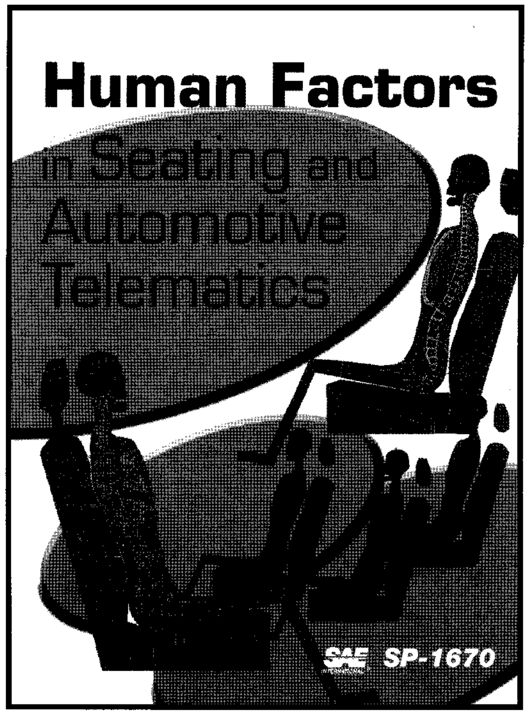
ISSN 1041-9489

SAFETY BRIEF

June, 2002 — Volume 20, No. 4

Triodyne Inc.
Consulting Engineers & Scientists – Safety Philosophy & Technology
5950 West Touhy Avenue Niles, IL 60714-4610
(847) 677-4730 FAX: (847) 647-2047
e-mail: infoserv@triodyne.com *www.triodyne.com*

Evaluating Driver Response to a Sudden Emergency: Issues of Expectancy, Emotional Arousal and Uncertainty



By Michael A. Dilich*, Dror Kopernik, P.E. and John M. Goebelbecker, P.E.*****

In April of 2001, Triodyne published a Safety Bulletin entitled " Evaluating Driver Response to A Life-Threatening Emergency- Issues of Behavior, Chance and Hindsight," by Michael A. Dilich and Dror Kopernik. We have had so many requests for more information that we decided to reprint this longer article which Michael and Dror along with John M. Goebelbecker wrote for the Society of Automotive Engineers. This paper is reprinted from SAE paper 2002-01-0089 © 2002 Society of Automotive Engineers, Inc. This paper was also presented to the Human Factors in Driving and Automotive Telematics Session on March 4, 2002 at the SAE World Congress in Detroit, Michigan.

No Charge

* Principal Engineer, Triodyne, Inc., Niles, IL
** Senior Mechanical Engineer, Triodyne Inc., Niles, IL
*** Senior Mechanical Engineer, Triodyne Inc., Niles, IL

2002-01-0089

Evaluating Driver Response to a Sudden Emergency: Issues of Expectancy, Emotional Arousal and Uncertainty

Michael A. Dilich, Dror Kopernik and John Goebelbecker
Triodyne Inc.

ABSTRACT

The definition of the term "sudden emergency" in a driving situation is explored. The research regarding driver response under various alerted and surprise test conditions was surveyed. It was found that certain factors which arise in a real life sudden emergency were typically not addressed. A survey of behavioral and psychological research concerning human response to emergencies identified several factors which can significantly interfere with successfully coping with an emergency driving situation. These factors include driver expectancies of normal traffic flow, emotional arousal when confronted with a sudden and real threat of serious injury, the uncertain behavior of other involved drivers and the uncertain outcome of attempting to perform avoidance maneuvers well beyond a typical driver's routine experience. Once it is determined that a driver was confronted with a sudden emergency demanding extraordinary response, the outcome of the accident is dictated more by the chance of the circumstances than by the performance abilities of the driver and his vehicle.

INTRODUCTION

While the research is replete with experimental data regarding driver perception-reaction times (PRT) and vehicle braking and steering thresholds for a variety of conditions, no tests have been performed which expose unsuspecting drivers in normal traffic conditions to the risks involved in real, sudden emergencies for the purpose of studying their behavior when confronted with an extreme threat of injury. Researchers have not been able to simulate the conditions of a real accident without altering factors which can influence the response of test subjects. Such factors include the expectancy of normal traffic flow, emotional arousal from a real threat of serious injury, the uncertain behavior of other involved drivers and the uncertain outcome of attempting to perform avoidance maneuvers well-outside one's daily experience of operating a motor vehicle. Nevertheless, conventional accident analysis methodology relies upon this experimental data for determining how an accident occurred and for evaluating driver responses which "could have" avoided the accident. Furthermore, the driver is criticized for not responding in a manner which allegedly *could have* avoided the accident. A giant leap is often made from concluding that it was scientifically possible for a driver to have avoided an accident to concluding that a driver acted unreasonably not avoiding it.

While it is true that some reasonable drivers would successfully avoid an accident in many driving emergency situations, it is also true that other reasonable drivers under identical circumstances would not. Whether they are successful or not depends not only on their driving skills, but also on other factors including expectancy, emotions and uncertainty, as well as luck.

When a traffic accident results in serious or fatal injuries and the cause of the accident is disputed, the matter frequently enters into litigation. To determine how the accident occurred (vehicle speeds, point of impact, evidence of braking or steering, etc.), the disputing parties request the assistance of scientific experts who study the available evidence and utilize accident reconstruction methodologies to draw conclusions. Additionally, experts are often obliged to opine upon the reasonableness of drivers' attempts to avoid an accident.

Consider a truck driver traveling 45 mph on a major highway who spots a car stopped in a driveway to his right poised to cross the road. The car doesn't move until suddenly, when the truck is only seconds away, it accelerates into the truck's lane. In an effort to avoid a collision, the truck driver sounds the horn and aggressively swerves to the left toward the median. However, the car doesn't stop! It keeps accelerating and the truck strikes it broadside in the median. After the investigators study the accident in detail, the truck driver is criticized for using poor judgment and overreacting. They show that if the truck driver simply continued to go straight, the car would have just cleared the truck's lane before the truck arrived and the collision would not have occurred. In hindsight, having knowledge of the outcome, the truck driver's response was wrong, i.e. the collision occurred. But, without the benefit of knowing the outcome, was the driver's response unreasonable under the circumstances of a sudden emergency? How would other reasonable drivers have responded?

