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16. Abstract

The research project investigated the influence of diazepam on the driving performance measured in the Daimler-Benz Driving Simulator. Test subjects were male students; 20 received a medium, and 20 received a high dosage of diazepam. A third group of 20 students served as a control group without diazepam.

The test drive involved ten standardized driving tasks (scenarios) which either required a normal every day response or represented an "emergency situation" with greater demands on the driver.

No significant differences were found between the three groups. In all scenarios the individual differences within groups were higher than differences between the groups.

Based on the results the hypothesis was derived that compensatory mechanisms may take effect in particular dosage ranges.

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- Joint Study

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0 Executive Summary

Drivers who drive under the influence of drugs may endanger both themselves and other road users. It is, however, difficult to quantify the type and level of dangers involved. Very few meaningful statistics from accident investigations are yet available. Although it is known that between 10 % and 25 % of drivers killed or injured had taken drugs, this does not prove the existence of a higher risk of accident. Usually, there are no figures available on the level of drugs taken by those not involved in accidents.

Our current knowledge of the impairment of driving ability due to drugs mainly stems from experimental laboratory investigations. The results of laboratory tests do not, however, allow direct prognosis of actual behavior in road traffic. Simulation of real traffic in a driving simulator can be useful here. The "realer" the simulated traffic situations are, the easier it is to translate the driving behavior observed into real driving behavior in traffic. The National Highway Traffic Safety Administration (NHTSA) therefore decided to investigate the influence of drugs on driving ability in tests employing a driving simulator. The driving simulator selected was built by Daimler-Benz AG, Berlin, and allows particularly realistic simulation of real traffic.

The research project "Test Drives in the Daimler-Benz Driving Simulator with Drivers under Diazepam" was carried out on the basis of a government agreement between the American Ministry of Transportation and the Ministry of Transport of the Federal Republic of Germany. The institutions responsible for carrying out the project were the Federal Highway Research Institute (BASt) in conjunction with the Institute for Legal Medicine of the Free University of Berlin and the automobile manufacturer, Daimler-Benz AG.

The psychopharmaceutical diazepam was selected because psychopharmaceuticals are significant drugs in terms of traffic medicine, diazepam is frequently taken and is often also identified in fatally injured drivers. It has also already been the subject of extensive laboratory investigations.

The test subjects in the driving simulator were 60 male students aged between 22 and 26 years who had between 5.7 and 6 years driving experience (with average annual mileage of 8,000 km). The subjects had to be in good health and not taking any other drugs at the time of the study. This was ensured by means of extensive medical and laboratory tests. Particularly excitable and/or aggressive individuals and those with hypochondriacal tendencies were excluded from the study (with the aid of a personality inventory). The average weight of the subjects was 69 kg. They were divided into three groups; 20 received a medium dosage of diazepam (0.11 mg/kg body weight) (Group "M") and 20 received a high dosage (0.22 mg/kg) (Group "H"), while the remaining 20 received no diazepam and served as a control group (Group "L"). Testing involved a single dosage in an acute test. The learning effect expected in the driving simulator prevented the use of the same persons in the three groups.

The high degree of reality required in the study made the use of a placebo group unnecessary. The aim was to test the driving behavior of subjects who knew they had taken the drug, as would be the case in the real situation. It was not the aim of the study to differentiate between the substance effects of drugs and placebo effects.

Before the actual test drive, each subject completed a ten-minute introductory drive to familiarize him with the simulator.

The twenty-minute test drive then involved ten standardized driving tasks which either required a normal, everyday response or represented an "emergency situation", placing considerably greater demands on the driver. The individual scenarios were as follows: Narrow Road Situation, Merge Into Traffic Situation, Snow on the Road, Free Road Situation, Dart-Out Situation with normal and quick response, Traffic Light Change from Green to Red with normal and quick response and Following Situation with normal and quick response. The variables used to describe driving behavior were speed, following distance, braking, change of lane, leaving the roadway, time gaps, number of collisions and response time. The level of diazepam in the serum of each subject was tested before and after the test drive and psychometric laboratory tests were also performed. These employed the Determination Apparatus, Attention Testing Apparatus, the Tachistoscopic Perception Test and the Basle Mood Scale.

It was observed during the tests that all subjects were highly motivated to drive well with the simulator and master the tests successfully.

The following results were obtained:

- No significant differences were found between the three groups tested for any of the variables considered in the ten scenarios. In all scenarios, the individual differences within groups were higher than the differences between the groups that might have existed.

In view of this high variability in driving performance, only a larger of number subjects might have generated significant differences between groups.

- In three scenarios, a trend was observed between the three groups. In two of these scenarios (Traffic Light Change from Green to Red, quick response, and Following Situation, quick response) there was a tendency towards potentially hazardous behavior due to drug effects. In one scenario (Dart-Out Situation, quick response) the opposite held true.

- In two scenarios (Traffic Light Change from Green to Red, normal response, and Merge into Traffic Situation), there was only some vague indication that there may have been some drug effect.

- In five scenarios (Narrow Road Situation, Following Situation with normal response, Dart-Out Situation with normal response, Snow on the Road Situation and Free Road Situation) no differences due to the drug were found.

- In six of the ten scenarios, twice as many subjects from Group M were involved in potentially hazardous maneuvers as from Group L, with subjects from Group H lying between Groups L and M.

- The results of the Vienna Determination Apparatus, the Attention Testing Apparatus and the Tachistoscopic Test, showed no significant differences between the groups.

- The Basle Mood Test showed the subjects in Group M to be significantly calmer and more stable in terms of intrapsychic equilibrium after the test drive than those in Group L, while the subjects in Group H were quieter and more withdrawn in terms of social extraversion than those in Group L.

The following hypothesis was derived from the individual results: Driving ability is not directly and solely dependent on the dosage of diazepam. Instead, compensatory mechanisms may take effect in particular dosage ranges. The subjects in Group H were obviously so aware of the effect of the diazepam that they made extra efforts to concentrate fully on the driving tasks required of them. This was probably the reason for their results being similar to those in the control group (L) who had been made nervous by the test situation and tended to be more easily distracted by external influences. The subjects in Group M tended, however, to make more driving mistakes than those in the two other groups. This was probably due to their not believing that the medium dosage would impair their driving ability and consequently failing to take compensatory action.

While the compensation variable must not be underestimated when investigating the effect of drugs, it remains to be established whether drivers take such successful compensatory action in real traffic as in the driving simulator.

1 Introduction

Assessment of the safe driving behavior of drivers who are under medication is a difficult task. No reliable epidemiological studies exist on the involvement of this group of persons in road accidents. Nevertheless, a series of investigations have shown that between 10 % and 25 % of killed or injured drivers had taken drugs (1). In a study performed by the Federal Highway Research Institute (BASt) in 1988 covering 501 drivers involved in accidents, the influence of legal drugs alone without alcohol was found in only 19 cases. These legal drugs included diazepam, barbiturates and codein (2). Positive findings in drivers involved in accidents do not, of course, prove that their involvement in accidents was the result of taking drugs. A higher risk can only be identified when the frequency of the taking of drugs among drivers involved in accidents is compared with that of a control group not involved in accidents. Usually, however, no figures are available on the level of drugs taken by the latter group and such figures are also difficult to obtain.

Terhune has compared the difficulties involved in determining alcohol-related increases in the risk of accident with the problems of proving increases in the risk of accident due to the effects of drugs. The detection of a relative crash risk increase due to alcohol was based on "data on the blood alcohol concentrations of drivers in accidents and those not in accidents but on the road at times and places similar to the accident drivers" (3). These data were collected in an epidemiological study by Borkenstein, known as the Grand Rapids Study. In his study, Terhune reached the conclusion that a "Grand Rapids Study" for drugs is not possible.

In contrast to the assessment of alcohol-related impairment of driver behavior, evaluation of the effects of legal drugs must also take account of the relevant illness. These drugs are used to treat illnesses and reduce the symptoms to a greater or lesser extent depending on how effective they are. Patients who have received no treatment or whose treatment has been unsuccessful may present a greater risk in road traffic than successfully treated patients (4).

Possible side-effects must also always be considered when assessing the effects of legal drugs on driver safety as they can also impair the driver's ability to drive safely.

The differing pharmacodynamic and pharmacokinetic characteristics of the legal drugs, the frequent combination with alcohol, different dosages and the sometimes complicated methods of detection present difficulties when analyzing any possible impairment of safety.

Consideration of the problems of drugs and road safety mainly concentrates on vehicle drivers, especially the drivers of private cars. Driving aptitude is understood (5, 6) as the capacity to drive a vehicle in the sense of a skill or personal aptitude which is unaffected by time and instantaneous situation parameters. In contrast, driving ability is to be understood as the actual instantaneous, situation-related fitness or ability to drive. With this definition, the influence of drugs primarily affects driving ability. Compton and Anderson reported on the state of knowledge in this field in 1985 (1).

According to Staak (5), the legal drugs which are of significance from the point of road traffic safety can be classified as follows:

Narcotics, sedatives, psychopharmaceuticals, anti-epileptics, antihistamines, analgesics, antihypertensive agents, antidiabetic agents and ophthalmic agents. According to Delay (8), psychopharmaceuticals can, in turn, be subclassified into psycholeptics with neuroleptics, tranquilizers and hypnotics, psychoanaleptics with antidepressants, psychostimulants, euphoretics and psychodysleptics. Neuroleptics, antidepressants and tranquilizers are defined as psychopharmaceuticals in the narrower sense (9).

In the analysis of characteristics affecting driving ability, Staak (5) makes the following distinctions: the psychophysical area with optics, visual perception, responses and attention and sensomotor reflexes, subjective functional capacity, intelligence, personality and biographical data.

Various methods can be adopted to measure these characteristics. In experimental tests, a distinction is usually made between real test drives, driving tasks on a test circuit closed to normal traffic, laboratory tests and test drives in simulators.

In many countries legal restrictions prevent real test drives under experimental conditions. Moreover, assessment is made difficult by the constantly changing traffic density and weather factors. In Europe, such tests are performed, for example, by O'Hanlon in Holland (10). Driving tasks on special test circuits often involve no other traffic in order to avoid endangering third parties. The reduced sense of reality and the consequent effect on the motivation of the subjects can complicate assessment of the results. Smiley (11) has pointed out the need to formulate relevant driving tasks which are representative of normal driving behavior and of traffic situations which often result in accidents.

The usually great variability in the results from practical test drives can be reduced in laboratory tests. Psychological characteristics such as vigilance, attention, responses and visual coordination can be assessed under standardized and reproducible conditions. The experiments can be performed quickly and economically and have, in the past, made considerable contributions to our understanding of such characteristics. It is, however, scarcely possible to recreate the real driving situation with its necessary multitude of physical and mental functions in the laboratory.

The impairment of driving behavior due to drugs has only been analyzed in vehicle simulators in a small number of cases (12). The great advantage of this approach is the degree of reality achieved without endangering the subjects themselves or third parties. The actual degree of reality is dependent on technical factors and may be extremely high.

Irrespective of the methodological approach adopted in laboratory tests, real test drives or simulator tests, there remains a central problem of validity. This concerns the relationship between the test procedure employed and the assessment of safe driving. Road traffic accident research and the safety measures derived from it are mainly oriented towards a safety concept which is derived from analysis of accident figures or accident rates (relative accident figures). A validity test would have to be based on the definition of hazardous driving arising from a continuum ranging from safe driving through near-accidents to actual accidents. Progress in the validation of experimental approaches can only be achieved if such a formulation is applied (13).

Against this background, the National Highway Traffic Safety Administration (NHTSA) has formulated a research project in which the effects of psychopharmaceuticals on driving behavior can be tested in a simulator. In this context, an agreement on cooperation in research projects has been reached between the American Department of Transportation (DOT) and the Ministry of Transport of the Federal Republic of Germany under which the NHTSA and the Federal Highway Research Institute (BASt) are responsible for project management. This contract defines in detail the test conditions and the selection of test groups, subjects and scenarios (see chapter 3).

The Institute for Legal Medicine of the Free University of Berlin and the automobile manufacturer, Daimler-Benz AG, have participated in the research project on behalf of the BASt. In an initial stage, the organisational sequences and problems occurring were examined in a pilot study involving 9 subjects. The procedure for the main study was defined on the basis of the results of this pilot stage.

2 Aims

The aim of the study was to determine the extent to which selected drugs impair the driver's driving ability. The drug chosen was the tranquilizer diazepam. The reason for choosing this drug was that it had frequently been identified in the bodies of fatally injured drivers (1). Diazepam is widely used (14) and numerous studies of its effect on driving performance have been made with the aid of laboratory tests.

The test equipment used was the simulator of Daimler-Benz AG in Berlin. This particular choice was made because NHTSA considered it to be the most "realistic" and technically mature of all simulators currently available in the world. It can be used to program a wide range of normal and critical traffic situations and also permits variation of factors such as road type and condition and weather and visibility conditions. The simulation must be as realistic as possible to allow the results obtained to be translated into driving behavior in real traffic.

3 Methodology

3.1 Drug and Dosage

Diazepam was administered orally (liquid) in a typical medium dosage (0.11 mg/kg body weight) and in a high dosage (0.22 mg/kg body weight), i.e., approx. 7 mg or 14 mg diazepam for a person weighing around 65 kg. Testing involved a single dosage in an acute test. This appeared realistic because individuals, especially students, often take tranquilizers on a sporadic basis and then drive a vehicle in full knowledge of this fact. In this study, it was most critical to compare drug induced performance where subjects knew they had taken the drug in question, as opposed to a no-drug situation where subjects knew they had not taken the drug. These are the real-world comparisons which are of most concern for highway safety research. Use of a placebo group, where subjects who have not taken the drug believe they have done so, is typically critical for medical research where researchers are interested in determining whether a particular medication itself has an effect or whether the effect is due to the subject's perception that he/she has taken the drug. In highway safety research, it is of utmost importance to determine whether a drug impairs driving performance. It makes little difference whether the drug effects are real due to the chemical properties of the substance or psychological because the individual believes his performance should change. The key comparison is therefore between various drug treatment conditions and a no-treatment control condition. The control group used here was a group of persons who had not taken drugs. 20 persons were selected for each of the three groups (control group (L), medium (M) and high dosage (H)). The use of the same persons for both dosages in order to reduce interindividual variations was not possible in view of the learning effect which would then result during the test drive in the simulator.

3.2 Selection of Subjects

Male students of the Free University and Technical University of Berlin who had good command of the German language were selected for the study. Their ages lay between 22 and 26 years and their body weights between 55 and 75 kg. The subjects had to be healthy and not taking drugs at the time of the tests. They were required to have between 3 and 8 years' car driving experience and their annual driving mileage had to lie between 3,000 km and 12,000 km.

An additional selection criterion was based on personality features which were determined with the aid of the "Freiburg Personality Inventory" (FPI) (16). All persons who achieved 9 points on the scales for "excitability", "aggressiveness" and "emotionality" and those with 8 or 9 points on the "physical complaints" and "health problems" were excluded from the study. The purpose of the exclusion procedure was to exclude persons who appeared particularly excitable and/or aggressive and to prevent persons with hypochondriacal tendencies from participating in tests involving drugs. The most frequent reason for exclusion was "health problems".

All students who satisfied the above conditions were required to undergo detailed medical and laboratory tests so as to ensure that they were indeed healthy.

Breath tests and urine screening (for opiates, cannabinoids, barbiturates, benzodiazepines, phenothiazines, neuroleptics, amitrityline and analgesics only available on prescription) were performed on the test day. Cannabinoids were identified in the urine of 4 subjects. These subjects were excluded from the test and replaced by reserve candidates.

3.3 Driving Simulator

Simulator Technique (15)

In order to give the driver in the simulator as realistic an impression of driving as possible, it is necessary to simulate the impressions gained during normal driving in the most realistic manner possible.

The driver gains his first impression when he steps into the simulator compartment. In the Daimler-Benz simulator, this is a real vehicle with the usual interior fittings and instruments and displays but without engine, transmission, drive shaft and axles. From the outside, it thus appears identical to a real car.

The driver does not, however, drive the vehicle. Instead, he "steers" the program of a mathematical vehicle model in the real-time travel-dynamic computer. This, in turn, supplies satellite computers with the necessary data for generation of the outside view, movements, vehicle noises and the forces at the steering wheel and pedals.

The "driver-vehicle-environment" control system is thus complete. The driver sees where he is going, feels the vehicle movements and acceleration, hears the vehicle noises and feels the changing steering torque, for example when cornering. The computer can detect collisions with obstacles. As collision acclerations are not, however, simulated, accidents present no danger to the driver or vehicle. Fig. 1 shows the functional diagram of the driving simulator.

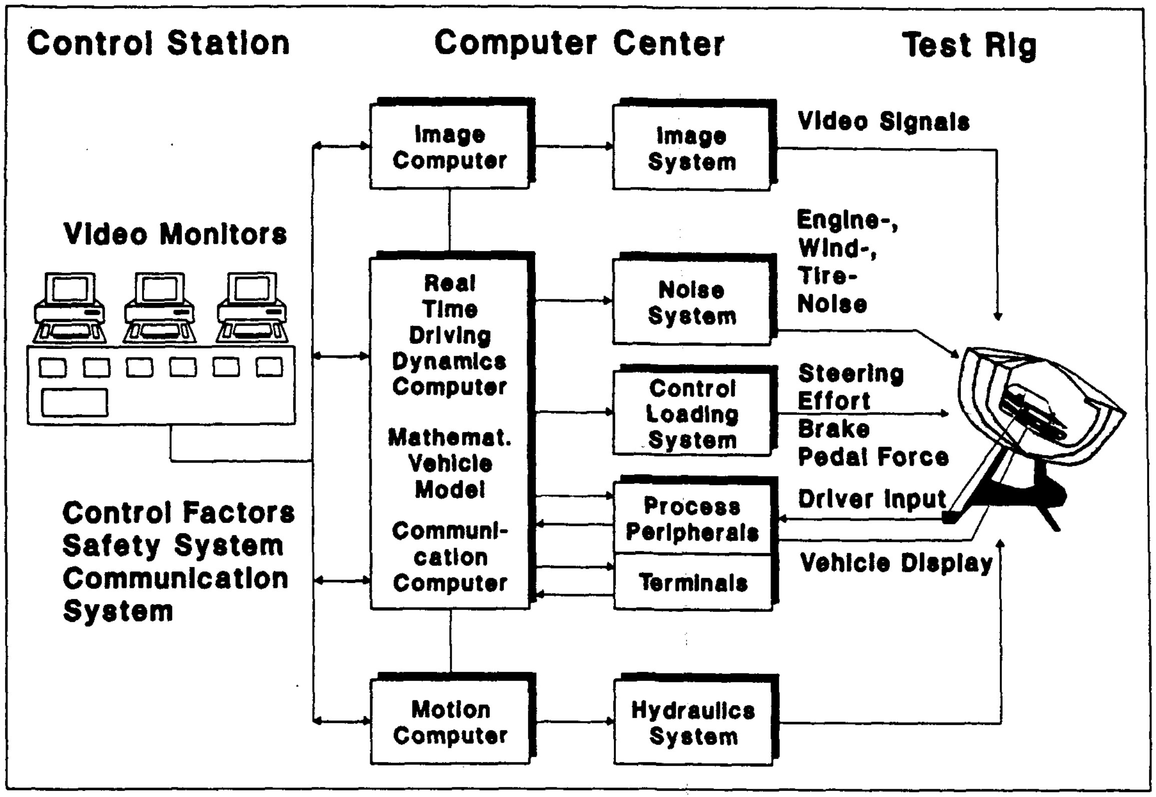


Fig. 1: Basic Elements of Daimler-Benz Driving Simulator

Overall Structure

The simulator compartment is positioned in the projection dome so that the driver is in the center of projection and is thus in the best position for seeing the 180° video projection of the outside view.
The vehicle is bolted to the floor of the projection dome which can be moved in all directions and angles by means of six hydraulic cylinders. As the driver is isolated from the surrounding area by the projection dome and cannot see how

he is being moved, a realistic impression of driving can be conveyed to him although the movements have to be falsified due to the limited room for movement.

The engine, wind and tire noises are generated in a digital sound system in accordance with the relevant driving situation and are emitted via various loudspeakers.

A controlling torque system generates the steering wheel feel which is so important for realistic simulation of driving by means of an electric torque motor controlled by a steering computer. This torque motor generates the return torques associated with the relevant driving situations.

The entire simulator system is operated and monitored from a control station where all the information comes together and from where the test engineer can observe and, if necessary, influence the progress of the test.

Image System

The driver's outside view is created in a digital image system. The landscape with roads, traffic signs, buildings and other vehicles is stored in data files in the image computer and is projected into the simulator with the right composition, perspectives, masking and colors as a 180° panoramic image by six video projectors in front of the simulator compartment. The driver thus has unrestricted vision to the front but no rear vision and, consequently, no rear-mirror images.

The driver's eyepoint and the vehicle angle are taken as the points of reference for representation of the outside view and are transmitted to the image system by the travel-dynamics computer.

Although a processing time of 80 ms is required to create an image frame, the fact that calculation is performed simultaneously on four successive frames means that projection is at the same frame frequency as in television, i.e. 50 Hz or every 20 ms.

Traffic Scenario

The landscape data bases of the image system store the roads required for this experiment. The test route consists of an autobahn (two lanes per direction of travel) and a country road (one lane per direction of travel) which have straight and also winding, slightly hilly sections. The hard shoulders are darker in color than the traffic lanes. They are delimited by the usual marker posts. There are crossroads with traffic lights and a T-junction with stop sign. Houses are only present in two scenarios. It is only possible to simulate snow on the roadway and not on the surrounding landscape. With the exception of the snow section, the road is always dry.

