percent of the drivers had no familiarity with driving on ice. Of those that applied only a braking maneuver, none had experience on ice. Successful strategies for driving on ice may necessitate both braking and steering maneuvers; however, this was not directly demonstrated by this experiment.

Effects of Speed

Speed was manipulated in several studies. At speeds at or above 90 km/h, approximately 70% of the drivers' initial maneuvers were braking (Lechner & Malaterre, 1991; Rice & Dell'Amico, 1974). Approximately 50% of the final maneuvers included both braking and steering (Lechner & Malaterre, 1991; Rice & Dell'Amico, 1974). Barrett et al. (1966) found that at a low speed (40 km/hr), 91% of the drivers responded by braking, and that 40% of those drivers were able to avoid the obstacle using this strategy.

Limpert and Gamero (1974), using accident data, found that as speed increases, the number of drivers who attempt to avoid the collision by steering also increases.

Effects of ABS

Several studies reported that a sudden application of the brakes caused them to lock, leaving the steering wheel inoperable. Two studies looked at the effects an antilock brake system (ABS) had on vehicle behavior.

Lechner and Malaterre (1991) added ABS to their simulator and found, by using the maneuvers actually performed by the drivers, that the success rate in missing obstacles increased from 20% to 35%. In these cases, the driver tried to swerve behind the obstacle but, because the wheels had locked, the steering wheel movements had no effect.

Rundkvist (1973) also looked at the effects of ABS. Drivers did not know when their vehicle was equipped with ABS, but were given the opportunity to practice driving around the track with ABS installed. The drivers had ABS available on two of the four encounters with the obstacle. Drivers who were able to avoid the obstacle on all four trials (25%) were considered skilled drivers. A majority of the drivers (64%) did not collide with the obstacle when ABS was installed, but did collide without ABS at least once. Several drivers (11%) collided with the obstacle even when ABS was installed.

Given that the driver performs the same control action both with and without ABS, these results suggest that, in accidents where an ABS was not available, drivers may have attempted a lateral maneuver, but because the brakes had locked, the maneuver was not reported. If this is the case, the percentage of drivers who actually performed lateral maneuvers would be larger than reported because the vehicle motion did not reflect the driver's control action.

Success Rate

Success rate (avoiding the obstacle) can be determined best by field or simulator studies, because accident data provide information for only failed situations. Drivers who steered had a higher success rate in relation to the number of drivers who braked (Lechner & Malaterre, 1991; Barrett et al., 1966). Lechner and Malaterre (1991) found that 32% of the drivers who attempted braking maneuvers, and 4% who combined braking and steering, avoided the obstacle; whereas 50% of drivers who executed a steering maneuver avoided the obstacle. Rice and Dell'Amico (1974) reported that one driver out of 34 steered first, then applied braking and managed to avoid the obstacle. However, this driver's approach speed (70 km/hr) was lower than the average (90 km/hr). The rest of the drivers in their study failed to avoid the obstacle.

Effects of Reducing Reaction Time

Lechner and Malaterre (1991) analyzed whether failed outcomes might have been successful if the drivers had reacted sooner. They divided the reaction time that would have been necessary for the maneuver to succeed by the actual reaction time, and plotted the cumulative distribution of that ratio. Their results reveal that a small decrease in reaction time (their suggested limit of a realistic aim was set at a 25% reduction) could lead to a high proportion of successful lateral maneuvers. However, for braking maneuvers to succeed, the required reaction time was unrealistic, because the driver would have to start to brake even before the obstacle appeared.

Optimal Maneuvers

Ferrandez et al. (1984) conducted a feasibility analysis that determined whether an accident could have been avoided if another feasible maneuver was executed by the driver. Out of a total of 72 accidents, 41 could have been avoided had a feasible maneuver been made and, in two thirds of the cases, the feasible maneuver was to steer. Hatterick and Bathurst (1976) reported that the maneuver with the highest average of success among all situations involved steering to the right (delayed or immediate) and nonbraked deceleration (coasting) in combination with braking. The least successful maneuvers were doing nothing, accelerating straight ahead, and steering straight ahead while trying to reduce vehicle speed, either by braking or combined braking and deceleration. Rice and Dell'Amico (1974) and Lechner and Malaterre (1991) reported that steering avoidance would have been more effective than braking in their studies as well.

