Summer 1989

The Effects of Life Stress and Risk-Taking Style on Risk Perception and Driver Performance

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B.S. August 1981, Old Dominion University

M.S. August 1983, Old Dominion University

A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

INDUSTRIAL/ORGANIZATIONAL PSYCHOLOGY

OLD DOMINION UNIVERSITY

August 1989

Approved by:

Glynn Coates (Director)

ABSTRACT

THE EFFECTS OF LIFE STRESS AND RISK TAKING STYLE ON RISK PERCEPTION AND DRIVER PERFORMANCE

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Old Dominion University, 1989
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This study examined the effects of risk-taking style, stress level, and highway environment on driver performance. In Phase I, 50 subjects were assessed for risk-taking style and stress level. In Phase II, the same subjects were presented with slides of traffic situations that varied in terms of risk of accident. This was a paired comparison task in which they rank-ordered ten highway sites, producing a measure of subjective risk. No significant relationships were identified between these subjective risk judgments and objective data regarding those sites (accidents and fatalities), though this is most likely due to problems with the slide presentation. In Phase III, the subjects drove in one of two scenarios (high-risk of accident or low-risk) in a highway simulator, and six vehicle operation variables were recorded, including time spent in each zone of the scenario, lane placement, average speed and standard deviation of speed over zones, number of accidents, and steering reversals. Evaluation of these variables indicated that risk-taking style and stress were good predictors of driver performance, though not as good as the difficulty of the roadway, which accounted for 87% of the variance. Of particular importance was the interaction of high levels of

stress and high risk-taking style on driver performance, causing decrements in the vehicle operation measures.

Dedication

To my mother, and my sister, Molly, who did everything to complete this venture, except write it themselves; to my children, Guy and Kate, who suffered through it with me; to my co-workers, who put up with bad temper, fits of self pity, and endless stories about its progress--it's finally over!

ACKNOWLEDGMENTS

This dissertation would never have been completed without the support and understanding of a great mary people. I would like, first of all, to thank my husband, Don, whose help throughout my graduate career was incalcuable. I also want to thank Dr. Glynn Coates for overseeing this venture, Dr. Peter Mikulka for his invaluable help in restructuring it, Mr. Joseph Hooks for his moral support and assistance with graphics, and Mr. Jerry Phillips for his generosity in allowing me time to complete it.

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Introduction

Driver performance, and the variables that interact with it, has been of continuing interest in the highway safety literature. Many different concepts and causes have been investigated, including the accident-prone driver, attentional failure, task overload, age and gender of the driver, and risk homeostasis. None have satisfactorily addressed individual differences in driver performance. This may be because driver performance is not a univariate concept, but consists of a number of interrelated variables, some of which have been the subject of scrutiny for years, while others have never been investigated.

The effect of life stress on driver performance has never been assessed. Various physiological measures of stress have been investigated, but these only tap relatively immediate changes in the autonomic nervous system induced by the experimenter. While these are useful in examining an individual's reaction time to critical events in the highway environment, they are less helpful in determining the degree of decrement in performance s/he might already be exhibiting due to cumulative life stressors.

The broad concept of risk has been explored in the highway safety literature, in several different forms. Because of these different forms, a review of the interrelated concepts of risk, risk-taking, and risk perception is needed. Risk is not a unidimensional concept, nor has it been succinctly defined. Instead, there exists a wide body of operational definitions, with only this in common: that risk is an objective danger in a particular situation, and that the probability of a negative outcome, and its severity can be measured (Shoptaugh, 1987).

Risk-taking is an observational measure of an individual's behavior. It is usually assessed by counting the number of risky behaviors a person exhibits. It presupposes that the individual has recognized the behavior as dangerous, and has then chosen to proceed with it, nonetheless (Kogan & Wallach, 1964).

While risk and risk taking are available to objective measurement, risk perception has been far less amenable to observation. First, it is a cognition, and thus not readily measured. Second, it has no clear-cut theoretical definition, and to date has only been operationally defined. It differs from risk in that it is a subjective assessment of danger, and thus frequently at variance with objective data about the risk itself. It is more difficult to separate from risk-taking, however. Both concepts utilize subjective data, and deal with the ability of a person to estimate correctly the probability of negative outcomes. However, perception of risk includes the possibility of failing to recognize a risky situation, thereby taking an action that may not accurately reflect risk-taking style.

A number of driver characteristics have also been postulated as affecting driving performance. Very young and very old drivers have higher accident rates. Gender has been found to be a potent discriminator of different driving behaviors (e.g. accident rate and driving speed). The amount and type of driving exposure has been shown to be related to likelihood of injury and accident, as well as to the skill of the driver.

None of the concepts mentioned have been examined within a multidimensional framework to determine their combined impact on driver performance. A review of the relevant psychological, and highway safety literature will expand on these concepts.

The results of this review can be loosely divided into three categories that pertain to driver performance. The first category is theoretical, and consists of concepts in the psychological literature, supported by either psychological studies, transportation-related studies, or both. These theoretical concepts are life stress and risk taking, and how these may be related to driver perception of risk (DPR). The second category contains three classes of variables that can be hypothesized to affect driver performance. The classes are driver-related variables (such as age and gender), vehicle-related variables (such as car size and brake force), and highway-related variables (such as type of roadway and traffic density).

The last section of this introduction will focus on two methodologies of note in exploring driver performance. These are highway simulation, and the use of photographic slides and paired comparisons to assess subjective estimates of risk.

Life Stress

There are generally considered to be several different types of stress. Some are highly situation-specific, and have been broadly classified as "fight-or-flight" related. These would include avoiding short-term, life-threatening events (e.g. steering around a possible high-speed collision). Here, stress can be operationally defined as a strictly physical response (heart rate, adrenal gland activation, changes in galvanic skin response, etc.). Some types of stress have been identified with stressful life situations with longer time components than fight-or-flight reactions (such as meeting a work deadline, dealing with the loss of a loved one, or recovery from an illness). This kind of stress has been called "life stress" and is sometimes measured physiologically as well. However, operational definitions of life stress that incorporate physiological measures may not accurately reflect the degree of hardship the individual is undergoing, due to the body's ability to adapt to prolonged distress (Selye, 1963). Because of this difficulty, life stress is most often assessed in interviews or with paper-and-pencil measures.

Stress has proved difficult to define. One of the most widely accepted definitions states that stress is "...the result of an imbalance between demand and the organism's capacity" (McGrath, 1970). Other researchers and theorists have developed more complex interpretations, involving multidimensional, interdisciplinary concepts. The link between stress and performance is one of the more crucial of these, particularly for highway research. This link, sometimes called "the inverted U hypothesis" (Welford, 1973), suggests that moderate amounts of stress can improve performance, but that as stress levels increase, performance drops incrementally. This hypothesis has formed the basis of many experiments in a wide range of disciplines (e.g. occupational safety, the Department of Defense, highway research).

Hans Selye was one of the first researchers to examine the effect of physiological stress on accident causation. He developed a biologically-grounded theory of stress called General Adaptation Syndrome (GAS). GAS involves three stages: 1) the alarm reaction, in which stress first appears and is defended against physically; 2) the resistance stage, in which the organism adapts to the stress; and, 3) the exhaustion stage, which occurs if the stress is severe and prolonged. While Selye uses physiological measures of stress, (particularly hormonal responses), he has acknowledged the need to examine the effects of GAS with other kinds of instruments (Selye, 1964).

The General Adaptation Syndrome has successfully linked stress with aging (Selye, 1981), and also has highlighted the effect of stress in producing illness. Selye postulated a relation to accident causation that is similar to Welford. Selye stated that stress, in moderation, can increase the quality of performance up to a certain point, while further increases in stress slow the organism's reaction to stimuli, and thereby increase the likelihood of mishaps.

Hogan and Hogan (1982) further refined the GAS by adding cognitive components. Their stress activation syndrome (SAS) consists of three parts. The first part contains the stressors themselves, which can be physical or emotional. The second part is the perception of the stressors. While stressors may be present at all times, they must be seen as such in order to create stress for an individual. An example of this is response to ambient temperature. Ambient temperature can be a stressor. If the temperature is high, and an individual is heat-sensitive, s/he will perceive stress. If the temperature is high, but the individual enjoys heat, or is not sensitive to it, s/he will not perceive stress. The third part is the response to a perceived stress. If the heat sensitive individual has options available to escape the heat, no stress will occur. If, however, there are highly limited options, or no options, then stress will be activated. Also, prior successful experience with a stressor can attenuate stress, while failure to deal successfully with it is a stress in itself. These authors also suggest that "stress is in the eye of the beholder".

Crump, Cooper, and Smith (1980) developed a grid (similar to those used by air traffic controllers) to produce a cognitive stress map, to observe changes in that map, and to document an individual's social support system. The inclusion of the social support system recognizes that the loss of a loved one, or the making of new supportive connections can have a dramatic impact on life stress, and how an individual copes with it.

As mentioned above, life stress theory suggests that all possible stressors in an individual's life must be assessed, not just those related to work, or to the physical environment. This theory holds that all things being equal, the total number of stressors in an individual's life, and each stressor's severity, is positively correlated with the incidence and onset of illness, and the individual's risk of accident. Schmale (1958) was the first to recognize the impact of life events on stress and illness. He discovered that onset of disease was correlated with a higher incidence of real, or imagined, loss, particularly of those close to them. Parkes, Benjamin, and Fitzgerald (1969) found that widowers had a 40% higher risk of death in the first six months following their wives' deaths than married men of comparable age. Holmes and Rahe (1967) constructed a rating scale of a wide variety of life events ranging from the loss of loved ones to minor traffic violations. Repeated research studies indicate that scores of over 300 on their scale are associated with a higher incidence of disease and accidents (Holmes & Masuda, 1974; Rabkin & Struening, 1976; Stewart & Salt, 1981).

There is little highway research into the effects of stress per se. Those studies examining stress have done so in the context of physiological measures (Alicandri & Roberts, 1985; Curry, Hieatt, & Wilde, 1975; Grubb, 1987; Roberts, 1982; Stevens, 1984). No studies have examined the effects of life stress on traffic accidents, despite the evidence cited earlier that suggests that life stress is related to rate of accidents on the job and in the home. Only one exception can be noted, and it comes from the psychoanalytic discipline, not from highway research. Sachs (1962) studied life stress retrospectively in an attempt to determine the psychosomatic component of accident involvement. He found that many personality correlates were strong predictors of many different types of accident involvement. Family problems, work problems, and low IQ were found to be predictors of highway accidents. As family and work problems can be considered stressors, this study has a clear impact on the investigation of life stress' relationship to driver performance.

Given the evidence cited above, that life stress plays an important role in accident causation, it should be investigated to assess its effect on driver performance.

Risk Taking

Most of the highway safety literature dealing with driver performance has examined decision making under conditions of risk. As stated previously, risk is the objective danger associated with a particular environment or event. Most of these studies measure risk-taking behavior as well, thus providing a link between decision making theory and risk taking. Because the direct observation of a cognition is not possible, many different methods of measuring risk taking have been developed. Most provide information at the ordinal level only (ranking one scenario riskier than another), and are severely limited in their generalizability because of weak or non-existent links with either decision making or risk taking theory (Shoptaugh, 1987). Such methods for measuring risk taking have included laboratory assessment of risk-taking style, psychophysical methods, and the observation of risk in the natural environment. Depending on the operational definition employed, they may or may not have contributed to an understanding of risky driving behavior. An exception is the Kogan-Wallach Choice Dilemma Questionnaire. Subjects are presented with 12 separate scenarios of different real-world situations. Six probabilities are provided for each scenario, ranging from assumption of no risk, to highly risky levels. Subjects select the risk level they would advise be taken in the situation, based on what they (the subjects) would find comfortable (Kogan & Wallach, 1964). This questionnaire has been used in many highway studies, and along with the other methods, will be reported below.

Berggren, Moore, and Stening (1970) found no effects for risk-taking style in a study of eight subjects in an automobile simulator. Four of these subjects were identified as low in anxiety and defensiveness, and four as high in anxiety and defensiveness. Subjects drove the simulator for three hours during which the same course was driven six times. Risk was manipulated by asking the subject to perform the course at successively higher speeds than he/she had previously exhibited. Each risk situation thus required progressively higher speeds than the last, increasing the risk progressively. Subjects were free, however, to decide on a lower speed. No significant difference was noted between the two groups, either in risk taking behavior, physiological measures (as measures of anxiety), or in accidents or violations in the simulator.

Wasielewski (1982) used speed (measured by radar) as an indicator of risk-taking behavior, and found that drivers who were young, had recorded accidents and violations, or drove newer or heavier cars drove faster (were greater risk takers). Also, those drivers with no passengers were inclined to drive at a higher rate of speed, though this was not statistically significant. These drivers were observed in a field study of over 6,600 cars observed in normal traffic. Drivers were unaware that they were being watched. State Motor Vehicle files were used to provide data on driver and vehicle characteristics that experimenters were not able to determine by observation.

In a study of 60 drivers, Watts and Quimby (1980) found that road layout affected drivers' risk-taking behavior. Subjects were required to drive a 16-mile route that encompassed a wide variety of conditions and safety hazards (including urban and suburban roads, rural roads, sharp hills and curves, and hazardous intersections). Subjective risk was assessed by asking the drivers to rate the possibility of an accident at 45 points along the route. Objective risk was the actual accident data for those points. Large, inconsistent, differences between subjective and objective risk were obtained.

In a study of perceived risk and its effect on driver behavior, Colbourn (1978) employed three different methodologies. First, 24 subjects performed a computer-generated simulation of a closing gap. Estimations of whether the gap could be successfully navigated were recorded, and incorrect decisions resulted in collisions. In the second experiment, subjects viewed color slides of actual locations and were asked to give their subjective estimation of whether evasive driving maneuvers would be needed to navigate successfully that area of the highway. Colbourn also interviewed subjects after this study, to determine what other information would have helped them with their judgments. The third experiment was similar to the slide viewing. Video tape of highway sites was presented, and subjective judgments were made by the subjects. Colbourn found that age had an effect on risk-taking behavior, and that it interacted with gender. This interaction indicated that older female drivers took more risks than any male driver or any younger person. This was not interpreted as suggesting that these women were risk-takers, but instead was thought to indicate degradation in perception of risk. Other results were unclear, based, he felt, on problems in simulating the driving experience.

Robinson (1975) examined the effects of risk-taking style on driver behavior. Using a simulator to present a car-following task, 10 subjects were tested. Five were high-risk and five were low-risk as determined by the Kogan-Wallach Choice Dilemma Questionnaire. Attention was measured in terms of how often the subject requested a look at a display showing the relationship of his/her vehicle to the lead vehicle. Each look (sample) cost the subject, and collisions also cost. These costs were deducted from the subject's pay for participating in the experiment.

Results showed a significant difference between high and low risk subjects. High risk subjects had a far lower percentage of time devoted to sampling, causing them to be at probable risk of collision nearly 60 percent of the time in one cost condition.

Shoptaugh (1987) also employed the Kogan-Wallach Choice Dilemma Questionnaire in determining risk-taking style.

Subjects were categorized as high or low risk takers, and then asked to view video tapes of various driving scenes. These video tapes were of intersections with light to heavy traffic flow. Subjects were asked to state whether they would proceed to cross these intersections. High risk takers would cross almost any intersection, even those that were rated as categorically unsafe. Low risk takers showed no consistent pattern in judging which they would cross or at which they would wait further.