The road cross-sections and dimensions are described in the following illustrations (Fig. 2).

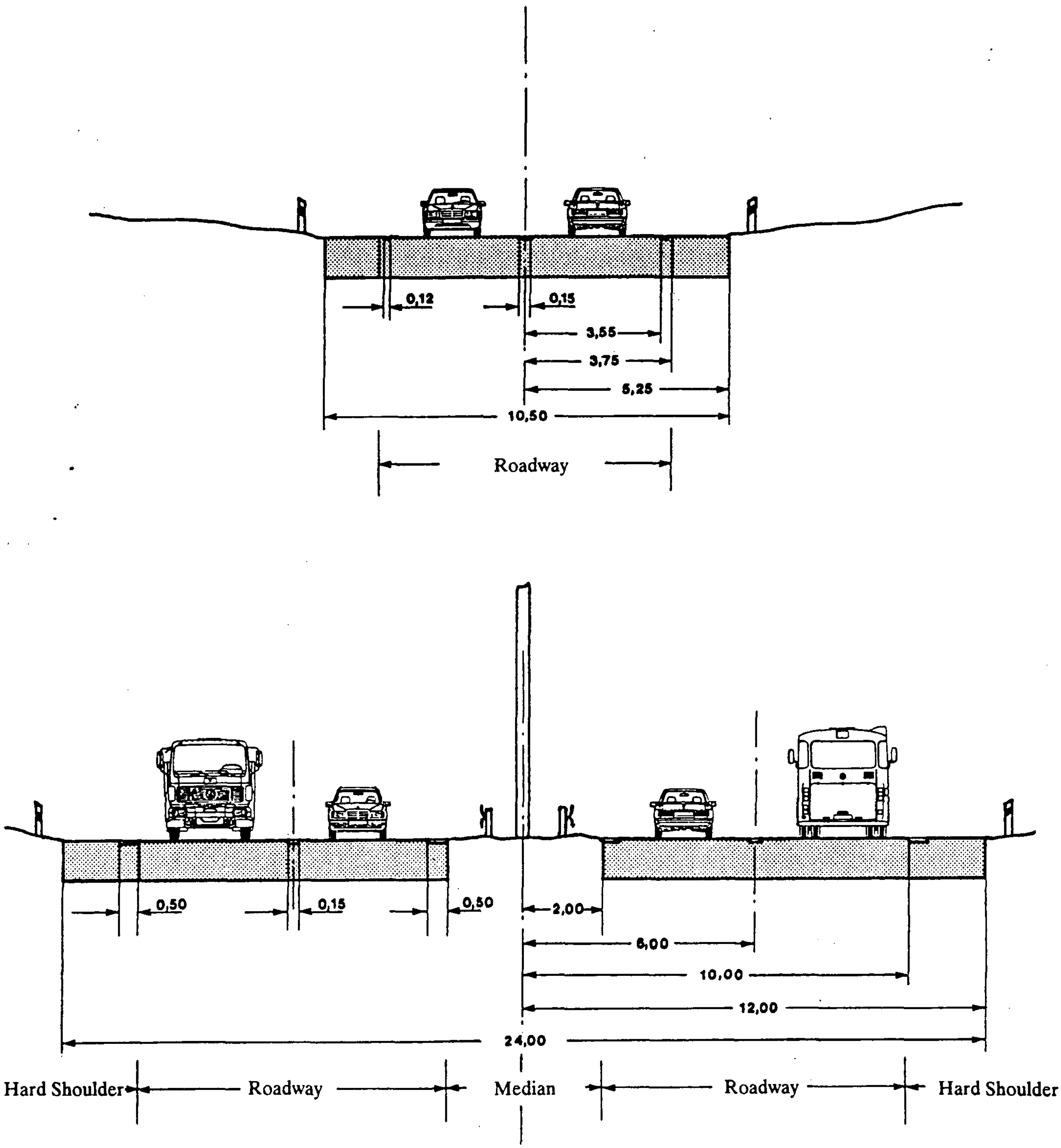


Fig. 2: Cross-sections of Country Road (top) and Autobahn (bottom), dimensions in m

Movement System

The projection dome containing the simulator is supported by six extremely low-friction hydraulic cylinders. The manner in which these are arranged and fixed to the movement platform and the base frame by means of universal joints permits movement of the entire structure (approx. 5 t) in six degrees of freedom. This allows simulation of vehicle movements at a limit frequency of 5 Hz and permits brief accelerations of 1 g. This makes it the best movement system currently available with six degrees of freedom (see Fig. 3).

Nevertheless, the limited cylinder stroke means that the possible scope for movement is too small to allow correct simulation of longer translational accelerations. In order to give the driver the right subjective impression of acceleration for these driving conditions, a special movement algorithm is employed to tilt the platform so that the resulting component of acceleration due to gravity which the driver feels acts in the right direction, e.g., the platform is tilted to the outside left when driving round a right-hand bend. The driver only sees the projection of the road he is traveling on and not the way he is being moved and thus feels the centrifugal acceleration.

This type of movement simulation is sufficient for most driving conditions. However, the above-mentioned limitations may cause the driver to gain unrealistic impressions of movement during violent braking or when turning off at right angles with tight cornering due to the resulting large changes in acceleration and rapid tilting of the platform.

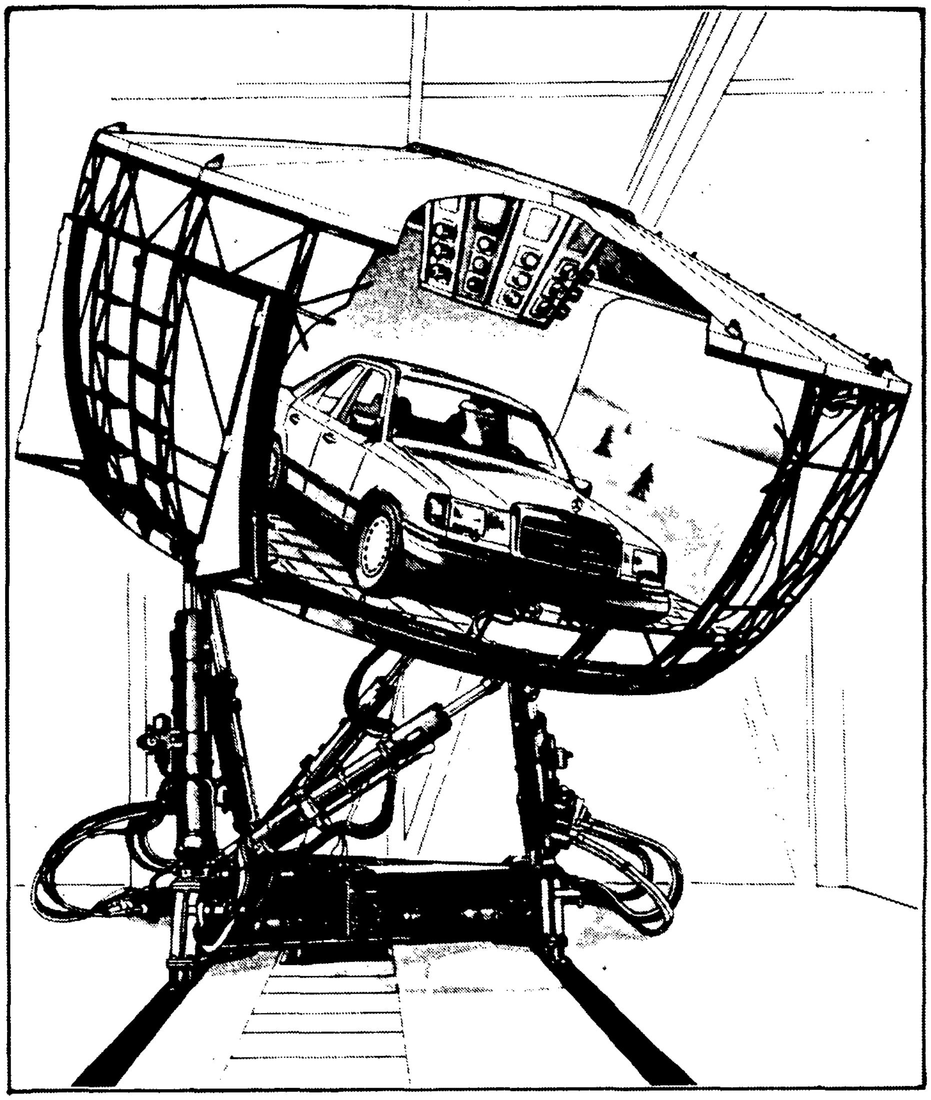


Fig. 3: Daimler-Benz Driving Simulator

Simulator Compartment

The simulator compartment (see Fig. 4) used in this test was a vehicle of the type "Mercedes-Benz 190 E" with the technical data given on the next page:

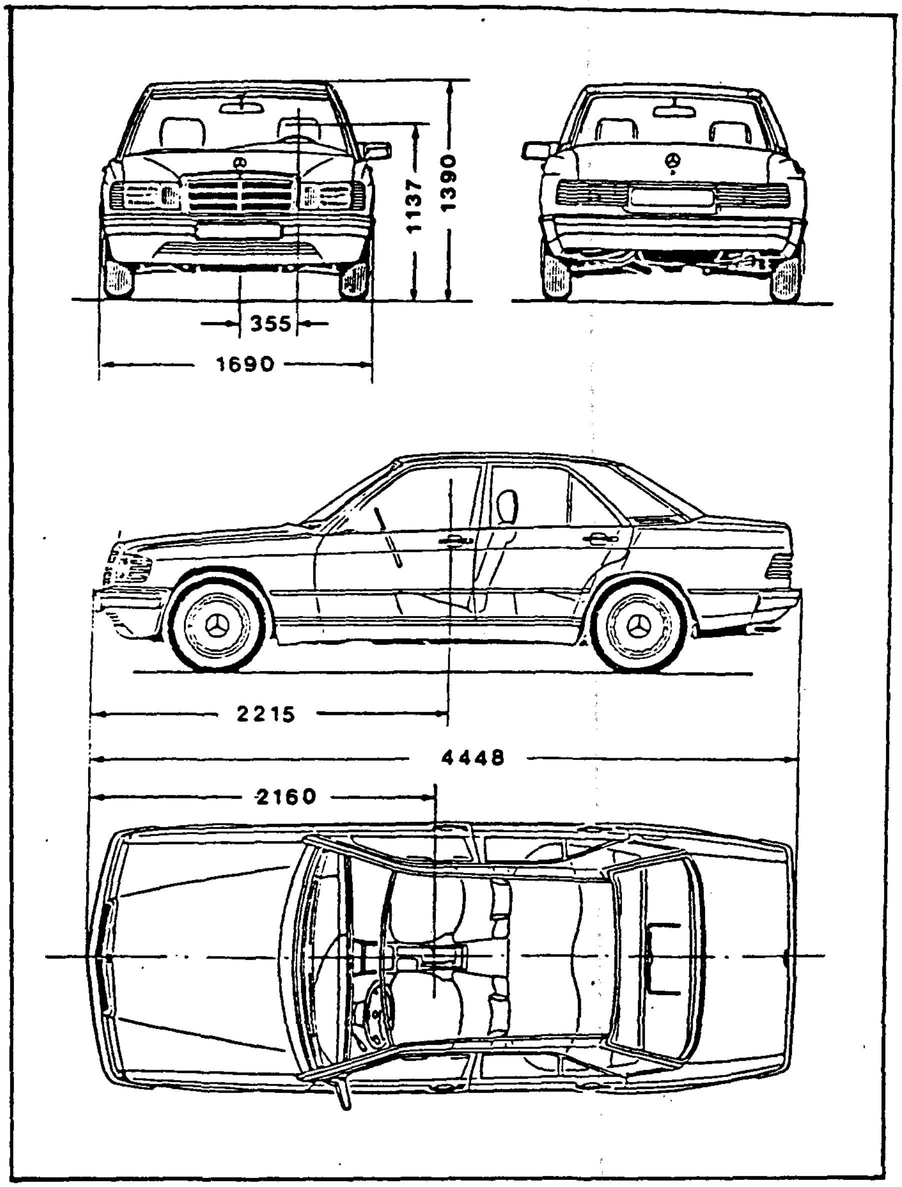


Fig. 4: Simulator Compartment, dimensions in mm

Length:	4448 mm
Width:	1690 mm
Vehicle weight:	1170 kg
Engine power:	75 kW
Transmission:	automatic
Maximum speed:	190 km/h
Brakes:	anti-locking braking system (ABS)

The subjects were required to perform various driving tasks (scenarios) in the simulator described above, e.g., approaching a junction controlled by traffic lights, driving along a narrow section of roadway or merging into a major road. The tasks selected either required a normal response or were more demanding in nature, as in the case of the sudden appearance of an obstacle on the roadway (dart-out). The scenarios selected are described in detail in chapter 5.

3.4 Psychometric Performance Tests

In addition to the test drive in the simulator, laboratory tests that have previously been shown to be sensitive to changes in performance were conducted with the same subjects. Key parameters affecting driving ability such as attention, concentration, perception, information processing and sensory coordination powers, and also situation-related mood were indentified by means of the following test procedures. The total duration of the test was around 40 minutes.

<u>Determination Apparatus (DTG)</u> (17)

This apparatus permits assessment of accuracy and speed of response, attention and concentration with regard to variable optical stimuli. The apparatus consists of a

screen to display 5 color stimuli (5 different colors, different positions for each color) and a console with corresponding color keys which the subjects must press with their fingers. They must respond to 2 additional light signals on the outside of the display by depressing 2 foot pedals. The object of the test is to respond to 180 optical stimuli as quickly and accurately as possible. The speed was determined by the subjects themselves as the next stimulus was not issued until the subject had pressed the key or foot pedal.
The sum of correct responses and the average total response time were recorded. The quotient was calculated from the correct responses and the total response time. While the sum of correct responses and the average total response time only give quantitative results, the quotient from the sum of correct responses and the total response time permits a qualitative assessment as it also considers the instruction issued to the subjects to respond as correctly and quickly as possible.

Attention Testing Apparatus (APG) (18)

This apparatus developed by Arnold Müller is used to investigate powers of attention, concentration and memory in the area of optical perception. The efficiency of the DTG method described above was extended in that the subjects had to move their eyes and sometimes even their heads because of the central and peripheral location of the stimuli.

9 white lamps were arranged on the central panel and 6 on each of the two side panels of a 3-wing display with a total angle of view of 130°. The lamps were arranged

in a geometrical pattern and the subjects were required to respond by pressing a button when four lamps lit up to form a square. A sequence of three colors was also run in front of the subjects at the same time. The subjects had to respond by pressing a button when the sequence blue-yellow-red occurred. After a brief introductory phase, the speed of the successive light and color stimuli was set at 1.2 seconds. The program was run a total of 4 times, the maximum possible number of correct responses for each run being 8 color sequences, 10 squares on the central panel and 2 squares on each of the side panels.

Besides the correct responses, the apparatus also records incorrect, i.e., extra or omitted responses. The sums of the correct and omitted responses gives the maximum number of correct responses. We recorded the sum of correct and of incorrect responses. The difference between correct and incorrect responses was evaluated.

Tachistoscopic Perception Test (TAVT) (19)

This test developed by Schubert in 1962 and modified by Hampel in 1974 detects the speed and accuracy of optical perception of complex traffic situations in the case of extremely brief exposure to stimuli. It provides information about the driver's ability quickly to distinguish the essential elements of any given traffic situation.

22 color slides (incl. 2 practice slides) were projected onto a screen for 1 second. The subjects were required to indentify five important traffic categories

(motor vehicles, cycle riders, pedestrians, traffic lights and traffic signs) on each slide and enter the answers on a form.

The number of omitted and extra incorrect responses was recorded. The sum of incorrect responses can be assigned to a percentage rating. The subjects were also requested to estimate their own performance, i.e., the number of correct responses.
The total number of incorrect responses was evaluated.

Basle Mood Scale (BBS) (20)

This questionnaire, conceived by Hobi, is intended to provide information on the situation-related, instantaneous mood of the subjects. Repeated testing of the same subjects permits quantification of brief changes in their condition. The questionnaire lists 20 opposing characteristics which are intended to determine the current mood of the subjects (see Table 3.4). The subjects were able to classify themselves on a 7-point scale.

The questionnaire was presented to them twice on the test day; immediately after their arrival at the test center and between the simulator test and the laboratory tests. 4 factors were recorded: vitality (VT), intrapsychic equilibrium (IE), social extraversion (SE), vigilance, cognitive control and capacity (VG). The sum of calculated values was also recorded.

Table 3.4: Personality Characteristics of the Basle Mood Scale (BBS)

Vitality (VT)		
fresh	......	tired
invigorated	......	weakened
energetic	......	exhausted
healthy	......	ill
Intrapsychic Equilibrium (IG)		
calm	......	nervous
stable	......	unstable
sure	......	unsure
not timid	......	timid
Social Extraversion (SE)		
talkative	......	quiet
gregarious	......	reserved
communicative	......	withdrawn
sociable	......	shy
Vigilance (VG)		
concentrated	......	unconcentrated
attentive	......	unattentive
vigilant	......	absent-minded
purposeful	......	easily distracted

3.5 Data Measurement, Processing and Evaluation

Evaluation of the scenarios frequently involved the consideration of time differences, e.g., between the moment when the traffic lights change and the moment when the driver releases the accelerator. These time differences were of the order of 0.2 seconds. In order to determine these times with sufficient accuracy, they were interrogated 50 times per second (0.02 sec). The following variables were also measured and stored in the data frame at the same frequency (0.02 sec): scenario and subject numbers, accelerator travel, braking force, longitudinal and lateral acceleration, coefficient of friction, traffic light state, longitudinal and transverse position of the test vehicle.

Data were also stored for "other vehicles" (oncoming vehicles or vehicles traveling ahead). The relevant data concerned the speed and position of the other vehicles and also the lighting up of the brake lights of a vehicle traveling in front of the test vehicle. The amplitude error of the analog data, e.g., braking pressure, was <1 %. Additional variables for describing the driving behavior (e.g., leaving the roadway, crash) were derived from the data collected.

In order to obtain an initial overview of the data, one "raw data extract" was prepared for each subject. Only every 50th data frame was printed out. An initial plausibility test was performed with the aid of a matrix which also permitted monitoring of the sequences of the individual scenarios. This procedure was required to determine whether the simulator was performing correctly.

The second stage involved calculating the variables as defined in the appendix and entering them in a standard file according to subject number and situation number. This file was supplemented with the information obtained by means of the psychophysical performance tests and subject questionnaires (chapter 3.4).

The data compiled in this way were listed according to subject and/or situation and dosage of the drug. The lists were output and statistical evaluation was performed with the aid of the $SPSS^{X}$ program package. Mann-Whitney U tests for unrelated random samples were accompanied by chi-square tests and Scheffe tests (21). Statistical tests for differences between the groups were only performed when these differences were not too small. Differences which were clear but not significant were described as tendencies or trends.

4 Performance of Tests

4.1 Description of Subject Group

The selection criteria listed in chapter 3.2 (age, body weight, driving experience and annual mileage) were distributed uniformly among the three groups (see Table 4.1.1): the average age was somewhat above 24 and the average weight around 69 kg. The subjects had average driving experience of 5.7 to 6 years, their average annual mileage was between 7,800 km and 8,200 km. The minimum/maximum variables were applied as described in chapter 3.2.

In addition to these variables, a whole series of other data was also gathered. Table 4.1.2 illustrates consumption of semi-luxury products. Almost all the subjects drink alcohol, beer being the most frequently consumed.

Questioned on the frequency of their alcohol consumption, 44 % replied "rarely", 36 % "occasionally" and 21 % "often/daily".

Only half the subjects were smokers. Their average daily consumption was 10 to 12 cigarettes, the minimum and maximum values ranging from 1 to 20.

Six subjects admitted to occasionally taking marijuana, most of these being in Group L (control group). The frequency of consumption was, however, low, as was shown by the negative THC result in a urine screening test performed on the test day. This indicated that the last time the subjects had taken marijuana was at least 14 days before the test date.

It was possible to elicit further information through questioning of the subjects (see Table 4.1.3). This showed that almost two thirds of the subjects had had at least one road accident when driving motor vehicles, although most of these involved only minor bodywork damage. 38 % said they had experienced other accidents, primarily sporting accidents. Four subjects had experienced serious illness, namely pneumonia, hepatitis, coarctation of the aorta and a kidney operation. The subjects were also asked if they suffered from any allergies such as hay fever, asthma or allergies to medicines or foods; 28 % responded affirmatively. A quarter of the subjects admitted to occasionally feeling dizzy or faint, this always being the result of orthostatic disturbances of circulatory regulation. 17 % of the subjects recalled having previously taken medication, including cough mixtures, gastro-intestinal medicines or antibiotics, mainly against acne.

To ensure that the individual groups did not differ in terms of traffic-relevant characteristics such as excitability, aggressiveness, emotionality or performance drive, the Freiburg Personality Inventory (FPI) was applied (see chapter 3.2). Table 4.1.4 indicates that, with two exceptions, the differences between the groups are minor. The exceptions were "physical complaints" which Groups L and M suffered less than Group H, and "self-consciousness" where Group M was more self-confident than Group H.