The key word in this example and in many traffic accidents is "suddenly." When a potential hazard appears in the distance, an approaching driver is not threatened and has time to rely on his routine responses and judgment to safely cope with the situation. However, when a hazard develops unexpectedly and the time to a potential collision is short, the situation demands extraordinary levels of perception, judgment and response that are well outside the usual experience of most drivers, the situation becomes an emergency and the driver's behavior changes.

Davis (1957) in his research regarding human errors in transport accidents recognized that man, like other animals, is equipped with "emergency mechanisms." When dangers, whether physical or psychological, appear imminent, the 'drives' which influence behavior become stronger and behavior undergoes certain characteristic changes. Responses are more readily elicited. They tend to be more forceful, more extensive and more rapid while at the same time they tend to be less regular, less organized and less coordinated. However, many of the dangerous situations which human adults meet require not vigorous activity but restrained, deliberate and accurate responses.

Evans and Schwing (1984) reported at a Symposium on "Human Behavior and Traffic Safety" that whereas driver performance measures what the driver *can* do, it is what the driver, in fact, *does* that plays a vital role in accidents. This actual behavior is of much greater relevance than the performance the driver can produce under monitored idealized conditions. The distinction between driver performance measures obtained from controlled testing methods and driver behavior during a real life-threatening conflict warranted a survey of the literature regarding human response to sudden emergencies and a search for other factors which extend beyond the standard assumptions regarding PRT and vehicle handling thresholds typically used in accident analysis. The survey encompassed not only popular accident reconstruction texts and research papers but also research in the fields of traffic safety, traffic engineering, human factors, and industrial and behavioral psychology.

Several of the factors identified from the survey will be discussed including the limitations of PRT testing, brake utilization, driver expectancy, emotional arousal and uncertainty.

THE SUDDEN EMERGENCY

The New Webster's Dictionary defines "emergency" as "a situation, often dangerous, which arises suddenly and calls for prompt attention." This definition is general in nature and does not relate specifically to driving situations.

A "sudden emergency," as it relates to a driving situation, imposes restrictions on a driver's *mental* ability to control a vehicle. Understanding these restrictions and having an interest in the evaluation of drivers' performance for the purpose of assessing liability in accident cases, the legal community has defined elements needed for a situation to be recognized as a sudden emergency. The legal considerations given in such situations are incorporated into the "Sudden Emergency Doctrine," which may either be introduced as a jury instruction in court cases or its elements may be used in the evaluation of comparative negligence.

The sudden emergency doctrine was developed in 1816 in England in response to a court case where the plaintiff jumped from a runaway coach as an alternative to remaining "at certain peril." The doctrine was first used in the U. S. in 1839 in a case which also involved a frightened individual leaping from a coach. (Maynard,1997).

The 1990 Black's Law Dictionary states that the Emergency Doctrine can be considered " ... when one is confronted with a sudden peril requiring instinctive action ..." and " ...in the event that a driver of a motor vehicle suddenly meets with an emergency which naturally would overpower the judgment of a reasonably prudent and careful driver, so that momentarily he is thereby rendered incapable of deliberate and intelligent action, ..."

Various courts have defined the term sudden emergency. Their definitions include the following elements.

- "A situation which is unusual (means varying from the everyday traffic routine confronting a motorist)." (Griffin, Gillis and Sawyer, 1990)
- "A sudden emergency is a combination of circumstances that calls for immediate action or a sudden or unexpected occasion for action." (Iowa Jury Instruction, 1999)
- "Sudden Emergency ... arising from events the driver could not be expected to anticipate." (McGiverin, 1999)
- "The time element in which action is required must be short enough to preclude the deliberate and intelligent choice of action." (Wisconsin Jury Instructions,1999)
- "... an actor is faced with a sudden and unexpected circumstance which leaves little or no time for thought, deliberation or consideration, causes the actor to be reasonably so disturbed that the actor must make a speedy decision without weighing alternative courses of conduct ..." (Bellacosa, 1991)
- " ... the actor does not have enough time under the circumstances for adequate thought, or is understandably so disturbed or excited that he cannot weigh alternative courses of action and must take a speedy decision based primarily upon impulse or guess ... " (Wasson, 1990)

A driver in a sudden emergency situation may become flustered making him respond in a way which, in hindsight, appears inappropriate for the situation.

It is interesting to note that while the terms "rapid decision," "immediate action," "little or no time," "speedy decision," "quick response" and the like suggest short time intervals for perception of and reaction to a hazard, no specific time frame is offered to define the "sudden emergency."

Driver performance research addresses *physical* perception and reaction but ignores emergency-inflicted *mental* disturbances resulting from intense arousal, violated expectations and the uncertainty of handling circumstances that the driver has rarely, if ever, encountered.

PERCEPTION-REACTION TIME STUDIES

Researchers in the field of highway safety have been interested in quantifying a driver's ability to react to roadway situations since the first studies conducted in the 1920's. Controlled tests of varying levels of sophistication have been conducted to learn about driver performance. These tests have generated data describing how quickly drivers can and do react when subjected to various levels of stimuli. However, these data are frequently referenced by accident reconstructionists who attempt to determine whether a driver's response to an imminent emergency situation was reasonable or not. The data are extrapolated from the experimental context from which they were generated to a context which existed in the moments just prior to a real-life accident.

For example, a male driver, age 18, drives his 1986 Firebird home after visiting a friend. The roadway is dark, a streetlight illuminates a T-intersection up ahead, and the speed limit is 55 mph. The driver notices a vehicle with its headlights illuminated parked on the opposing shoulder. Suddenly, he detects something blocking his path on the roadway. He attempts to brake just prior to striking a disabled vehicle. The vehicle, dark blue in color and with no lights illuminated, had been involved in an accident several minutes prior to the Firebird's arrival.