Driver Perception of Risk

There are problems in formulating an operational definition for perception of risk. Cognition is essentially an "invisible" process. One cannot sample the domain of thinking in the same fashion that behavior can be examined. This means that behavior needs to be linked theoretically to processes that have been hypothesized to exist, but cannot be seen. This is a difficult task, and one subject to a certain amount of controversy (Catania, 1979).

While perception of risk has received much attention in recent highway research, the difficulties in defining it are apparent in the variety of operational definitions these studies have generated. The majority of research has involved risk taking as the objective measure. That research has been cited, for the most part, in the previous section. However, other research has focused on attentional failure and task overload in the highway environment. Both of these areas are closely related to stress.

Most of the attentional literature uses retrospective, in-depth accident investigation to establish whether inattention was the causal factor in traffic accidents. In an investigation of 210 accidents, Clayton (1972) obtained results of particular relevance to the concept of perception of risk. He found that failure to look and misperception accounted for 48 percent of the driver error that resulted in accidents. Failure to look was defined as failing to scan visually an area of the highway environment that could be assumed to be hazardous. Misperception was defined as failing to perceive a hazard as such, even though it had been seen. The results of this investigation can be seen as related to two concepts: stress, and risk taking. Both failure to look and misperception can be examined with Welford's inverted U theory of stress. If great stress were present, the individual's ability to perceive correctly the environment could be seriously hampered, and his/her attention to the roadway could be impaired. Misperception could further be related to risk-taking style with the high risk taker failing to see a risk as such.

Summala and Naatanen (1974) explored ability to perceive roadway signs. Citing literature that indicated that 47 percent of motorists fail to process signs, these researchers further investigated this phenomenon using nine subjects, each of whom drove a 257 km route. For all subjects, 5229 signs were passed of which 154 signs were not detected (2.95% of total). They concluded that drivers were in fact able to perceive relevant signing in the highway environment with a high degree of accuracy. However, it should be noted that their subjects had been instructed to look for signs, decreasing the ambiguity of the testing situation, and presumably any stress associated with such ambiguity.

Task load research in perception of risk suggests that failure to perceive risky situations is caused, in the main, by stress. Stress reduces attentional capacity available for unexpected, dangerous situations (Curry, Hieatt, & Wilde, 1975). Thus, decreases in perception of risk can be linked to task overload and stress.

Curry, Hieatt, and Wilde (1975) note that to measure task load and its inherent stress effectively, it is necessary to be able to define units of mental load and its manifestation in behavior. Kalsbeek (1968) emphasizes that individuals' life experiences must be incorporated into any assessment of task load, a concept clearly related to the idea of life stress.

Other Variables Related to Driver Performance

There are several types of variables that are of importance in research pertaining to driver performance. These are driver variables, vehicle variables, and highway variables. Unlike concepts such as risk taking and life stress, they are more difficult to subject to rigorous experimental design. Most of these variables have been examined in correlational analyses of driving. In that capacity they can be roughly divided into three categories. Driver variables are almost always predictor variables. They are hypothesized to precede vehicle operation characteristics, which serve as criterion measures of performance. Highway variables are essentially modulator variables, and the only ones subject to experimental manipulation. The relationship among these categories, and their interaction with risk taking, life stress and risk perception are presented in Figure 1.

Predictor Variables

Gender - Hagen (1975) found that gender had a significant effect on driving performance. In a test of 89 male and 74 female drivers on 13 psychomotor measurements in a driving simulator, gender was shown to cause profound differences in vehicle operation. These differences were particularly striking in conjunction with age of subject. The author found that young male drivers were the greatest risk takers, and young female drivers the most timid of the groups tested. He suggested that driver education needs to be redesigned to bring both of these extremes more in line with the "typical" driver. Gender has been found to be a potent variable in a great many studies of driver performance (Colbourn, 1978; Galin, 1981; Klipple & Roberts, 1973; Wasielewski, 1982).

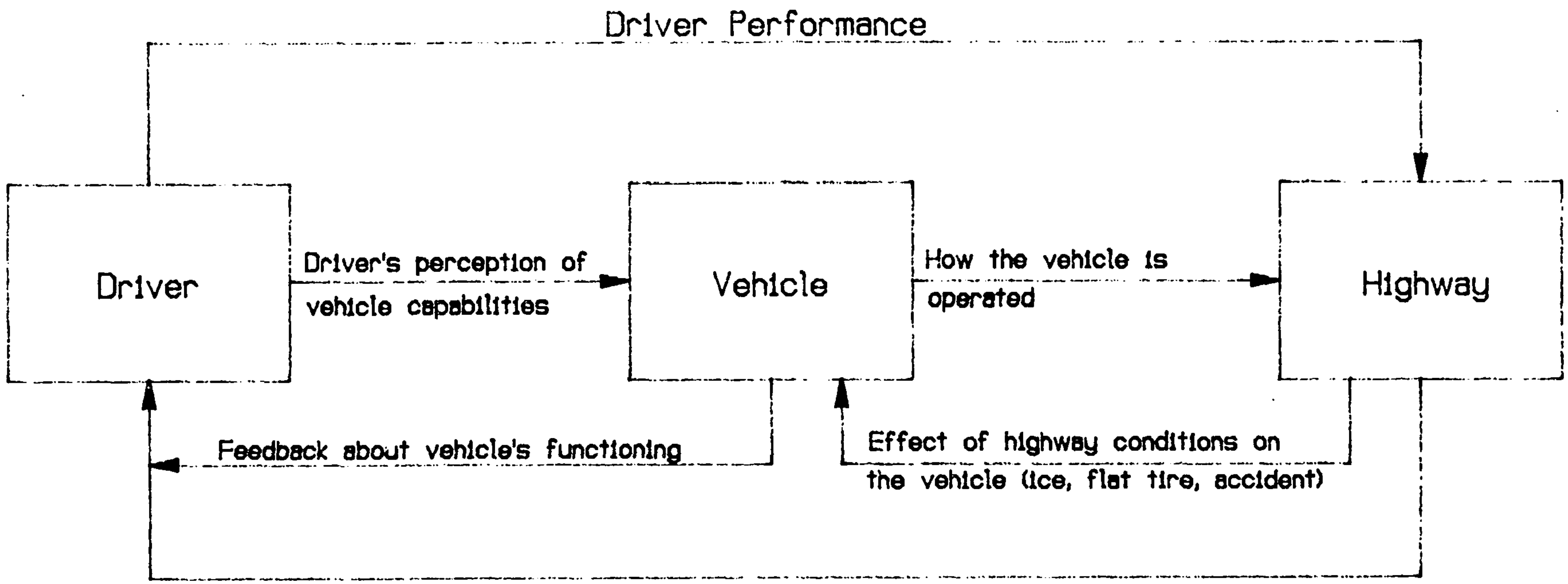
Age--Kochhar and Ali (1979) conducted a study to examine age as a function of speed of motor performance and ability to make decisions. They found significant differences between 52-63 year old subjects and those from 18-29 years of age. Differences became greater as information load increased, indicating that older subjects may suffer an increased problem with information processing.

In a study by Galin (1981) age was found to be related to drivers' speed in light vehicles, but not in heavier ones. Wasielewski (1982) also found that speed was affected by driver age, with younger drivers going at greater speeds. Summala and Naatanen (1974) found that age had no effect on perception of highway traffic signs when subjects received a monetary reward. This marked contrast to studies mentioned previously may be due to methodological problems, such as the small number of subjects tested or the experimental instructions having explained that perception of highway signs was being researched.

Driving Record - Prior violations and accidents are good predictors of future violations and accidents. An excellent review of pertinent studies is available in Goldstein (1961).

A widely researched concept in the literature of the 1940's and 1950's was accident proneness. The study of

Figure 1. Relationship of Driver, Vehicle, and Highway Variables on Risk Peception



DRIVER VARIABLES

Age
Sex
Driving record
Driving experience
Impairment:
- physical
- mental/emotional

VEHICLE OPERATION

Speed
Gap or headway

HIGHWAY VARIABLES

Curves
Hills
Signing
Traffic density
Roadway geometry
Construction

drivers with histories of multiple accidents was deemed of importance in the isolation of a profile of the "high risk driver." The hypothesis was that these drivers "perceived" the highway environment differently from other individuals on the road. The hope was that these differing perceptions could be brought closer to the norm through education and training. To that end, exhaustive studies were conducted which, in fact, supported the contention that there were factors about these drivers that differed from the norm. Unfortunately, these factors varied from study to study (Arbous & Kerrish, 1951; Brody, 1951; Farmer & Chambers, 1945), rendering a conclusive profile of the "high risk driver" impossible to determine. This was also true for the "normal" or "low-risk" driver, thus highlighting the individual differences of drivers without shedding light on how they perceive risk.

Farmer and Chambers (1939) examined accident-proneness in 166 bus drivers. They studied the driving records for these subjects over a 4-year span. Significant correlations were found that suggested that drivers having accidents in one year were more likely to have had accidents in any of the other years.

Sixty-nine female and 246 male drivers served as subjects in the research of Goldstein and Mosel (1958). Previous violation histories for each subject were compared with accident histories (where the subject was at least partially responsible) and significant positive correlations were obtained. However, the researchers point out (Goldstein, 1961) that violations are probably over represented because accident-related violations are not separated from violations for other causes.

The studies discussed in this section have elicited widely divergent results in terms of the characteristics of the high risk driver. Only a few characteristics emerge consistently. The most reliable have indicated that young male drivers are the most at risk. While previous accidents and violations have also proved to be good predictors of future accidents, correlations have been uniformly low, though significant. There are also several problems inherent in assessing this variable. First, accidents are under-reported. "Fender-benders" frequently are settled between the parties involved to keep insurance complications minimal, and to protect both clean and less-than-spotless driving records. Single vehicle crashes are also suspected of occurring with more frequency than they are reported. This reduces the accuracy of drivers' histories. Second, as mentioned earlier, violations issued in conjunction with accidents are rarely separated from those for other reasons. This inflates correlations between the histories and accidents (Goldstein, 1961; Lynn, 1976).

Lynn (1976) summarized several of the characteristics that have been associated with the high risk driver. Among those that are positively correlated are previous violation/accident history, education level, and acceptance of risk. Income level, socioeconomic class, type and time of driving exposure, and age are negatively correlated.

Driving Experience - Studies of driving experience have produced some contradictory findings. Zwahlen (1984), in an extensive study of drivers' visual scan and fixation patterns as a function of highway signs and geometry (i.e. type of side lines, arc of curve, or type of paint illumination), has found no significant differences in how inexperienced or experienced drivers perceive the highway environment. Blaauw (1982) found mixed results. He compared experienced and inexperienced subjects in real and simulated driving situations. While both groups of subjects performed the same in both conditions for lateral movements, experienced drivers were found to exercise more consistent longitudinal control than inexperienced drivers in both conditions.

Driving Exposure - Insurance companies use number of miles driven as one of their criteria in computing rates. The more miles driven per annum, the higher the rate. While evidence suggests clearly that violations, particularly for speeding, increase with miles driven (Goldstein, 1961), the picture is not as clear for miles driven and accident rate (Goldstein, 1961; Goldstein & Mosel, 1958).

Performance, or Criterion Variables

Speed - Driving speed has been used frequently as a measure of risk taking behavior. Common sense dictates that if a dangerous hazard has been perceived and understood, then slowing down is the cautious and sensible thing to do. Conversely, if a driver travels at a speed faster than highway conditions indicate, it is evident that the driver is either willing to assume more risk or is not aware of it. (Berggren, 1970; Billion, 1958; Blaauw, 1982; Curry et al., 1975; Emmerson, 1976; Evans et al., 1982; Farouki & Nixon, 1976; Galin, 1981; Krzeminski, 1976; Mclean & Hoffman, 1973; Munden, 1967; Oppenlander, 1966; Shinar, McDowell & Rockwell, 1974; Taragin, 1958; Wasielewski, 1982.)

Accelerator Variables - As the name implies, these are vehicle operation variables related to the use of the accelerator. The most commonly examined of these is accelerator reversals. This is measured in terms of a set degree-of-arc change in either direction. Thus, if a 30° change were specified, then either depressing or releasing the accelerator by 30° would constitute a reversal. This variable allows an experimenter to track speed adjustments made by the subject in response to the highway environment in the absence of braking (Hagen, 1975; Roberts & Alicandri, 1985).

Steering Variables - Two steering variables are of note: Steering reversals and lane placement. Steering reversals are changes in the position of the steering wheel and are measured in the same manner as accelerator reversals. Lane placement refers to the position of a vehicle in its lane of travel as measured in terms of feet from either the center line or edge line. While steering reversals and lane placement clearly are related, it is possible to obtain a significant deviation in lane placement without a change in steering wheel position large enough to be termed a reversal. Studies taking these measures find them useful in ascertaining driver skill, difficulty of the driving task in certain highway environments, and differences due to gender or age of driver (Alicandri & Roberts, 1985; Hagen, 1975; Robinson, 1975).

Braking Variables - These include the average brake force used in any one brake application, the number of brake applications, and the maximum brake force used during any application. Argument exists as to whether more skillful drivers control speed through the use of accelerator or braking variables (Hagen, 1975). Both types provide useful information, however. Again, research has used braking variables to predict driver performance based on age and experience, to ascertain the difficulty of the driving task under high information load, and to examine driver skill (Curry, Hieatt & Wilde, 1975; Roberts & Alicandri, 1985; Stephens, 1984).

Highway, or Modulator Variables

Curves - Curves have long been considered among the most dangerous features of the highway environment.

Attempts have been made to warn drivers of this danger through the use of signs (both before, and during the curve), different types of road delineation, and optical illusions to make curves appear sharper. Most changes are aimed at reducing a driver's speed on entering the curve and have met with varying degrees of success (Emmerson, 1970; Lefeve, 1954; Krzeminski, 1976; Shinar, McDowell & Rockwell, 1974; Rockwell, Malecki, & Shinar, 1975; Taragin, 1954).

Restricted Preview and Hills - These two variables are closely related. Restricted preview is reduced visibility due to weather conditions, or physical/environmental obstruction. While restricted preview can occur with any highway geometry (including straight-aways in adverse weather), it is restricted preview itself that causes the danger on hill crests. Restricted preview has been researched to ascertain what is the minimal distance necessary to perceive accurately the possible risk. Hills have been studied in much the same fashion as curves. Again, speed is frequently the variable used to judge whether the danger has been perceived (Eck & Leckok, 1980; Lovegrove, 1979; Mast, 1984; Mclean & Hoffman, 1973).

Signs and Signals - While intended to warn motorists of dangers and improve traffic flow, this aspect of the highway environment has its own problems and risks. Failure to perceive and understand signs is a common and widespread problem, despite the thousands of dollars and man-hours committed to it by FHWA, various State agencies, and academic communities (Rutley, 1979; Shinar, 1983; Smith & Lovegrove, 1983; Summala & Naatanen, 1974).

Methodologies Used in Highway Safety Research

Highway Simulation

Simulation is an important tool in highway safety research. It allows a wide variety of potentially dangerous situations to be observed, while protecting the safety of human subjects. Driving simulators are used to gather information about drivers' behaviors that is too expensive, time consuming, or dangerous to gather in the field. However, as simulators are not perfect replications of the real world, they must be validated. If they are not, the data collected through their use cannot be generalized to the real world, which is where the information is needed.