Table 4.1.1: Data on the Subjects (Averages)

Variables \ Subject group	L	M	H
Age in years	24.1	24.2	24.6
Body weight in kg	69.4	69.9	68.5
Body height in cm	181	180	179
Driving experience (yrs)	6.0	5.7	5.8
Annual mileage (km)	8,172	7,885	7,840

Table 4.1.2: Consumption of Semi-Luxury Products

Variables \ Subject group	L	M	H	Total N = 60	Total %
Alcohol	20	19	20	59	98
- rarely	14	5	7	26	44
- occasionally	3	11	7	21	36
- often/daily	3	3	6	12	21
Daily consumption of cigarettes	8	9	13	30	50
Marijuana	4	1	1	6	10

Table 4.1.3: Information Obtained From Questioning of Subjects (Number of Subjects)

Variables \ Subject group	L	M	H	Total N = 60	%
Persons with traffic accidents	13	11	14	38	63
Number of traffic accidents	15	14	14	43	
Persons with other accidents	6	11	6	23	38
Number of other accidents	7	14	8	29	
Persons with serious illnesses	3	1	2	6	10
Persons with allergies	3	7	7	17	28
Persons with occasional dizziness or faints	5	3	7	15	25
Persons with previous history of medication	3	3	4	10	17

Table 4.1.4: Evaluation of the Freiburg Personality Inventory (Stanine Averages)

Variables \ Subject group		L	M	H
1	Satisfaction with life	5.55	5.45	4.95
2	Social orientation	6.00	6.60	5.75
3	Performance drive	5.05	4.60	5.10
4	Self-consciousness	4.95	4.30	5.30
5	Excitability	4.35	4.30	4.45
6	Aggressiveness	3.65	4.15	4.45
7	Stress/strain	3.95	3.25	3.95
8	Physical complaints	3.20	3.10	4.20
9	Health problems	5.15	5.40	4.55
10	Openness	5.10	5.70	5.40
E	Extraversion	4.80	5.10	5.10
M	Emotionality	3.75	3.85	4.15

4.2 Test Sequence and Findings on Test Day

Table 4.2.1 shows the timetable of the individual test days. On each test day, three subjects arrived at the test center at around 8.30 am. Testing was performed four days a week. Since the medical history and clinical tests had sometimes taken place several weeks before the test day, some additional medical tests were performed on the test day itself. Each subject was required to undergo a breath test and also urine screening for drugs. If the breath test proved positive the subject was replaced immediately. In the case of urine screening, the results were only available the following day so the subject was replaced afterwards if drugs were detected in his urine (see chapter 3.2). The subjects had been instructed to breakfast normally. 63 % had drunk coffee or, in a few cases, tea with breakfast (usually at least two hours before the test) and 25 % of them had smoked (see Table 4.2.2). Their pulse and blood pressures were measured, all results being normal. The subjects were then asked for the first time to answer the Basle Mood Scale questionnaire.
After a 10-minute introductory drive (see chapter 4.3) in the simulator which was aimed at familiarizing the subjects with the equipment, the subjects were randomly allocated to the test groups. For organizational reasons, the first subject served as control candidate (without diazepam), the second received 0.11 mg/kg and the third 0.22 mg/kg of liquid diazepam.

The first subject then completed the 20-minute test drive in the simulator. The second and third subjects each performed the test drive 1 hour after taking the drug. They waited in a quiet room in the intervening period. It was ensured that the subjects could not discuss the simulator test drive. Blood samples were taken immediately before and after the test drive to determine the level of active substance in the blood.

The simulator tests were supervised by the same test director during the entire six-week period of testing. He kept a brief record of the introductory and test drive. No subject was forced to interrupt or abandon the simulator test due to nausea or circulatory collapse. Some faults occurred both in the computer and the image system. If these faults occurred on an open stretch of road (usually the case), the subjects were allowed to continue after clearance of the faults; if they occurred during a scenario, the scenario was repeated. Table 4.2.3 lists all technical faults which occurred.

The simulator test drive was followed by the psychometric tests which began with completion of the Basle Mood Scale questionnaire, followed by the tests with the determination apparatus and the attention testing apparatus, and ended with the tachistoscopic peception test.

All tests were usually completed by 1 pm. The two subjects who had taken diazepam were driven home by the test director. The subjects reported the following day for clinical and laboratory reexamination. This was intended both to protect the health of the subjects and to protect the test director in case damages claims were raised at a later date.

Table 4.2.1: Timetable on Test Day

Time	Subject 1 L Control group	Subject 2 M Medium dosage	Subject 3 H High dosage
8.30	Arrival of 3 subjects at Daimler-Benz test center, reception by test director, doctor and psychologist		
8.45	Breath test (alcohol), recording of findings, Basle Mood Test, urine screening, measurement of blood pressure and pulse		
9.30	Introductory drive		
9.45		Introductory drive	
10.00		Taking of drug	Introductory drive
10.15	Test drive		
10.30			Taking of drug
10.55	Laboratory tests BBS, APG, DTG, TAVT	Blood sample	
11.00		Test drive	
11.25			Blood sample
11.30		Blood sample	Test drive
11.40		Laboratory tests BBS, APG, DTG, TAVT	
12.00			Blood sample
12.10			Laboratory tests BBS, APG, DTG, TAVT
13.00	End of tests		

BBS = Basle Mood Scale, APG = Attention Testing Apparatus,
DTG = Determination Apparatus, TAVT = Tachistoscopic Perception Test

Table 4.2.2: Consumption of Semi-Luxury Products Before Testing

Variables \ Subject group	L	M	H	Total N = 60	%
Nicotine consumption	4	5	6	15	25
Coffee (tea) consumption	14	9	15	38	63

Table 4.2.3: Test Director's Notes on Test Drives

No.	Group	Time of start of test	Type of fault and time of occurrence
4	M	11.02	11.19-11.23 Image fault at right and left of image. Test continued
10	M	10.59	11.08 Interruption (2 sec) due to recording problems
11	H	11.29	11.39 Test image stopped for 2 sec 11.40 Test image stopped for 2 sec (did not affect test drive)
13	M	11.00	11.08-11.21 Color fault at right of image; affected landscape but not roadway. Did not distract driver
15	L	10.34	10.41-10.42 Image fault, test drive continued
19	M	11.01	11.03 Brief image fault (< 30 sec) in Scenario 3 11.18-11.19 } Image fault affecting 11.20-11.27 } landscape Test drive not interrupted
20	H	11.35	11.35 Brief stop due to image fault, test drive then continued
23	H	11.30	11.41 Interruption of Scenario 6 (when turning right) due to recording problems 11.45 Test continued from point before interruption (entire merging process repeated)
31	M	11.05	Driver stopped in Scenario 8 because he did not want to overtake
39	L	10.20	10.28 Image stopped on free section of road. Test drive repeated from start. In the second run, the cones did not appear; test stopped again. Third test run was successful
42	L	10.21	Image fault at start; test repeated
57	L	10.32	Nausea, especially when cornering, sweating. Continued test, however
117	H	12.00	12.13 Scenario 6, image stopped 12.14 Test drive continued (before turning right)

4.3 Test Drives in Simulator

4.3.1 Introductory Drive

An introductory drive lasting approx. 10 minutes was needed in order to familiarize the subjects with the simulator environment. It was intended to familiarize them with the synthetic image and also to give them the feel of the simulated movements of the vehicle. It was also important to familiarize the subjects with the vehicle itself, a Mercedes-Benz, as the test group consisted entirely of young students who were not likely to be frequent drivers of upper medium range cars (with anti-locking braking system (ABS), automatic transmission and power steering). The subjects were instructed to keep to a speed of 22 m/s (approx. 80 km/h) and not to overtake any vehicles.

The introductory drive began on a long straight section of two-lane country road (1 lane in each direction). A crossroads with a set of traffic lights appeared after one kilometer. A truck approached from the left and stopped at the crossroads. The traffic lights for the test vehicle were green. The test vehicle followed the country road for approx. another 2 km until reaching an intersection with a "Stop" sign at its junction. The test vehicle turned right and continued its journey. There was occasional oncoming traffic. After some 1.3 km, the test vehicle reached a snow-covered road section (white road surface) which was announced by an information sign. In this section, the test vehicle had to drive round an obstacle in the right-hand lane.

The next section of country road was clear of snow and straight. There was no oncoming traffic. After some 1.8 km, the straight section was replaced by a broadly winding section. After 25 seconds on this section, a car appeared in front, which the test vehicle followed. After approx. 110 seconds, the car braked briefly and moved onto the right-hand hard shoulder, where it stopped. There was occasional oncoming traffic during this section. The test vehicle continued its journey along this slightly winding, uphill road section and, about 1.3 km further on, passed a bus parked on the right-hand hard shoulder.

After another 2 km - and announced to the driver by means of information signs - the country road turned into an autobahn. After 400 m, the right-hand lane was somewhat narrowed by a row of traffic cones. The traffic cones stood at 10-m intervals on the left and right-hand lane markings. While passing though the row of traffic cones, the director of the test asked the driver to perform an emergency stop. After coming to a halt, the test vehicle set off again. It was accelerated back up to approx. 22 m/s and then slowly braked to a halt. The total road section covered was about 10 km long. The roadway was dry apart from the snow-covered section.

4.3.2 Test Drive

The test drive lasted approx. 20 minutes. The test director instructed the subjects to keep to a speed of 22 m/s and not to overtake any vehicles in front. The test drive consisted of different situations (scenarios) which placed differing requirements on the driver. The individual scenarios were separated by a free section of road to allow the drivers to get back to the speed of 22 m/s. The drivers occasionally encountered oncoming traffic to make the route as realistic as possible. The test drive took place during daylight and always on a dry roadway (apart from the snow-covered section). In the "Narrow Road" scenario, a 2-lane autobahn (2 lanes in each direction) was simulated, in all other scenarios the subject drove on a country road (1 lane in each direction, see p. 29) which included both straight and broadly winding sections. The key characteristics of the individual scenarios were as follows:

In the "Traffic Light Change" experiment, the driver was faced with two different situations. In the first case, the lights changed from "green" to "yellow" when the driver was 110 m from the stop line so that a normal response was sufficient to bring the car to a halt. In the second case, a quick response was required as the lights changed when the driver was only 67 m from the stop line.

The "Following Situation" scenario also required a normal response in one case and a quick response in the other. The driver was required to follow the vehicle in front at a comfortable distance. In the first case, the other vehicle drove for a considerable time at a constant speed and then decelerated gradually before stopping on the right-hand hard shoulder. This did not involve a particularly demanding response. In the second case, the other vehicle decelerated very sharply and stopped on the roadway. Various driving strategies were possible to avoid collision.

There were also two versions of the "Dart-Out Situation". In one case, a vehicle parked on the right-hand hard shoulder suddenly pulled out into the road and then stopped again on the right-hand hard shoulder after proceeding for a short while. In the second case, a skateboarder darted out from behind a bus parked on the right-hand hard shoulder and crossed the road. A normal braking response was sufficient to avoid collision with the vehicle in the first case, but an extremely quick response was required to prevent collision with the skateboarder.

A snow-covered road was simulated for the "Snow on Road" scenario. The coefficient of friction was considerably reduced but not as low as on ice.

In the "Merge into Traffic Situation", the driver had to choose between three options. The driver approached a junction with a stop sign and was instructed to turn right into the major road. Two cars were approaching from the left on the major road. The driver had to respond very quickly in order to move into the major road ahead of the first of these cars. He had a little more time to turn into the road ahead of the second car. The third option was to let both cars pass before turning into the road.

The "Narrow Road Situation" was the only scenario which took place on a section of autobahn. The presence of traffic cones narrowed the roadway and the drivers were instructed to avoid hitting the cones.

The object of the last scenario, the "Free Road Situation", was to observe the lane behavior of the driver to determine whether he was suffering fatigue.

During the test drive, the scenarios were performed in the following order:

Narrow Road Situation
Following Situation, Normal Response
Dart-Out Situation, Normal Response
Traffic Light Change from Green to Red, Normal Response
Traffic Light Change from Green to Red, Quick Response
Merge into Traffic Situation

Snow on the Road Situation
Following Situation, Quick Response
Dart-Out Situation, Quick Response
Free Road Situation

The individual scenarios are further described in chapter 5. The evaluated variables such as speed, vehicle position, maximum deceleration, response time, time gap are described in the appendix.
An impression of the simulator images is given by the photos on the next page.

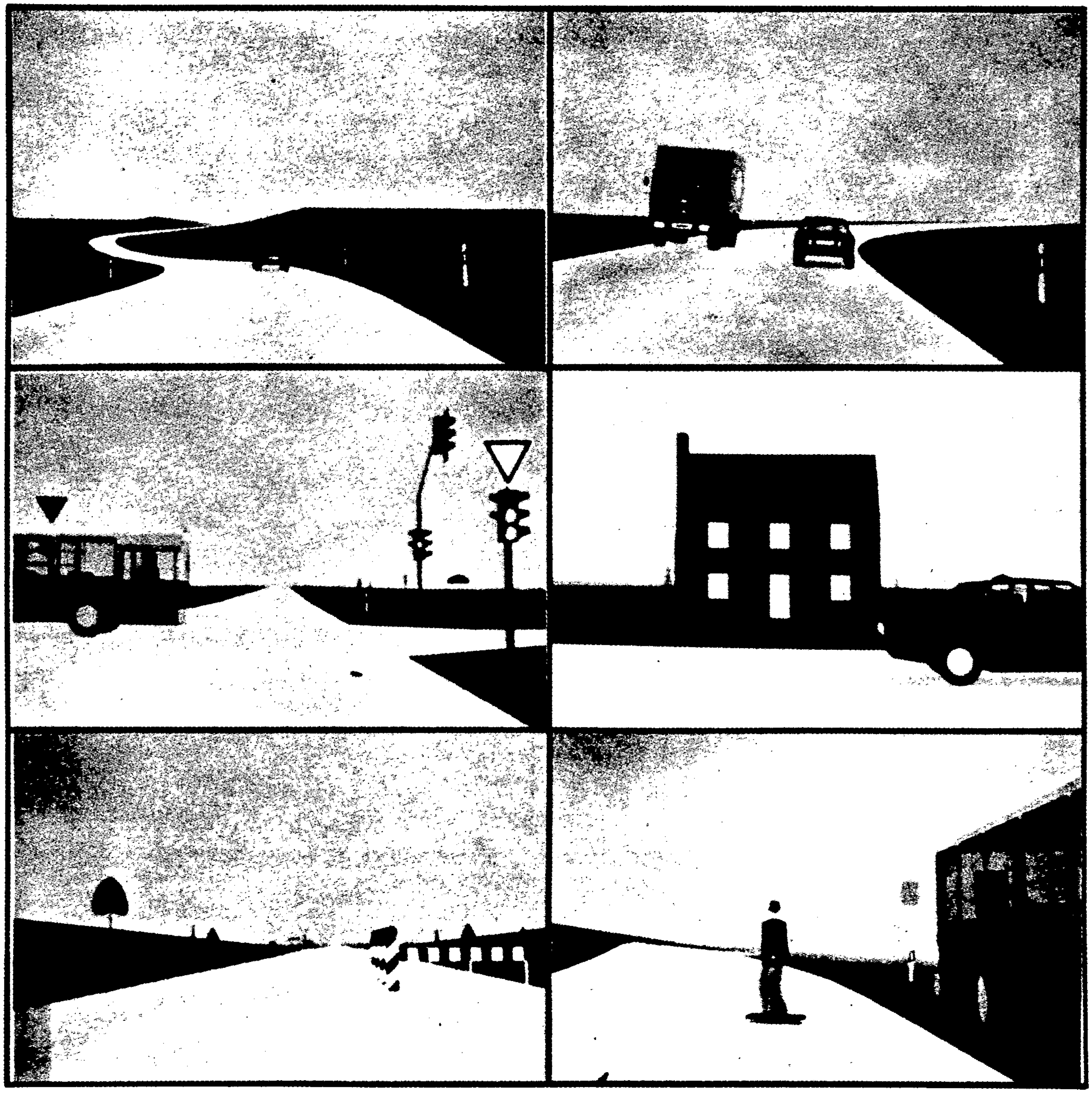
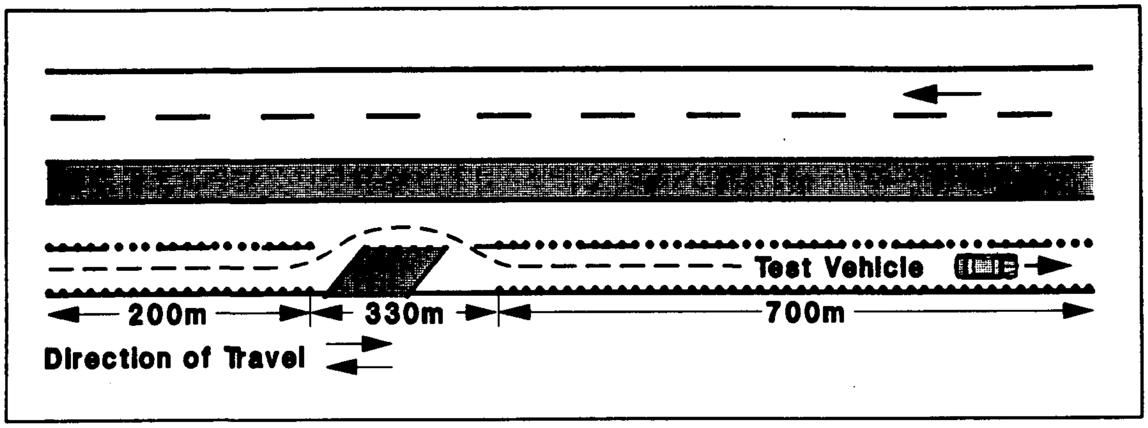


Fig. 5: Simulator images from some szenarios: "Following Situation" (upper two), "Traffic Light Change Situation" (middle left), "Merge into Traffic Situation" (middle right), "Snow on the Road Situation" (bottom left), "Dart out Situation" (bottom right).

5 Evaluation of the Scenarios

5.1 Scenario: Narrow Road Situation



5.1.1 Description

The test vehicle drove along the right-hand lane of an autobahn. After approx. 140 m, the test vehicle had to drive through a 200-m-long row of traffic cones in the right-hand lane. The cones were placed at 10-m intervals on the left and right-hand lane markings, barely restricting the width of the right-hand lane. In the 330-m-long cone-free section which followed, the test vehicle had to drive round an obstacle (striped barrier) blocking the right-hand lane. The test vehicle then continued through a second, 700-m-long row of traffic cones in the right-hand lane. It took approx. 32-38 seconds to drive through the second cone section. The entire scene lasted approx. 70-80 seconds. This scenario was designed to test prolonged driving in a restricted lane, and to see whether negotiating an obstacle in any way affected driving ability in restricted lane situations. This scenario formed the start of the simulated drive.

5.1.2 Evaluation

5.1.2.1 First Row of Traffic Cones (200 m long)

In this scenario, the driving behavior was analyzed at various points along the highway and while driving through a cone section. The measured local speeds before the traffic cones came into sight were very homogeneous in each of the three groups, and there were no differences between the groups (see Table 5.1.1). The local speeds were also approximately the same in all groups at the start of the row of cones. There was no reduction in speed.
There was also almost no reduction in speed within the approx. 200-m-long cone section. The difference between reduced minimum and maximum speeds while passing through the first row of cones revealed no fundamental differences between the subjects nor between the groups.

No subjects ran over cones, nor did any come critically close to cones. Changes in lateral position within the cone section were very small. The groups did not differ in terms of keeping in lane.

5.1.2.2 Second Row of Traffic Cones (700 m long)

Not all subjects entered the second row of cones in the right-hand lane immediately after driving round the obstacle. Five subjects in Group L , two in Group M and four in Group H initially remained in the left-hand lane and (in part) only moved into the row of cones when requested to do so by the director of the test. These subjects were therefore excluded from the scenario assessment.

The local speeds are given in Table 5.1.2. Prior avoidance of the obstacle meant that driving speeds at the start of the second row of traffic cones were noticeably lower than at the start of the first. There were no differences between the groups. At the end of the second row of cones, speeds increased back up to the levels recorded at the end of the first row of cones. Differences between the groups could not be identified. Due to the lower entry speeds, the maximum increases during the second cone section were larger than in the case of the first. No cones were run over in the second section and no vehicles came critically close to the cones here, either.

Because of the need to drive round the obstacle, changes in lateral position were not observed during the second row of cones.

5.1.3 Assessment

The subjects coped easily with the first scenario. The late entry by some subjects into the second row of cones was more the result of misunderstandings between the test director and subjects than of inadequate attention.

Effects from medication could not be identified in this scenario.