Some reconstructionists might determine that the driver of the Firebird had adequate visibility distance to avoid striking the disabled vehicle. Citing previous studies, they determine that had the driver perceived and reacted (by steering to avoid) within the commonly accepted ranges of driver performance, the collision could have been avoided. Furthermore, since the driver *could have* reacted in a certain way, he, in fact, *should have* reacted in such a manner. Then finally, since he *could have* and *should have* avoided the accident, the driver was negligent for not having avoided the accident. However, a more realistic and fair assessment would evaluate whether or not any reasonable driver in like or similar circumstances would have behaved in a similar manner. The issue, therefore, is whether or not driver performance studies adequately represent the conditions faced by drivers in real-life accidents. Since a person's reaction to a particular event depends on such delicate factors as mental state, previous driving experiences, expectancy, level of comfort aggressively controlling a vehicle (i.e. a hard brake application or a rapid swerve), ability to control stress, the intensity of the event, the driver's perception of the event's potential for injury to the driver and others, a review of the protocol employed in PRT studies often cited by reconstructionists is warranted.

Geoffrey Grime (1952) describes a study using a test car driven in an urban environment. A camera was positioned behind the driver to show the road in front of the car, instruments showing when the brake was applied and a time counter. A pedestrian stepping off the pavement in a pedestrian crossing was the external stimulus which the test subjects were exposed to. The drivers were "instructed to react to a pedestrian stepping off the pavement by applying the brake." These drivers, therefore, were aware that their performance was being evaluated, they were aware of the nature of the imminent road hazard and they were instructed how to respond.

Johansson and Rumar (1971) conducted a test in which 321 random test subjects were stopped by police and invited to participate in an experiment. "Sometime during the next 10 km, the driver would hear a loud klaxon horn sound at the side of his car. This was the signal for immediate braking." The authors acknowledge that the subjects were operating their own vehicles under "normal driving conditions, but with some degree of braking expectation." To evaluate the influence of the test subject's awareness of the test, the authors instrumented personal vehicles of five participants. The driver was instructed to brake when the buzzer sounded and the time from onset of the buzzer to the application of the brake pedal was recorded. The buzzer sounded in time intervals of greater than one hour of vehicle operation which often resulted in the buzzer sounding once a week. The true surprise nature of the system was observed in the first two or three buzzer signals. "It was found that a certain amount of familiarization with the signal was necessary. On the first signal occasion, the driver often had a short moment's confusion before he realized that a braking reaction was called for. The first three signal occasions were used only for allowing the driver to become accustomed to the buzzer signal for braking and the corresponding three brake reaction time measurements were not included in the final results." The subsequent data generated from the second part of the study reflects the reaction of drivers whose behavior was conditioned to respond in a specific way to an audible signal. This signal became familiar to the driver and although it occurred at an unexpected time, the driver could reasonably anticipate that the sound would cease shortly and that neither he, nor anyone or anything else was in imminent danger.

Summala (1981) conducted a test in which unalerted drivers were confronted with the sudden opening of a door of a car parked on the side of the travel lane. The car was parked about .65 m from the edge of the road. The lateral displacement of 1,326 vehicles was measured by infrared photocells appropriately placed across the road. Door-opening time was measured using two microswitches attached to the door of the parked car. The approaching drivers were unaware that they were participating in a test and were driving their own vehicles on a public road. When the approaching vehicle was 1 to 5 seconds away from the parked car, an occupant in the parked car opened the driver-side door. "The road was wide enough for a safe (lateral) maneuver, and the experiment was conducted in a safe manner." In fact, the outward swing of the door was mechanically limited so that the outer edge of the door never crossed the edge line of the road. The roadway was straight and level with no visibility obstructions, allowing the approaching drivers to observe the parked car for some distance. No other vehicles were present in the measuring area. "The present study was conducted in daylight and in a situation that may involve some expectancy. ('The driver of that car may open the door and get out.')" In fact, the occupant never did exit the vehicle and the intensity of the roadside stimulus was relatively weak compared to what one would expect if the door had swung out into the travel lane or if the driver had stepped out into the travel lane. The nature of the stimulus (the opening of a door of a parked car) elicited a predictable response – steer. The confusion of whether to swerve left or right or to brake or steer was minimal.

Triggs and Harris (1982) describe a test in which the authors placed various static stimuli along the roadway and observed the brake reaction time of unalerted drivers. The static stimuli included red reflective triangles on the road edge at night, a motorcycle on the shoulder of a road in daytime, a "Traffic Hazard Ahead" sign, a vehicle slightly protruding on the road with a tire change in progress, a police car on the shoulder, etc. The roadway geometry (hill crest or horizontal curve) prevented the drivers from observing the stimuli until a pre-determined point. A hidden camera recorded the time and position at which the brake lights of passing vehicles were observed illuminated. "The aim was to select situations that might cause a significant proportion of drivers to make a braking response that could be regarded as a speeded reaction. The approach was a conservative one where the initial situations studied were selected so as to be most unlikely to result in an extreme braking maneuver or avoidance response. In fact, there were no extreme maneuvers observed in the entire study." Situations which might have resulted in steering maneuvers were intentionally avoided so as not to induce urgent lateral movements toward the center of the road. None of the situations studied involved emergency situations where the driver was faced with a potentially serious accident.

Olson et al. (1984) conducted a test in which subjects were asked to drive an instrumented test vehicle with a researcher present in the back seat. Test subjects "were told that they were going to participate in a study of driving performance." After driving for about 6 km to become familiar with the vehicle, the test subject approached a hill crest. Beyond the hill crest a 15 cm high by 91 cm wide yellow foam obstacle was placed "on the left side of the subject's lane." Shortly before the object came into view, the researcher in the back seat activated a distance counter and timer. The time at which the test subject moved the foot from the accelerator pedal to the brake pedal was recorded. Although the subjects were described as "surprised" in the initial test (several tests were conducted with each subject), the authors note, "The subjects in this study were possibly abnormally alert relative to the general population of drivers. They had been driving for only about 10 to 15 minutes (in the context of a driving performance test) at the time of the surprise event, and the presence of the experimenter in the back seat may have made them more cautious and attentive than usual. Given these circumstances, the distributions shown are probably conservative relative to what would be found in the 'real world.' However, there is no way to accurately estimate the correction required." The authors note further that the stopping sight distance time estimate of 2.5 seconds currently used is not too short, suggesting that the data is useful for highway design. "The intent is to provide adequate forward visibility so that a driver could stop short of an unexpected obstacle."