There are currently several different models that prescribe the maneuver a driver should execute in an accident situation. Limpert and Gamero (1974) describe the critical speed analysis developed by the University of Utah Crash Team, which indicates a critical speed below which braking will be the correct maneuver, and above which steering will be the correct maneuver. Allen (1994) suggests a kinematic analysis of obstacle avoidance with braking and steering maneuvers. He plotted a function of speed and obstacle headway time that determines cases in which the driver must steer or brake in order to avoid the obstacle. Because of the differences in

reaction time found among drivers and among individual system dynamics (e.g., brake, steering, and suspension systems), these models cannot be generalized across all situations, but do provide guidelines for maneuvers that may yield higher success rates.

Wolf and Barrett (1978) developed the Driver Vehicle Effectiveness Model (DRIVEM) in order to predict the probability of an accident and to determine how it can be altered by changing key parameters. Included in the model is the decision either to steer or brake (or both) in order to avoid a collision. This computer model is based on data from Rice and Dell'Amico (1974) and Indiana University (1975). According to Reid (1983) this model has been difficult to apply because of the complexity of its program and the lack of a sufficient data base.

CONCLUSIONS

The reviewed literature suggests that in emergency situations drivers are more likely to brake than to steer, while the optimal maneuver would more frequently be steering alone, or steering in combination with braking, rather than braking alone. Although it is unclear why drivers tend not to use the optimal strategy in emergency situations, it is possible that drivers' reluctance to steer is due to a tendency to maintain their own lanes of travel at all costs, their lack of knowledge about alternative maneuvers and the handling capability of their vehicles, or their preference to lessen the severity of the accident by applying the brakes rather than risking a different collision by executing a lateral maneuver. Informing drivers about which maneuvers maximize their success may decrease the number of accidents. Furthermore, as IVHS capabilities are developed, systems that take active control of the vehicle and perform the optimal maneuver automatically may be the solution for avoiding accidents in the future.

ISSUES FOR FURTHER RESEARCH

Malaterre et al. (1988) found that drivers are more likely to think a lateral maneuver is feasible when there is shorter distance to the obstacle, certainty about the object's trajectory, and good visibility. Lechner and Malaterre (1991) also found that a lateral swerve can be successful long after braking is no longer effective. It appears, however, that drivers tend to brake, regardless of the effectiveness of a lateral maneuver. This may indicate driver's lack of knowledge about the importance and effectiveness of lateral maneuvers, or that drivers see braking as at least reducing the impact of an accident. Regardless, investigating the effects of training the driver to execute more effective means of accident avoidance would be worthwhile. Research has already been conducted in the area of improving drivers' reactions to accident situations. Hatterick and Bathurst (1976) and Barrett et al. (1973) studied the feasibility of improving the skills and decision-making performance of drivers during critical event situations. Hoskovec et al. (1971) studied the influence of simulator training on drivers' ability to avoid a pedestrian suddenly appearing on a road. However, a proven way to train drivers in the proper use of steering or braking to avoid an emergency situation has not yet been detailed.

The effect of experience on a driver's strategy is another promising topic for research. Drivers who have been involved in accidents (or near misses) may learn from their past experience and change their strategy.

Existing studies have not investigated how avoidance strategies vary with a driver's sex, age, or driving experience. Nor have they investigated whether drivers have a greater sense of urgency, or execute different strategies, based upon the type of obstacle in their path (e.g., another vehicle versus a pedestrian). Knowing whether any of these factors influence drivers' strategies would be useful for understanding the reasons behind those strategies.

SELECTED ABSTRACTS OF THE REVIEWED PUBLICATIONS

Barrett, G., Kobayashi, M., & Fox, B. (1966). Feasibility of Studying Driver Reaction to Sudden Pedestrian Emergencies in an Automobile Simulator. Presented at the 10th Annual Human Factors Meeting, Anaheim, CA.

ORIGINAL ABSTRACT:

An experiment was conducted to determine the feasibility of studying driver reaction to sudden pedestrian emergencies in an unprogrammed automobile simulator. A random sample of 11 male subjects followed an identical procedure. Each subject completed a speed estimation study which was designed so that the subject would drive past a shed containing a pedestrian (dummy) 11 times. This was done so that the emergence of the pedestrian would be completely unsuspected. The subject drove in the right lane of the road at approximately 25 mph. When the front bumper was 76.5 ft. from the shed containing the pedestrian, a microswitch was tripped which released the dummy into the center of the road at a controlled rate. During the study a continuous record of speed, time, brake position, and steering wheel position, lateral position of vehicle, longitudinal position of vehicle, and position of pedestrian was recorded. All of the subjects attempted to avoid the pedestrian either by brake application or by a steering change. Since this was a feasibility study with a small sample, no conclusions were drawn beyond the data, but the possibility of projective research in this area using simulation techniques seems to have been opened up.