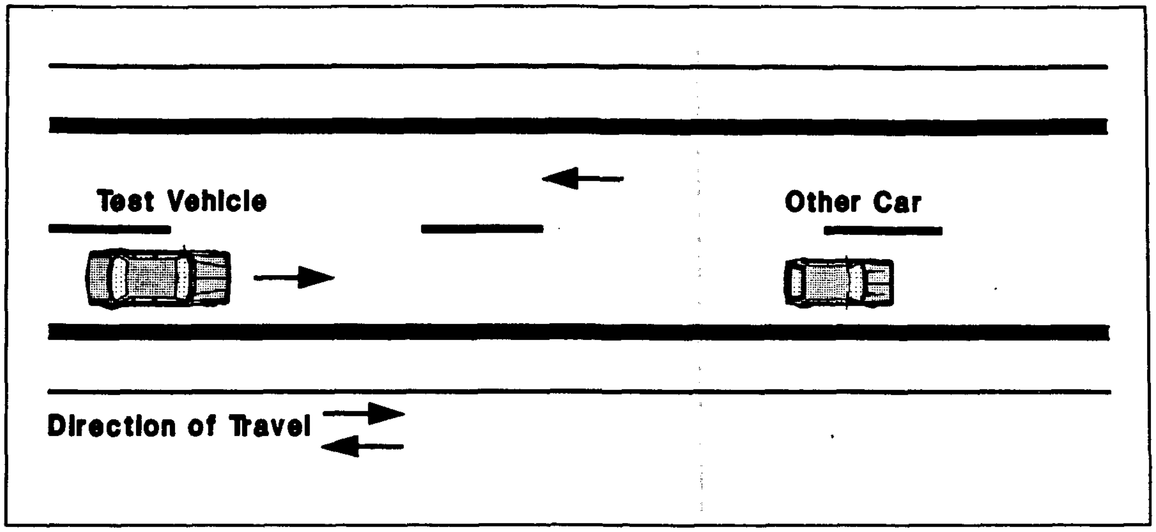
Table 5.1.1: Driving Behavior in Scenario 1 (Speeds and Positioning Behavior in the First Row of Cones)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Local speed, before cones in sight (m/s)	$\bar{x}$ s min. max.	22.95 0.96 21.30 24.98	22.64 0.99 20.92 25.06	22.45 1.04 20.64 24.21
Local speed at start of row of cones (m/s)	$\bar{x}$ s min. max.	22.56 0.89 20.39 23.84	22.28 0.92 20.46 23.96	22.06 1.06 19.45 24.04
Local speed at end of row of cones (m/s)	$\bar{x}$ s min. max.	22.11 1.48 17.45 24.35	21.98 1.22 20.04 23.97	21.76 1.59 17.76 23.93
Speed difference while driving through cones (max V - min V) (m/s)	$\bar{x}$ s min. max.	0.69 0.88 0.05 3.10	0.67 0.67 0.01 2.15	0.81 0.77 0.05 3.45
Average distance of left-hand side of vehicle from center of road (m)	$\bar{x}$ s min. max.	6.77 0.19 6.50 7.16	6.77 0.17 6.52 7.11	6.87 0.18 6.52 7.18

Table 5.1.2: Driving Behavior in Scenario 1 (Speeds in the Second Row of Cones)

Variables \ Subject group		L	M	H
Number of subjects	n	15	18	16
Local speed at start of row of cones (m/s)	$\bar{x}$	19.94	18.59	18.42
	s	2.92	3.21	2.87
	min.	12.74	7.75	11.84
	max.	23.80	23.04	23.46
Local speed at end of row of cones (m/s)	$\bar{x}$	22.47	22.36	22.43
	s	0.89	1.18	1.31
	min.	20.50	20.20	19.33
	max.	23.49	24.46	24.91
Speed difference while driving through cones (max V - min V) (m/s)	$\bar{x}$	4.02	4.91	5.12
	s	2.40	3.11	2.14
	min.	0.56	0.56	2.77
	max.	8.37	15.49	10.43

5.2 Scenario: Following Situation, Normal Response



5.2.1 Description

The test vehicle drove along a country road at the prescribed speed of approx. 22 m/s. The road followed a broadly winding course; there was occasional oncoming traffic. After approx. 1000 m, the test vehicle caught up with a car in front. The test vehicle followed this car for a distance of approx. 1100 m. The car maintained a constant speed of 18 m/s on this section. The subject was expected to follow the car at a comfortable distance and not to overtake it. The other car then clearly reduced its speed to 11 m/s and continued for a further approx. 600 m at this lower speed, before stopping on the right-hand hard shoulder.

The entire scene lasted approx. 150-160 seconds. The object of the scenario was to analyze how the subjects reacted to the car when in front and when slowing down.

5.2.2 Evaluation

This scenario was used to record the behavior of the subject

- during the period from the appearance of the car in front until it braked
- at the moment when the car in front braked
- during the period from when the car in front braked until it disappeared.

The distance between the test vehicle and the car in front up to the moment of braking was characterized in terms of minimum, maximum and average time gaps. Table 5.2.1 shows that these variables differed very little between the three groups. There were clear differences within the groups, however. A time gap of less than 1 second was recorded for one subject in Group M and two in Group H, while no such gap was recorded for any subject in Group L. When considering the maximum time gap it must be remembered that it occurred at the start of the scene when the distance to the car in front was particularly large at approx. 150 m. The mean value for average time gaps was some 3.3 seconds in all groups.

A high scanning frequency allowed approx. 5500 time gap values to be recorded per subject over a period of 100-110 seconds while the test vehicle was following the car in front. These values were then used to calculate individual standard deviation from the average time gap of each subject. Table 5.2.2 shows the average group values and standard deviations for the three groups. There were no differences between the groups.

While following the car in front, drivers in all groups displayed a clear tendency to cross the center line. This was partially due to the fact that a large number of subjects attempted to overtake the other car. This behavior can also, however, be interpreted as a cautionary measure as the car in front gradually reduced its speed from 18 m/s to 11 m/s over the 1100-m test route and the subjects had to be prepared for it stopping suddenly. Particularly in this scenario, when the car in front reduced its speed to 11 m/s, the subjects often had to be warned not to overtake or instructed to stop an overtaking maneuver and keep behind the other car. Although all subjects had received repeated instructions not to overtake, they often asked whether they could do so during this situation. There were no differences between the groups. There were only three subjects in Group L, four in Group M and two in Group H who remained within the right-hand lane at all times (see Table 5.2.3).

Following distances at the moment of braking by the car in front differed widely within the individual groups (see Table 5.2.4). It was noticeable that subjects in Group H tended to follow at a closer distance. Average time gaps at the start of braking by the car in front lay between 2.7 and 3.0 seconds. As a result of these lengthy time gaps, average response times (before touching the brake pedal) lay between 1.66 and 1.98 seconds. There were no differences between the groups.

Three subjects in Group L did not brake. Two of these were following at distances of 76 and 97 meters respectively when the car in front braked, so that they were able to avoid a collision without leaving their lane. One subject from Group L accelerated and overtook the car in the left-hand, opposite lane. In Groups M and H one subject accelerated and overtook the car in the left-hand, opposite lane. The other three were a long way behind and so did not have to brake (see Table 5.2.5). The speeds of the five subjects who did not brake and did not overtake lay between 16.7 and 18.3 m/s. They were barely slower than the average group speeds (18.9 m/s).

Test vehicle deceleration was described by instantaneous maximum deceleration (see Table 5.2.6), ignoring the distribution of braking pressure over time. Deceleration was the result of braking and/or easing acceleration. This variable did not differ between the groups. There was moderate deceleration in all three groups in response to the behavior of the other car.

Each group contained one subject who did not slow down. Two of these overtook the car on the left, as described above. The third was 113 meters behind the car in front and therefore did not need to brake.

There were no differences in the following distances (average time gap) of the three groups after braking and up to the disappearance of the car in front. The individual range of scatter after braking of the other car was narrowest in Group M (see Table 5.2.6).

The result of the response to braking by the car in front was that the subjects in all three groups closed up to an average following distance of 30 meters behind the car in front. No collisions took place. None of the subjects stopped.

5.2.3 Assessment

The second scenario did not present the subjects with any major difficulties. Some subjects wanted to overtake the car in front but were instructed by the test director not to do so. Most subjects responded in the same way to the car in front braking and then continuing at a lower speed. Two subjects overtook it at this point. There were no differences between the groups under medication and the control group.

Table 5.2.1: Driving Behavior While Following and Before Braking by the Other Car in Scenario 2 (Time Gaps)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Minimum time gap (s)	$\bar{x}$	2.05	1.93	1.96
	s	0.84	0.76	0.69
	min.	1.08	0.71	0.74
	max.	4.19	3.89	3.28
Maximum time gap (s)	$\bar{x}$	6.55	6.76	6.63
	s	0.20	1.06	0.47
	min.	6.13	6.10	6.20
	max.	6.89	11.13	8.37
Average time gap (s)	$\bar{x}$	3.32	3.39	3.36
	s	0.84	0.96	1.00
	min.	2.21	2.07	1.82
	max.	5.39	5.32	6.02

Table 5.2.2: Driving Behavior While Following and Before Braking by the Other Car in Scenario 2 (Standard Deviation of Individual Time Gaps)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Standard deviation of individual time gaps	$\bar{x}$	1.10	1.19	1.13
	s	0.25	0.41	0.25
	min.	0.65	0.77	0.70
	max.	1.64	2.62	1.89

Table 5.2.3: Changing of Lane While Following and Before Braking by the Other Car in Scenario 2 (Number of Subjects)

Variables \ Subject group	L	M	H
- Remained in right-hand lane	3	4	2
- Crossed center line (max. at least half of test vehicle in left-hand lane)	16	15	18
- Test vehicle in left-hand lane	1	1	0
Σ	20	20	20

Table 5.2.4: Driving Behavior at the Moment of Braking by the Other Car in Scenario 2 (Following Distance, Time Gap and Response Time)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Distance between test vehicle and other vehicle (m)	$\bar{x}$ s VK[1] min. max.	50.04 18.54 0.37 24.48 97.73	51.21 21.50 0.42 13.03 112.93	47.45 15.55 0.33 21.29 80.98
Number of subjects	n	20	20	20
Time gap (s)	$\bar{x}$ s VK[1] min. max.	2.81 1.02 0.36 1.29 5.30	2.96 1.26 0.43 0.73 6.46	2.68 0.90 0.34 1.20 4.60
Number of subjects	n	17	18	18
Response time before touching brake pedal (s)	$\bar{x}$ s min. max.	1.81 0.71 1.00 3.59	1.98 0.82 1.20 3.90	1.66 0.53 0.60 2.74

[1]VK = Coefficient of variation: $\frac{s}{x}$

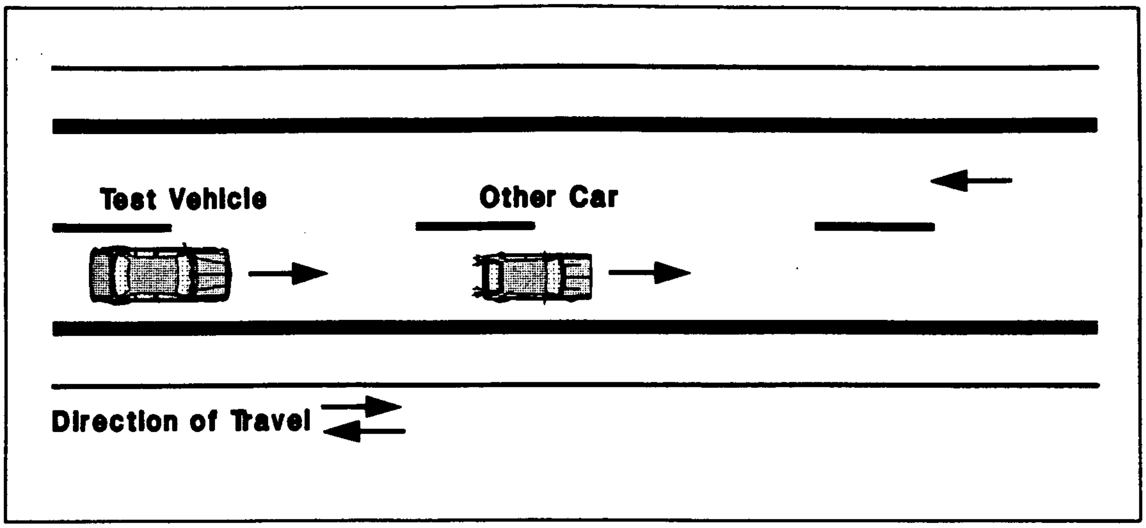
Table 5.2.5: Response at the Moment of Braking by the Other Car in Scenario 2 (Number of Subjects)

Variables \ Subject group	L	M	H
- Braked	17	18	18
- Did not brake because: large following distance overtook instead	 2 1	 2 0	 1 1
Σ	20	20	20

Table 5.2.6: Driving Behavior after Braking by and until Disappearance of Other Car in Scenario 2 (Deceleration, Time Gap and Standard Deviation of Individual Time Gaps, Following Distance)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Maximum deceleration (m/s^2)	$\bar{x}$ s min. max.	4.95 2.75 0.77 10.56	3.99 2.29 0.46 9.53	4.98 2.96 0.07 10.05
Number of subjects	n	19	20	19
Average time gap (s)	$\bar{x}$ s min. max.	2.70 1.08 1.20 5.33	2.36 0.66 1.37 3.87	2.65 1.12 1.45 4.70
Number of subjects	n	19	20	19
Standard deviation of individual time gaps (s)	$\bar{x}$ s min. max.	0.38 0.22 0.04 0.87	0.29 0.18 0.05 0.78	0.37 0.29 0.04 1.01
Number of subjects	n	19	20	19
Minimum distance between test vehicle and other car (m)	$\bar{x}$ s min. max.	31.11 10.34 10.85 46.06	30.43 10.74 5.54 47.39	31.67 11.65 15.41 59.02

5.3 Scenario: Following Situation, Quick Response



5.3.1 Description

The test vehicle drove along a broadly winding country road. There was occasional oncoming traffic. At the beginning of the scene, a car appeared 150 m in front traveling at a constant speed of 18 m/s. The test vehicle was instructed to follow this car at a distance the driver felt to be comfortable and not to overtake. The car drove for a distance of 1900 m before suddenly braking very sharply and coming to a halt in its lane (deceleration -10,5 m/s^2). After approx. 7-8 seconds, the car moved off and parked on the right-hand hard shoulder. The whole scene lasted approx. 115 seconds.
The object of this scene was to analyze how the subjects responded to the car traveling in front and then braking suddenly.

5.3.2 Evaluation

This scenario was used to record the behavior of the subjects

- while following the other car until it braked
- at the moment when the other car braked
- during the period between braking and disappearance of the car in front.

One subject in Group M, who stopped on a free section of road and then drove off again, was not included in the evaluation.

The average local speeds before the car braked did not differ between the three groups (see Table 5.3.1). At 18.7 m/s, they were of the same order as the speed of the car which the subjects were instructed not to overtake.

Following behavior is illustrated in the time gaps between the test vehicle and the car in front: the average minimum time gap did not differ between the three groups. Within the groups, however, the range of scatter was broad. The maximum time gap was excluded from the evaluation as it necessarily occurred at the start of the scene when the distance between the test vehicle and other car was particularly large (about 150 m). The minimum following speed did not differ between the groups either (see Table 5.3.1).

The average range of scatter of individual time gaps while following was higher for subjects in Group M than for those in Groups L and H (see Table 5.3.2).

The distance between test vehicle and the car in front when the car braked thus differed within the groups. The average distance to the car in front at the moment of braking was

62 meters for Groups L and H and 10 meters lower for Group M (see Table 5.3.3). The time gaps when the car in front braked were also larger in Groups L and H than in Group M. Three subjects in Group L, three in Group H and five in Group M followed with time gaps of less than 2 seconds, i.e. at too close a distance. Two subjects from Group H passed the other vehicle on the left (see below).

There were no differences in response time before touching the brake pedal. Driver response times longer than one second may reflect greater following distances behind the car in front, making a more rapid response unnecessary. There were no differences in maximum decelerations between the groups (see Table 5.3.3).

Two cases were excluded from the calculations. One subject in Group L did not brake and one in Group M did not decelerate as he only touched the brake pedal gently for less than one second. These two subjects overtook the car on the left at speeds of 17 and 18 m/s respectively. Two subjects in Group H and one in Group M only decelerated slightly, also overtaking the car on the left (Table 5.3.4).

Only one subject from Group M collided with the other car; despite a good response time (1.06 sec.) and maximum deceleration, his following distance at the moment of braking was too close (18 m).

In this scenario it was possible to differentiate between subjects who stopped and those who did not. Fifteen drivers in Groups L and H and twelve in Group M came to a halt, with fifteen from Group L, seven from Group M and nine from Group H remaining in the right-hand lane (see Table 5.3.4). Three subjects from Group M and two from Group H came to a halt with the left side of the test vehicle up to max. 1 m inside the left-hand lane. In addition, one subject from Group M stopped with the left side of the vehicle 2 meters inside the opposite lane.

The subjects who did not stop can be differentiated as follows: those who overtook on the left without deceleration or after only slight deceleration and those who overtook on the left after sharp deceleration (staying in left-hand lane for short or longer period/see Table 5.3.4).

The shortest following distances of the subjects who stopped are listed in Table 5.3.5. There were no significant differences between the groups.

Driving behavior was also observed with regard to the lateral position of the test vehicle. One subject in Group L and two in Group H passed the other car with less than half a meter lateral clearance. The remaining drivers passed further to the left of the car. No-one left the road (see Table 5.3.6).

5.3.3 Assessment

This scenario was extremely demanding for the subjects. They responded in different ways to the car which initially drove in front before braking sharply and coming to a halt. Most subjects stopped behind the other car, while others passed it quickly. The following maneuvers were regarded as hazardous or unsuitable:

- Stopping on the opposite lane
- Passing the other car with very little lateral clearance
- Collision.

These more or less serious driving errors were made by only one subject from Group L but by four from each of the two groups under medication.

Table 5.3.1: Driving Behavior While Following and Before Braking by Other Car in Scenario 3 (Speed and Time Gap)

Variables \ Subject group		L	M	H
Number of subjects	n	20	19	20
Local speed before braking by other car (m/s)	$\bar{x}$	18.77	18.94	18.70
	s	0.98	0.94	0.88
	min.	17.15	17.66	17.40
	max.	20.40	21.27	20.61
Minimum time gap (s)	$\bar{x}$	2.61	2.41	2.76
	s	1.02	0.94	1.10
	min.	1.15	0.83	0.56
	max.	4.78	4.67	4.56
Maximum time gap (s)	$\bar{x}$	6.71	6.71	6.67
	s	0.44	0.56	0.34
	min.	6.18	5.94	6.26
	max.	8.22	8.67	7.47
Average time gap (s)	$\bar{x}$	3.85	3.76	3.95
	s	1.02	1.02	1.11
	min.	2.26	2.44	2.30
	max.	5.95	7.11	6.01
Minimum speed (m/s)	$\bar{x}$	16.68	16.80	16.78
	s	0.72	0.47	0.58
	min.	15.05	15.90	15.61
	max.	17.57	17.58	17.52
Standard deviation of minimum speed (m/s)	$\bar{x}$	1.59	1.54	1.46
	s	0.36	0.23	0.29
	min.	0.86	1.04	0.85
	max.	2.16	1.90	2.03

Table 5.3.2: Driving Behavior While Following and Before Braking by Other Car in Scenario 3 (Standard Deviation of Individual Time Gaps)

Variables \ Subject group		L	M	H
Number of subjects	n	20	19	20
Standard deviation of individual time gaps	$\bar{x}$	1.06	1.16	1.03
	s	0.28	0.32	0.32
	min.	0.30	0.56	0.58
	max.	1.50	1.72	1.74

Table 5.3.3: Driving Behavior At Moment of Braking by Other Car in Scenario 3 (Following Distance, Time Gap, Response Time and Deceleration)

Variables \ Subject group		L	M	H
Number of subjects	n	20	19	20
Distance between test vehicle and other car (m)	$\bar{x}$	62.13	51.91	61.92
	s	23.68	19.88	23.10
	min.	32.71	18.20	27.07
	max.	112.53	90.96	100.53
Time gap (s)	$\bar{x}$	3.31	2.74	3.30
	s	1.25	1.05	1.21
	min.	1.71	1.03	1.47
	max.	6.27	4.80	5.78
Number of subjects	n	19	19	20
Response time before touching brake pedal (s)	$\bar{x}$	1.65	1.49	1.62
	s	0.42	0.41	0.46
	min.	0.84	0.80	0.98
	max.	2.40	2.32	2.51
Number of subjects	n	19	18	20
Maximum deceleration (m/s^2)	$\bar{x}$	9.34	9.09	8.96
	s	1.14	1.95	1.64
	min.	6.95	2.68	4.58
	max.	10.73	10.38	10.53

Table 5.3.4: Result of Driving Behavior in Scenario 3 (Number of Subjects)

Variables \ Subject group	L	M	H
Stopped	15	12	15
- in right-hand lane	15	7+1[1]	13
- on opposite lane[2]	0	3+1[3]	2
Did not stop	5	7	5
- overtook without deceleration/after slight deceleration	1	2	2
- overtook other car on left after sharp deceleration	4	5	3

[1] Collision between test vehicle and other car

[2] Left-hand side of vehicle in opposite lane (max. 1.0 m)

[3] In one case, the left-hand side of test vehicle was 2 meters inside the opposite lane