The FHWA's driving simulator (HYSIM) is an interactive, computer-generated simulation that samples a wide variety of driver behaviors as often as every .03 seconds. It is a fixed-base system, and is limited to the simulation of night driving only. This limitation exists for several reasons. First, as the computer-generated simulation lacks visual complexity, this has been overcome in part by creating a night scene, where complexity is expected to be limited. Second, if research must be limited to either day or night conditions, the night condition is the more dangerous of the two, allowing for more generalization of results. Last, simulation of night conditions allows the experimenter a broader choice in the degree of luminosity for various highway markers, such as lane and edge lines, road signs, and signals. More information on HYSIM is provided in Appendix B.

As mentioned above, the utility of this simulator for research depends on its ability to present accurately the essential characteristics of actual driving. The validation of this simulator was undertaken in 1984, using a correlational design. One hundred subjects drove a 10-mile stretch of roadway in the Northern Virginia suburbs. This roadway consisted of interstate highway, rural 2-lane roads, and undivided 4-lane highway near a major shopping mall. They drove a simulation of the same in the HYSIM. Correlations ranged from moderate (.49 for left turn simulation) to quite high (.98 for some aspects of rural road, such as speed of curve negotiation), indicating that HYSIM does a respectable job of mimicking the real world (Roberts & Alicandri, 1985).

HYSIM provides a number of advantages for highway research. It allows actual roadways to be simulated with a high degree of fidelity, thus letting experimenters test driver performance in unsafe situations, and generalize that behavior to the environment. Accidents, and the events leading to them, can be studied at will, creating much new information about drivers and their perceptions of the road.

The Use of Photograhic Slides with Paired Comparisons

Transportation research has employed two other methods of note for assessing driver behavior. These are the use of photographic slides (as opposed to motion pictures, video tape, or simulation), and the presentation of paired comparisons.

Photographic slides have been used to observe a variety of driver characteristics/attitudes. They offer several advantages. First, as with simulation, they allow subjects to provide information on highway safety without placing them in possibly dangerous situations. Second, they are inexpensive, easily obtained, and involve little specialized equipment. Last, and most important, unlike motion pictures and video tape, the static images of slides provide no clues to the possible risk inherent in a traffic site that acceleration and braking provide in moving images.

Colbourn (1978) used slides to determine perception of risk in British drivers. Slides of various roadway sites were taken based on the experimenter's or the camera operator's decision that such a site appeared "risky". Groups of subjects were shown each slide for a five second interval, followed by a five second period in which to record their responses. Subjects were to decide if each site would require them to make a "driving maneuvre" such as braking, accelerating, or changing their steering direction, and then rate the probability of that maneuver as 1/10, 3/10, 5/10, 7/10, or 9/10. The groups of subjects received differing instructions about the driving scene, such as being on a family drive, rushing to a hospital (alone), being late for a business appointment, teaching a younger person to drive, or taking a regular commuting or shopping drive. Results indicated that family drives and teaching situations generated the same estimates of risk, which were substantially lower than for other conditions. This suggested that "stressful" driving instructions caused the roadway in general to be perceived as more dangerous. A problem with this method was noted. When subjects were asked what information could have helped them in their decisions, they suggested that they lacked valuable data that would have been gained in the drive approaching the sites.

Gallagher and Lerner (1983) used slides to examine the degree of visual complexity in various highway environments. The slides were originally created by the Institute for Research (see Mace, Pollack, & Perchonok, 1981, for further details). Twelve men and 13 women were shown the slides and asked to rate "how difficult the view was for driving". A 9-point Likert format was provided ranging from "not difficult" to "extremely difficult". Results indicated that subjects used the entire range of the scale, and that the ratings were strongly dependent on the slide.

The technique of paired comparisons is a psychophysical method that allows for the scaling of data that otherwise would be restricted to the ordinal level (Kling & Riggs, 1972). Cohn (1894) first introduced the method of paired comparisons, which was later refined by Thurstone in his Law of Comparative Judgments (Kling & Riggs, 1972).

This method requires subjects to view all possible pairs of stimuli, and decide which member of each pair is greater (or less) on the variable of interest. The pairs are presented randomly. The number of pairs is determined by the formula, N(N-1)/2. The repeated presentations of the stimuli produce a distribution that is assumed to be the same whether it was obtained from different individuals on one trial or from one individual on different trials. An advantage of this method, in addition to the quantitative ones listed above, is that it can be used with any stimuli that can be presented in pairs. It should be noted, however, that boredom and fatigue can present a problem when the number of stimuli generate large numbers of pairs.

Bragg and Cousins (1978) used this technique in assessing perceived likelihood of arrest for driving under the influence of alcohol. Subjects were asked to indicate if their chances of arrest for each specified set of driving behaviors (i.e. driving under the influence, speeding, etc.) were closer to one in 100 or one in 10,000. The most frequently chosen alternative is the best estimate of the perceived risk.

The combination of static slides presented in paired comparisons has been rarely used. This is due, in part, to the belief that the static nature of slides produces an artificial visual environment, devoid of some of the information provided by film, video tape, or simulation. However, moving images, with the exception of computer generated simulation, provide valuable clues to the danger of a particular traffic situation through the acceleration and braking done by the driver of the vehicle from which they are filmed. The use of paired comparisons has been rare not because of criticisms of the methodology as much as because the creation of a scale can require excessive time.

Operational Definitions and Experimental Hypotheses

Risk taking, life stress, and the perception of risk are cognitive processes, inaccessible to direct measurement. Thus, carefully defined behavioral units that are theoretically linked to cognition must be established. Risk-taking can be behaviorally and operationally defined, and the probabilities assigned to outcomes provide a means of measuring the risk involved in any alternative. Life stress can also be assessed through paper-and-pencil measures, and its influence on driving behavior can be determined.

In defining perception of risk, it is necessary to make a distinction between this concept and actual, objective risk. Objective risk can be measured with accident and violation data for specific sites. It can be calculated based on the geometry of the road, and available information of usual speeds. In contrast, perception of risk is a subjective measure of risk, based on an individual's experience in the highway environment, his/her current level of stress, and his/her proclivity for risk-taking behavior.

This study was undertaken to explore the effect of life stress (as measured by the Holmes Stress Scale), risk-taking style (as measured by the Kogan-Wallach Choice Dilemma Questionnaire), perception of risk, and gender on driver performance. Specifically, this study examined the hypothesis that as risk-taking and stress increase, so does the likelihood of misperception of highway stimuli, and the likelihood of inaccurate and dangerous driving maneuvers. Driver gender and type of roadway driven were also expected to be related to performance. Further, this experiment was designed to test the hypothesis that subjective perception of risk is frequently different than the objective risk actually present. To achieve these goals, the study consists of two components. In the first, the impact on driving performance of four variables, risk-taking style, life stress, gender, and degree of difficulty of the highway, were assessed. In the second, subjective estimates of risk were obtained and compared with the objective associated with 10 highway sites.

The above variables were used to dichotomize subjects into discrete groups. Risk taking and life stress were subdivided into two major ordinal categories, High and Low, based on the mean score for subjects on these measures. Including gender, this resulted in eight groups. Specific hypotheses for these variables are as follows:

1) Subjects categorized as High Risk (HR) and High Stress (HS) have the poorest driving performance, and are the most likely category to experience an accident in the simulator.
2) Subjects categorized as Low Risk (LR) and Low Stress (LS) perform the best in the the simulator, with the smallest chance of accident.
3) Males have more accidents, and drive at higher speeds than females.

The fourth independent variable will be the type of scenario driven in a highway simulator (HYSIM). Two scenarios were constructed, one considered to be a dangerous (hard) highway environment, and one considered to be safe (easy). The hard scenario had a probability of accident of .90, while the easy scenario had a probability near zero. These probabilities were constructed based on objective accident data for similar highway features in the natural environment. The dependent measures of driving performance were 1) maximum brake force, 2) average brake force, 3) number of brake applications, 4) speed through zones, 5) number of accidents, 6) lane placement, and 7) steering reversals. The eight groups were subdivided into hard and easy task groups. This results in a 2 x 2 x 2 x 2 between subjects design (hard and easy scenario, by high and low stress, by high and low risk, by gender). It was hypothesized that no accidents would occur in the easy scenario, and that HR subjects would drive at significantly faster speeds than LR subjects. HR-HS subjects were hypothesized to show more corrective driving manuevers in the hard scenario (steering reversals, changes in lane placement, higher scores on braking variables). LR-LS subjects were expected to travel more slowly in either scenario, with fewer corrective driving maneuvers.

The second component of this study was the paired comparisons of slides of 10 highway sites for which actual risk data were obtained from law enforcement agencies. Subjective estimates of risk were generated for each subject, and over all subjects, and compared to the actual accident data. It was hypothesized that individual estimates of risk would vary, with some closely approximating objective risk, while others would not. It was further hypothesized that subjects who were both HR and HS would do the most poorly at accurately assessing risk.

Several driver variables were also examined. These were age, driving experience, driving exposure, type of exposure, and accident/violation history. Subjects were pre-screened by phone for impairment and access to driving records. Individuals with poor accident/violation histories were expected to perform more poorly in the simulator.

Method

Because of the complexity of some of the procedures used in this study, the methods are presented as three phases. Phase 1 involved the administration of paper-and-pencil measures, such as the life stress, risk-taking and demographic questionnaires. Phase 2 marks the presentation of the paired comparisons presentation of slides of highway sites. The use of the FHWA highway simulator comprises Phase 3.

Subjects

Twenty-four women and 26 men (N=50) served as subjects for this study. All were recruited through a newspaper advertisement in a local newspaper in McLean, Virginia. All subjects were pre-screened for the following:

1) Impairment--only physically and mentally healthy individuals participated. Mental health was operationally defined as no prior history of psychiatric hospitalization, and no psychotherapy in the last 2 years
2) Driving records--all individuals were told that they would have to sign a release giving the experimenter access to their Department of Motor Vehicles record. This was not actually done, but was mentioned to help ensure accurate reporting of accident/violation history.

Each subject received $25.00 for his/her participation.

Apparatus

Phase 1 - The 12-item Kogan-Wallach Choice Dilemma Questionnaire, the 42-item Holmes Stress Scale, and a 1-page questionnaire on driver variables were given in this phase (see Appendix A). The Holmes Stress Scale uses a cutoff score of 300 to indicate highly stressed subjects. Anyone with a score less than 300 is not considered at risk for accident or illness. The Kogan-Wallach has a range of possible scores from 12 to 72, with higher risk taking associated with lower scores. A score between 30 and 40 generally is used to divide high and low risk takers. For this study, subjects were placed into 4 high-low risk and stress categories based on the mean value on the Kogan-Wallach and Holmes measures.

Phase 2 - Two Kodak Carousel Slide Projectors and four carousel trays were used to present 270 slides to the subjects. The slides were of 10 highway sites in Virginia Beach and Fairfax County in Virginia. A rear projection screen in the Pupilometry Laboratory at the Turner-Fairbanks Highway Research Center was used. An answer sheet was provided to every subject.

Phase 3 - In this phase, subjects drove in the Highway Simulator located in the Turner-Fairbanks Highway Research Center. For an explanation of the simulator's capabilities and specifications, see Appendix B.

Procedure

Phase 1 - In this phase, subjects answered the three questionnaires: the questionnaire on driver variables, the Holmes Stress Scale, and the Kogan-Wallach Choice Dilemma Questionnaire. The questionnaires were presented in counter-balanced order to counteract fatigue effects. This phase was self-administered, and took from 20-45 minutes to complete.

All subjects signed an informed consent sheet (see Appendix A) before beginning the experiment. At the same time, they were apprised of FHWA's adherence to strict subject confidentiality standards.

Phase 2 - Rural highway sites in Virginia Beach and suburban sites in Fairfax County were selected to represent a wide range of risk, from none, to extremely high (a high priority for Virginia Traffic Engineers to replan and restructure, based on high numbers of accidents, with concomittant injuries, and deaths). In order to provide as much information as possible to the subjects, highway sites were presented in a series of 3 slides: two of the approach to the site, the third of the site itself. This was done to avoid the major difficulty with static images (lack of preview information) while avoiding the clues provided by film and video tape.

The task of subjects in this phase was to decide which of a pair of highway sites was the more dangerous, in their opinion. A rear projection system was used to present 45 independent trials of paired comparisons of slides to the subjects. A total of 10 highway sites were presented, each site paired with every other site (no. of comparisons = $(N^2-N)/2$). Each highway site consisted of three slides: the first two providing an idea of what it would be like on the approach drive to the site (step-up slides), with the third slide being of the site itself. Subjects were provided with clipboards, pens, and answer sheets and were given verbal instructions on the presentation method. They were then taken through example slides to make sure they understood the procedure. The procedure was as follows: (1) the screen was labeled with the letter "A" on the left-hand side, and the letter "B" on the right-hand side; (2) one step-up slide was presented, followed by the second step-up slide, followed by the site slide, which was left up on the screen; (3) the first step-up slide for the second site was projected on the other half of the screen, followed by the second step-up slide, and finally the site slide; (4) with both site slides side-by-side on the screen, subjects were asked to check the box on the answer sheet corresponding to the side of the screen in which, in their opinion, the more dangerous highway site had been projected.

The experimenter controlled the pace of the slide presentation, but subjects were allowed to request a slower or faster pace. There were four different orders of slides, each of which had been generated randomly. Which slide order a subject saw was determined through counter-balancing. This phase took about 20 minutes.

<u>Phase 3</u> - In this phase, subjects drove one of two

scenarios in HYSIM. These scenarios differed as follows:

1) Hard Scenario--high risk of accident--probability of accident if misleading road signs were obeyed was approximately .90. This scenario included several of the riskiest slide sites (a changing radius curve, and an unmarked intersection with a partially obscured view)

2) Easy scenario--low risk of accident--probability of accident, regardless of conditions, near zero. This scenario included the safest sites from the slide presentation (unobscured straightaways, gentle curves).

Due to the limitation of HYSIM, many roadway features could not be simulated (such as signals, hills, and daytime features). However, the entire gamut of vehicle operation characteristics was available (with the exception of gap acceptance, which could not be simulated at the time) and was used. These included 1) maximum brake force, 2) average brake force, 3) number of brake applications, 4) speed through zones, 5) number of accidents, 6) lane placement, 7) steering reversals, and 8) time spent in a zone.

1. Maximum brake force represents the largest single application of brake force in a zone. It is measured in pounds of pressure per a .03 second sample.

2. Average brake force is also measured in pounds of pressure, but is averaged across the .03 second samples of each brake application.

3. Number of brake applications is a frequency measure for each zone. A threshold pressure of .5 lbs was needed to be counted as a brake application. Pressure was required to return to zero to mark the end of the application.

4. Speed through zones was measured twice, both as the average of .03 second samples, and as the standard deviation of those same samples. Standard deviation of speed provided the extra dimension of how much speed varied within a zone. Feet traveled per second was the computation used to determine speed.

5. Number of accidents is how often a driver had an accident in the simulator. An accident occurred whenever the car left the simulated roadway. This could happen in any of three fashions: 1) the driver could lose control of the vehicle, 2) the driver could leave the shoulder of the road, and 3) the driver could ignore a directional sign and enter a section where the simulation ceased.

6. The standard deviation of lane placement represents the amount of variability the driver shows in maintaining his/her vehicle within a certain number of feet from the center line. The more accurate the individual's perception of upcoming highway, the more likely that individual will use speed and braking variables to compensate, rather than change position.

7. Steering reversals were determined by a change of 15^{o} arc or more. Number of reversals is related to lane placement, but provides much information that is not

redundant. It is possible to have a steering reversal while negotiating a curve or turn, without deviating significantly from the center line.