Lechner and Malaterre (1991) researched the behavior of 49 drivers who were faced with "an unexpected emergency situation at a junction" using the Daimler-Benz driving simulator (RFA). The driving simulator was utilized to "reproduce realistic emergency situations which were too dangerous to be experimented under real conditions." The participants were experienced drivers (25,000 km to 800,000 km) who had previously driven "large cars." They were instructed to "drive as they usually do and to become familiar with the simulator. The trial situation took place after they had driven 10 minutes. No further instructions were given. This ensured that the situation was unexpected." The authors argue that "the driving simulator is clearly a very useful device with which to study emergency maneuvers, as it enables (researchers) to recreate, in a sufficiently realistic fashion, situations which would be much too dangerous to carry out as actual experiments." They admit "the driving simulator is in some ways limited," although further discussion about those limitations does not follow. It should be noted that the test subjects were acutely aware that they were participating in a research study being performed with the "most advanced driving simulator in use today." The drivers were not driving their own vehicles under normal driving conditions and would be considered highly attentive throughout the duration of the experiment (in comparison to their mental state, for example, driving home from work on a familiar route in their own car). Furthermore, although the stimuli created by the simulator were intended to be realistic, the test subjects were aware of the context of the experience and that they and others would not be harmed.

Koppa, Fambro and Zimmer (1996) recognized the innate difficulty of measuring a driver's behavior without the test conditions affecting that behavior. "A real phenomenon persists through all research into driver behavior: the effect on performance produced by drivers' awareness that they are in an experimental situation." In an effort to minimize behavior modification due to driver awareness of the testing environment, the authors developed a testing protocol that involved monitoring driver behavior by means of innovative vehicle instrumentation which could be installed in test vehicles or in the test subject's personal vehicle. The instrumentation required, however, that an experimenter be present in the vehicle. In the first part of the test program, drivers were asked to participate in a test to be conducted on a closed facility, the Riverside Campus of Texas A&M University. "After a few practice runs through the test course to gain some familiarity with the vehicle and the course, the drivers were presented with a completely unexpected barrier that suddenly sprang up from the pavement in their path." This "barrier" consisted of a three foot high fabric emblazoned with four stop signs. Although the appearance of the barrier may have been "completely unexpected" in the context of the test protocol, the drivers, nevertheless, were aware that they were participating in a test of sorts.

The authors noted that the aggressiveness of the driver's avoidance maneuver appeared to be dependent on whether the test subject was operating his own vehicle or one provided by the research team. Test participants who drove their own vehicles tended to conduct significantly less aggressive crash avoidance maneuvers than those who were supplied with a test vehicle.

Another part of the Koppa test involved "on-road braking maneuvers." A two-lane rural road with unpaved shoulders was the setting for twelve test participants to operate their own vehicles while subject to an unexpected event. The unexpected event was the emergence of a 100 gal. cardboard drum from the rear of a pickup truck parked perpendicular to the roadway. The drums were allowed to move toward the travel lane of the approaching vehicle, but were prevented from actually entering it. The vehicle was equipped with the author's monitoring instrumentation and an experimenter escorted each of the test subjects on the course after they were told that the authors "wanted to see how the car and driver performed on such a rural road and we also wanted the driver's comments on the roadway geometrics, pavement and signage." Drivers were "asked to drive as they normally would on such a road." When the test vehicle was about 75 feet from the pickup, a drum was triggered. Time from release of the drum to first reaction by the driver was recorded. These drivers, like those in the previous tests, were keenly aware of their participation in a test designed to evaluate, at least in part, their driving performance.

D. McGehee et al. (2000) describe a study in which the primary objectives were to examine driver crash avoidance behavior and the effect antilock brakes had on the behavior of drivers subject to a "crash-imminent situation." The study was conducted on the Iowa Driving Simulator. "Test subjects were recruited using advertisements placed in local newspapers and flyers distributed throughout eastern Iowa." The subjects received an Information Summary which explained that the "purpose of the study is to evaluate the realism of the Iowa Driving Simulator." The Study Description outlines the test protocol. The subjects first performed several touch screen calibration tasks, then viewed a video tape about the driving simulator. The subject then entered the driving simulator where an experimenter seated inside the vehicle instructed him or her to adjust the mirrors and seat. The subject was allowed to drive for about five minutes to become comfortable with the feel of the simulator. After the initial orientation, the subject was told to drive normally and to assess the simulator. Several minutes later, the subject approached an intersection at which a light truck was stopped at a stop sign on the left side of the intersection and a Buick Regal was stopped at a stop sign on the right side of the intersection. When the subject was a specified time-to-intersection (TTI), the Buick pulled out into the intersection. The response of the test subject was monitored by sensors, videotape and the in-vehicle experimenter.

Subsequent analysis of the data obtained in the tests examined the influence of anti-lock brakes to driver response and vehicle performance, general patterns of crash-avoidance maneuvers (braking v. steering), the effect of TTI with respect to driver response, and other factors. With a robust set of dependent variables listed by the authors, this study may be described as a parametric sensitivity analysis of driver response to an unexpected event. The test parameters were carefully controlled and the repeatability of the protocol is unquestioned. However, as realistic as the simulator may appear, the drivers, nevertheless, were aware that they were participating in a test and they would not be harmed. The subjects did not drive their own vehicles, but rather, operated a technologically advanced driving simulator which the operators were asked to evaluate.

The tests briefly discussed above have provided valuable information about the manner in which drivers respond to expected and unexpected stimuli in the context of controlled tests. Appendix A summarizes the conditions of these tests. The data has been used in developing and evaluating highway design standards for stopping sight distance, decision sight distance, intersection sight distance and other factors considered by highway design engineers. In recent years, driving simulators have been employed to evaluate the interaction between driver, vehicle and environment under conditions which elicit "emergency response." The data obtained in such studies may be valid in the context from which they were obtained. However, there is no scientific basis to directly apply such data obtained under controlled conditions to the analysis of real-life sudden emergency accidents.

BRAKE UTILIZATION STUDIES

When attempting to determine if a driver could have avoided impact with an intruding vehicle, analysts typically assume that the maximum friction force available between the tires and the road surface could have been utilized to slow the vehicle or bring it to a stop. While this hypothetical "threshold braking" assumption establishes boundaries for a given situation, research indicates that only some drivers apply their brakes to such an extreme. In their research regarding the parameters affecting stopping sight distance, Olson et al. (1984) recognized that the view traditionally held by the highway community that drivers apply their brakes sufficiently to lock all the wheels, "is rather removed from reality."