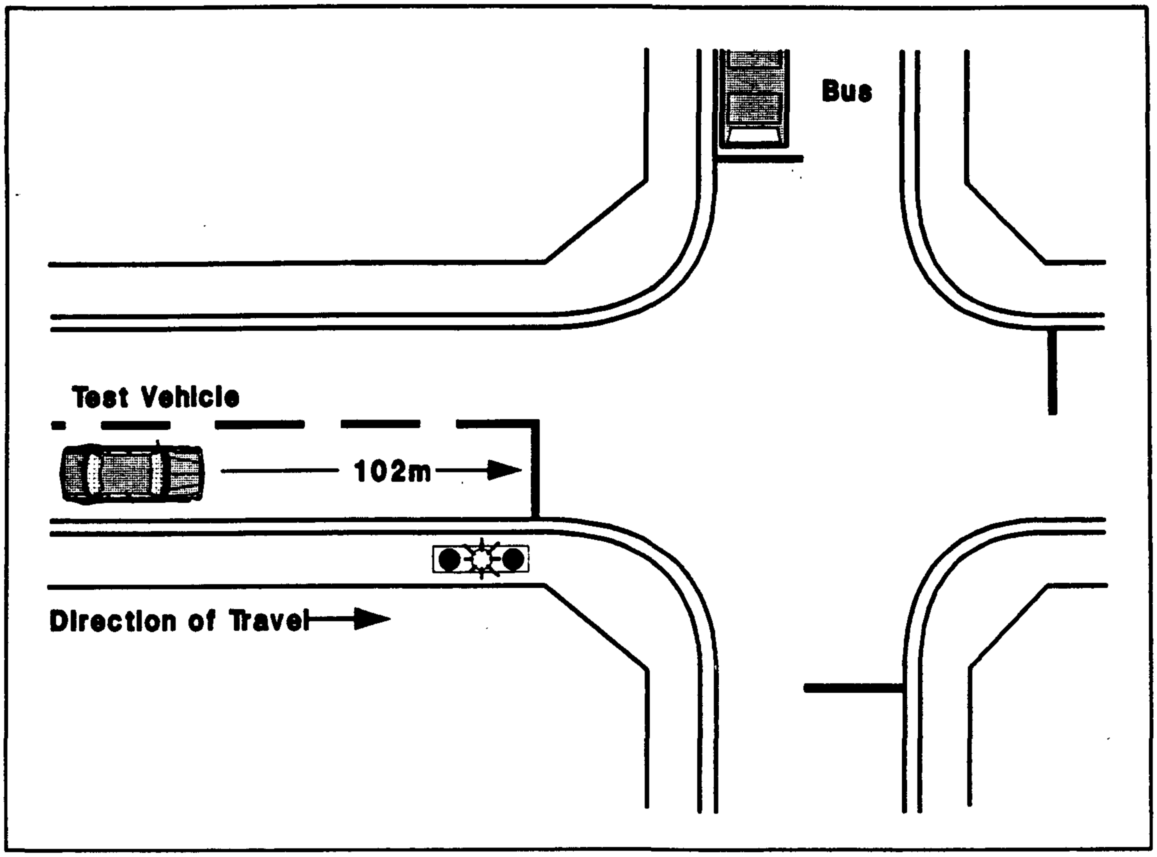
Table 5.3.5: Longitudinal Distance of Test Vehicles Which Stopped in Scenario 3

Variables \ Subject group		L	M	H
Number of subjects	n	15	11	15
Smallest distance between test vehicle and other car (vehicles which stopped) (m)	$\bar{x}$ s min. max.	14.07 9.68 4.97 37.15	10.36 5.41 1.75 18.06	15.49 10.17 3.00 39.28

Table 5.3.6: Lateral Distance Between Test Vehicle and Other Car (Vehicles Which Did Not Stop in Scenario 3) (Number of Subjects)

Variable \ Subject group	L	M	H
Distance: < 0.5 m	1	0	2
Distance: 0.5 - 1 m	0	0	0
Distance: > 1 m	4	7	3
Σ	5	7	5

5.4 Scenario: Traffic Light Change from Green to Red, Normal Response



5.4.1 Description

Driving along a country road, the test vehicle approached a crossroads with a set of traffic lights (see Fig. 4 "Country Road Crossroads"). As it drew closer, a bus came into sight, traveling towards the crossroads on the road from the left. 102 m before the test vehicle reached the stop line, the traffic lights for the test vehicle changed from green to yellow and, after three seconds, to red. The red phase lasted 20 seconds. For subjects who stopped at the red light, the scene lasted approx. 60 seconds. The object of this scenario was to examine how subjects responded to traffic light phase changes in relatively straightforward conditions.

5.4.2 Evaluation

This scenario was used to record the behavior of the subjects

- during the green phase of the traffic lights
- at the moment when the lights changed to red
- with regard to positioning of the vehicle during red.

> One subject from Group M could not be included in the evaluation due to a system error in the simulator.

The average approach speed over approx. 300 m before the lights changed was 21 m/s (see Table 5.4.1). There were no differences between the groups; the range of scatter was narrow. Instantaneous speeds were somewhat lower when the lights changed to yellow than in the green phase which indcates that the simple appearance of the traffic lights caused the subjects to reduce their speed slightly. There were no differences between the groups.

> The following cases were not included in response time calculations: One subject from each of Groups L and H braked before the lights turned to yellow and stopped in front of the stop line. Two subjects in Group M and one in Group H did not decelerate; they drove over the crossroads at a speed of between 21 and 25 m/s. They were still over 27 meters from the stop line when the light turned to red. The two subjects in Group M accelerated a little, while the subject in Group H increased his speed in the yellow phase by 2.5 m/s.

19 subjects from Group L, 17 from Group M and 18 from Group H were included in calculation of the response time. The average response time until touching of the brake pedal did

not differ between the three groups. It was just below 1 second (see Table 5.4.1).

The maximum deceleration values were measured during the yellow phase; there were no differences between the groups. The result of the recorded driving behavior was that 3 subjects drove through the lights at red. All other subjects, i.e., twenty subjects in Group L, seventeen in Group M and nineteen in Group H came to a halt in front of the stop line (see Table 5.4.2).

5.4.3 Assessment

The subjects were able to cope with this scenario without difficulty. It should, however, be noted that the three subjects who drove through the red lights - and hence accepted a greater level of risk - were from the groups under medication.

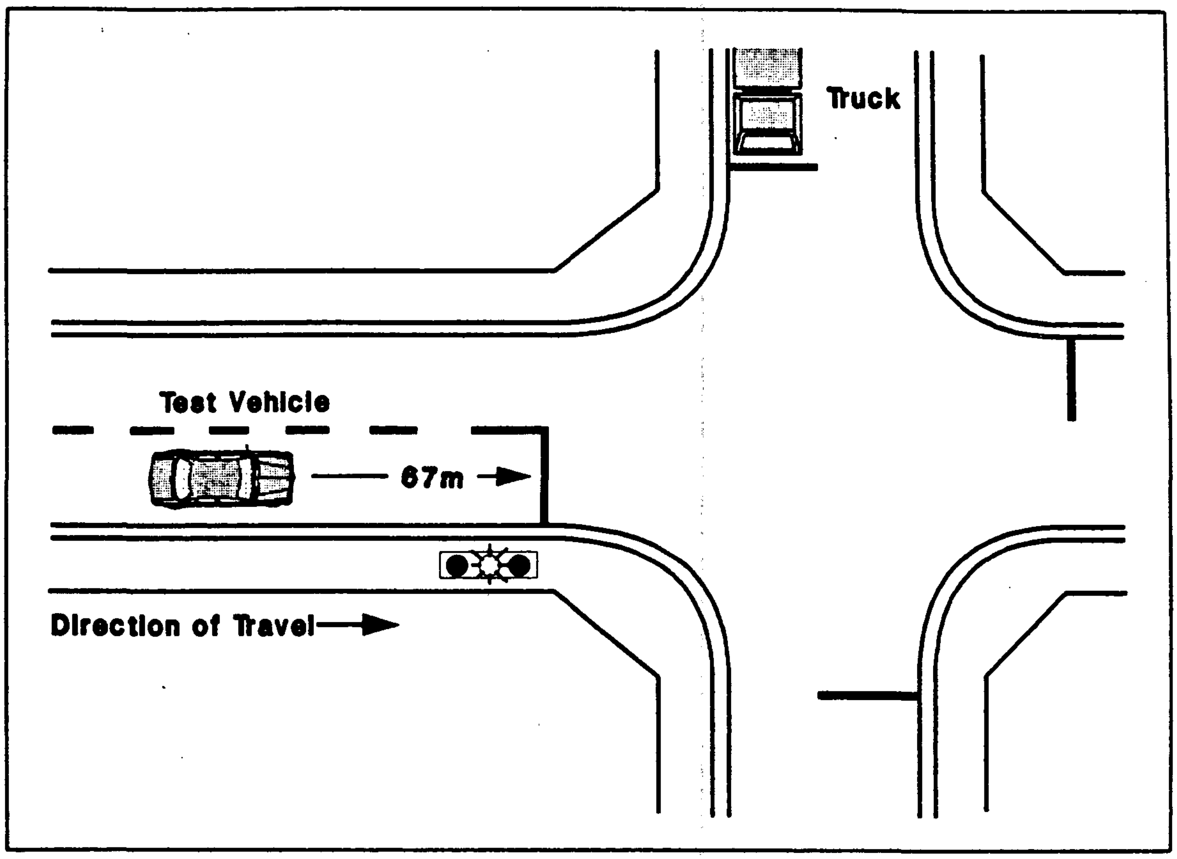
Table 5.4.1: Driving Behavior in Scenario 4 (Speed, Response Time and Maximum Deceleration)

Variables \ Subject group		L	M	H
Number of subjects	n	20	19	20
Average speed during green phase (m/s)	$\bar{x}$ s min. max.	21.12 1.00 19.39 22.54	21.05 1.12 18.34 22.64	21.52 0.98 19.55 22.96
Number of subjects	n	20	19	20
Instantaneous speed at change to yellow (m/s)	$\bar{x}$ s min. max.	19.66 1.55 16.66 22.03	19.49 1.45 15.96 22.23	19.89 1.70 17.17 22.95
Number of subjects	n	19	17	18
Response time before touching brake pedal at yellow (s)	$\bar{x}$ s min. max.	0.88 0.20 0.66 1.46	0.99 0.21 0.66 1.34	0.84 0.19 0.56 1.30
Number of subjects	n	20	17	19
Maximum deceleration during yellow (m/s^2)	$\bar{x}$ s min. max.	7.36 1.39 4.37 10.22	6.75 1.42 3.86 9.78	7.39 1.36 4.43 10.51

Table 5.4.2: Braking Behavior in Scenario 4: (Number of Subjects)

Variable \ Subject group	L	M	H
- Braked before change to yellow	1	0	1
- Did not brake and drove through red	0	2	1
- Stopped before stop line	20	17	19
- Stopped over stop line	0	0	0

5.5 Scenario: Traffic Light Change from Green to Red, Quick Response



5.5.1 Description

Driving along a country road, the test vehicle once again approached a crossroads governed by a set of traffic lights. As it drew closer, a truck appeared on the road coming from the left. The test vehicle was 67 meters away from the stop line when the traffic lights changed from green to yellow. For subjects stopping at the red light, the scene lasted 70 seconds. The object of this scenario was to examine how subjects responded to the lights changing when they are relatively close to the traffic lights and can still choose whether or not to drive through.

5.5.2 Evaluation

This scenario was used to record the behavior of the subjects

- during the green phase of the traffic lights
- at the moment when the lights changed to yellow
- at the moment when the lights changed to red
- with regard to the position of the vehicle during red.

The average approach speeds over approx. 300 m during the green phase were 21 m/s. There were no differences between the groups (see Table 5.5.1). Speed behavior in the groups was very homogeneous.

Instantaneous speeds were somewhat lower when the lights changed to yellow than the average speeds in the green phase (average 1.4 m/s lower). This indicates that the simple appearance of the traffic lights caused the subjects to reduce their speed slightly.

After the lights changed to yellow, nine subjects in Group L and fourteen in each of Groups M and H did not brake, deciding instead to drive on through. Table 5.5.2 shows that about half of those who did not stop drove through a yellow or red light. A subject was considered to have driven through yellow if he crossed the stop line when the light was yellow. All subjects who drove through increased their speeds (see Table 5.5.3). No differences can be seen between the groups. In all three groups, the speed increase was achieved by means of accelerating early. In the case of the subjects who drove through, the response time until acceleration was measured.

> Those whose times were below 0.2 seconds were not included in the calculation because their response time was so short that it could not have been triggered by the lights changing to yellow. The calculations also excluded a further two subjects who did not respond during the yellow phase and crossed the stop line at 21 or 24 m/s during the yellow or red phase respectively.

Table 5.5.4 shows that the average response times do not differ between the groups. It is, however, noticeable that the average response time of Group H was lowest.

Table 5.5.3 shows the response times before braking of those subjects who stopped their vehicles. All subjects braked during the yellow phase, none during green. It was noticeable that the two groups on medication responded quicker than the control group.

Tables 5.5.2 and 5.5.3 show the maximum decelerations and vehicle positions of the subjects who stopped. There were no differences in deceleration in the groups, and all the subjects stopped before the stop line.

5.5.3 Assessment

This scenario placed higher demands on the subjects than the preceding scenarios. The subjects adopted the following strategies to deal with these demands:

- stopping in front of the stop line
- driving through yellow
- driving through red.

It was thus possible to distinguish correct, hazardous and incorrect driving behavior.

Although the number of subjects who stopped was clearly higher in the control group than in the two groups under medication, the difference was not significant in itself. Nevertheless, there was a trend towards running the red or yellow lights in the drug groups.

With regard to "incorrect" behavior (driving through red) and "hazardous" behavior (driving through yellow), the differences between the groups were small. In all three groups, the majority of these subjects had decided to drive through the lights.

The few subjects in the two medication groups who stopped actually reacted quicker than the control group, but not significantly so.

Table 5.5.1: Driving Behavior in Scenario 5 (Speed)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Average speed during-green phase (m/s)	$\bar{x}$ s min. max.	21.29 1.03 19.32 23.09	21.32 0.98 19.23 23.00	21.65 1.09 20.10 23.50
Instantaneous speed at change to yellow (m/s)	$\bar{x}$ s min. max.	19.92 2.03 14.52 23.00	19.93 1.25 17.83 22.22	20.19 1.73 17.77 23.72

Table 5.5.2: Position of Test Vehicle in Scenario 5 (Number of Subjects)

Variable \ Subject group	L	M	H
- Stopped before stop line*	11	6	6
- Total driving through* at yellow at red	9 5 4	14 8 6	14 7 7

* $chi^2_{0.05;2} = 3.40$, not significant

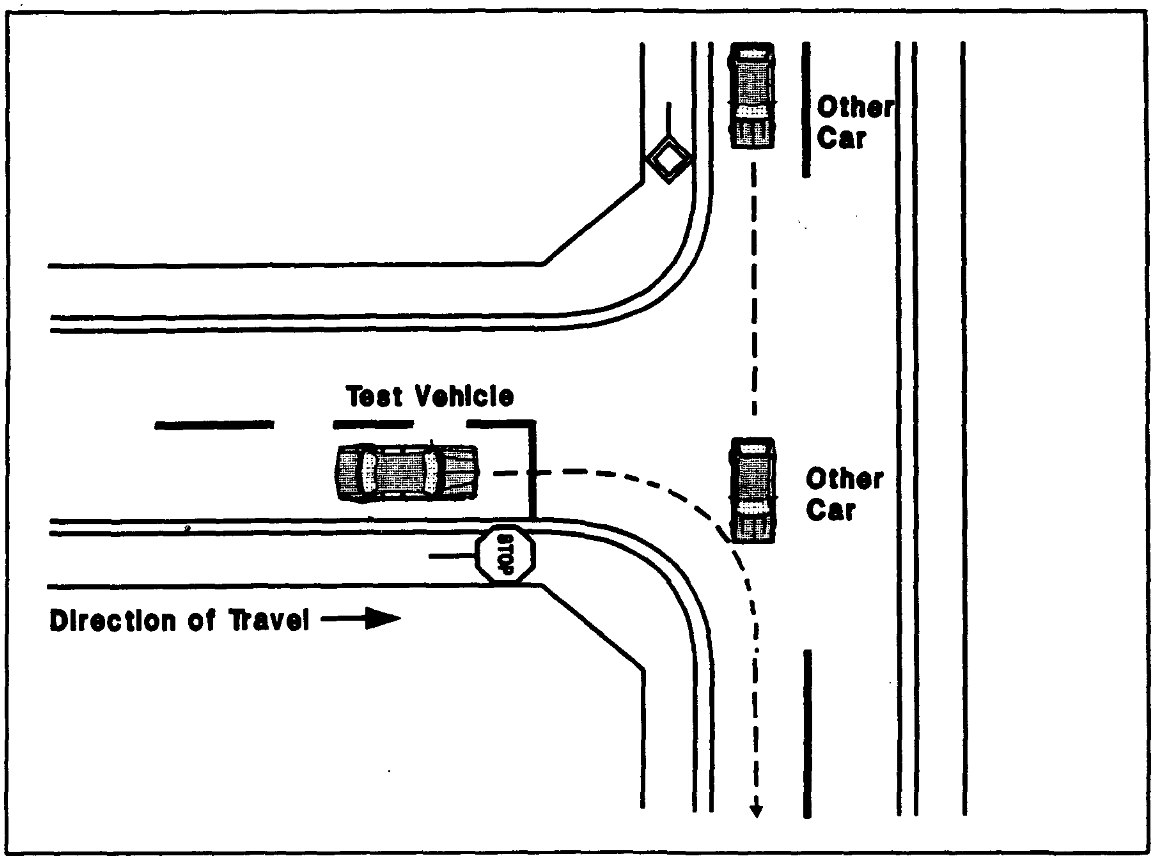
Table 5.5.3: Driving Behavior in Scenario 5 (Speed Difference, Response Time and Maximum Deceleration)

Variables \ Subject group		L	M	H
Number of subjects	n	9	14	14
Speed differential for drivers driving through (V "red" - V "yellow") (m/s)	$\bar{x}$ s min. max.	1.80 0.80 0.21 2.66	2.39 1.18 0.36 5.44	1.73 0.68 0.54 2.96
Number of subjects	n	11	6	6
Response time before brake pedal touched by subjects who halted (s)	$\bar{x}$ s min. max.	0.92 0.23 0.66 1.40	0.81 0.09 0.71 0.95	0.78 0.18 0.64 1.08
Number of subjects	n	11	6	6
Maximum deceleration of subjects who halted (m/s^2)	$\bar{x}$ s min. max.	9.33 1.14 6.87 10.40	8.61 1.25 6.76 10.21	9.54 0.60 8.69 10.19

Table 5.5.4: Driving Behavior in Scenario 5 (Response Time of Subjects Driving Through at Yellow or Red)

Variable \ Subject group		L	M	H
Number of subjects	n	7	13	9
Response time before acceleration	$\bar{x}$ s min. max.	0.73 0.41 0.46 1.61	0.71 0.27 0.46 1.25	0.58 0.24 0.25 0.98

5.6 Scenario: Merge into Traffic Situation



5.6.1 Description

Driving along a country road, the test vehicle approached a junction with a major road into which it had to turn right. For technical reasons, drivers found turning right unpleasant (see chapter 3.3). After the test vehicle had stopped at the stop line (STOP sign), two other cars, coming from the left, crossed the area into which the test vehicle had to turn. The first car reached the junction area after approx. 17 seconds, and the second followed approx. 10 seconds later. These two cars maintained a constant speed whose level was dependent on the local speed (35 m before the junction) of the approaching test vehicle. The entire scene lasted about 75 seconds. The object of this scenario was to examine how subjects merged into a major road with traffic.

5.6.2 Evaluation

This scenario was used to record the number of subjects who decided to enter the major road ahead of the approaching vehicles.
Nineteen subjects in the control group, seventeen in Group M and nineteen in Group H did not turn into the main road until the second car had passed. Two subjects from Group M and one from Group L turned into the main road before the second car had passed. One subject each from Groups M and H turned into the major road before the first car. The subject from Group M did not observe the stop sign and entered the major road without stopping (see Table 5.6.1).

There were collisions in three of the five cases above (see Table 5.6.2), whereby one of the passing cars, driving on without braking, drove into the test vehicle. Table 5.6.2 shows the maximum accelerations and time gaps for the five subjects who turned into the road in front of one of the two cars.

5.6.3 Assessment

Although three different reactions were possible in this scenario, only five of the 60 subjects turned into the major road in front of one of the two other cars. This may have been because the subjects had found fast turning to be

unpleasant during the introductory drive and hence avoided it during the test drive (see chapter 3.3).
Of the five above-mentioned subjects, one came from each of Groups L and H and the remaining three from Group M. Due to this low number of subjects involved in collisions, it remains open to question whether the greater willingness to take risks was the result of taking diazepam.