8. Time spent in a zone is a measure that incorporates the amount of time a subject spent driving a particular zone, and as such, combines information received about speed and crashes. It is measured by the number of seconds an individual took to complete a fixed number of feet while driving the FHWA simulator. A long zone time is caused by slow driving speeds, by an accident occurring within the zone, or both.

Subjects were randomly assigned to a scenario by the HYSIM operator, to avoid experimenter bias. This assignment was done by pairs of subjects. The first subject of each pair was assigned randomly. The second subject was then placed in the other scenario. The only restriction on scenario assignment was a history of motion or simulator sickness. If a subject reported previous problems with motion or simulator sickness, s/he was assigned to the easy scenario, which was less likely to cause nausea.

Before driving the actual scenario, each individual was given a 15 minute practice drive in the simulator with the experimenter present. S/he was told to operate the vehicle as s/he would normally, and to feel free to adjust the seat if necessary, wear a seat belt (if that was what would happen normally), and to listen to the radio, if that was a routine part of driving. At the end of the practice drive, subjects were given an opportunity 1) to stop if they felt dizzy or nauseous 2) to re-drive the practice route if they were not yet accustomed to the simulator, or 3) to proceed with the scenario. Both scenarios were about 30 minutes long, depending on driving speed, and whether a crash occurred. A crash in the simulator is signaled by the "blanking" of the projection screen and a 70 decibel crash sound. The blanking of the screen occurs because the car is no longer on the computer generated track. It takes approximately one minute for the operator to re-synchronize the car and the screen, which allows the subject to recover from the sometimes startling effects of a simulated accident.

The three phases described above were given in counterbalanced order to correct for fatigue. The entire experiment took about 1 1/2 hours for the subjects. Subjects were usually run in pairs. Each pair would see the slides together, but one would drive the simulator while the other answered the paper and pencil measures. Fifty subjects answered the questionnaires and drove in HYSIM. However, one subject was lost in Phase 2 (paired comparisons) due to equipment malfunction.

As outlined in the introduction, a number of variables were examined for their possible influence on stress, risk, driver performance, and each other. Due to the number of subjects who participated in this study, these variables could not be incorporated in an experimental design, but had to be assessed correlationally. While these variables have relevance to this study, they were not experimentally controlled.

RESULTS

All variables in this study were examined to ensure that they were normally distributed. None were found to violate this assumption significantly.

As subjects drove only one scenario in this study, t-tests were calculated to compare differences between the hard and easy scenario on all demographic variables, stress level, and risk. No significant differences were found, confirming that subjects had been assigned randomly to each of the scenarios.

Although maximum brake force, average brake force, and number of brake applications were measured for all subjects, they were not analyzed because braking variables were only used in the hard scenario. No one applied the brakes in the easy scenario.

The results have been organized in the following manner. First, the effects of scenario, gender, risk, and stress are presented with specific HYSIM performance variables discussed under the headings of all main and interaction effects. Second, the ability to judge risk accurately is presented in a section on the paired-comparison method. Last, the correlational assessment of other driver variables is discussed.

Effects of Scenario, Stress, and Risk on HYSIM Performance

To assess the effects of risk-taking style (high and low), life stress (high and low), gender, and HYSIM scenario (hard and easy) on the six driver performance variables (average speed over zones, standard deviation of speed over zones, number of accidents, standard deviation of lane placement, steering reversals, and time spent in zone), a 2x2x2x2 MANOVA was computed. The results of this MANOVA showed that there was no significant main effect for gender, nor for any of its seven interaction terms. It was then decided to remove gender from the subsequent MANOVA calculations, resulting in a more conservative set of computations, as the original 16 cell design contained some cells with extremely small n's. The resulting 2x2x2 design was computed on the same 6 performance measures. Omega sqares were calculated for all significant multivariate and univariate effects. Significant univariate interactions were further examined, using Tukey's HSD for mean comparisons.

The MANOVA yielded statistically significant main effects for Scenario ($F(6,37)=109.36$, $p<.0001$), Stress ($F(6,37)=3.26$, $p<.01$), and Risk ($F(6,37)=4.04$, $p<.005$), confirming the hypothesis that these variables affect driving performance.

All of the interaction effects attained significance. These were Scenario x Stress ($F(6,37)=3.11$, $p<.05$), Scenario x Risk ($F(6,37)=4.48$, $p<.005$), Stress x Risk ($F(6,37)=3.33$, p<.01), and Scenario x Stress x Risk (F(6,37)=3.34, p<.01). These interactions are discussed in more detail below.

All significant effects, both in the MANOVA and the ANOVAs are presented in Table 1.

Scenario. The univariate analyses of variance reveal that there was a significant main effect for every variable except number of accidents. The hard scenario had significantly longer zone times than did the easy scenario (F(1,42)=496.81, p<.0001). Standard deviation of lane placement, representing variability within the lane over time (as measured in feet from center line), indicated that subjects driving the difficult scenario had larger deviations from the center line (F(1,42)= 27.52, p<.001). Average speed over all data zones was slower in the hard scenario (F(1,42) = 23.39, p<.0001). Standard deviation of speed (F(1,42)=133.64, p<.0001) demonstrated higher variability in speed in the hard scenario than in the easy one. Also, there were more steering reversals in the hard scenario than in the easy one (F(1,42)=205.31, p<.001). The omega squared for this main effect shows that scenario accounts for 87% of the variance in the MANOVA.

Stress was a significant main effect for all variables except average speed through zones. Highly stressed subjects had longer zone times than subjects under less stress (F(1,42)=17.29, p<.05). Highly stressed subjects had larger

Table 1. Summary table for multivariate analysis of variance (MANOVA) and associated univariate ANOVAs

MANOVA

Effects	F-value	p-value	w2
Scenario (S)	109.36	0.0001	.87
Stress (ST)	3.26	0.05	.02
Risk (R)	4.04	0.01	.02
S x ST	3.11	0.05	.02
S x R	4.48	0.001	.03
ST x R	3.33	0.01	.02
S x ST x R	3.34	0.01	.02

UNIVARIATES (F, w2)

EFFECTS	Speed (AVG)		Crash		Lane	
	F	w2	F	w2	F	w2
Scenario	23.39	.69	---	--	27.52	.54
Stress	---	--	---	--	4.39	.07
Risk	10.72	.30	---	--	---	--
S x ST	---	--	6.31	.32	---	--
S x R	---	--	6.69	.34	14.05	.27
ST x R	---	--	6.31	.32	---	--
S x ST x R	---	--	---	--	4.47	.07

EFFECTS	Steer		Speed (SD)		Zone	
	F	w2	F	w2	F	w2
Scenario	205.31	.82	133.64	.92	496.81	.82
Stress	5.00	.02	4.12	.02	17.29	.03
Risk	13.83	.05	---	--	17.19	.03
S x ST	10.29	.04	---	--	18.61	.03
S x R	---	--	6.62	.04	19.24	.03
ST x R	4.69	.01	5.08	.03	18.30	.03
S x ST x R	14.12	.05	---	--	17.66	.03

deviations from the center line ($F(1,42)=4.39$, $p<.05$). There was more variability in speed in stressed drivers ($F(1,42)=4.12$, $p<.05$). Finally, highly stressed individuals reversed course more often than those less stressed ($F(1,42)=5.00$, $p<.05$). This variable accounted for only 2% of the total variance in the MANOVA.

Risk was a significant main effect for average speed, time spent in zones and number of steering reversals. Risk taking style indicated that high risk takers took longer to complete zones than low risk takers ($F(1,42)=17.19$, $p<.05$). Average speed over all data zones indicated that high risk drivers actually drove slower than low risk drivers ($F(1,42)=10.72$, $p<.005$). High risk takers made significantly more course corrections than those with low risk-taking profiles ($F(1,42)=13.83$, $p<.05$). This variable accounted for only 2% of the total variance.

Scenario x Stress. For time spent in zones, the hard scenario had the longest zone times. Within the easy scenario, zone time was greater for highly stressed subjects, while no comparable increase was found in the hard scenario (see Figure 2). Mean comparisons indicated that all cells differed from one another, with the exception of both cells in the hard scenario, which were essentially equal to each other.

Scenario x Stress for number of accidents indicated that low stress produced more accidents in the hard scenario, none in the easy, and that high stress had an intermediate number of accidents in both scenarios ($F(1,42)=6.31$, $p<=.01$, see Figure 3). Tukey's HSD indicates that this was the only significant difference. Essentially, stress level only affected performance in the easy scenario.

For number of steering reversals, HS-HR subjects also corrected course significantly more often than any of the drivers of the easy scenario (see Figure 4). There were no differences within scenarios.

Scenario x Risk. These results were comparable to those for scenario by stress for time spent in zones, with low risk subjects in the easy scenario having the shortest zone time (see Figure 5). The results for the Tukey HSD displayed the same pattern as reported for the Scenario x Stress interaction, with the 2 cells in the hard scenario being not different from each other.

This was the only significant 2-way interaction for lane placement. Subjects with low risk-taking styles who drove the hard scenario had the highest degree of variability from the center line while low risk takers in the easy scenario had the least (see Figure 6). Here, values within each scenario were not significantly different from each other, but low risk-takers in the hard scenario differed from any drivers of the easy one. Additionally, high risk-takers in the hard scenario showed significantly more variation in lane placement than low risk-takers in the

Figure 2. Scenario x Stress Interaction for Time Spent in Zones

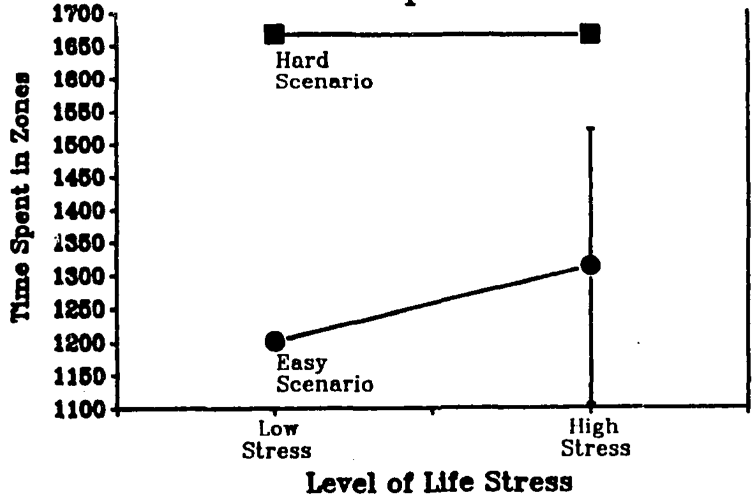


Figure 3. Scenario x Stress Interaction for Number of Accidents

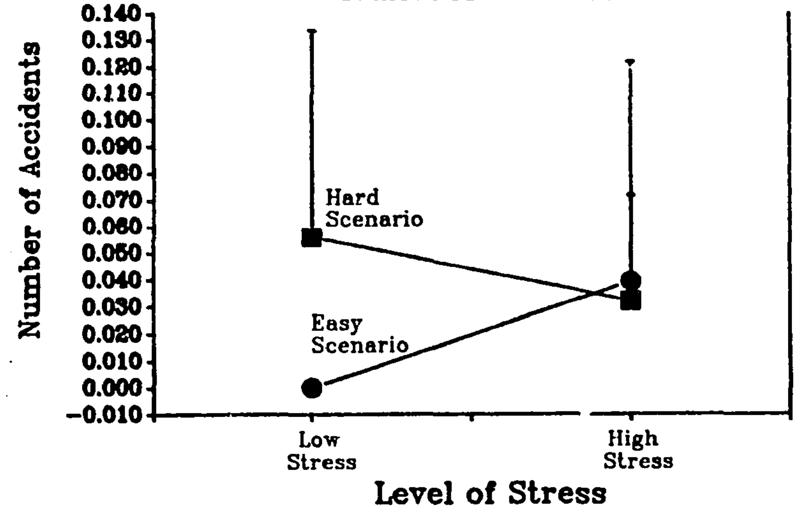
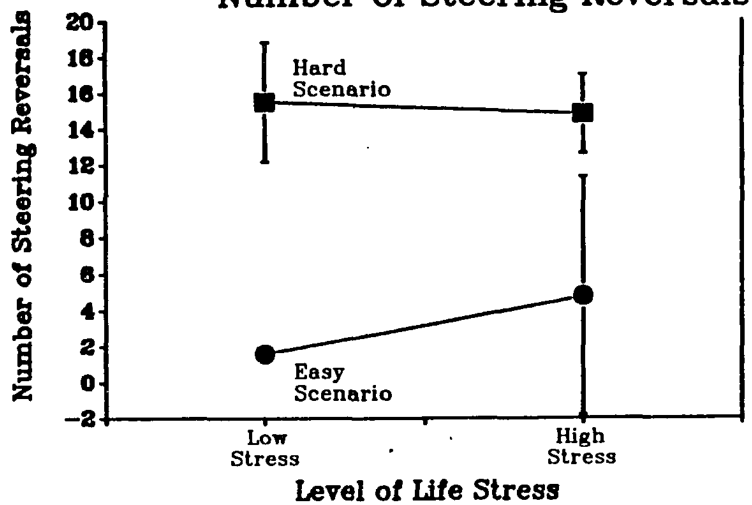


Figure 4. Scenario x Stress Interaction for Number of Steering Reversals



easy scenario.

For number of accidents, low risk drivers in the hard scenario had the highest rate of accidents, but were only significantly different from the low risk drivers in the easy scenario (see Figure 7). This was the only significant mean comparison.

For standard deviation of speed, Scenario x Risk continues to show the markedly higher variability in the hard scenario (see Figure 8). In addition, the highest variability is shown in low-risk subjects in the hard scenario, with the lowest variability in speed again in low-risk subjects, in the easy scenario. This was confirmed by Tukey's HSD. Within scenarios, there were no differences between risk levels.

Stress x Risk. In this interaction, LS-LR subjects had the shortest zone times, and HS-HR subjects the longest (see Figure 9). Mean comparisons indicate that the HS-HR individual is significantly different from any other, and that low risk takers, who have low life stress have significantly shorter zone times than low risk takers with high stress.

For number of accidents, HS-HR subjects had the most crashes, with low-stress high-risk subjects having the least in the stress x risk interaction (see Figure 10).