The manner in which a driver applies the brakes or controls the steering has not been tested during real-life sudden emergency situations. In fact, most PRT research regarding driver brake response addresses only the time delay between the appearance of a hazard and the driver's initial contact with the brake pedal. The manner in which drivers operated the brakes, if at all, after first contact with the pedal was rarely monitored.

We know from skid mark evidence in real accidents that some drivers do apply their brakes to the point of locking wheels. While the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS) database indicates that some drivers performed braking and/or steering maneuvers in an attempt to avoid accidents, the data also indicate that most drivers did not perform any avoidance maneuvers. FARS summarizes investigation data regarding all fatal vehicle accidents in the United States on an annual basis.

Threshold braking and/or steering are well outside the usual experience of most drivers. When a threatening situation arises which demands hard braking, swerving or both, most drivers lack experience to predictably and successfully handle their vehicles. The uncertain and potentially dangerous outcome of such aggressive handling may restrain drivers from fully utilizing the capability of their vehicle's control systems. Panic braking and swerving at high speed is uncomfortable to most drivers. Furthermore, some drivers under extreme stress are unable to take any physical action at all. Pyrnne and Martin (1995) found that "this phenomenon tends to affect cautious drivers more severely because the accident situation is even further beyond their normal driving experience."

Koppa and Hayes (1976) performed a number of tests for NHTSA with an objective of determining the extent to which drivers utilize the full capability of their vehicles. Several "surprise" tests presented test drivers with unexpected obstacles or traffic control devices which they were instructed to avoid. Parameters which were measured during the testing included lateral and longitudinal acceleration, steering angle and brakeline pressure. These tests indicated that drivers rarely use the vehicle's full capabilities. Mean maximum decelerations were about 80 to 90 percent of the vehicle's limits.

Prynne and Martin (1995) studied braking behavior in emergencies by suddenly throwing a pedestrian dummy into the path of unsuspecting test drivers while simultaneously recording brake fluid pressure in the vehicle's master cylinder. They concluded that emergency braking is often a two-stage process with drivers rapidly depressing the brake pedal to their normal limit of depression (about a third of the full range available), pausing, and then depressing the pedal further to some lower position after momentarily assessing the situation. Out of 77 subjects, 66 showed some kind of pause or break in their brake application.

In another test, drivers were told to brake as if they were faced with an emergency upon observing a dashboard mounted red light turn on. Master cylinder brake pressure, brake pedal depression, brake on/off, throttle on/off and vehicle velocity were measured with respect to time. Even when faced with a simple instruction, i.e. "Brake hard when the light goes on," many drivers did not approach the car's maximum braking capability.

Fambro, Fitzpatrick and Koppa (1997) studied stopping sight distances. In one series of tests, drivers were told to stop their vehicles as quickly as possible while staying within a 12-ft lane when the test administrator counted down "Ready, set..." and then illuminated a windshield-mounted signal. In a second series of tests, the subjects were instructed that somewhere along the test course the windshield-mounted signal would illuminate. At the onset of this signal, the driver was to bring the vehicle to a stop as quickly as possible. While the maximum decelerations attainable were in a 0.7 g to 0.9 g range on dry pavement, the 85th percentile drivers achieved only 0.47 g to 0.54 g of equivalent constant deceleration.

The experimental setting in which these tests were done would have likely altered the behavior of the test subjects as compared to a real-life emergency. Nonetheless, within that recognized constraint, the results indicate that drivers do not necessarily use the full capabilities of vehicles during emergency maneuvers. Assuming that they do is not supported in the research.

EXPECTANCIES

Olson (1996) defines expectancy as a predisposition of persons to believe that things will happen or be configured in certain ways. In a driving situation, Luenenfeld and Alexander (1990) point out that expectancy relates to a driver's readiness to respond to situations, events and information in predictable and successful ways. While it is recognized that there is no data to determine to what extent driver response may be altered by expectancies that fail, the scientific community is consistent in their view that violated expectancies can compromise safety by causing confusion, hesitation, unusual response times, inappropriate responses and errors. The following views expressed by a variety of transportation researchers regarding expectancy and violated expectancies in particular represent a concensus position that expectancy plays a significant role in a drivers' ability to successfully cope with a sudden emergency.

"Expectancy relates to a driver's readiness to respond to situations, events, and information in predictable and successful ways. It influences the speed and accuracy of driver information processing and is a major factor in design, operation, and traffic control. Aspects of the highway system that agree with commonly held expectancies facilitate the driver's task. Violated expectancies, on the other hand, lead to longer reaction time, confusion, inappropriate responses, and errors." (Lunenfeld and Alexander, 1990)

"...one tends to perceive what one expects to perceive." (Davis, 1959)

"The surprise evoked by the occurrence of an accident or near-accident in participants is presumably often directly proportional to the strength of the expectancy that failed." (Naatanen and Summala, 1976)

"Perhaps the exceptionally long delays in drivers' reactions sometimes observed when a sudden, unexpected change takes place in a traffic situation are not due to the human necessary slowness of responses to unexpected stimuli but rather to confusion or hesitation as to the kind of response which should be made." (Naatanen and Summala, 1976

"When expectancies are violated it requires a more potent stimulus and/or more information to reliably capture the driver's attention to communicate the essential data then would otherwise be the case. The result is that perception-response time may be increased, primarily because the detection and/or identification intervals are lengthened. There are, unfortunately, no data to provide guidance in determining how much longer perception-response time should be when expectancies are violated." (Olson, 1989)

"The conditions under which an engine driver, or pilot or other operator perceives a signal are usually such that he has a strong expectation of what he will perceive, this expectation being derived perhaps from a lengthy experience of similar situations and an appraisal of the current situation which is usually both confident and correct. Sometimes he is alert for departures from what he would normally expect. If he is not, he may fail to look out for or fail to perceive correctly, a signal of considerable clarity in terms of strength and duration. Thus he may totally neglect a signal which he does not expect, or misread a signal if what it indicates is contrary to what he expects. He then makes an error because his appraisal or conception of the situation and its probabilities is false." (Davis, 1959)