Table 5.6.1: Merging in Scenario 6 (Number of Subjects)

Variable \ Subject group	L	M	H	Σ
- After both vehicles	19	17	19	55
- Before 2nd vehicle	1	2	0	3
- Before 1st vehicle	0	1	1	2
Σ	20	20	20	60

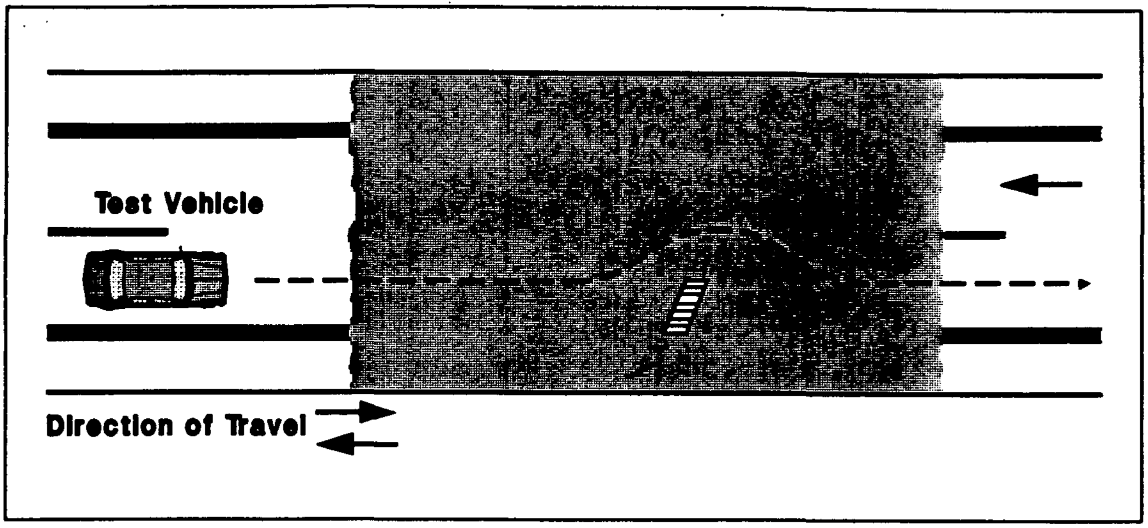
Table 5.6.2: Case Description of Subjects Merging in Front of One of the Two Passing Vehicles in Scenario 6

Group	Subject No.	Time gap* (s)	Max. acceleration (m/s^2)	Average acceleration (m/s^2)	Collision
L	54	4.4	2.35	2.10	No
M	13	5.6	1.80	1.24	Yes, with vehicle 2
M	46	5.9	2.08	1.63	No
M	52**	3.4	1.90	1.59	Yes, with vehicle 1
H	23	2.5	2.50	1.98	Yes, with vehicle 1

*) Time gap between passing vehicle and test vehicle at turning.

**) This driver did not observe the stop sign; he turned into the road in front of the first passing vehicle without stopping.

5.7 Scenario: Snow on the Road Situation



5.7.1 Description

Driving along a country road, the test vehicle approached a snow-covered (white) section of road, announced by a traffic sign approx. 170 m in advance. This snow-covered road section was approx. 350 m long. The test vehicle was required to drive round an obstacle (striped barrier) which was projecting 1.73 m into the right-hand lane. There was a specified friction coefficient of 0.30 (adhesion between road and wheels). The whole scene lasted approx. 45 seconds. The road markings could not be seen under the snow covering, and thus the edge of the road could not be distinguished from the road proper. The object of the scenario was to examine how the subjects responded to a snow-covered road section.

5.7.2 Evaluation

This scenario was used to record the driving behavior of the subjects

- before the start of the snow
- at the start of the snow
- while driving on the snow
- at the end of the snow.

At the start of the scenario, the local speeds averaged 22 m/s. There were no differences between the groups, and the range of scatter was narrow (see Table 5.7.1). At the start of the snow section, all groups reduced their local speed by an average 5 m/s; the range of scatter broadened in each group. In Group H, two subjects halved their previous speed of over 20 m/s and then reduced it further on the snow. There were nevertheless no differences between the groups.

All the groups decelerated chiefly by means of reducing their acceleration. Three subjects in Group L, two in Group M and four in Group H braked sharply before the start of the snow (i.e. over 50 % of the maximum braking pressure/see Table 5.7.2). The necessary reduction in speed was thus achieved either by brief but sharp deceleration or longer, less sharp deceleration.

On the snow-covered section, speeds were generally further reduced (see Table 5.7.1). The average speed here was 15 m/s, the minimum speed being about 2 m/s less. The differences between minimum and average speed per subject were small, suggesting very homogeneous driving in all groups. An examination of acceleration values shows that abrupt maneuvers were generally avoided. Two drivers in Group L and three in Group M braked gently on the snow, while no-one in Group H braked (see Table 5.7.3).

It was noticeable that in each group one subject drove through the section without slowing down, at speeds lying between 22 and 25 m/s. On the other hand, one subject in Group L and two from Group M sharply reduced their speeds (see Table 5.7.4).

No subject lost control of his vehicle or left the road. All subjects were able to avoid the obstacle by using the left-hand lane, without using the - invisible - hard shoulder.

5.7.3 Assessment

The object of this scenario was to investigate driving behavior on a snow-covered road. The friction coefficient was set at 0.3 in order to simulate such road conditions as realistically as possible. The subjects all reacted so quickly to the obstacle that abrupt maneuvers were not necessary. Loss of vehicle control and skidding did not therefore occur. It should, however, be noted that some subjects skidded during the introductory drive. They possibly then drove more carefully during the test drive to prevent this happening again.

Effects of medication could not be demonstrated by means of this scenario.

Table 5.7.1: Driving Behavior in Scenario 7 (Speeds)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Local speed before start of snow (m/s)	$\bar{x}$ s min. max.	22.07 0.86 19.73 23.87	22.25 0.76 20.44 23.41	22.40 0.99 20.33 24.61
Local speed at start of snow (m/s)	$\bar{x}$ s min. max.	17.36 3.23 12.04 22.55	17.30 2.60 13.45 23.41	16.68 3.42 9.39 22.59
Average speed on snow (m/s)	$\bar{x}$ s min. max.	15.07 3.25 8.27 22.69	14.62 3.13 9.40 21.67	14.86 3.66 7.31 23.07
Minimum speed on snow (m/s)	$\bar{x}$ s min. max.	13.45 3.89 3.10 22.55	13.13 3.48 7.35 21.29	13.85 3.82 5.82 22.49
Local speed at end of snow (m/s)	$\bar{x}$ s min. max.	14.56 2.84 11.08 22.83	13.92 3.20 7.93 21.99	14.58 3.76 8.45 24.62

Table 5.7.2: Reduction in Speed Before Start of Snow in Scenario 7 (Number of Subjects)

Variable \ Subject group	L	M	H
- Only by easing accelerator	14	15	12
- Below 50% of maximum braking force	2	2	3
- Over 50 % of maximum braking force	3	2	4
Σ	19*	19*	19*

* one subject accelerated slightly

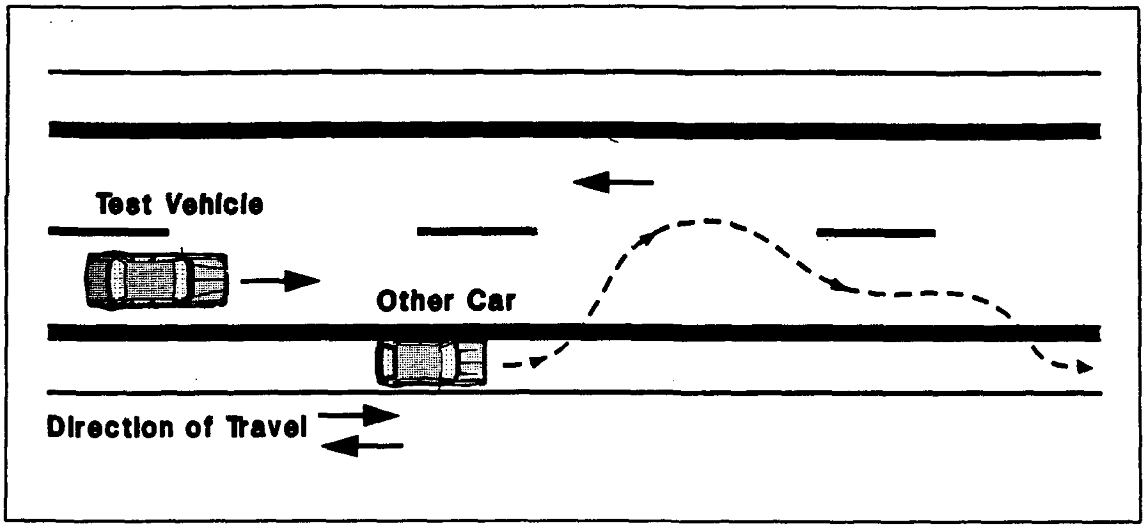
Table 5.7.3: Minimum Longitudinal Acceleration on Snow in Scenario 7 (Number of Subjects)

Variable \ Subject group	L	M	H
(-0.1) - (-1.0) (m/s^2)	18	17	20
(-1.0) - (-4.0) (m/s^2)	2	3	0
Σ	20	20	20

Table 5.7.4: Subjects with Extreme Speeds in Scenario 7 (Number of Subjects)

No.	Group	Initial speed (m/s)	Speed at start of snow (m/s)	Minimum speed on snow (m/s)	Average speed on snow (m/s)	Speed at end of snow (m/s)
15	L	22.09	22.55	22.55	22.69	22.83
19	M	22.33	21.94	21.29	21.67	21.99
8	H	21.01	22.59	22.49	23.07	24.62
42	L	21.65	12.17	3.10	8.27	11.08
22	M	21.85	14.40	7.35	11.46	11.89
28	M	22.08	13.45	7.82	9.40	7.93

5.8 Scenario: Dart-Out Situation, Normal Response



5.8.1 Description

Driving along a country road, the test vehicle approached a car standing on the right-hand hard shoulder. As the test vehicle approached, the car indicated briefly and suddenly started off, pulling out into the road 30 meters in front of the test vehicle. It accelerated to 20 m/s in one second as specified by the simulator program. After proceeding for short while, the car then stopped again on the right-hand hard shoulder. The period between the car moving off and its leaving the road lasted only approx. 7 seconds.
The entire scene lasted approx. 52-60 seconds. The object of the scenario was to examine how the subjects reacted to this sudden occurrence.

5.8.2 Evaluation

This scenario was used to record the behavior of the subjects

- during the period between the appearance and moving off of the other car
- at the moment when the other car moved off
- while following the other car.

The average speed over approx. 300 m before the other car moved off did not differ between the three groups (around 22 m/s). The range of scatter was narrow. Differences in speed at the start of the scenario tended to be greatest within Group L (see Table 5.8.1).

There was almost no reduction in local speed in any of the groups when the other car moved off, speed remaining around 21 m/s. In Groups M and H, the range of scatter showed a tendency towards increase (see Table 5.8.2). The average group response time before starting to brake lay between 1 and 1.3 seconds. The subject with the shortest response time (0.59 sec.) belonged to the high-dose diazepam group (H). There were no differences between the groups in response times before releasing the accelerator.

One subject belonging to the control group (L) only decelerated and did not brake when the other car moved off.

Maximum deceleration and minimum speed of the test vehicle were recorded for the period the other car was on the road (see Table 5.8.3). There were large differences in maximum deceleration within the groups. Although the average maximum deceleration in Group H (6.0 m/s^2) was considerably higher than the 3.7 m/s^2 average in the two other groups, this difference was not significant in itself. A breakdown of maximum deceleration (see Table 5.8.4) clearly showed that the number of sharply decelerating subjects was largest in Group H. Overall, subjects in all groups reduced their speed by an average 5 m/s.

None of the subjects left the road during braking (see Table 5.8.5). Seven subjects in Group L, eight in Group M and five in Group H crossed the center line. It cannot be distinguished whether this was in order to avoid a collision or simply to pass. None of the subjects collided with the other car.

5.8.3 Assessment

This scenario did not represent an emergency situation requiring extreme action to be taken. The very rapid acceleration of the other car meant there was almost no need to take avoiding action and little danger of a collision. Response time was longest in Group M. Maximum deceleration in Group H was clearly greater than in the two other groups, but not significantly so.

Table 5.8.1: Driving Behavior Between Appearance and Moving Off of Other Car in Scenario 8 (Speeds)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Average speed before other vehicle moved off (m/s)	$\bar{x}$	21.52	21.95	22.19
	s	1.54	0.97	0.86
	min.	17.25	18.98	20.82
	max.	24.02	23.37	24.26

Table 5.8.2: Driving Behavior at Moment when Other Vehicle Moved Off in Scenario 8 (Speed and Response Time)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Local speed when other vehicle moved off (m/s)	$\bar{x}$ s min. max.	21.03 1.12 18.35 22.38	21.05 1.62 16.60 22.87	21.62 1.27 18.56 24.46
Number of subjects	n	20	20	20
Response time before easing accelerator (s)	$\bar{x}$ s min. max.	0.56 0.15 0.17 0.90	0.63 0.18 0.40 1.14	0.58 0.11 0.24 0.84
Number of subjects	n	19	20	20
Response time before touching brake pedal (s)	$\bar{x}$ s min. max.	1.06 0.23 0.72 1.55	1.30 0.54 0.70 2.72	0.99 0.24 0.59 1.54

Table 5.8.3: Driving Behavior While Following Other Car in Scenario 8 (Max. Deceleration and Min. Speed)

Variables \ Subject group		L	M	H
Number of subjects	n	20	20	20
Maximum deceleration (m/s^2)	$\bar{x}$ s min. max.	3.7 2.4 0.4 9.9	3.7 2.6 0.4 10.0	6.0 2.3 0.6 9.7
Minimum speed (m/s)	$\bar{x}$ s min. max.	16.47 1.07 14.50 18.31	16.36 1.65 11.86 18.31	15.36 1.72 11.64 17.92

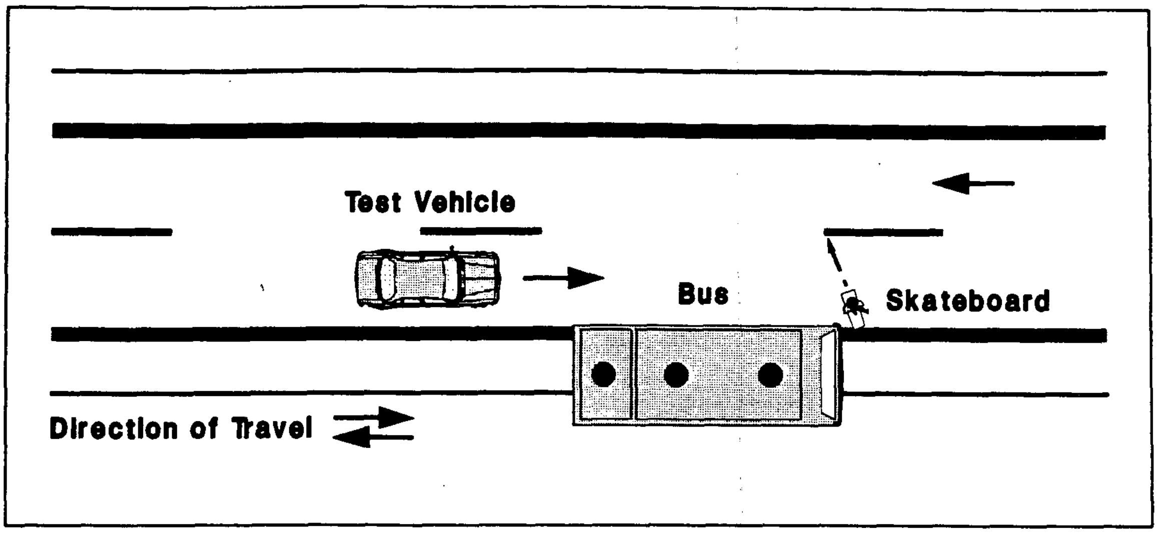
Table 5.8.4: Max. Deceleration While Following Other Car in Scenario 8 (Number of Subjects)

Variable \ Subject group	L	M	H
- over 7 m/s^2	1	3	10
- between 7 and 4 m/s^2	9	6	7
- below 4 m/s^2	10	11	3
Σ	20	20	20

Table 5.8.5: Changing of Lane in Scenario 8 (Number of Subjects)

Variable \ Subject group	L	M	H
- Did not leave right-hand lane	13	12	15
- Crossed center line	7	8	5
- Left road	0	0	0
Σ	20	20	20

5.9 Scenario: Dart-Out Situation, Quick Response



5.9.1 Description

The test vehicle drove along a country road. After some time, a bus came into view on the right, standing on the hard shoulder. As the test vehicle reached the bus after approx. 300 meters, a skateboarder darted out from behind the bus and crossed the road. The distance between seeing and reaching the skateboarder was 40 m. The scene lasted some 20-25 seconds. The object of the scenario was to examine how subjects reacted to the bus and the sudden appearance of the skateboarder.

5.9.2 Evaluation

This scenario was used to record the behavior of the subjects

- at the start of the scenario before the bus came into view

- during the period between the appearance of the bus and the sudden appearance of the skateboarder
- at the moment of the sudden appearance of the skateboarder
- during the period between seeing and reaching the skateboarder.

Before the bus came into view on the right-hand edge of the road, local speeds in all three groups averaged the prescribed 22 m/s. Within the groups, these initial speeds varied between 18 and 24 m/s. When approaching the bus - but before the skateboarder darted out - all three groups reduced their speed by an average 3 m/s (see Table 5.9.1). This was also true for individual subject values, i.e., with the exception of two in Group M who accelerated somewhat, all the subjects reduced their speed. The scatter of the average speed within the individual groups was considerably broader than for the local speeds at the start of the scenario (see Table 5.9.1).

Three subjects from Group L, two from Group M and one from Group H already had their foot on the brake when the skateboarder appeared (see table 5.9.2). One subject from Group L did not brake at all during the scenario. He passed the skateboarder on the left at a speed of 20 m/s. Table 5.9.1 shows those cases used for calculating response time before braking. Subjects in Group H tended to react somewhat faster, only two of the nineteen subjects evaluated in this group having a response time longer than 1 second. Six of the eighteen subjects assessed in Group M and seven in Group L had a response time longer than one second.

Maximum deceleration between seeing and reaching the skateboarder was also considered. Deceleration of more than

8 m/s^2 was recorded for nineteen subjects in Group L, all twenty in Group M and eighteen in Group H. In Group H, two subjects had a noticeably lower maximum deceleration of 5 - 7 m/s^2. One of these subjects passed the skateboard on the right without colliding. As mentioned above, one subject in Group L drove without braking throughout the entire scenario (see Table 5.9.3).

As can be seen from Table 5.9.4, eight subjects from Group L, fourteen from Group M and seven from Group H collided with the skateboarder. Four subjects passed the skateboarder, thereby avoiding a collision. The remaining subjects came to a halt before reaching the skateboarder (see Table 5.9.5).

It was noticeable that all subjects tended to steer their vehicles towards the center line after seeing the skateboarder.

Table 5.9.6 describes the site of those collisions taking place between skateboarder and test vehicle. It was noticeable that in Group L the majority of subjects collided with the skateboarder in the opposite lane, while in Groups M and H the majority of collisions took place in the right-hand lane. Consideration of the collision speeds (see Table 5.9.7) shows that those in Group L using the opposite lane had high collision speeds ($\overline{x}$ = 14.9); the speeds of those in all groups in collision in the right-hand lane were lower. The differences in the collision speeds are probably due to the fact that those who collided with the skateboarder in the right-hand lane had attempted to stop before reaching him, while those who collided in the left-hand lane had hoped to be able to pass him. There were no group differences in terms of distance to the skateboarder in the case of those drivers who stopped in time (see Table 5.9.7).

5.9.3 Assessment

This scenario was extremely demanding for the subjects. The resulting driving behavior can be described as follows:

- Stopping before the skateboarder
- Passing the skateboarder
- Collision with the skateboarder at low speed
- Collision with the skateboarder at high speed.

The driving behavior in this scenario can thus be divided into correct, hazardous and incorrect driving with more or less serious consequences.

About the same number of subjects from Groups L and H came to a halt, while considerably fewer from Group M stopped. Although the avoiding action taken by four subjects in passing the skateboarder on the left or right was successful, it must be regarded as hazardous. This is particularly true of the subject from Group L who passed the skateboarder without decelerating at a speed of around 20 m/s. The speeds of the other 3 subjects from Group H were considerably lower at between 5.7 and 10.4 m/s.

The same number of subjects from Groups L and H collided with the skateboarder, while the number from Group M was considerably but not significantly higher. Compared to the two medication groups, collisions in the control group occurred at higher speeds.

This would appear to show that maneuvers with serious consequences were less frequent in Group H and more frequent in Group L, with subjects from Group M lying between.