Stress x Risk indicated that HS-HR subjects corrected their course significantly more often than any

Figure 5. Scenario x Risk Interaction for Time Spent in Zones

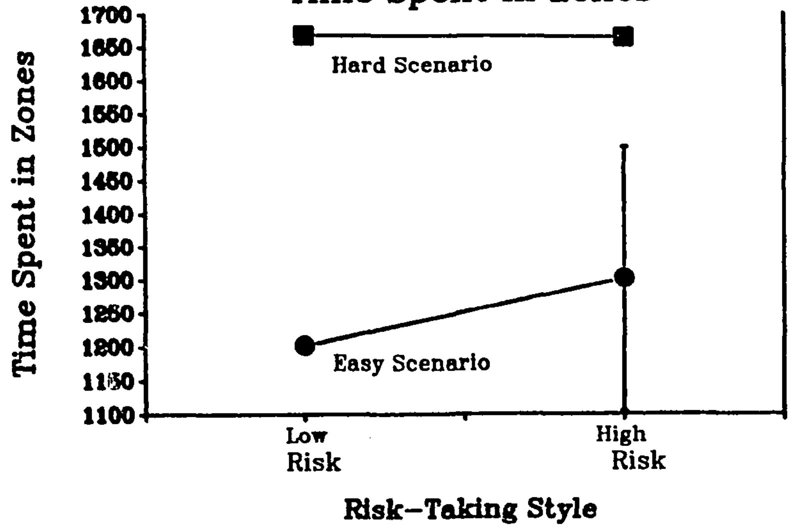


Figure 6. Scenario x Risk Interaction for Lane Placement

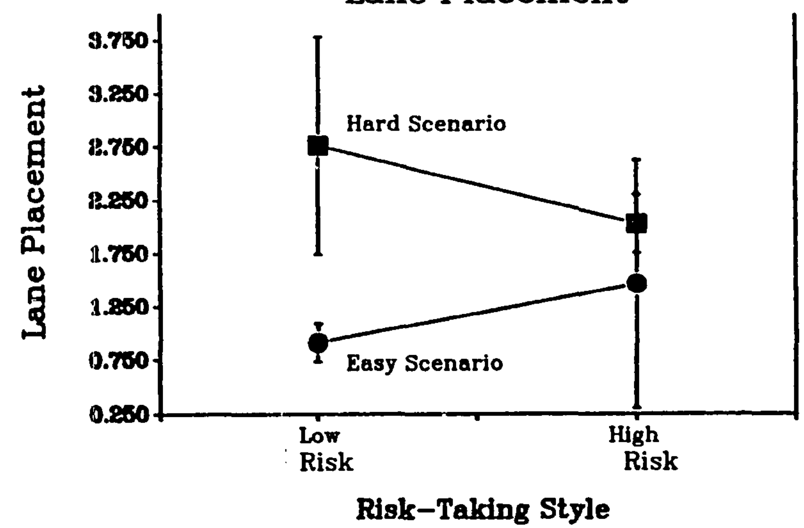


Figure 7. Scenario x Risk Interaction for Number of Accidents

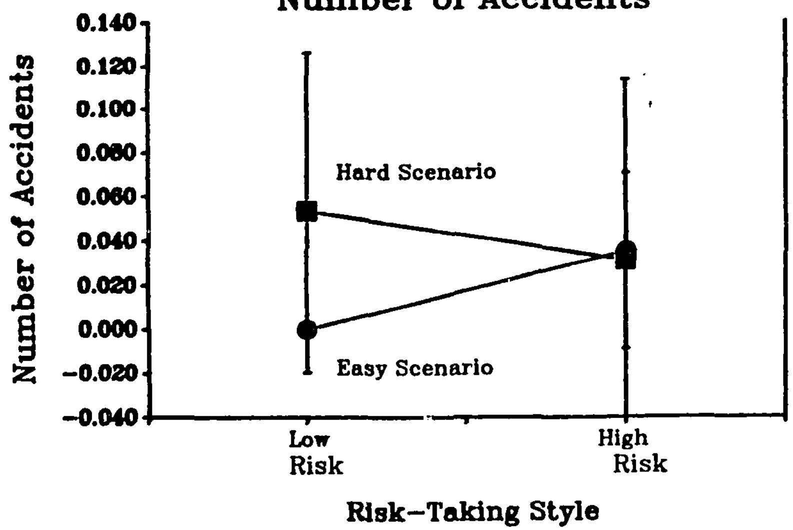
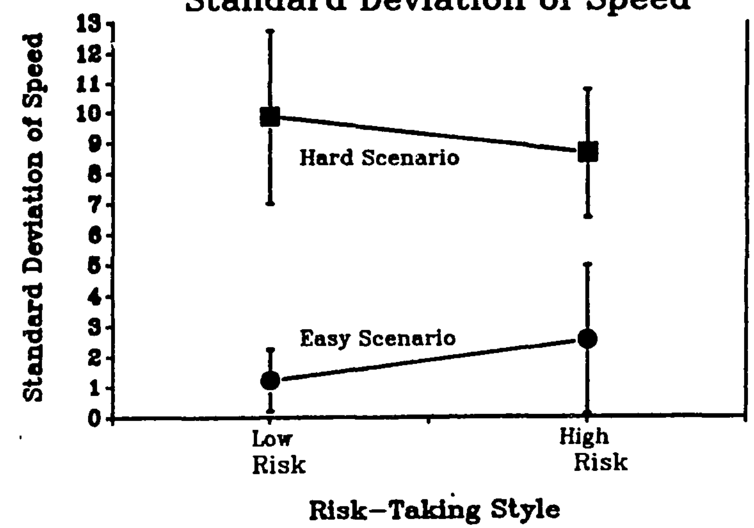


Figure 8. Scenario x Risk Interaction for Standard Deviation of Speed



other drivers, who were not statistically different from each other (see Figure 11).

Finally, Stress x Risk was also significant for standard deviation of speed. HS-HR subjects were significantly more variable than LS-LR and LS-HR individuals. HS-LR drivers were significantly more variable than LS-LR ones (see Figure 12).

As a general pattern, the LS-LR drivers were best across all driving variables while HS-HR were the poorest drivers. Clearly the combination of high risk and high stress puts the driver in the greatest danger regardless of scenario. When scenario difficulty is considered, as in the Scenario x Stress x Risk interaction, the same pattern reappears, but only in the easy scenario. The hard scenario apparently is sufficiently difficult as to minimize the importance of the other variables.

Scenario x Stress x Risk. Time spent in zones produced essentially equal mean times for the hard scenario regardless of stress level and risk-taking style. These means were uniformly large, and significantly different from any easy-scenario mean. HS-HR drivers of the easy scenario had significantly longer zone times than any other drivers of the same scenario, though these zones were still smaller than those in the hard scenario (see Figure 13).

For lane placement, Scenario by Stress by Risk indicated that HS-HR risk subjects in the easy scenario

Figure 9. Stress x Risk Interaction for Time Spent in Zones

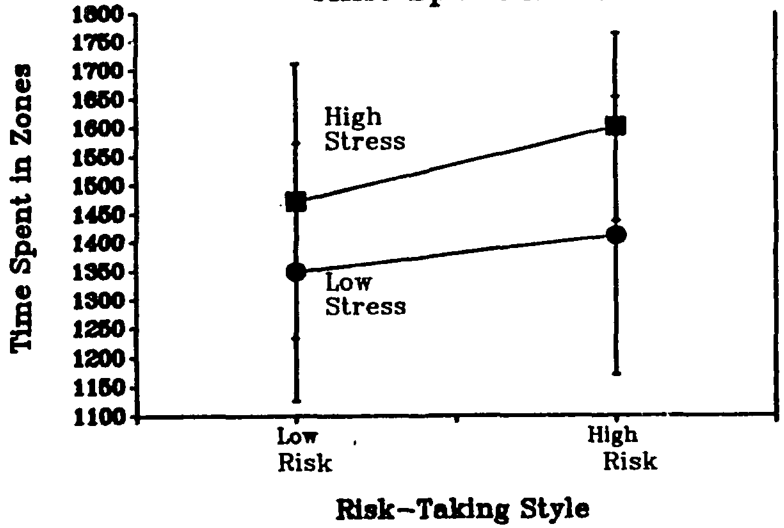


Figure 10. Stress x Risk Interaction for Number of Accidents

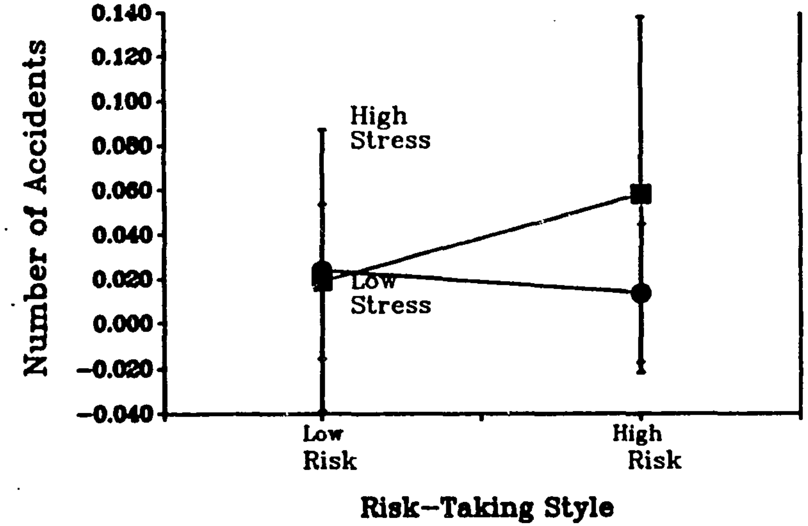


Figure 11. Stress x Risk Interaction for Number of Steering Reversals

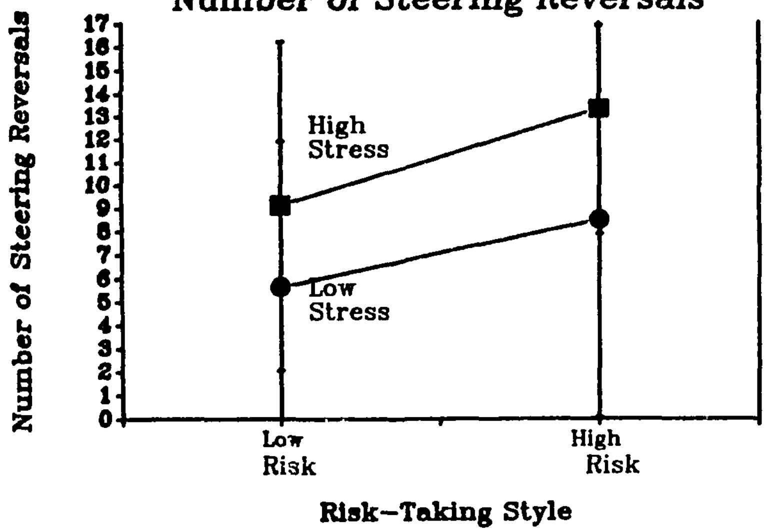
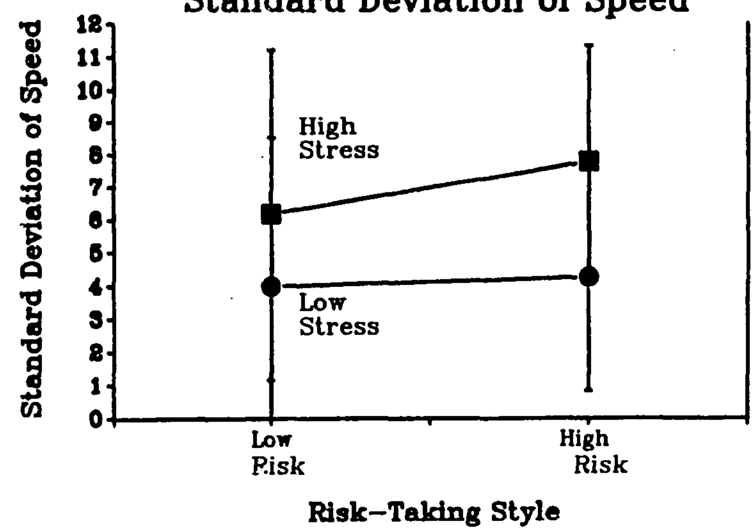


Figure 12. Stress x Risk Interactions for Standard Deviation of Speed



varied more from the center line, with HS-LR subjects in the easy scenario varying the least (see Figure 14). Low risk subjects in the hard scenario showed no differences attributable to stress, nor did they differ from high risk subjects in the same scenario. They were significantly different from all low stress subjects in the easy scenario, regardless of risk style, and different from HS-LR drivers of the easy scenario.

For the scenario x stress x risk interaction, few steering corrections were made at all in the easy scenario except by HS-HR drivers, who made significantly more. However, the number of corrections was still smaller than the number made by any driver of the hard scenario (see Figure 15). Within that category, LS-HR drivers made the most, differing significantly from all drivers in the easy scenario, and none in the hard.

Comparison of Subjective Estimates of Risk and Objective Risk

The paired comparisons of the 10 highway sites were evaluated for both individual and cumulative scale values. Correlations between these scales and the real-world scale (based on objective accident data) were run. While individual correlations varied from -.61 to +.70, the mean correlation was not statistically or practically significant ($r=-.02$), indicating that these drivers were not able to judge the risk involved at the various sites as presented in

Figure 13. Scenario x Stress x Risk Interaction for Time Spent in Zones

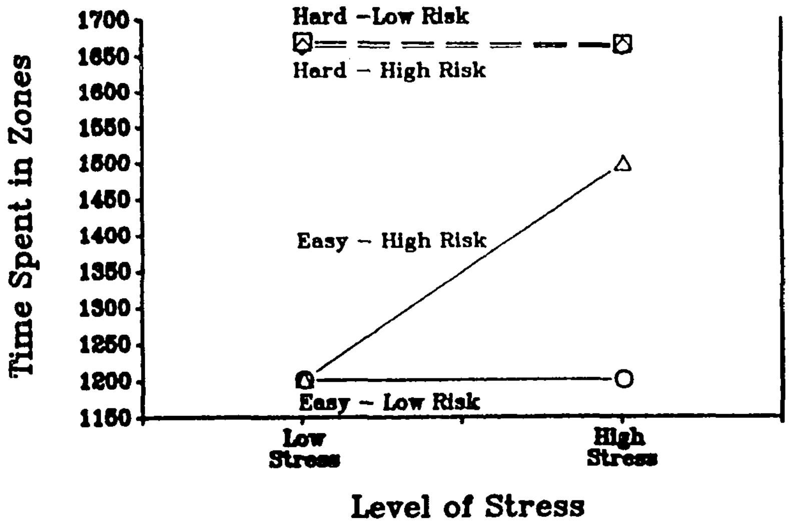


Figure 14. Scenario x Stress x Risk Interaction for Lane Placement

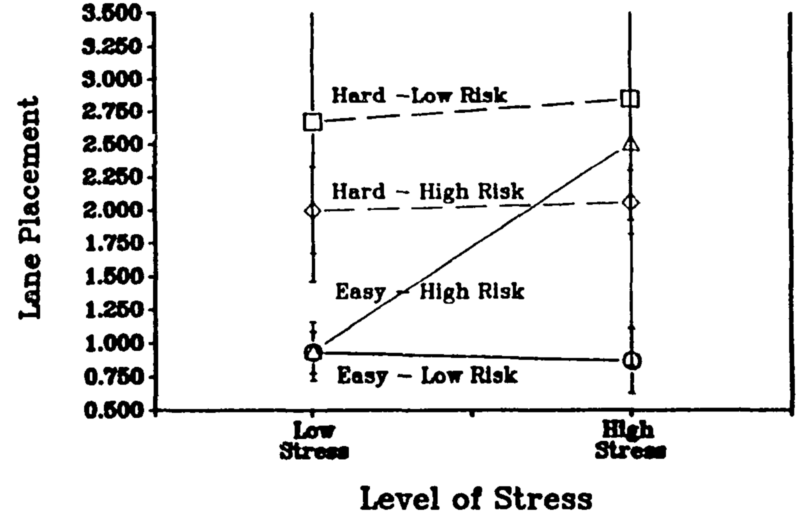
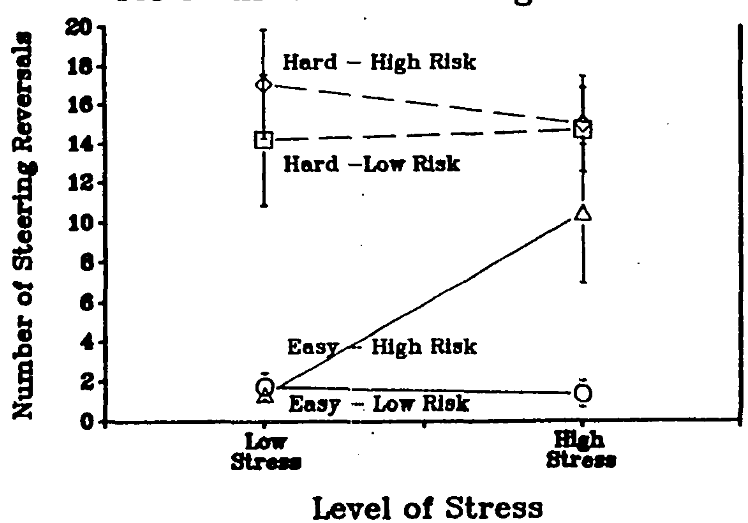


Figure 15. Scenario x Stress x Risk Interaction for Number of Steering Reversals



static slides (see Table 2).