"As to the road user, if say, the thousand most recent oncoming cars have carefully stayed in their driving lane, the driver apparently, has become 'internally' convinced of the (moment-to-moment) continuation of the state of affairs in similar situations; the proof is sufficient for his cognitive system. Again it has to be emphasized that 'knowing' has many levels. The most cognitive of these levels, that being closest to the 'surface' is involved as the driver, when, for example, interrogated upon it, 'of course' knows that an oncoming car might, in principle, suddenly dangerously change its course. Another thing might be, however, how he really, at a deeper level of his personality, experiences the matter, and it appears to be that level which has the closest connections to the determination of his behavior." (Naatanen and Summala, 1976)

"...car driving emergency situations usually arise because of expectancy violations." (Evans p127)

"A third condition confounding predictions was deviant action, in which a driver did something illegitimate and improbable, and thus not expected by others. Examples are failure to turn when the signal is activated, or going through a red light. Even the best driver cannot always allow for the possibility of deviant action, if traffic is to be efficient." (Ross, 1960)

"First of all, the autonomic, relatively primitive and non-cognitive nature of the expectancy phenomena should be emphasized. Hence, these phenomena are difficult or impossible to resist, or to compensate for, consciously and it appears also that, for the same reason, training programs and similar long-term attempts to teach road users to perceive and interpret traffic events with considerably less distortion by expectancy are deemed to fail." (Naatanen and Summala, 1976)

"these estimates may not adequately characterize PRT under conditions of complete surprise, i.e., when expectancies are greatly violated. Detection times may be greatly increased if, for example, an unlighted vehicle is suddenly encountered in a traffic lane in the dark, to say nothing of a cow or a refrigerator." (Koppa, Human Factors, 1975)

"...the serious conflict situations which demand fast and accurate responses are so infrequent that the drivers do not learn the requested behavioral models: in fact these are against their daily experience in traffic. The very problem in road safety is indeed that such severe conflicts and accordingly, accidents are so infrequent that drivers are not able to take them into account and, what more, it would not even be rational." (Summala, 1985)

EMOTIONAL AROUSAL

Emotional arousal (i.e. fear, shock, startle, panic) within the context of a sudden driving emergency relates to the mental state of the driver evoked by a threatening event. Although the psychological community has recognized for many years the fight, flight and freeze responses of humans confronted with a threat, data regarding how these feelings affect the performance of a driver confronting a true sudden emergency is non-existent. In their research regarding sudden aircraft emergencies, Thackray and Touchstone (1988) used auditory stimuli (e.g. a pistol shot) to evoke a startle response which they believed created human responses similar to a sudden and threatening emergency. They found a significant disruption of complex perceptual-motor behavior within the first 3 seconds following stimulation and impaired ability to process information for as long as 60 seconds following stimulation. Other research involving issues of traffic safety has also recognized the disruptive affects that emotional arousal has on performance.

"In many types of emergency situations, however, one has not only the factor of unexpectedness to contend with, but also the additional and potentially disruptive factor of intense emotional arousal. Actual data with regard to response time to traumatic emergency events, to say nothing of the time-course of behavioral recovery

following such experiences, are virtually nonexistent. Part of this is clearly due to the extreme difficulty of creating under controlled, experimental conditions the particular perceptual/cognitive events that, because of their meaning or significance to the individual, are the usual trigger for the emotional reactions associated with real-life emergencies." (Thackray and Touchstone, 1983)

"In evaluating these findings with regard to their applicability to emergency behaviors in real-life situations, it is important to recognize that unexpected and traumatic emergency situations in real life probably involve at least two phases. The first phase, which could be termed a "shock phase," constitutes the initial reaction. In this phase, the individual attempts to respond with immediate behaviors that are intended to cope with or rectify the unexpected event. It is during this phase that emotional-physiological reactions to the emergency may produce behavioral disruption or even temporary immobility." (Thackray and Touchstone, 1983)

"Man like other animals is equipped with so-called "emergency" mechanisms. When dangers, whether physical or psychological appear imminent, the 'drives' underlying behavior become stronger and behaviour undergoes certain characteristic changes. In particular, response are more readily elicited; that is to say they are elicited by less intense and less specific stimuli. They tend to be more forceful; more extensive and more rapid. At the same time they tend to be less regular, less organized and less coordinated. The emergency mechanisms enable the subject to react rapidly and vigorously to situations which threaten him and facilitate the overcoming of obstacles of certain kinds. They are of biological value for this reason but their effects on behavior are not always advantageous, for many of the danger situations which human adults meet require not vigorous activity but restrained, deliberate and accurate responses." (Davis, 1959)

"Such very slow response in sudden threatening traffic situations may also be due to the immobilizaton reaction associated with immense fear or just to a very low level of vigilance, or to drowsiness, of the driver when confronted with the situation concerned." (Naatanen and Summala, 1976)

In moments of extreme stress, humans tend to revert to the response they have used most often to a particular stimulus so if a new response has been learnt recently the older response will be used instead. This means that training cannot be expected to have much, if any, effect on behavior in emergencies. There is a second phenomenon which can affect some drivers under extreme stress - the inability to make any physical action at all. This paralysis can cause drivers to sit passively before a collision when they have plenty of time to react. It tends to affect cautious drivers - again because the accident situation is well outside their normal experience." (Prynne and Martin, 1995)

"It is, of course, the height of absurdity to apply 20/20 hindsight to a situation in which a driver must make a quick decision under life-threatening circumstances. It is generally impossible to know with great precision what that individual perceived in the brief time interval before a decision had to be made. Therefore it is generally impossible to pass judgement on their actions." (Olson, 1996)

"The input and response parameters in the closed-loop tests usually increased as the difficulty increased (allowed maneuvering time or distance decreased) up to a point, then fell off. This indicates that the drivers tended to "give up" if the task seemed impossible." (Koppa and Hayes, 1976)

"A driver is generally unaware of failure to execute the maneuver decided on. Often part of the operation is an unconscious reflex reaction. The result of the reaction is sudden, unexpected , and even terrifying. Afterwards, the driver remembers his decision, what he intended to do, but is quite unaware of his response, what he actually did." (Fricke, 1990)

UNCERTAINTY

A sudden emergency is by definition an unexpected and unusual event. While normal events in traffic flow are predictable, the outcome of a sudden emergency is dictated by several uncertain factors which cause the outcome to be dictated by the chance of the circumstances.