Hatterick, G. R., & Bathurst, J. R. (1976). Accident Avoidance Skill Training and Performance Testing (Final Report No. DOT/HS 801852). Falls Church, VA: URS/Matrix Company.

ORIGINAL ABSTRACT:

The purpose of this 2-phased study was to determine the feasibility of training drivers to acquire the skills needed to avoid critical conflict motor vehicle accidents, and to develop the procedures and materials necessary for such training. Basic data was derived from conduct of in depth accident investigations and task analyses of driver behavior. A specification was prepared for curriculum development and performance measurement, and a prototype bimodal simulator was developed as a training tool for acquisition of key perceptual and decision making skills. A concept was also defined for behind-the-wheel training on an Advanced Drivers Range. Results to date indicate that the program should continue to complete materials development and training of drivers.

Lechner, D., & Malaterre, G. (1991). Emergency Maneuver Experimentation Using a Driving Simulator. Presented at Autotechnologies, 5th Conference and Exposition, Monte Carlo, Monaco. Report No. SAE 910016.

ORIGINAL ABSTRACT:

This research was carried out by INRETS (France) using the Daimler-Benz driving simulator (RFA), in order to analyse the behaviour of 49 drivers, when faced with an unexpected emergency situation at a junction. This experiment enables us to collect driver reaction times, and to validate our previous work dealing with the choice of an emergency manoeuvre. Most drivers resorted to braking. Only 1 out of 5 drivers succeeded in avoiding the collision, whereas an appropriate and correctly performed manoeuvre, in particular a wider use of lateral swerving, would have allowed a higher success rate. The advantage of ABS, the influence of the obstacle movement with regard to the outcome of the emergency situation, and the prior benefit obtained by reducing reaction times are also discussed. Therefrom the main objective of driving aid devices should be to prevent the driver from being faced with such a situation.

Limpert, R., & Gamero, F. E. (1974). The Accident Avoidance Potential of the Motor Vehicle: Accident Data, Vehicle Handling and Safety Standards. In *Proceedings of the Third International Congress on Automotive Safety, Volume II.* Washington D.C., GPO, 61 p.

AUTHOR'S SUMMARY:

Accident data are taken from 3000 cases. Authors claim avoidance maneuvers entail braking, steering, or both as a function of the road geometry, road surface, and vehicle speed. For instance, figures from the data indicate that most drivers tend to brake on a straight road section in order to prevent or to ameliorate the consequences of a collision. More than 50% of the drivers attempt to steer or steer and brake in a straight roadway accident maneuver. Road surface did not significantly affect the driver control action relative to braking and steering. The number of drivers that attempt to avoid a collision through steering wheel inputs is increasing with speed, indicating a desirable driver action.

Review of approximately 100 MDAI (Multi-disciplinary Accident Investigation) cases investigated indicated that 56% of the drivers applied the brakes, 7.5% attempted to steer out of the collision, and approximately 15% applied both braking and steering inputs during the precrash phase of the accident.

A methodology must be developed in which the vehicle response capability is evaluated in terms of what maneuver (braking only, steering only (that is a lane change), or braking while lane changing) would have resulted in a noncollision or significant reduction in collision impact speed. The procedure developed by the University of Utah Crash Team yields a critical speed value above which steering or below which braking would have led to a noncollision.

Two equations for stopping distance were developed. Two figures show the stopping distance versus approach speed and the lane-change distance versus the speed. By combining the two, critical speed is obtained. The critical speed analysis indicates that, in cases where actual approach speed exceeds the critical speed, a steering maneuver will require less theoretical distance than a braking maneuver alone, and that more high speed accidents could have been prevented provided the driver attempts to steer.

Malaterre, B., Ferrandez, F., Fleury, D., & Lechner, D. (1988). Decision Making in Emergency Situations. *Ergonomics*, 31(4), 643-655.

ORIGINAL ABSTRACT:

This paper presents in summary form a body of research dealing with emergency manoeuvres. Several complementary research projects are still in progress at INRETS. The typological approach is based on kinematic reconstruction of actual accidents and tries to establish whether there is an optimal manoeuvre for the driver to make in the circumstances. The performance-level approach is aimed at estimating the gains that could be obtained from improvements in the performance levels of vehicles. The driver approach attempts to explain the manoeuvres carried out, with particular emphasis on the under-utilization of lateral avoidance manoeuvres. To that end, two experiments were conducted. One concerned users' descriptions of, and familiarity with, the manoeuvres best suited to particular problems encountered at intersections. The other studied drivers' ability to make an accurate assessment, on a circuit, of the limit beyond which a manoeuvre is no longer feasible. The consistency between the different approaches is also discussed, as are the presumed effects of stress and time pressure, on which no experiments have yet been conducted.