Evaluation of Driver Variables

The majority of these subjects held white collar jobs and had had no accidents or traffic violations within the last year. Six of the subjects were professional drivers, and everyone drove at night. The means and standard deviations for other driver variables, and the stress and risk-taking measures, are presented in Table 3.

Simple Pearson correlation coefficients between the stress and risk-taking measures and driver variables largely yielded insignificant results with a few notable exceptions (see Table 4). Percentage of freeway driving was significantly correlated with risk-taking ($r=.38$, $df=49$, $p<.01$), indicating that people who drove the freeways frequently tended to be conservative risk takers.

All other significant correlations occurred among driver variables, and either confirmed results seen elsewhere in the literature, or were self-explanatory (as in the high correlation between age and driving experience). Further information is supplied by Table 4.

Table 2. Correlations for Subjective Estimates of Risk

Subject	Correlation	Subject	Correlation
1	-0.12	26	-0.08
2	0.35	27	0.12
3	-0.52	28	0.27
4	-0.28	29	0.21
5	0.37	30	-0.12
6	-0.16	31	-0.15
7	0.04	32	-0.64*
8	-0.70*	33	-0.30
9	-0.50	34	0.22
10	-0.49	35	-0.41
11	0.35	36	.
12	-0.28	37	0.03
13	-0.38	38	0.26
14	0.18	39	0.31
15	0.42	40	0.36
16	0.55	41	0.38
17	-0.18	42	-0.32
18	0.21	43	0.08
19	-0.28	44	0.37
20	-0.57	45	-0.13
21	-0.21	46	-0.15
22	-0.38	47	0.42
23	0.08	48	0.66*
24	0.47	49	-0.24
25	-0.26	50	-0.09

* $p<.05$

Table 3. Means and standard deviations for driver variables, stress and risk

	Means	Standard Deviations	N
Stress	256.6	165.19	50
Risk	42.0	7.67	50
MPW	172.7	160.34	50
MPY	11069.4	9921.64	50
Freeway %	33.2	23.07	50
City %	20.7	19.18	50
Suburb %	34.8	23.39	50
Rural %	11.3	13.44	50
Driving Experience	18.4	12.79	50
Traffic Violations	2.2	.30	50
Accidents	1.2	.27	50
Age	36.7	13.29	50

Table 4. Correlations Among Driver Variables

	Age	Gender	MPW	MPY	Freeway	Suburb	City
Age	1.00	-.10	.08	.04	-.22	.45**	-.23
Gender	--	1.00	.32**	.38**	.23	-.24	.07
MPW	--	--	1.00	.81**	.16	-.23	.13
MPY	--	--	--	1.00	.35**	-.35**	.03
Freeway	--	--	--	--	1.00	-.55**	-.22
Suburb	--	--	--	--	--	1.00	-.36**
City	--	--	--	--	--	--	1.00

	Rural	Driving Exper'nce	Traffic Violations	Accident	Stress	Risk
Age	-.04	.98**	.25	.16	-.23	.07
Gender	-.06	.01	.55**	.24	-.11	.01
MPW	-.04	.14	.59**	.29*	.18	.26
MPY	-.03	.09	.48**	.28*	.04	.19
Freeway	-.33**	-.23	.09	.00	-.13	.38**
Suburb	-.21	-.44**	-.10	-.12	-.17	-.17
City	-.31**	-.22	.14	.03	.33**	.05
Rural	1.00	-.04	-.13	.11	.03	-.27
Driving Exper'nce	--	1.00	.23	.16	-.26	.09
Traffic Violations	--	--	1.00	.40**	.11	.21
Accidents	--	--	--	1.00	-.19	-.13
Stress	--	--	--	--	1.00	.03
Risk	--	--	--	--	--	1.00

* p<.05
** p<.01

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Discussion

The effects of life stress, risk-taking style, and dangerousness of the highway environment were all hypothesized to impact driver performance. This study found all these factors to be important in assessing drivers' behavior. As the multivariate and associated univariate analyses of variance produced an abundance of significant differences, and the overall pattern of these differences may be of importance, the framework for this discussion will follow the sources of the variance.

Scenario

Of the six driver-performance measures examined in this study, the highway simulator scenario factor was a significant main effect for every one of the dependent variables (time spent in zones, standard deviation of speed over zones, average speed over zones, standard deviation of lane placement, and steering reversals). Also, an examination of the strength of association (as measured by omega squared) shows that 87% of the variance in the MANOVA is accounted for by this variable. This continues in the ANOVAs with the largest proportion of the variance for each of the five performance measures represented by type of scenario driven. These results were not surprising given the dramatic difference between the two roadway simulations. The hard scenario, due to the roadway geometry, could not be driven at excessive speeds in all zones, and required far more course corrections and speed corrections than did the easy scenario. What was surprising, and contrary to the original hypothesis, was that there was not a difference in the number of accidents in the two scenarios. The probability of an accident in the hard scenario was estimated to be .90, but the actual accident rate was far lower (.43). Further, the easy scenario had a probability of accident near zero, and drivers exceeded that probability (.11). While the simulation by the FHWA computer is not perfect, other studies, including HYSIM's validation experiment, indicate that the accident rates in this study are not due to problems with the instrumentation used. As the scenarios were designed to incorporate highway sites with objective accident data (thus allowing the computation of the probability of accident), it is unlikely that the probability levels were calculated incorrectly. This suggests that the differing accident rates were due to factors inherent in the subjects themselves.

Stress

Stress was also a good predictor of driver performance. It achieved statistical significance for time spent in zones, number of accidents, standard deviation of speed across zones, standard deviation of lane placement, and steering reversals. It was predicted that high-stress subjects would exhibit more erratic and dangerous driving behaviors, and that they would be at higher risk of an accident in the simulator. This was found to be the case. Highly stressed individuals had significantly more accidents, displayed a larger degree of driving corrections, and showed much higher variability in their speed and lane placement. This suggests that life stress impinge on the driver's ability to assess the highway environment accurately. These results are in contrast to the findings of Berggren, Moore and Stening (1970). In that experiment, no differences in driver performance were noted between subjects who experienced low or high amounts of stress. These varying results may be due to the use of different measures of stress, or due to the detailed instructions given in the Berggren et al. study. Despite this pattern, stress accounted for only 2% of the variance.

Risk

Risk was a significant main effect for three performance variables: time spent in zones, average speed, and number of steering reversals. The finding for average speed was not in the anticipated direction. It has been widely reported that high-risk drivers travel at higher speeds than do other people (Wasielewski,1982; Lynn, 1976). However, in this study, these drivers traveled significantly slower than other individuals, while the variability of speed was not different. They also showed no difference in the number of accidents. Perhaps the rate of accidents was consistent with low-risk drivers because of the slower speeds. If this is the case, it suggests that high risk-takers may decrease their speed to trade off the risk of accident.

High-risk drivers were in zones longer than low-risk drivers. As this variable is related to the speed through a zone, the longer zone times are most likely a function of the slower speeds.

The only finding that conforms to the original predictions is that high-risk drivers have almost twice as many steering reversals as low-risk drivers. The high number of reversals indicates that these subjects are not anticipating the behaviors needed to keep them on course, and therefore need to make more hasty changes in direction. When examined in conjunction with high-risk drivers' lower speeds, it does suggest that these drivers are not able to view upcoming sections of highway and "anticipate" accurate placement.

Gender

It has been widely reported that men and women do not approach the driving task in the same manner. Insurance rates indicate that men are considered more likely to drive in a fashion that will result in claims being filed. While there was some support for this in a significantly higher accident rate in males, with a ratio of over 3 to 1 (a univariate ANOVA for number of accidents was statistically significant), no significant effect for gender was found in the original MANOVA . No other significance was found for gender or for its interaction with any other variable.

Scenario by stress

In all of the interaction, there is essentially a ceiling effect for the hard scenario. The variables of risk and stress are not noticeable, while in the easy scenario their effects can be seen more readily.

Of the three variables (time spent in zones, number of accidents, and number of steering reversals) that were significant for Scenario by Stress, one pattern emerged consistently. Highly-stressed drivers in the easy scenario consistently performed more poorly than drivers in the same scenario who were not as stressed. This suggests that high levels of stress cause degradation of driver performance in situations that are not, of themselves, demanding. This suggests that the best driving performance for low stressed subjects occurs in a low-risk environment, while highly stressed individuals may over-estimate the kind and number of actions needed in the same environment.

The significant effect for steering reversals indicated, not surprisingly, that more steering reversals occurred in the hard scenario than in the easy one. As there were more and sharper curves in the difficult scenario, to fail to find this would have been disconcerting. The largest and smallest cell means are for the low-stress individual. However, it should be noted that the plot of steering reversals in the hard scenario is nearly flat (see Figure 4), suggesting that the scenario driven is somewhat more important than stress level.

The interaction of stress and scenario on rate of accidents is contrary to what was predicted, but consistent with the results reported above. The largest number of accidents occurred in low-risk subjects in the hard scenario, with the smallest number of accidents occurring in low-risk subjects in the easy one. This crossover effect suggests two things: 1) that low-stress individuals are at a distinct disadvantage when faced with a dangerous environment, and 2) that high-stress people are likely to misjudge the degree of safety in an undemanding environment.

Time spent in zones would appear to be largely due to scenario (see Figure 2). There are no differences in time between stress levels within a scenario. However, all differences between scenarios are significant. As the hard scenario required slower speeds to complete, it is not unexpected that zone times are longer there.

Scenario by risk

The overall pattern suggested by this interaction is similar to the one for Scenario by Stress. High risk takers in the easy scenario consistently perform more poorly than low risk takers in the same scenario.

Lane placement and number of accidents have significant interaction effects for risk by HYSIM scenario. As mentioned above, there are nearly equal cell means for high risk-takers across scenarios for both vehicle operation variables (see Figures 6 and 7). This implies that high risk-takers adjust their driving so that amount of deviation in lane placement stays constant, and that they maintain the same probability of accident even when the highway environment is more hazardous. This has important implications for traffic safety. Risk-takers clearly perform to maintain a relatively constant rate of risk, regardless of the type of highway driven. They will therefore display comparatively riskier driving in non-taxing situations, sometimes causing them to appear to others as careless, or even reckless. In contrast, in risky situations, they may, in fact, perform better than the others in the same environment.

The pattern reported above holds for zone time and variability in speed, with low-risk individuals representing the extreme ends of the continuum in both cases. However, high-risk individuals are not statistically equal here, and show a significant difference based on the scenario driven. As would be expected, drivers of the hard scenario displayed far more variability in speed, and far longer zone times than drivers of the easy scenario.

Stress by risk

For Stress by Risk, the overall pattern indicated a sharp decline in performance for all HR-HS individuals. This can be seen in all four of the dependent measures that were significant for this interaction: time spent in zones, number of accidents, number of steering reversals, and standard deviation of speed through zones. In addition, in time spent in zones, number of steering reversals, and standard deviation of speed show a sharp performance decrement for LR-HS individuals as well. This pattern supports the hypothesis that the combination of high risk-taking and high levels of stress would cause a deterioration in driving performance. It also suggests that high levels of stress can cause a decline even in drivers who do not take inordinate risks.

For number of accidents, the results confirm the original hypothesis: drivers who were high risk-takers and under much stress had significantly more accidents in the simulator than any other drivers. While LS-LR risk drivers had the second highest rate of accident, this was not statistically significant from other groups. The implications of this are two-fold. First, these results replicate those of Holmes (1972) in his original research on the stress scale: that life stress, as measured with his instrument, is an excellent indicator of the likelihood of accident involvement. Second, and perhaps more importantly, stress in conjunction with risk, appears to have a dramatic effect on perception of risk. If an individual driver was disinclined to take risks, one would assume his/her chances of being involved in a single-car accident would be slim. If the driver was a risk-taker, the assumption would be that the probability of accident would be greater. The results for the stressed, risk-taking driver confirm these assumptions. Stressed risk-takers have far more accidents than stressed individuals who take no chances. This indicates a problem with perception of risk for the stressed, risk-taking driver.

Scenario by stress by risk

For all three of the dependent measures that were significant for this interaction (time spent in zones, lane placement, and number of steering reversals), the HR-HS drivers in the easy scenario showed sizeable drops in driving performance. As in the Stress by Risk interaction, this supports the hypothesis of a relationship between driving performance and risk and stress. It was not predicted, however, that this effect would be as striking, or as consistent, in the easy scenario as it is (see Figures 13, 14, and 15). As has been suggested previously, this pattern strengthens the idea that the effects of stress and risk are particularly pronounced in a less demanding highway environment, partially due to high risk-takers propensity for keeping the level of risk constant, and partially due to the effects of high stress levels on accurate assessment of roadway demands. It should be noted, however, that the degradation of performance is due to the interaction of risk and stress, and not to either alone.

All conditions of stress and risk in the hard scenario differed significantly from drivers in the easy scenario who were not stressed, and from those who are stressed, but not given to taking risks. Again, the road itself appears to create a task overload that results in an inability to assess accurately the position the car should be maintaining.

For time spent in zones, the effect for scenario is a large component. All means in the hard scenario are uniformly long, and statistically longer than any in the easy scenario. As has been discussed earlier, increased zone times were expected in the hard scenario, where drivers were at higher risk for accident and safe speeds were lower than in the easier driving task. The difficulty of the driving environment apparently overpowered any effect of life stress and risk-taking style. This is not the case for the easy scenario. Zone times for the HS-HR driver in this scenario were significantly longer than for any other driver in this condition, while the means for all other drivers were comparable. This is due in part, to the high rate of accidents for HS-HR drivers of the easy scenario, but does not duplicate this information completely.

For standard deviation of lane placement in the hard scenario, low risk increased variability in lane placement no matter the stress level. This variability is significantly larger than any produced in the easy scenario with the exception of the HS-HR driver. In addition to these findings between scenarios, HS-HR drivers of the difficult scenario, showed significant differences in lane placement from low stress-low risk drivers in the easy. These results suggest that in a less challenging highway environment, high amounts of stress and risk cause detrimental changes in driving performance. Low risk takers in a challenging environment, however, are not able to navigate without a higher degree of variability than exhibited by those in a risk-free environment, particularly those who are not stressed.

There are many more steering corrections in the hard scenario than in the easy one, though within scenario there are no differences. Risk takers in the hard scenario who were not stressed made more course corrections than any drivers of the easy scenario. The interaction here clearly causes a decrement in performance when the environment is demanding that is not seen when the highway itself is less stressful. This suggests that the roadway creates overload.