In 1991, Lechner and Malaterre performed emergency driver response studies with the use of the Daimler-Benz driving simulator in Berlin. 49 test subjects were placed in a sudden emergency situation at an intersection where a vehicle, stopped on an intersecting road, unexpectedly accelerated into the test subject's lane and then stopped in the middle of the road. The intruding simulated vehicle accelerated for 1.9 seconds and then braked to a stop in 2.6 seconds. Almost all the test subjects responded with an avoidance maneuver in less than 1.5 seconds and before they could have know whether the other vehicle was going to come to a stop in their lane or was going to continue accelerating across the lane. Some braked, some swerved left, some swerved left and braked, some braked and swerved right and only 10 of the 49 avoided a collision. If instead the intruding vehicle had continued to accelerate across the lane, the test subjects would still have responded in the same way since they responded before they knew what it was going to do. The nature and mix of the types of collisions would have been different but there would still have been some collisions.

From these simulator tests and other research they had done involving studies of real accidents, Lechner and Malaterre concluded that above all, the result of an emergency situation is completely uncertain and that the behavior of the obstacle to be avoided, in particular in the case of an intersection, is a determining factor. The consequences of driver actions are therefore uncertain, even if some maneuvers have more chance of being successful than others.

Others involved with traffic safety research and human response under time pressure support the findings of Lechner and Malaterre.

"Accidents are therefore a matter of chance combinations of circumstances." (Baker, 1960)

"...the briefness of emergency situations lead some to consider that the driver no longer has the possibility of choosing what he does, but that he simply relies on primary reflexes, which makes all drivers equal when it comes to emergency avoidance." (Malaterre, Ferrandez, Fleury and Lechner, 1988)

"The prediction of the path of a vehicle is very difficult for two reasons. First, vehicles can accelerate, brake, and change direction relatively easily, while giving little or no advance warning of these maneuvers to other drivers. Second, the behavoior of each driver depends on what he thinks the other is going to do but neither can be sure of the other's actions in advance, so both must guess." (Ross, 1960)

"Even if the subjects generally appreciated the gains obtainable from alternative actions, in terms of time and distance, there were considerable variations between them, and their knowledge of actual avoidance possibilities remains vague and irregular." (Malaterre, Ferrandez, Fleury and Lechner, 1988)

"Drivers may make errors that result in a collision with another vehicle, even when they are aware of the presence of the conflicting vehicle. This is because perceptual judgements about time, space, and speed are imperfect, and can lead to misjudgments about the adequacy of a situation to allow some driving maneuver. Drivers may err in thinking there is more time available for the maneuver that is actually the case; or err in thinking the maneuver takes less time to execute than it actually does." (Lerner, Steinberg and Hanscom, 1999)

"In reaction time tasks, and in speeded performance in general, people often make errors. Furthermore, they tend to make more errors as they try to respond more rapidly. This reciprocity between latency and errors is referred to as the speed-accuracy trade-off." (Wickens, 1992).

SUMMARY

Current accident analysis methodology which utilizes the results of perception-reaction time experiments and vehicle braking and steering performance thresholds to determine if a driver *could have* avoided an accident is simplistic for evaluating the reasonableness of a driver confronted with a sudden emergency. Behavioral factors which interfere with drivers' ability to successfully cope with emergencies must also be addressed. Research indicates that during an emergency, factors such as expectancies, intense emotional arousal and uncertainty can be significant to a driver's ability to reliably, predictably and successfully cope with the situation.

When one considers the frailty and uncertainty of human behavior during sudden emergencies, it becomes apparent that determining whether a driver *could have* avoided a particular collision is only of peripheral interest. A more significant question regarding the culpability of a driver is "Would all reasonable drivers under identical circumstances have avoided the collision?" In many cases, some drivers would have avoided the collision and others would not, yet all are reasonably skilled, attentive and competent. Once it is determined that a driver was confronted with a sudden emergency which demanded an extraordinary response, outside the normal experience of most drivers, the outcome of the accident is dictated more by the chance of the circumstances than by the performance abilities of the driver and his vehicle.

REFERENCES

Baker, J. Stannard, "Experimental Case Studies of Traffic Accidents," Northwestern University, Traffic Institute, Evanston, Illinois, 1960.

Davis, D. Russell, "Human Errors and Transport Accidents," Egonomics, v.2 #2, February 1959, pp. 24-33.

Bellacosa, Judge, "Ada Rivera v. The New York City Transit Authority," Appellant. 77 N.Y. 2d, 569 N.E.2d 432 N.Y.S.2d 629, 1991.

Evans, L., Human Behavior & Traffic Safety, General Motors Research Laboratories, 29th Symposium, September, 1984.

Fambro, D., K. Fitzpatrick, and R. Koppa, "Determination of Stopping Sight Distances," Texas Transportation Institute, Texas A&M University, Transportation Research Board, National Research Council, National Cooperative Highway Research Program Report 400, 1997.

Griffin, P.J., Gillis and Sawyer, "Young v. Flood," Court of Appeals of Michigan: Docket No. 107700, March 6,1990.

Grime, G., "Traffic and Road Safety Research at the Road Research Laboratory, England," Road Research Laboratory, Harmondworth, Middlesex, England, National Research Council, Proceedings of the Thirty-First Annual Meeting, Washington, D.C., Publication 238, January, 1952.

Johansson, G. and K. Rumar, "Drivers' Brake Reaction Times," Department of Psychology, University of Uppsala, Uppsala, Sweden, Human Factors 13(1), pp. 23-27, 1971.

Koppa, Rodger J. and Gordon G. Hayes, "Driver Inputs During Emergency or Extreme Vehicle Maneuvers," Texas Transportation Institute of Texas A&M University, College Station, Texas. Human Factors, 18(4), 1976, pp. 361-370.

Lechner, D. and G. Maleterre, "Emergency Manuever Experimentation Using a Driving Simulator," INRETS, Society of Automotive Engineers, Inc., SAE Technical Paper No. 910016, 1991.