Table 5.9.1: Driving Behavior in Scenario 9: (Speeds, Response Time and Maximum Deceleration)

Variable \ Subject group		L	M	H
Number of subjects	n	20	20	20
Local speed before bus appeared (m/s)	$\bar{x}$ s min. max.	22.49 1.24 18.50 24.25	22.21 1.02 19.44 23.85	22.02 1.61 17.81 24.18
Number of subjects	n	20	20	20
Average speed after bus appeared but before skateboarder appeared (m/s)	$\bar{x}$ s min. max.	18.83 2.64 12.33 23.76	19.23 1.96 12.88 21.99	18.62 2.15 12.17 21.81
Number of subjects	n	16	18	19
Response time before touching brake pedal after seeing skateboarder (s)	$\bar{x}$ s min. max.	0.95 0.14 0.71 1.18	0.93 0.12 0.65 1.07	0.87 0.13 0.62 1.02
Number of subjects	n	19	20	20
Maximum deceleration between seeing and reaching skateboarder (m/s^2)	$\bar{x}$ s min. max.	10.18 0.60 8.60 11.04	10.22 0.54 8.24 10.72	9.96 1.41 5.28 11.57

Table 5.9.2: Braking Behavior in Scenario 9 (Number of Subjects)

Variables \ Subject group	L	M	H
Braked before skateboarder appeared	3	2	1
Did not brake during scenario	1	0	0
Braked when skateboarder appeared	16	18	19
Σ	20	20	20

Table 5.9.3: Maximum Deceleration Between Seeing and Reaching Skateboarder in Scenario 9 (Number of Subjects)

Variables \ Subject group	L	M	H
Did not brake during scenario	1	0	0
Maximum deceleration between 5 and 7 m/s^2	0	0	2
Maximum acceleration > 8 m/s^2	19	20	18
Σ	20	20	20

Table 5.9.4: Avoiding Action in Scenario 9 (Number of Subjects)

Variables \ Subject group	L	M	H
Collision with skateboarder*	8	14	7
No collision*	12	6	13
Σ	20	20	20

* $chi^2_{005;\ 2} = 5.72$, not significant

Table 5.9.5: Driving Maneuvers in Scenario 9 (Number of Subjects)

Variables \ Subject group	L	M	H
Stopped before skateboarder	11	6	10
Passed skateboarder at high speed	1	0	0
Passed skateboarder at < 10 m/s^2	0	0	3
Collided at < 10 m/s^2	2	11	6
Collided at > 10 m/s^2	6	3	1
Σ	20	20	20

Table 5.9.6: Vehicle Position of Test Vehicles Colliding in Scenario 9 (Number of Subjects)

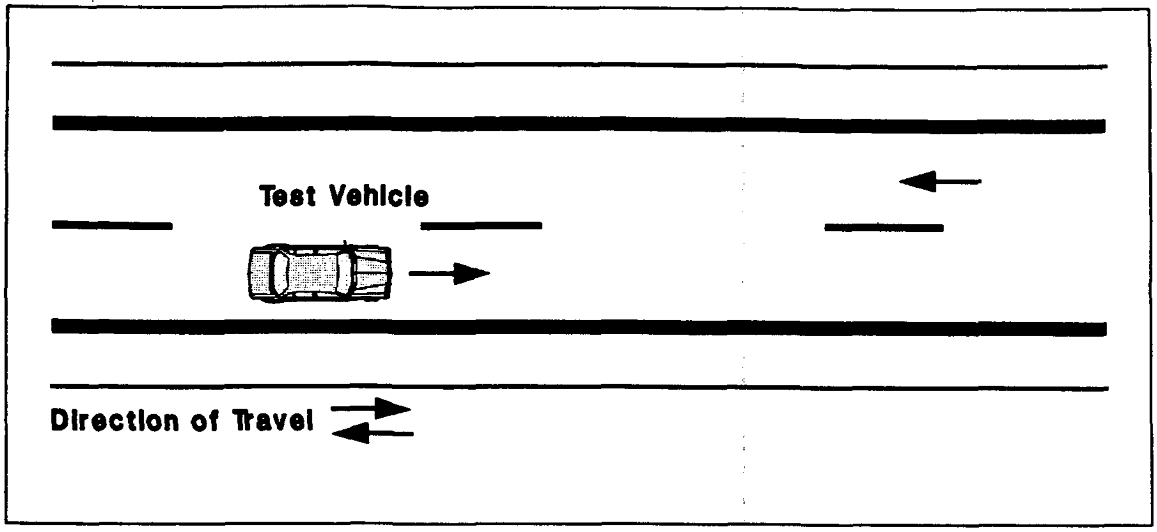
Variables \ Subject group	L	M	H
In right-hand lane near center line* (left side of vehicle max. 70 cm from center line)	3	10	6
Left side of vehicle in opposite lane (max. 1 m)	5	4	1
Σ	8	14	7

* $chi^2_{005;\ 2} = 4.27$, not significant

Table 5.9.7: Driving Behavior in Scenario 9 (Speed and Distance)

Variable \ Subject group		L	M	H
Number of subjects	n	3	10	6
Collision speed when test vehicle in right-hand lane (m/s)	$\bar{x}$ s min. max.	6.14 6.98 1.12 14.11	7.17 4.54 2.89 18.72	7.90 1.18 6.39 9.16
Number of subjects	n	5	4	1
Collision speed when test vehicle in left-hand lane (m/s)	$\bar{x}$ s min. max.	14.91 3.50 11.56 19.57	8.95 4.82 3.89 14.13	17.57
Number of subjects	n	11	6	10
Distance between vehicles which stopped and skateboarder (m)	$\bar{x}$ s min. max.	7.48 5.95 0.80 19.81	7.79 8.53 1.81 24.17	6.23 4.46 1.70 15.04

5.10 Scenario: Free Road Situation



5.10.1 Description

At the end of the test drive, the subjects drove along a 2000-m section of country road (1 lane in each direction) which was first gently winding and then straight for the last 600 meters. Only the straight section was free of oncoming traffic. The scenario was considered to have started as soon as speed increased back up to over 18 m/s. The end of the scenario was determined by a specified number of kilometers.

The object of this scenario was to examine whether drivers at the end of the experiment were suffering from fatigue or other effects influencing normal driving on a straight road.

5.10.2 Evaluation

This scenario was used to observe the behavior of the subjects during the last two minutes of the test drive. The average lengths of the sections traveled were approximately the same in all groups (around 2100-2300 meters).

No test data were available for one subject in Group M; the evaluation for this group was therefore only based on 19 subjects.

Minimum, maximum and average speeds are shown in Table 5.10.1. There were no differences between the groups. Since the director of the test instructed drivers to keep to the prescribed speed of 22 m/s, maximum speeds displayed a narrower range of scatter than minimum speeds.

There were only slight differences between the groups with regard to average standard deviation in individual speeds. This was also true for the average standard deviation among individual accelerations. The various average values for acceleration (min., max.) also showed no significant deviations. The values indicate that the speed behavior of all subjects was generally very homgenous (see Table 5.10.2).

Four subjects in Group L, three in Group M and six in Group H remained exclusively within the right-hand lane for the entire two minutes. The majority of subjects crossed the center line at points of good visibility during the approx. 1400-m-long section of winding road.

There were no differences between the groups in terms of minimum distances betwen the left side of the vehicle and the center line. On average, the subjects drove 33 cm over the center line, i.e. only the tire width of the test vehicle crossed into the opposite lane in left-hand bends. Only one subject in each of Groups L and M briefly drove with more than 80 cm (≈ half vehicle width) in the opposite lane.

5.10.3 Assessment

The object of this scenario was to assess driving behavior after a 20-minute simulated drive. Since the entire scenario lasted only about 2 minutes, this section could not be expected to cause fatigue. Furthermore, subjects could be expected to drive with greater attentiveness in this scenario since it followed the Dart-Out Situation with the skateboarder. Due to the shortness of the section, it was not possible to judge increased "weaving" behavior.

All subjects drove normally in this scene and observed the instructions given. There were no differences between the groups.

Table 5.10.1: Driving Behavior During Last Two Kilometers of Scenario 10 (Speeds)

Variable \ Subject group		L	M	H
Number of subjects	n	20	19	20
Minimum speed (m/s)	$\bar{x}$ s min. max.	19.51 1.49 16.11 21.73	19.91 0.87 17.56 20.99	19.62 1.35 17.49 21.78
Maximum speed (m/s)	$\bar{x}$ s min. max.	24.06 0.84 22.43 25.77	24.10 0.73 22.76 25.76	24.39 0.66 23.31 25.54
Average speed (m/s)	$\bar{x}$ s min. max.	22.25 0.65 20.20 23.00	22.39 0.56 20.98 23.19	22.39 0.44 21.65 23.04
Scatter of individual speeds (m/s)	$\bar{x}$ s min. max.	0.97 0.36 0.28 1.68	0.95 0.23 0.59 1.37	1.13 0.43 0.42 1.88

Table 5.10.2: Driving Behavior During Last Two Kilometers of Scenario 10 (Acceleration)

Variables \ Subject group		L	M	H
Number of subjects	n	20	19	20
Minimum acceleration (m/s^2)	$\bar{x}$	-0.48	-0.46	-0.68
	s	0.15	0.24	0.54
	min.	-0.80	-1.38	-2.42
	max.	-0.24	-0.19	-0.25
Maximum acceleration (m/s^2)	$\bar{x}$	0.53	0.51	0.54
	s	0.19	0.22	0.19
	min.	0.23	0.29	0.27
	max.	0.91	1.11	0.86
Average acceleration (m/s^2)	$\bar{x}$	0.01	0.01	0.01
	s	0.02	0.01	0.02
	min.	-0.03	-0.02	-0.02
	max.	0.03	0.03	0.04
Standard deviation of acceleration (m/s^2)	$\bar{x}$	0.17	0.17	0.20
	s	0.05	0.06	0.08
	min.	0.07	0.10	0.08
	max.	0.28	0.30	0.41

Table 5.10.3: Change of Lane in Scenario 10 (Number of Subjects)

Variables \ Subject group	L	M	H
- Always remained in right-hand lane	4	3	6
- Left wheel crossed center line	2	1	4
- Drove on opposite lane (max. 1 m)	14	15	10
Σ	20	19	20

6 Comparison of Scenarios and Subjects

6.1 Casuistics

In the course of the evaluations, a number of subjects stood out for their potentially hazardous driving behavior in several scenarios. These cases are briefly described below:

Subject No. 23: (Group H)

In Scenario 2 (Following Situation, Normal response) the subject did not brake and overtook the car in front against the instructions of the test director. In the normal traffic light change (Scenario 4), he again failed to brake and drove through the traffic lights at red. In the quick change of traffic lights (Scenario 5) he drove through the lights at yellow. When he turned into the major road (Scenario 6), the first passing car collided with him. In Scenario 3 (Following Situation, Quick response) he overtook the other car with very little lateral clearance. Finally, he collided with the skateboarder in Scenario 9.

Subject No. 52: (Group M)

In Scenario 5 (Change of Traffic Lights, Quick response) the subject drove through the lights at red. In Scenario 6 (Merge into Traffic Situation) he was the only subject who failed to stop in front of the stop sign and the passing car collided with him when he turned into the major road. Finally, he collided with the skateboarder (Scenario 9).

Subject No. 8 (Group H)

In Scenario 5 (Change of Traffic Lights, Quick response) the subject drove through the lights at red. He did not reduce his speed either before or during the snow-covered section (Scenario 7). When the vehicle in front suddenly braked (Scenario 3), he stopped with part of the test vehicle in the opposite lane, and in Scenario 9 he collided with the skateboarder.

Subject No. 13 (Group M)

In Scenario 5 (Change of Traffic Lights, Quick response) the subject drove through the lights at red. When he entered the major road, the second passing car collided with him and in Scenario 9 he collided with the skateboarder.

Subject No. 34 (Group M)

The subject drove through both sets of traffic lights at red (Scenarios 4 and 5). In Scenario 9 he collided with the skateboarder.

No other subjects showed such a concentration of driving errors or hazardous driving behavior.

6.2 "Potentially Hazardous Driving Behavior"
(see Table 6.2.1)

In six of the ten scenario evaluations, subjects from the three groups stood out because of hazardous or incorrect driving behavior. If the behavior of the groups is considered in quantitative terms, twice as many subjects from Group M were involved in potentially hazardous maneuvers as from Group L, with subjects from Group H lying between Groups L and M.

In contrast, if we consider the subjects who did not make any hazardous or incorrect maneuvers, it can be seen that there were none at all in Group M, seven in Group L and four in Group H.

Comparison of the driving behavior in Scenario 5 (Traffic Light Change from Green to Red, Quick response) together with Scenario 9 (Dart-Out Situation, Quick response) showed that, in Groups L and M, the same subjects who drove through the lights at red often also collided with the skateboarder. The contrary conclusion also proved correct, i.e., the subjects in Groups L and H who stopped in front of the lights also came to a halt before the skateboarder (see Table 6.2.2).

Table 6.2.1: Driving Behavior of Subjects in the three Groups, Quantitative Evaluation (Number of Subjects)

Scenario	Driving behavior	Subject group		
		L	M	H
9	Collided at high speed	6	3	1
9	Collided at low speed	2	11	6
3	Collision	0	1	0
6	Passing car collided with test vehicle	0	2	1
9	Passed at high speed	1	0	0
9	Passed at low speed	0	0	3
4	Drove through red light	0	2	1
5	Drove through red light	4	6	7
5	Drove through yellow light	5	8	7
7	Drove at high speed on snow	1	1	1
7	Braked sharply on snow	1	2	0
3	Stopped in opposite lane	0	4	2
3	Passed with too little lateral clearance	1	0	2
	Σ	21	40	31

Table 6.2.2: Driving Behavior in Scenario 5 as well as in Scenario 9 (Number of Subjects)

Variable / Subject group	L	M	H
- Drove through at red (Scenario 5)	4	6	7
- Collided with skateboarder (Scenario 9)	8	14	7
- Both incorrect	3	6	2
- Stopped at lights (Scenario 5)	11	6	6
- Stopped before skateboarder (Scenario 9)	11	6	10
- Achieved both	8	2	5

6.3 Response Times

In six of ten scenarios, the response time before touching the brake pedal was considered. Subjects with particularly long or short response times were of special interest. Since the individual scenarios set differing demands, different limit values were applied in each scenario. In the case of the short response time, the highest of the minimum values for the group was taken as a basis and all subjects who achieved this value or lower were identified. In the case of the long response time, the lowest of the minimum values for the group was taken as a basis and all subjects who achieved this value or higher were identified (see Table 6.3). It was noticeable that Group H included particularly many subjects with very fast responses and particularly few with very slow responses. The tendency in Groups L and M was reversed; the number of subjects with slow responses exceeded that of subjects with fast responses. Groups L and M each also included one subject who responded particularly quickly or slowly in at least three of six scenarios, while Group H only included one subject who responded particularly fast in three of six scenarios.

Table 6.3: Subjects with Particularly Short or Long Response Times before Touching Brake Pedal

Scenario	Response time (s)	L	M	H
Scen. 2	≤ 1.20	54, 57	**43**	**11**, 62, 65
Scen. 3	≤ 0.98	**45**	**43**	44
Scen. 4	≤ 0.66	57	**43**	**11**
Scen. 5	≤ 0.71	**45**	25, 49	32, 38, 118
Scen. 8	≤ 0.72	**45**	22	32, 119
Scen. 9	≤ 0.71	36	10, **43**	**11**, 47, 119
Σ		7	8	13
Scen. 2	≥ 2.74	**51**, 27	19, 46 **61**	8
Scen. 3	≥ 2.32	24	58	38, 64
Scen. 4	≥ 1.30	3	16	64
Scen. 5	≥ 0.95	9,15,**51**	**61**	47
Scen. 8	≥ 1.54	**51**	4, 13,19 31, 43	117
Scen. 9	≥ 1.02	3, 15,18 21,27,48	4, 7,13 19, 55, **61**	20,65
Σ		14	17	8

(**Heavily printed** figures show subjects with particularly short or long response times in three of six scenarios.)

7 Evaluation of the Psychometric Tests

The psychometric tests are described in detail in chapter 3.4

7.1 Determination Apparatus (DTG)

In this test, the subjects were required to respond to optical stimuli as quickly and accurately as possible by pressing color keys or foot pedals. The speed was determined by the subjects themselves as the next stimulus was not issued until after the response.

The quotient of the number of correct responses and the response time was selected as the most suitable variable for assessment. The differences between the groups were extremely small. Group L tended to achieve the best results and Group H the worst, although the number of correct responses was approximately the same in all groups. The real differences lay in the response times; Group H had as many correct responses as Group L, but required more time. Scatter within the groups was almost always lowest in Group L and highest in Group H (see Table 7.1).

7.2 Attention Testing Apparatus (APG)

In this test, the subjects were required to respond by pressing a key to a specific color sequence in front of them and to 21 lamps, arranged in a 130° field of vision, when these lit up to form a square. The stimulus frequency was 1.2 sec.

The difference between the number of correct responses minus the incorrect responses was selected for the purposes of assessing the test results. Since more incorrect responses were possible than correct responses, the constant 100 was added to the number of correct responses so as to avoid working with negative figures.

The differences between the groups were very small. Group M achieved the best result and Group H the worst. Scatter within the groups was lowest in Group L and highest in Group H (almost twice the level in Group L). Group M achieved its good result as it had both more correct and fewer incorrect responses than the other two groups (see Table 7.2).

7.3 Tachistoscopic Perception Test (TAVT)

In this test, the subjects were required to identify traffic features on 20 color slides which were projected for one second. The number of errors resulting from omitted and extra responses was evaluated.

No significant differences were found between the groups. Group L tended to make least errors and Group H most errors, the broadest scatter being in Group M (see Table 7.3).

7.4 Basle Mood Scale (BBS)

The Basle Mood Scale (see chapter 3.4) was used to detect changes in instantaneous mood caused by the effects of medication. For this reason, all subjects were given a questionnaire with 4 variables, each including 8 items, at the start of the test day (Basle 1) and then after the test drive (Basle 2).

No differences existed between the groups in Basle 1, i.e., the mood situation was the same in all groups at the start of the test day and before the medication groups had taken the diazepam.

There were, however, differences between Basle 1 and Basle 2 in all three groups. In the control group (L), there was no change in the average values or in the correlation of vitality, intrapsychic equilibrium and vigilance, while social extraversion increased significantly. In both groups under medication, the numerical values for vitality, intrapsychic equilibrium and vigilance dropped significantly over the same period, while social extraversion remained unaltered (see Table 7.4).

After the test drive, the subjects in Group M were significantly calmer and more stable in terms of intrapsychic equilibrium than those in Group L, while the subjects in Group H were quieter and more withdrawn in terms of social extraversion than those in Group L. There were no significant differences in the other factors in Basle 2.

Table 7.1: Results at Determination Apparatus (DTG)

Variables \ Subject group		L	M	H
Number of correct responses	$\bar{x}$	174.5	176.4	174.5
	s	4.3	2.6	5.9
	max.	180	180	180
	min.	162	171	153
Response time in 1/100 s	$\bar{x}$	89.0	91.3	95.0
	s	7.8	9.7	14.3
	max.	108	107	136
	min.	77	74	78
Number of correct responses per unit of time	$\bar{x}$	1.98	1.95	1.87
	s	0.19	0.22	0.27
	max.	2.26	2.24	2.26
	min.	1.50	1.65	1.29

Table 7.2: Results at Attention Testing Apparatus (APG)

Variables \ Subject group		L	M	H
Number of correct responses	$\bar{x}$	53.0	54.6	50.6
	s	5.9	8.6	10.8
	max.	65	70	63
	min.	44	42	23
Number of incorrect responses	$\bar{x}$	12.3	11.6	14.0
	s	4.0	4.5	6.9
	max.	18	25	34
	min.	6	6	4
Difference between correct and incorrect responses (plus 100)	$\bar{x}$	140.6	143.1	136.5
	s	8.2	11.6	16.1
	max.	158	162	154
	min.	128	121	92

Table 7.3: Results of Tachistoscopic Perception Testing (TAVT)

Variables \ Subject group		L	M	H
Total numbers of errors	$\overline{x}$	8.2	9.3	9.9
	s	3.0	5.4	3.6
	max.	14	27	18
	min.	4	1	3

Table 7.4: Basle Mood Scale (BBS)

Variable \ Subject group		L	M	H
Basle 1				
- Vitality	$\bar{x}$	20	21	21
	s	4	3	4
- Intrapsychic equilibrium	$\bar{x}$	21	21	21
	s	3	3	2
- Social extraversion	$\bar{x}$	18	19	16
	s	4	4	5
- Vigilance	$\bar{x}$	21	22	22
	s	4	3	4
Basle 2				
- Vitality	$\bar{x}$	20	18	18
	s	3	3	4
- Intrapsychic equilibrium	$\bar{x}$	20	23	22
	s	4	2	2
- Social extraversion	$\bar{x}$	21	19	18
	s	3	3	4
- Vigilance	$\bar{x}$	20	19	17
	s	4	3	5

8 Determining Level of Active Substance in Blood

The subjects in Group M received 0.11 mg diazepam (liquid form) per kg body weight, while those in Group H received twice this dosage. The first blood sample was taken one hour after the medicine was administered and the second was taken after the 20-minute test drive in the simulator.

Comparison of the levels of active substance showed that there were no differences in the average values between the two blood samples in Group M, while the values in the second sample were already somewhat lower than in the first in Group H. Examination of the individual values showed that values from the second blood sample were found to be both higher and lower than those from the first. This would indicate that the timing of the test drive one hour after administering the tranquilizer was correct.

The average of the values from the first and second blood sample was taken as the level of active substance during the simulated drive. This was 155 ng/ml in Group M and 294 ng/ml, i.e., almost twice as high, in Group H. As expected, there was a large degree of scatter in both groups (see Table 8.1).

While subjects with extremely low levels in the blood (< 101 ng/ml) were only found in Group M and those with extremely high levels (> 300 ng/ml) only in Group H, most subjects from the two groups had levels between 101 and 300 ng/ml (see Table 8.2).

Table 8.1: Level of Active Substance in the Blood of Both Subject Groups in Two Blood Samples (Averages)

Level of active substance (ng/ml) \ Subject group		M n = 20	H n = 20
1st blood sample	$\bar{x}$	154.7	306.9
	s	70.2	119.4
	min.	18	101
	max.	283	499
2nd blood sample	$\bar{x}$	155.6	281.4
	s	67.6	118.1
	min.	34	125
	max.	261	553
Average of 1st and 2nd blood sample	$\bar{x}$	155.1	294.2
	s	65.9	105.8
	min.	26	113
	max.	272	472

Table 8.2: Distribution of Levels of Active Substance (Average of 1st and 2nd Blood Sample)

Level of active substance (ng/ml) \ Subject group	M	H	Total
< 100	4	-	4
101 - 200	12	4	16
201 - 300	4	7	11
301 - 400	-	6	6
> 400	-	3	3
	20	20	40

9 Discussion and Conclusions

The object of the study was to examine driving behavior under acute medication with the tranquilizer diazepam using the Daimler Benz driving simulator. For this purpose, 60 students who were comparable in terms of age, body weight, personality features, driving experience and annual driving mileage were divided into three groups of twenty. One group of subjects received 0.11 mg/kg (Group M), a second group received 0.22 mg/kg (Group H), while a third group received none (Group L). The subjects in the medication groups were aware that they had taken a sedative. This approach was adopted because it is often the case that individuals drive cars while fully in the knowledge of having taken tranquilizers.