Driver Variables and Questionnaire

As noted in Table 4, the drivers in this study fell close to national population norms on most driver variables. Miles driven per year had a mean value of nearly 11,000 miles, slightly more than the standard of 10,000 miles. Drivers with white-collar jobs were over-represented, though this is not surprising in view of the recognized national trend towards a service-based economy, staffed largely by office-bound workers (Davis, 1984).

The mean score on the Holmes Stress Scale of 256.6 indicated that this subject sample was moderately stressed overall. A score of 300 on this scale suggests that an individual is currently under severe enough stress to put him/her at risk of a stress-related major illness or at increased risk of accident-related injury (Holmes, 1972).

The Kogan-Wallach Choice Dilemma Questionnaire mean of 42.06 suggests that this particular sample of drivers is somewhat conservative in risk-taking style. This questionnaire has a range of possible scores from 12 (takes any risk) to 72 (takes no risks), with 30-40 generally considered the area to use to dichotomize high and low-risk takers (Kogan and Wallach, 1984). Due to the restricted range encountered in this sample (28-60, with more than 50 percent of the scores higher than 40), the mean score of 40.5 was used as the cutoff score. It should be noted that a possible consequence of this procedure may have been a suppression of the effect of risk taking.

Simple Intercorrelations of Driver Variables and Questionnaire Scores

Only one of the driver variables, the amount of city driving, was significantly correlated with level of stress. As the amount of city driving increased, so did life stress. This confirms the sociological tenet of higher stress for city dwellers, and suggests, when this study's stress findings are considered that city dwellers may also have a higher rate of accident.

Risk-taking style, as measured by the Kogan-Wallach Choice Dilemma Scale (Appendix A), was significantly correlated with type of driving environment (as measured in percent of freeway and suburban driving). However, neither of the two correlations were in the predicted direction. As mentioned previously, higher freeway exposure was associated with more conservative risk-taking behavior, while higher suburban exposure was linked to more risk-taking behavior. The meaning of this is unclear. It is impossible to say either that risk-taking style dictates exposure preference, or that type of exposure molds risk-taking. Either or neither may be true. It is conceivable that both explanations together provide the answer. Suburban driving is less risky than freeway. Speeds are considerably lower, traffic volume greatly reduced, and driver route familiarity high. Because of this, drivers with higher tolerance for risk-taking may be safer in suburban areas than they would be on Interstate systems. In contrast, individuals who have spent considerable driving time on freeways have probably been exposed to more serious accidents, and may be more aware of dangers in freeway environment. A self-perpetuating cycle of behavior modification could be in motion: driving in a less risky environment reinforcing risk-taking behavior, which reinforces driving in the less risky environment. This is highly speculative, but suggests that experience in different highway settings may be a potent variable in perception of risk.

The other significant correlations (Table 1) largely support findings elsewhere in the literature. The relationship between sex of driver and miles driven per week and year indicates that males are inclined to have accumulated higher mileage than females. This trend has been observed for most of this century (Goldstein and Mosel, 1958; Farmer and Chambers, 1945).

Type of exposure (as measured by percent of driving in rural, city, suburban or Interstate settings) has been discussed earlier in relation with risk-taking. Intercorrelations among types of exposure were all in the negative direction. This is to be expected as a high percentage of one kind of exposure would necessitate a lower percentage of another. A significant correlation between freeway driving and receiving a traffic violation in the past year was obtained. Here, increased chances of having received a ticket recently was associated with higher amounts of freeway driving.

Of note were the correlations between driving exposure (MPY) and percent of suburb and freeway driving. Both r's are identical, but in different directions (see Table 1). An inverse relationship exists between MPY and suburban driving: as one increases, the other decreases. On the other hand, MPY and freeway driving decrease and increase together. Neither correlation is unforeseen, as both types of exposure are subject to vastly different speed limits. Higher Interstate speeds allow more miles to be acquired at a faster pace than is possible in suburban neighborhoods.

Risk perception

The major finding here was that drivers did not perceive accurately the objective risk inherent in certain rural traffic sites. While it would be preferable to suggest that these results show that some rural roadways fail to convey their relative dangers adequately, statistical analysis confirms that this was more likely due to problems with the method.

The slide presentation method used in this study proved an ineffective tool. First, failure to collect data on why subjects rated sites the way they did hampered interpretation of results. It was difficult to state with complete certainty that the slides accurately presented the roadway. While the step-up procedure is superior to the use of video tape in that no speed clues are provided the subject in assessing subjective risk, the static nature of the picture may cause other elements in the roadway to take unnatural precedence over more relevant cues. For example, one woman volunteered that the straightaway site (the least dangerous set of slides) was the most dangerous because telephone poles at the side of the road slanted over it, creating a hazard for unaware motorists. The angle between the roadway and the poles was not a perfect 90°, but about 80°, an angle that does not present a hazard to anyone. It is probably a feature of the highway environment that would usually go undetected. It is likely that its prominence was a function of the method of presentation.

Second, it was difficult to reconcile the need to present all significant information about a site with the experimentally desirable attribute of presenting equal distances in each slide. Distances presented in sets of three slides (two step-up slides and the slide of the site itself) varied from slightly less than 200 feet to over 700 feet. This raises the question of whether or not changing distances affected risk perception, a question that cannot be answered by this study.

In its favor, the slide presentation method did remove cues about speed, steering, and braking that could bias results achieved with film or video tape. The step-up slides provided more information about the sites than could be obtained from single slides alone, thus presenting an improvement over previous methods. However, before this method can be used, much more scale development must occur. While the slide method yields poor subjective estimates of risk, it should be noted that studies employing video tape do no better in improving the accuracy of these estimates.

Of note was that the extreme ends of this "dangerousness continuum" were fairly correctly ranked. The section of rural straightaway which was least dangerous, was, in fact, rated so overall (see Table 1). Also, the 1-lane bridge was ranked as the most risky of the sites. While in actuality it was the second most dangerous site, this still represents a close approximation of the objective risk. This may imply that the average driver can perceive gross distinctions in highway hazards, but has a harder time as the distinctions become finer.

Correlations between individual subjects' rank orderings and the objective risk scale varied widely. There were no significant correlations when drivers' subjective estimates were compared with the demographic variables, or with life stress or risk. Because of problems with the methodology, it cannot be stated that these variables are unrelated.

CONCLUSIONS

This study has demonstrated that each of the independent variables of type of scenario, life stress, and risk-taking style has had a significant impact on driver performance. Moreover, the interaction among these produce different patterns of behavior, depending upon the degree of attention demanded by the roadway. The most notable of these are as follows;

1) Difficulty of the roadway was the most powerful delineator of driver performance, accounting for 87% of the variance
2) Risk takers maintain a constant probability of

accident by altering their behavior to suit the environment

3) High-stress, high-risk individuals have trouble in non-taxing environments, indicating that the propensity to take risks, coupled with high life stress cause a degradation in driving performance.

The interaction of risk-taking style and stress level on the possibility of accident clearly points to the impact stress has on the ability of the cautious driver to recognize potential accident sites. That careful drivers who are stressed make poorer judgments than risk takers is of immeasurable importance. Ours is a society where stress is an everyday phenomenon. If it impairs perception of risk, then further study is imperative to determine how to re-design the highway to convey hazards to stressed individuals.

It was also demonstrated that static slides of highway sites were not a reliable method of assessing perception of risk. Slides appear to cause unimportant features in the highway to stand out and therefore effect judgments about the risk involved in a site.

Several other interactions among variables are of note and warrant further investigation. The first of these is the effect of freeway driving on risk-taking style. This interaction suggests that freeways may, in fact, convey adequately the risk inherent in traveling on them. This is not a conclusive finding, as it is correlational, thus rendering statements to subject these results to a causal analysis to determine whether or not freeway driving effects perception of risk.

The present study has yielded results that indicate the direction that future research should take. Stress, risk-taking style, and, perhaps, type of driving exposure appear to be areas that will supply more knowledge on how drivers perceive the risk on the highways.

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Appendix A: Paper and Pencil Measures

RECORD OF INFORMED CONSENT

Part 46, Subtitle A to Title 45 of the Code of Federal Regulations relating to the Protection of Human Subjects in research requires your informed consent for participation in Federal Highway Administration driving studies. Section 46.103(c) gives the following definition: "Informed consent means the knowing consent of an individual or his legally authorized representative, so situated as to be able to exercise free power of choice, without undue inducement or any element of force, fraud, deceit, duress or other form of constraint."

If you consent, you will be participating in a study of driver behavior under various highway conditions. Please consider the following infor-
mation in reaching your decision whether or not to consent.

1. You will be given a basic eye examination to determine your corrected visual acuity and color vision. If results are within the accepted range and you have a valid drivers license, you can participate in the study.

2. You are free to decline consent, or withdraw consent and discontinue participation at any time. If at any time you feel uncomfortable, you should immediately indicate your concern to the experimenter.

3. Other than possible fatigue due to extended concentration, you should not experience discomfort and you will not be subjected to risks.

4. Your will be asked for biographical information necessary to the study. <u>ALL</u> information is kept strictly confidential, and your name will not be associated with it in any way. You will be identified <u>only</u> by a number that you will select, and that only you, not the experimenter, will know.

5. You will answer 3 questionnaires that are designed to evaluate how much stress you are under, and your particular style in making choices. You may have access to the results, if you wish.

6. You will examine a number of slides of various highway areas and rate them in terms of their dangerousness.

7. You will drive a simulated roadway in the HYSIM Laboratory under night conditions. You will be given verbal instructions along the way.

8. The session should last from 2 to 2 1/2 hours. You will be paid $25.00 for your participation. You must complete the entire session to receive full

remuneration.

The basic elements of information have been presented and understood by me and I consent to participate as a subject.

Name:_______________________
Signature:__________________
Date:_______________________

INSTRUCTIONS

This packet contains three questionnaires. the first one asks for information about you and your driving habits. The second assesses the amount of stress you are currently experiencing in your life. The third looks at how you make choices. All of these questionnaires are completely confidential. At no point will your name be linked to them. Not even the experimenter will know which packet you answered. Please feel free to ask any question you may have as you have finished, please place your packet in the box shown to you by the experimenter. Thank you for your cooperation.

DRIVER VARIABLES QUESTIONNAIRE

Age:____________ Sex:____________
Profession:_________________________

Type of car usually
driven:____

Miles driven a week:________ Miles driven per year:_________

Approximately what percent of your driving time is spent on the following kinds of roads:

Freeway _____________

City roads _____________

Suburban _____________

Rural roads _____________

How many years have you been driving? _______________

How many moving violations have you been convicted of since you first started driving? ________________

How many reported accidents have you been involved in since you started driving? _________________

Do you drive at night? YES NO

Do you drive professionally? YES NO

Have you had a moving violation this year? YES NO

Have you been involved in an accident this year? YES NO

HOLMES STRESS SCALE

Please circle either Y for yes or N for no.

LIFE EVENT	ANSWER	
Death of spouse	Y	N
Divorce	Y	N
Marital Separation	Y	N
Jail term	Y	N
Death of close family member	Y	N
Personal injury or illness	Y	N
Marriage	Y	N
Fired at work	Y	N
Marital reconciliation	Y	N
Retirement	Y	N
Change in health of family member	Y	N
Pregnancy	Y	N
Gain of new family member	Y	N
Business readjustment	Y	N
Change in financial state	Y	N
Death of close friend	Y	N
Change to different line of work	Y	N
Change in number of arguments with spouse	Y	N
Mortgage over $10,000	Y	N
Foreclosure of mortgage or loan	Y	N
Change in responsibilities at work	Y	N
Son or daughter leaving home	Y	N
Trouble with in-laws	Y	N
Outstanding personal achievement	Y	N
Spouse begins or stops work	Y	N
Begin or end school	Y	N
Change in living conditions	Y	N
Revision of personal habits	Y	N
Trouble with boss	Y	N
Change in work hours or conditions	Y	N
Change in residence	Y	N
Change in schools	Y	N
Change in recreation	Y	N
Change in church activities	Y	N
Change in social activities	Y	N
Mortgage or loan less than $10,000	Y	N
Change in sleeping habits	Y	N
Change in number of family get-togethers	Y	N
Change in eating habits	Y	N
Vacation	Y	N
Christmas	Y	N
Minor violations	Y	N

KOGAN-WALLACH CHOICE DILEMMA QUESTIONNAIRE

Instructions. On the following pages, you will find a series of situations that are likely to occur in everyday life. The central person in each situation is faced with a choice between two alternative courses of action, which we might call X and Y. Alternative X is more desirable and attractive than alternative Y, but the probability of attaining or achieving X is less than that of attaining or achieving Y.

For each situation on the following pages, you will be asked to indicate the minimum odds of success you would demand before recommending that the more attractive or desirable alternative, X, be chosen.

Read each situation carefully before giving your judgement. Try to place yourself in the position of the central person in each of the situations. There are twelve situations in all. Please do not omit any of them.

1. Mr. A, an electrical engineer, who is married and has one child, has been working for a large electronics corporation since graduating from college five years ago. He is assured of a lifetime job with a modest, though adequate, salary, and liberal pension benefits upon retirement. On the other hand, it is very unlikely that his salary will increase much before he retires. While attending a convention, Mr. A is offered a job with a small, newly founded company which has a highly uncertain future. The new job would pay more to start and would offer the possibility of a share in the ownership if the company survived the competition of the larger firms.

Imagine that your are advising Mr. A. Listed below are several probabilities or odds of the new company's proving financially sound.

Please check the lowest probability that you would consider acceptable to make it worthwhile for Mr. A to take the new job.

-----The chances are 1 in 10 that the company will prove financially sound.
-----The chances are 3 in 10 that the company will prove financially sound.
-----The changes are 5 in 10 that the company will prove financially sound.
-----The chances are 7 in 10 that the company will prove financially sound.
-----Place a check here if you think that Mr. A should not take the new job no matter what the probabilities.

2. Mr. B, a 45-year-old accountant, has recently been

informed by his physician that he has developed a severe heart ailment. The disease would be sufficiently serious to force Mr. B to change many of his strongest life habits -- reducing his work load, drastically changing his diet, giving up favorite leisure-time pursuits. The physician suggests that a delicate medical operation could be attempted which, if successful, would completely relieve the hear condition. But its success could not be assured, and in fact, the operation might prove fatal.

Imagine that you are advising Mr. B. Listed below are several probabilities or odds that the operation will prove successful.

Please check the lowest probability that you would consider acceptable for the operation to be performed.

-----Place a check here if you think Mr. B should not have the operation no matter the probabilities.
-----The chances are 9 in 10 that the operation will be a success.
-----The chances are 7 in 10 that the operation will be a success.
-----The chances are 5 in 10 that the operation will be a success.
-----The chances are 3 in 10 that the operation will be a success.
-----The chances are 1 in 10 that the operation will be a success.

3. Mr. C, a married man with two children, has a steady job that pays him $18,000 per year. He can easily afford the necessities of life, but few of the luxuries. Mr. C's father, who died recently, carried a $12,000 life insurance policy. Mr. C would like to invest this money in stocks. He is well aware of the secure "blue-chip" stocks and bonds that would pay approximately 6% on his investment. On the other hand, Mr. C has heard that the stocks of a relatively unknown Company X might double their present value of a new product currently in production is favorably received by the buying public. However, if the product is unfavorably received, the stocks would decline in value.

Imagine that you advising Mr. C. Listed below are several probabilities or odds that Company X stocks will double their value.

Please check the lowest probability that you would consider acceptable for Mr. C to invest in Company X Stocks.