Lerner, N., G. Steinberg, and F. Hanscom, "Development of Countermeasures for Driver Maneuver Errors," U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-RD-00-022, December 1999.

Luenenfeld and Alexander, "A Users' Guide to Positive Guidance," U.S. DOT, Report No. FHWA-SA-90-017, 1990.

Maynard, Justice, "Moran v. Atha Trucking, et. al. and Fletcher v. Sias," West Virginia Supreme Court of Appeals, December, 1997.

McGehee, D., E. Mazzae, G. Baldwin, P. Grant, C. Simmons, J. Hankey and G. Forkenbrock, "Examination of Drivers' Collision Avoidance Behavior Using Conventional and Antilock Brake Systems on the Iowa Driving Simulator," University of Iowa, NHTSA Light Vehicle Antilock Brake Systems Research Program Task 5, Part 1, August 2000.

McGiverin, Chief Justice, "Beyer v. Todd's Flying Service Inc.," Supreme Court of Iowa, 1999.

Naatanen, R. and Heikki Summala, Road-User Behavior and Traffic Accidents, University of Helsinki, Finland, 1976

NHTSA Fatality Analysis Reporting System

Olson, Paul, D. Cleveland, P. Fancher, L. Kostyniuk and L. Schneider, "Parameters Affecting Stopping Sight Distance," University of Michigan, Transportation Research Institute, Transportation Research Board, National Research Council, National Cooperative Highway Research Program Report 270, June 1984.

Olson, Paul L., Forensic Aspects of Driver Perception and Response, Lawyers & Judges Publishing Company, Inc. 1996.

Prynne, Katharine and Peter Martin, "Braking Behavior in Emergencies," Lucas Automotive, Society of Automotive Engineers, SAE Technical Paper Series 950969, 1995.

Ross, H. Laurence, "Recognition of Collision Course in Traffic Accidents," Department of Sociology, New York University, National Safety Congress, Traffic Safety, pp. 8-12, 1960.

Summala, Heikki, "Driver/Vehicle Steering Response Latencies," Department of General Psychology, University of Helsinki, Helsinki, Finland, Human Factors, 23(6), pp. 683-692, 1981.

Summala, Heikki, "Modeling Driver Behavior: A Pessimistic Prediction?," Human Behavior and Traffic Safety, Plenum Press, 1985, pp. 43-61.

Thackray, Richard I. and R. Mark Touchstone, "Rate of Initial Recovery and Subsequent Radar Monitoring Performance Following a Simulated Emergency Involving Startle," FAA Civil Aeromedical Institute Paper, September, 1983.

Triggs, T. and W. Harris, "Reaction Time of Drivers to Road Stimuli," Department of Psychology, Monash University, Melbourne, Australia, Human Factors Group Report HFR-12, June 1982.

Wasson, G., "Existence of Sudden Emergency," 8 Am Jur Proof of Facts 3d, Chapter 1, *Part 2 Reference to Jones v Munn (1984) 140 Ariz 216, 681 P2d 368; Di Cenzo v Izawa (1986) 68 Hawaii 528, 723 P2d 171.)*

See back cover for Appendix A

SAFETY BRIEF

June, 2002 – Volume 20, No. 4

Editor: Paula L. Barnett
Illustrated and Produced by
Triodyne Graphic Communications Group

Appendix A - Summary of Driver Perception-Reaction Time Research Test Conditions

Grime - Traffic and Road Research at the Road Research Laboratory, England, 1952	Driver instructed to react to a pedestrian stepping off the pavement at a pedestrian crossing by applying the brake. Movie camera mounted beside driver. Time-to-collision: Unknown.
Johansson and Ruma - Drivers' Brake Reaction Times, Sweden, 1971	Drivers were stopped by police and instructed to brake immediately upon hearing loud klaxon horn sound during next 10 km of driving. Time-to-collision: Not Applicable.
Summala - Driver/Vehicle Steering Response Latencies, Finland, 1981	Unalerted drivers were induced to steer away from the sudden opening of a door on a car parked on the shoulder. Open door did not extend into travel lane. Test drivers could see driver in parked car as they approached. Time-to-collision: 1 to 5 seconds.
Triggs and Harris - Reaction Time of Drivers to Road Stimuli, Australia, 1982	Over a hill crest or around a curve, unalerted drivers were confronted with various static stimuli on the side of the road. Stimuli included red reflective triangles, a motorcycle, a "Traffic Hazard Ahead" sign, a driver in the process of changing his tire and a police car. The aim was to elicit a speeded braking response but not extreme braking. Time-to-collision: Unknown.
Olson and Sivak - Parameters Affecting Stopping Sight Distance, USA, 1984	Drivers were told they were to participate in a driving performance study after getting accustomed to driving a test car. After driving only 10 to 15 minutes, a small piece of yellow foam rubber suddenly appeared over a hill crest on the left side of their lane. Experimenter sitting in the back seat. Time-to-collision: About 4 seconds.
Lechner and Malaterre - Emergency Manuever Experimentation Using a Driving Simulator, France, 1991	Drivers were tested in the world's most advanced driving simulator at the time. They drove a test car mounted in the simulator. Their view of the road was supplied by an image generator. They were asked to drive and get familiar with the simulator, but after 10 minutes, a stopped vehicle pulled out into their lane from the right. Time-to-collision: 2.0, 2.4 and 2.8 seconds.
Fambro, Fitzpatrick and Koppa - Determination of Stopping Sight Distances, USA, 1997	Drivers were led to believe that they were involved in a roadway evaluation test. As they approached a parked pick-up truck, a cardboard barrel rolled out to the edge of the road. A test administrator was in the vehicle. Time-to-collision: 1.1 seconds.
McGehee - Examination of Drivers' Collision Avoidance Behavior Using Conventional and Antilock Brake Systems on the Iowa Driving Simulator, USA, 2000	Drivers were tested in the most advanced driving simulator in the world. They were asked to assess the feel of the simulator for about 30 minutes. After 15 minutes they approached an intersection where a stopped car on the right pulled out and then stopped 6 feet into their lane. Time-to-collision: 2.5 and 3.0 seconds.