Includes reference to Malaterre et al. (1987), Ferrandez et al. (1984), Fleury et al. (1988).

Malaterre, G., Peytavin, J. F., Jaumier, F., & Kleinmann, A. (1987). L'estimation des manoeuvres realisables en situation d'urgence au volant d'une automobile. Rapport INRETS, No 46. France.

ORIGINAL SUMMARY:

The aim of this study was to determine if subjects (12 experienced drivers) placed in a simulated emergency situation, were able to perceive that sideways avoidance remained possible nearer from the obstacle than braking. The subjects, who drove an instrumented car, were invited to indicate by pressing a switch the last moment beyond which the maneuver would not be possible. The obstacle was simulated by plastic cones. The data, expressed in time to collision, were collected for speed varying from 40 to 120 km/h. It was shown that people do perceive the gains associated to sideways avoidance although they tend to under-estimate them for high speeds. However, the estimation laws follow functions of different shape according to individuals. So, it seems wiser to establish typologies rather than mean functions. Some people seem to behave quite in agreement with the physical phenomenon, when some others react more with constant times to collision. The relationship to accident cannot be assessed on a sample of 12 people. Nevertheless, it was shown that subjects with an accident or more were more prone to give exaggeratedly optimistic responses (corresponding to unfeasible maneuvers) than others. This experiment indicates that the reasons to the under-use of sideways avoidance do not come from a mis-perception of the gains associated to it.

Ferrandez, F., Fleury, D., & Lepasant, C. (1984). Analyse typologique des manoeuvres d'urgence. Rapport ONSER. France.

Fleury, D., Ferrandez, F., Lepasant, C., & Lechner, D. (1988). Analyse typologique des manoeuvres d'urgence en intersection. Rapport de recherche INRETS. No. 62. France.

Rice, R. S., & Dell'Amico, F. (1974). *An Experimental Study of Automobile Driver Characteristics and Capabilities* (Final Report No. ZS-5208-K-1). Buffalo, NY: Calspan Corporation.

ORIGINAL ABSTRACT:

An experimental program to obtain quantitative data on how drivers utilize the performance and handling properties of their vehicles has been performed. Over one hundred drivers participated in the experiment, which consisted of self-paced driving through a specially-constructed proving ground handling course several times. Continuous measurements of primary input variables (steering wheel motions and brake pedal activity) and the principal vehicle responses (speed and lateral and longitudinal accelerations) were made throughout each trial. Total time in the course and incidents of failure to maintain path were also measured. Driving techniques (e.g., hand position on the steering wheel, foot used for braking) of the subjects, who were selected to provide an appropriate representation of the driving population with respect to age, sex, and years of driving experience, were subjectively observed.

The subject sample was separated into four groups according to which of two vehicles (having somewhat different handling characteristics) was driven and to whether the subject was familiar or unfamiliar with the type (size and operational characteristics) of car being used.

Experimental results are analyzed primarily in terms of the application of the maneuvering potential of the vehicle (i.e., lateral acceleration) used by the subjects in negotiating the various driving tasks which they encountered in the course. The results are given in terms of mean values and standard deviations for various groupings within the total sample and, in some cases, have been evaluated for the statistical significance of different factors. It is particularly interesting to note that the subjects, even when encouraged to drive at their limit of willingness, did not normally attempt to operate near the limiting capabilities of the automobiles. It is concluded that in addition to the analyses given in this report the expensive data accumulated in this program can also be applied to many other investigations of driver behavior.

Rundkvist, S. (1973). *Field Testing Statistical Tests* (Report No. 4-01). Sweden: Swedish Experimental Safety Vehicle Program.

ORIGINAL SUMMARY:

One part of the Swedish ESV program "Steerability during Emergency Braking" is a statistical field test with the objectives: to find out how an average driver behaves in an unexpected situation, to determine the advantage to the average driver with steerability during emergency braking.

When the average driver is involved in an unexpected situation his reaction, according to the results of the statistical field tests with 55 different drivers, would be to brake and steer 49 (89%) or brake only 6 (11%). The behaviour of the driver during four "unexpected situations" with and without anti-locking system has been summarized to a judgment. The estimated value of steerability during braking, made possible through an anti-locking system, for the 55 drivers is good value for 35 drivers (64%) and no value for 20 drivers (36%). Of the 20 drivers who had no value of the steerability 11% (6) did not turn the steering wheel, and 25% (14) would not collide with the obstacle even without an anti-locking system. (Might be categorized as skilled drivers.)

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