-----The chances are 1 in 10 that the stocks will double their value.
-----The chances are 3 in 10 that the stocks will double their value.

-----The chances are 5 in 10 that the stocks will double their value.
-----The chances are 7 in 10 that the stocks will double their value.
-----The chances are 9 in 10 that the stocks will double their value.
-----Place a check here if you think Mr. C should not invest in Company X stocks, no matter what the probabilities.

4. Mr. D is the captain of College X's football team. College X is playing its traditional rival, College Y, in the final game of the season. The game is in its final seconds, and Mr. D's team College X, is behind in the score. College X has time to run one more play. Mr. D, the captain, must decide whether it would be best to settle for a tie score with a play which would be almost certain to work or, on the other hand, should he try a more complicated and risky play which could bring victory if it succeeded, but defeat if not.

Imagine that you are advising Mr. D. Listed below are several probabilities or odds that the risk play will work.

Please check the lowest probability that you would consider acceptable for the risky play to be attempted.

-----Place a check here if you think Mr. D should not attempt the risky play no matter what the probabilities.
-----The chances are 9 in 10 that the risky play will work.
-----The chances are 7 in 10 that the risky play will work.
-----The chances are 5 in 10 that the risky play will work.
-----The chances are 3 in 10 that the risky play will work.
-----The chances are 1 in 10 that the risky play will work.

5. Mr. E is president of a light metals corporation in the United States. The corporation is quite prosperous, and has strongly considered the possibilities of business expansion by building an additional plant in a new location. The choice is between building another plant in the U.S., where there would be a moderate return on the initial investment, or building a plant in a foreign country. Lower labor costs and easy access to raw materials in that country would mean a much higher return on the initial investment. On the other hand, there is a history of political instability and revolution in the foreign country under consideration. In fact, the leader of a small minority party is committed to nationalizing, that is, taking over, all foreign investments.

Imagine that you are advising Mr. E. Listed below are several probabilities or odds of continued political stability in the foreign country under consideration.

Please check the lowest probability that you would consider acceptable for Mr. E's corporation to build a plant in that country.

-----The chances are 1 in 10 that the foreign country will remain politically stable.
-----The chances are 3 in 10 that the foreign country will remain politically stable.
-----The chances are 5 in 10 that the foreign country will remain politically stable.
-----The chances are 7 in 10 that the foreign country will remain politically stable.
-----The chances are 9 in 10 that the foreign country will remain politically stable.
-----Place a check here if you think Mr. E's corporation should not build a plant in the foreign country, no matter what the probabilities.

6. Mr. F is currently a college senior who is very eager to pursue graduate study in chemistry leading to the Doctor of Philosophy degree. He has been accepted by both University X and University Y. University X has a world-wide reputation for excellence in chemistry. While a degree from University X would signify outstanding training in this field, the standards are so very rigorous that only a fraction of the degree candidates actually receive the degree. University Y, on the other hand, has much less of a reputation in chemistry, but almost everyone admitted is awarded the Doctor of Philosophy degree, though the degree has much less prestige than the corresponding degree from University X.

Imagine that you are advising Mr. F. Listed below are several probabilities or odds that Mr. F will be awarded a degree at University X, the one with the greater prestige.

Please check the lowest probability that you would consider acceptable to make it worthwhile for Mr. F to enroll in University X rather than University Y.

-----Place a check here if you think Mr. F should not enroll in University X, no matter what the probabilities.
-----The chances are 9 in 10 that Mr. F would receive a degree from University X.
-----The chances are 7 in 10 that Mr. F would receive a degree from University X.
-----The chances are 5 in 10 that Mr. F would receive a degree from University X.
-----The chances are 3 in 10 that Mr. F would receive a degree from University X.
-----The chances are 1 in 10 that Mr. F would receive a degree from University X.

7. Mr. G, a competent chess player, is participating in a national chess tournament. In an early match he draws the top-favored player in the tournament as his opponent.

Mr. G has been given a relatively low ranking in view of his performance in previous tournaments. During the course of his play with the top favored man, Mr. G notes the possibility of a deceptive, tough, risky maneuver which might bring him a quick victory. At the same time, if the attempted maneuver should fail, Mr. G would be left in an exposed position and defeat would almost certainly follow.

Imagine that you are advising Mr. G. Listed below are several probabilities or odds that Mr. G's deceptive pay would succeed.

Please check the lowest probability that you would consider acceptable for the risky play in question to be attempted.

-----The chances are 1 in 10 that the play would succeed.
-----The chances are 3 in 10 that the play would succeed.
-----The chances are 5 in 10 that the play would succeed.
-----The chances are 7 in 10 that the play would succeed.
-----The chances are 9 in 10 that the play would succeed.
-----Place a check here if you think Mr. G should not attempt the risky play, no matter what the probabilities.

8. Mr. H, a college senior, has studied the piano since childhood. He has won amateur prizes and given small recitals, suggesting that Mr. H has considerable musical talent. As graduation approaches, Mr. H has the choice of going to medical school to become a physician, a profession which would bring certain prestige and financial rewards; or entering a conservatory of music for advanced training with a well-known pianist. Mr. H realizes that even upon completion of his piano studies which would take many more years and a lot of money, success as a concert pianist would not be assured.

Imagine you are advising Mr. H. Listed below are several probabilities or odds that Mr. H would succeed as a concert pianist.

Please check the lowest probability that you would consider acceptable for Mr. H to continue with his musical training.

-----Place a check here if you think Mr. H should not pursue his musical training, no matter what the probabilities.
-----The chances are 9 in 10 that Mr. H would succeed as a concert pianist.
-----The chances are 7 in 10 that Mr. H would succeed as a concert pianist.
-----The chances are 5 in 10 that Mr. H would succeed as a concert pianist.
-----The chances are 3 in 10 that Mr. H would succeed as a concert pianist.

-----The chances are 1 in 10 that Mr. H would succeed as a concert pianist.

9. Mr. J is an American captured by the enemy in World War II and placed in a prisoner-of-war camp. Conditions in the camp are quite bad, with long hours of hard physical labor and a barely sufficient diet. After spending several months in this camp. Mr. J notes the possibility of escape by concealing himself in a supply truck that shuttles in and out of the camp. Of course, there is no guarantee that the escape would prove successful. Recapture by the enemy could well mean execution.

Imagine that you are advising Mr. J. Listed below are several probabilities or odds of a successful escape from the prisoner-of-war camp.

Please check the lowest probability that you would consider acceptable for an escape to be attempted.

-----The chances are 1 in 10 that the escape would succeed.
-----The chances are 3 in 10 that the escape would succeed.
-----The chances are 5 in 10 that the escape would succeed.
-----The chances are 7 in 10 that the escape would succeed.
-----The chances are 9 in 10 that the escape would succeed.
-----Place a check here if you think Mr. J should not try to escape no matter what the probabilities.

10. Mr. K is a successful businessman who has participated in a number of civic activities of considerable value to the community. Mr. K has been approached by the leaders of his political party as a possible congressional candidate in the next election. Mr. K's party is a minority party in the district, though the party has won occasional elections in the past. Mr. K would like to hold political office, but to do so would involve a serious financial sacrifice, since the party has insufficient campaign funds. He would also have to endure the attacks of political opponents in a hot campaign.

Imagine that you are advising Mr. K. Listed below are several probabilities or odds of Mr. K's winning the election in his district.

Please check the lowest probability that you would consider acceptable to make it worthwhile for Mr. K to run for political office.

-----Place a check here if you think that Mr. K should not run for political office no matter what the probabilities.
-----The chances are 9 in 10 that Mr. K would win the election.
-----The chances are 7 in 10 that Mr. K would win the

election.

-----The chances are 5 in 10 that Mr. K would win the election.

-----The chances are 3 in 10 that Mr. K would win the election.

-----The chances are 1 in 10 that Mr. K would win the election.

11. Mr. L, a married 30-year-old research physicist, has been given a five-year appointment by a major university laboratory. As he contemplates the next five years, he realizes that he might work on a difficult, long-term problem which, if a solution could be found, would resolve basic scientific issues in the field and bring high scientific honors. If no solution were found, however, Mr. L would have little to show for his five years in the laboratory, and this would make it hard for him to get a good job afterwards. On the other hand, he could, as most of his professional associates are doing, work on a series of short-term problems where solutions would be easier to find, but where the problems are of lesser scientific importance.

Imagine that you are advising Mr. L. Listed below are several probabilities or odds that a solution would be found to the difficult, long-term problem that Mr. L has in mind.

Please check the lowest probability that you would consider acceptable to make it worthwhile for Mr. L to work on the more difficult long-term problem.

-----The chances are 1 in 10 that Mr. L would solve the long-term problem.

-----The chances are 3 in 10 that Mr. L would solve the long-term problem.

-----The chances are 5 in 10 that Mr. L would solve the long-term problem.

-----The chances are 7 in 10 that Mr. L would solve the long-term problem.

-----The chances are 9 in 10 that Mr. L would solve the long-term problem.

-----Place a check here if you think Mr. L should not choose the long-term, difficult problem, no matter what the probability.

12. Mr. M is contemplating marriage to Miss T, a girl whom he has known for a little more than a year. Recently, however, a number of arguments have occurred between them suggesting some sharp differences of opinion in the way each views certain matters. Indeed, they decide to seek professional advice from a marriage counselor as to whether it would be wise for them to marry. On the basis of these meetings with a marriage counselor, they realize that a happy marriage, while possible, would not be assured.

Imagine that you are advising Mr. M and Miss T. Listed below are several probabilities of odds that their marriage would prove to be a happy and successful one.

Please check the lowest probability that you would consider acceptable for Mr. M and Miss T to get married.

-----Place a check here if you think Mr. M and Miss T should not marry, no matter what the probabilities.
-----The chances are 9 in 10 that the marriage would be happy and successful.
-----The chances are 7 in 10 that the marriage would be happy and successful.
-----The chances are 5 in 10 that the marriage would be happy and successful.
-----The chances are 3 in 10 that the marriage would be happy and successful.
-----The chances are 1 in 10 that the marriage would be happy and successful.

SLIDE RATING SHEET

Place an "X" in the space that matches the more dangerous highway scene.

	A	B		A	B
1.	________	________	24.	________	________
2.	________	________	25.	________	________
3.	________	________	26.	________	________
4.	________	________	27.	________	________
5.	________	________	28.	________	________
6.	________	________	29.	________	________
7.	________	________	30.	________	________
8.	________	________	31.	________	________
9.	________	________	32.	________	________
10.	________	________	33.	________	________
11.	________	________	34.	________	________
12.	________	________	35.	________	________
13.	________	________	36.	________	________
14.	________	________	37.	________	________
15.	________	________	38.	________	________
16.	________	________	39.	________	________
17.	________	________	40.	________	________
18.	________	________	41.	________	________
19.	________	________	42.	________	________
20.	________	________	43.	________	________
21.	________	________	44.	________	________
22.	________	________	45.	________	________
23.	________	________			

Appendix B: Highway Simulator

Appendix B: Department of Transportation/Federal Highway Administration Simulator (HYSIM) by Elizabeth Alicandri

HYSIM is composed of several subsystems, or modules, which operate in various configurations. This modular system maximizes flexibility and facilitates modification. A discussion of each module follows.

Scenario Computer: The scenario computer is a DEC PDP 11/34 with 128K memory (124K usable, 4K permanently assigned to I/O devices). Its secondary storage is one 256MB disk and one 9-track 800 bpi magnetic tape. It has an affiliated 300 lpm line printer and two terminals; one VT 100 and one DEC writer II LA 36. The operating systems is a multi-user system; therefore, both terminals can be used concurrently. During a simulation, the real-time software is run at a high priority; the user at the other terminal has a degraded computer response. The scenario computer has several functions: it provides primary control of the experimental scenario; performs navigational calculations; controls peripheral devices (sign generators, rear projector, HAR simulator); and executes data collection. The scenario computer outputs to and receives input from the graphics computer.

Graphics Computer: The graphics computer is a DEC PDP 11/34, with 96K of memory. Its secondary storage is a 256MB disk.

Its affiliated terminal is a VT 55 CRT terminal. The graphics computer has two major functions: it controls the vehicle dynamics and hosts the computer graphics unit (graphics generator). Vehicle dynamics, which can be altered to the needs of the experiment, include two-degrees-of-freedom lateral equations, side velocity and yaw rate; a simplified model of a 3-speed automatic transmission; tire skid limits based on braking force, steering wheel disturbances to simulate lateral wind gusts; and longitudinal wind disturbances. The graphics computer relays information on the updated car position and velocity, which is the output of the vehicle dynamics software, to the scenario computer for navigational calculations.

Graphics Generator: The computer graphics unit is an Evans and Sutherland Picture System 2. This system matrix transforms the aerial view of a predefined roadway generated by the graphics computer to a perspecitve view of the roadway. The output is caligrahically drawn and displayed on a high resolution color monitor.

Roadway Projector: The roadway projector consists of a Sharp XC-802RA color TV camera and an Aquastar 80090 TV projection system. The Aquastar is mounted in the gantry above the car cab. The camera views the caligraphically drawn road-way on the color monitor and raster scan converts it. This output is projected onto a wide screen by the Aquastar projector.

<u>Sign Generators</u>: There are four sign generators, which are also mounted in the gantry. Each of these consists of a Mast random access slide projector (80 slide capacity); a zoom lens with computer controlled servos on the zoom and aperture; and a servo controlled yaw mirror. The scenario computer constantly monitors all of the servos. The zoom lens controls the size of the sign as it is approached, the aperture controls the brightness, and the yaw mirror controls the lateral placement of the sign on the roadway. The images from these systems are projected onto the wide screen in conjunction with the roadway projected by the roadway projector system.

<u>HAR Cassette Tape Recorder</u>: The simulation of highway advisory radio (HAR), if desired is controlled by the scenario computer. A series of prerecorded advisory messages can be accessed at a specific point in the scenario and played through the car radio. The cassette recorder/player is a Sony TCK-65.

<u>Sound Generator</u>: Both the scenario computer and the graphics computer have outputs to the sound generator. The scenario computer controls the crash sound and the siren sound. The graphics computer controls wind noise, engine sounds, and tire squeals.

Car Cab: The car cab module is a 1980 Ford Fairmont with the engine and drive train removed. Outputs from the car cab to the graphics computer (analog signals) include steering wheel position, accelerator position, and brake force. This information is used by the graphics computer to computer updated car position and velocity. there is one analog signal from the graphics computer to the car cab to drive the speedometer. Discrete signals from the car cab to the scenario computer include turn signals, headlights and horn.

Psychophysiological Module: This Gould system is located in the back seat of the car cab. It provides appropriate measures of the driver's physiological state to the graphics computer. These measures include respiration rate (RR), heart rate (HR), and muscle action potential (EMG) (Stapleford and Blauvelt, 1982).

Appendix C: Ranking of Highway Sites

Appendix C: Ranking of Highway Sites

The highway sites used in this study were selected based on police information on accidents and injuries. The police departments of Fairfax County, Virginia, and Virginia Beach, Virginia, were most cooperative in this endeavor.

Accidents were assigned points as follows: minor property damage/human injury = 1; moderate damage/injury = 2; severe damage/injury = 3; and fatality = 4. These categories were based on police reports of estimated property damage and assessment of driver/passenger condition at the scene. Fairfax county sites were rated on one year's data: 1983. Virginia Beach sites were based on the mean for five years' data: 1979-1983. Points accumulated for each site were used to determine the rank order of the site.