The simulated drive comprised 10 different scenarios, including some surprise factors. As a learning effect was expected if subjects were exposed to repeated measures in the same scenarios, a repeated-measure design was not possible.

The students demonstrated extremely great interest in the Daimler-Benz driving simulator and their motivation to succeed in the tests can be regarded as very high. All subjects remained at the test center until the end of all the tests, even though they could have gone home (with driver who had not received drugs) after completing their own test drive. Although some subjects were sleeping during the one-hour absorption phase, they succeeded in devoting their full attention to the tests. No subject had to interrupt or stop the simulated drive (past experience of the simulator operator would suggest an interruption rate of 5 % due to nausea). In order to ensure the same conditions for evaluation of the scenarios, the subjects were repeatedly instructed to observe a speed of 80 km/h. Many subjects confirmed afterwards that they would have driven considerably faster if given the choice. Subjects in the two groups under medication needed to be reminded particularly frequently and insistently to observe the above speed restriction.

No significant differences were found between the three groups tested for any of the variables considered in the ten scenarios. In all scenarios, the individual differences within groups were greater than the differences between groups that might have existed. In view of this high variability, only a larger number of subjects might have generated significant between-group differences.

The differences in the subjects' driving behavior were probably made possible by the complex situation structure of the individual scenarios which allowed sufficient scope for a variety of acceptable actions. This could be the reason why subjects were thus able to cope successfully with the respective tests even when under medication.

In three scenarios a trend was observed between the groups. In two of these scenarios, there was a tendency towards potentially hazardous behavior due to drug effects, in one scenario the opposite held true.

- In the Traffic Light Change from Green to Red - Quick Response Scenario, the number of subjects who stopped was considerably higher in the control group than in the two groups under medication.

- In the Following Situation - Quick Response Scenario, serious driving errors (e.g., stopping in the opposite lane, passing with too little lateral clearance, collision) were more frequent in the medication groups than in group L,

- In the Dart-Out Situation - Quick Response Scenario, the subjects from Group H made the least errors.

These scenarios were all particularly demanding for the subjects. The results observed were not uniform. Subjective judgments were at least partially inevitable when assessing the dangerousness of the driving behavior. If the driving behavior in scenarios 5 (Traffic Light Change from Green to Red - Quick Response) and 9 (Dart-Out Situation - Quick Response) scenarios are considered together, it can be seen that the number of subjects with driving errors was highest in Group M in both scenarios. In contrast, the number of subjects who stopped at the lights (in the Traffic Light Situation) and before the skateboarder (in the Dart-Out Situation) was greater in Groups L and H than in Group M.

In two scenarios there was only some vague indication that there may have been some drug effect.

- In the Traffic Light Change from Green to Red - Normal Response Scenario, all three subjects who drove through the red lights came from the groups under medication,

- In the Merge into Traffic Situation Scenario, three of the five subjects who turned into the major road in front of one of the two passing cars were involved in collisions; these three subjects were all from the medication groups. It must, however, be noted that the other cars continued travel without reacting to the test vehicle.

In five scenarios (Narrow Road Situation, Following Situation - Normal Response, Dart-Out Situation - Normal Response, Snow on the Road Situation and Free Road Situation) no differences due to the drug were found.

Comparison of driving behavior in six of the ten scenarios demonstrated that subjects from Group M obtained worse results than those in the other two groups and also that Groups H Group L were often very similar. The following hypothesis might present a possible explanation: As already mentioned, the subjects were all highly motivated to drive well in the simulator and to cope well with the tests. The subjects in the control group were nervous and were more easily distracted by external factors. In contrast, the subjects in Group H noticed the effect of the medication and made an effort to concentrate fully on the relevant tests. This allowed them to cope as well as the subjects in the control group. The subjects in Group M were unwilling to accept that their driving ability had been impaired by the drug and thus overestimated it. This also became clear after completion of the tests when the subjects from the medication groups were driven home. Many subjects in Group M did not accept the need for this precautionary measure. They overestimated their own functional abilities and then had to admit to experiencing coordination difficulties as they stumbled when getting out of the car or climbing steps. In contrast, no subject in Group H refused assistance.

In overall terms, it was not possible to demonstrate any significant or clear impairment of driving behavior due to diazepam, e.g., in the form of sedation with reduced levels of attention, in the scenarios considered. The complex and highly realistic design of the scenarios obviously allowed scope for compensatory action.

This study cannot, for example, be used to show whether greater motivation on the part of the subjects under medication compensated for reduction in performance or whether, in fact, there was no reduction in driving performance due to diazepam. The question as to how long possible compensatory effects can be maintained also remains open. This simulator experiment is also unable to show whether and to what extent compensatory mechanisms would occur in drivers driving their vehicles in real traffic situations after taking one dose of diazepam. Since this study cannot exclude compensatory mechanisms, it is suggested that this aspect should not be ignored in future research.

A fundamental problem in simulator experiments concerns the selection of scenarios. There is generally no taxonomy of the dangerousness of traffic situations which could be used to derive suitable scenarios for the simulated drive.

There were also no significant differences between the groups in the three psyschometric performance tests. The range of scatter within the groups was again greater than that between the groups. In the test with the determination apparatus, Group L tended to achieve the best results and Group H, the worst. The same was true in the tachistoscopic perception test where the subjects in Group L made least errors and those in Group H, most errors.

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11 Appendix

11.1 Description of the Variables in the Scenarios

Two types of measurement variables were applied in description and evaluation of the scenarios:

- analog variables, e.g., braking pressure which could achieve any value between two extremes (zero and maximum pressure). The analog variables were digitized at 10 bits. The digitization error was therefore lower than 1 $^{o}/_{oo}$ (2^{10} bits).
- digital variables, e.g., at the moment when the lights changed from green to yellow. The accuracy or error rate of the digital variables was dependent on the scanning frequency. With infinitely high scanning rates, the level of error would tend to zero, but the data flow would become immeasurable. The scanning rate and accuracy requirements therefore had to be carefully balanced. The Daimler-Benz simulator permitted scanning frequencies of 0.5 or 0.02 seconds. Since the response times were expected to be of the order of 0.2 to 1.0 second, it was necessary to select the scanning rate of 0.02 seconds. In the least favorable case, this resulted in a scanning error of 20 % for response times of 0.2 seconds (200 milliseconds). With response times of 1 second, the error was only 4 % in the least favorable case.

For the sake of completeness, it should be noted that the digitization error is not the only factor which should be considered with regard to conversion of the analog variables. The scanning error should also be taken into account, even though it is rendered negligible by the relatively slow speed of change of the analog variables.

Definition of the variables used in the evaluation of the scenarios is described below:

Speeds

The variable "speed" was defined in meters per second (m/s). The values given in m/s must be multiplied by 3.6 for conversion into km/h, i.e., 22 m/s is approx. 80 km/h.

Distinctions were made between:

- local speed: speed on a particular section of road, e.g., at the start of a scenario.

- instantaneous speed: speed at a particular moment, accurate to within 0.02 seconds.

- average speed: average speed over a particular route section, e.g., 300 m, or for the length of the scenario.

- maximum speed: highest value for a specific route section or period of time. All measurement frames recorded in a 20 ms (milliseconds) cycle were "searched" to locate the highest value.

- minimum speed: smallest value for a specific route section or period of time. Determined in same manner as maximum speed.

- speed difference: difference between maximum and minimum speed over a particular route section, e.g., during cone section.

- collision speed: difference in the instantaneous speeds of the two colliding objects at the time of collision.

Accelerator Position

Accelerator travel was quoted in percentage values. 100 % meant that the accelerator was fully depressed. A reduction in acceleration was recorded when the accelerator pedal was moved back by at least 15 %. The accelerator pedal was defined as having been released when depressed by no more than 5 %. An increase in acceleration meant an increase in depression of the accelerator by at least 8 %.

Brake Pedal Position

Actuation of the brake pedal was defined as application of a force of at least 5 Newtons.

Response Times

These were given in seconds. All response time measurements concerned time differences dependent on a particular occurrence. Distinctions were made between:

- response time before reduction in acceleration: time difference between a specific occurrence and a reduction in depression of accelerator by at least 15 %, but with accelerator still depressed by at least 5 %.

- response time before increase in acceleration: time difference between a specific occurrence and an increase in depression of the accelerator by at least 8 %.

- response time before braking: this response time was defined as the time difference between releasing the accelerator and touching the brake pedal.

Time Gaps

The time gap is defined as the quotient of the instantaneous distance from and instantaneous speed relative to a defined point at constant speed. Measurement was in seconds. Distinctions were made between:

- minimum time gap: the lowest value for a specific period of time or route section was collected from the values determined every 20 ms.

- maximum time gap: the highest value for a specific period of time or route section was collected from the values determined every 20 ms.

- average time gap: the values calculated every 20 ms over a specific period of time or route section were used to form averages.

- standard deviations of the individual time gaps: the individual standard deviation was calculated from the values determined every 20 ms over a specific period of time or route section. This figure provided an indication of the constancy of the following distance.

Accelerations

Both longitudinal and lateral accelerations were recorded. They were measured in m/s^2 (meters per square second). Acceleration was only recorded when the numerical value exceeded 2 m/s^2. Distinctions were made between:

- maximum longitudinal acceleration: highest value over a specific period of time or route section, possibly only lasting 20 ms.

- minimum longitudinal acceleration: lowest value over a specific period of time or route section, possibly only lasting 20 ms.

- average longitudinal acceleration: average longitudinal acceleration over a specific period of time or route section.

The above also applied to lateral accelerations.

Decelerations

Deceleration was recorded when the values for longitudinal acceleration were negative.

Note: Values in the tables which exceed 9.81 m/s^2 (gravity) were the result of transverse forces and/or tire deformations.

Dimensions and Distances

The dimensions of the roads (country road and autobahn) are illustrated in Fig. 2 and those of the test vehicle in

Fig. 4. The diameter of the skateboarder was calculated to be 0.5 m.

Distances were measured in meters and distinctions were made between:

- distance to other vehicle: distance between rear bumper of other vehicle and front bumper of test vehicle, taking account of vehicle dimensions.

- distance to skateboarder: the distance was determined taking account of the test vehicle dimensions and the diameter of the skateboarder.

- lateral distance between test vehicle and other vehicle: distance between left-hand side of other vehicle and right-hand side of test vehicle.

- distance to stop line: distance between front bumper of test vehicle and center of stop line.

Position

This value described the position of the test vehicle in various situations during the scenarios.

- right-hand lane: the test vehicle remained entirely within the right-hand lane during a particular period or route section.

- crossed center line: a maximum of half the width of test vehicle was in the left-hand lane.

- left-hand lane: more than half the width of the test vehicle was in the left-hand lane.

- left roadway: the entire width of the test vehicle was outside the roadway.

- "drove through at yellow or red" meant that the front bumper of the test vehicle crossed the stop line when the lights changed to yellow or red.

Coefficient of Friction

The adhesion between the roadway surface and vehicle tires is described as the coefficient of friction and may lie between 0 and 1. In the scenario, it was programmed to 0.3. This roughly corresponds to the value for a driven-down covering of snow.

11.2 Description Of Research And Scope Of Work (Excerpt)

Introduction

Previous crash investigation research suggests the potential for a sizable drugs and driving problem. However, we cannot say at this time which, if any, drugs present a hazard to the safe operation of a motor vehicle. A number of studies have revealed the presence of drugs in from 10% to 25% of fatal and seriously injured drivers. However, the mere presence of drugs in drivers, at any indidence rate, does not necessarily mean that the use of the drug was causally related to the crash. Only if the drug occurs significantly more frequently in crash-involved drivers than it does in non-crash-involved drivers can it be considered a possible causal factor. The greater the overrepresentation of a drug in a crash-involved sample, the more likely the drug is a significant highway safety hazard. Unfortunately, we do not have drug frequency rates for non-crash drivers, and the possibility of obtaining this information, which would require collecting volunteered blood samples from drivers stopped at checkpoints, is relatively remote.

An alternative approach that can be used to determine whether drugs precipitate crashes is to examine their effects on driver performance in a driving simulator. Sufficient driver impairment in this situation would lend support to the position that the drug is a real world crash hazard. It is critical that the simulator used in this type of research be as realistic as possible, so that the results can be more easily generalized to real world driving situations. Based on a review of available driving simulators worldwide, we believe that the simulator developed by Daimler-Benz (Mercedes) in Berlin is the most "realistic" and sophisticated driving simulator currently in existence. Its key elements are a highly realistic motion system with six degrees of freedom, and a projection system that simulates the vehicle environment with a sharply focused seamless 180 degree picture in the driver's visual field. A complex mathematical model of dynamic vehicle behavior simultaneously guides a number of computers in simulating motion, reaction forces of the steering wheel, brake and accelerator pedals, as well as the visual field and noises associated with a simulated drive. Using this simulator, we would be able to program a variety of routine and emergency driving situations, varying the road type and condition, weather conditions, and visibility. Driver performance (e.g. type and severity of accidents, and dangerous situations avoided) could be recorded for various drug and dosage conditions.

The purpose of this project is to assess the degree of driver impairment associated with specific drugs and dose levels, as measured using the Daimler-Benz (Mercedes) driving simulator in Berlin. This cooperative agreement between the U.S. Department of Transportation (DOT) and the Ministry of Transport of the Federal Republic of Germany. The National Highway Traffic Safety Administration (NHTSA) is the unit of the U.S. DOT responsible for the U.S role in the project. The Bundesanstalt für Straßenwesen (BASt) is the German transportation research institute that will manage the German role in the project. The actual research data will be collected in Berlin where the Daimler-Benz (Mercedes) driving simulator is located. All interaction with Daimler-Benz personnel will be coordinated by BASt. NHTSA will deal directly with BASt for this project, and BASt will oversee other parties involved in the execution of the research. The implementation of the research, including the medical supervision of participating subjects and the laboratory blood tests required, will be supervised by personnel from the Insitute for Legal Medicine (Institute für Rechtsmedizin) in Berlin. Daimler-Benz will have responsibility for the preparation of the simulator driving scenarios that will be experienced by the participating subjects, and the actual running of the simulator.

The following sections provide details regarding what specific drugs are to be studied, how subjects will be recruited and supervised, what experimental procedures will be used, what driving tasks will be run on the simulator, and what driving performance and other self-report measures will be recorded. A summary of the proposed schedule, and specification of who will have responsibility for what activities, and the estimated costs are also provided.

Selection of Drug and Dose Levels

Two drugs will be evaluated, each at two dose levels, and a no drug condition. These drugs were selected because of their potential as highway safety hazards. Valium (representing the class of tranquilizers) appears frequently among drugs found in fatally injured drivers. Valium is also widely used in the general population. The antihistamine selected, diphenhydramine, represents a class of widely used over-the-counter drugs that has been shown in the laboratory to have the ability to impair driving-related performance. The two dose levels specified for each drug represent typical dosages.

Tranquilizer - Diazepam:

No drug, 0.11 mg/kg, and 0.22 mg/kg.

> These dose levels translate to approximately 7.5 mg and 15 mg doses for a 70 kilogram person.

Antihistamine - Diphenhydramine:

No drug, 0.71 mg/kg, and 1.07 mg/kg.

> These dose levels translate to approximately 50 mg and 75 mg for a 70 kilogram person.

The doses administered shall be expressed in terms of mg/kg bodyweight, to minimize variability between subjects.

We are most interested in studying the effects of the drugs on drivers that are occasional users, i.e. individuals that take the drug as needed on a prescription basis or individuals that use the drug occasionally on a recreational basis. Therefore, single acute doses shall be studied.

Procedures

Subjects

The Institute for Legal Medicine (Institut für Rechtsmedizin) in Berlin will be responsible for implementing the recruitment, selection and supervision of subjects who participate in the research.

Subject Selection

Between 60 and 120 volunteers will be solicited from the Free University of Berlin (10 to 20 subjects for each condition - no drug and two dose levels). Only male licensed drivers between the ages of 21-25, weighing between 65-75 kilograms will be selected. Prospective volunteers will be screened to obtain both medical and drug histories. Only persons who show no medical contraindications, who are only occasional users of the drugs being studied, and who agree to be drug free prior to participation in the study, will be considered. Driving experience is another factor that will influence subject selection. Only individuals that drive between 3,000 km and 10,000 km per year will be considered for selection. In addition, the subjects should not be experienced in driving with power steering.

Medical Supervision During the Course of the Study

The Institute for Legal Medicine will have the primary role in the medical and drug history screening of volunteers. Medical personnel (doctor or nurse) will be present during the course of each experimental session. At the conclusion of each experimental session, the subjects will remain under medical supervision for a specific period of time, after which they will be driven home.

Experimental Design

The drugs shall be studied independently. All of the simulator data for the first drug shall be collected before the simulator runs for the second drug are initiated. Accordingly, this project actually involves two phases, each using the same subject recruitment and processing procedures as well as the same simulator scenarios and driving performance measures. The evaluation of each drug may be considered a stand-alone study and a separate report shall be prepared describing its results.

The experimental design is essentially the same for each study. In each case, a between-subject design shall be used with a target sample size of between 10 and 20 subjects per condition for each of the three conditions (no drug, low and high dose conditions). Note that a pilot test, with from 5 to 9 subjects may be run prior to initiation of the first drug study. This will enable all logistic and organizational problems (subject transport and supervision, simulator set up and run, data collection and reduction, etc.) to be tested and resolved.

Experimental Procedure

This section sketches what will happen to a volunteer subject from the time of his arrival at the laboratory/simulator until the time he is safely home.

After reporting to the study site, the subject will be asked to first give a urine specimen. The purpose of collecting the urine specimen is to screen for alcohol and other licit or illicit drugs in the subject's system, to verify that the subject is starting the session drug free.
After the urine specimen has been collected, the subject will take the prescribed drug (or nothing). When the drug has had sufficient time to be absorbed into the bloodstream, the simulator drive will commence.
Immediately following the simulator drive, a blood sample will be drawn to obtain a measure of the drug-blood concentration. The simulator drive itself (described below) will run about 20 minutes. Following the collection of the blood sample, a short questionnaire (also described below) will be administered, the subject will be asked to complete a series of laboratory psychomotor tasks independent of the simulator. Following this, the subject will be monitored by the medical personnel present until it is determined that the acute drug effects are over and it is safe for the subject to be driven home.

Simulator Scenarios

Prior to drug dosing each subject will be exposed to a ten minute training session on the simulator. This will ensure that each subject is sufficiently familiar with how the simulator operates. On the day of the experimental session the subject will receive one drug condition (no drug, low or high dose) and then be exposed to a 20 minute simulator drive. At the beginning of the simulator test drive, the subject will be exposed to a straight 2-lane road, and instructed to maintain a cruising speed of about 80 km/h unless the situations he encounters require a different speed (e.g., car following, stopping at an intersection, etc.).

During the course of his 20 minute drive, the subject will encounter a number of different scenarios that will impose varying demands on him. Between each scenario, the driver will drive along a straight road for about 30 seconds. This will allow him time to get his speed back up to 80 km/h. Set up procedures for the training and test drives will require an additional 10 minutes of simulator time. The general description of each scenario is presented below:

1. Traffic Light Change from Green to Red

Qualitative Description of Scenario

In this situation, the subject will approach a traffic light controlling the flow of traffic. This drive will be under dry road conditions in clear weather. Under these conditions, the driver will be exposed to two different situations, one requiring a QUICK RESPONSE, and the other requiring a NORMAL RESPONSE. In the QUICK RESPONSE situation, the driver will be cruising at about 80 km/h and will see the traffic signal change from green to yellow to red at 75 meters from the intersection. In the NORMAL RESPONSE condition, the traffic signal will change when the driver is 110 meters from the intersection.

Response Measures

Driver attempts to stop

- o Reaction time to initiation of braking
- o Vehicle velocity when light changes
- o Maximum deceleration

- Position when stopped (in relation to intersection - ± number of meters from the edge of the intersection)

Driver travels through the red light

- Does driver accelerate (yes or no)
- Reaction time to initiation of acceleration
- Maximum acceleration
- Color of signal (yellow or red) when the driver enters the intersection

2. Following Situation

Qualitative Description of Scenario

In this situation, a driver will be cruising at approximately 80 km/h following traffic in front of him. This drive will be under dry road conditions in clear weather. The driver will be instructed to maintain a safe and comfortable following distance for some period of time (e.g., 30 seconds). To add realism to the situation, there may be occasional oncoming traffic going in the opposite direction, though this information would not be relevant to the task at hand in this situation. While in a steady state condition, there will be two situations to which the driver will be exposed, one requiring a QUICK RESPONSE, and the other requiring a NORMAL RESPONSE. In the QUICK RESPONSE condition, the lead car will decelerate as rapidly as possible and come to a complete stop, and we will assess the response of the following vehicle. In the NORMAL RESPONSE condition, the lead car will brake, but its deceleration will be gradual, not requiring an extraordinary response for our driver-subject to compensate for the slowdown. In this situation, the lead vehicle will decelerate to about 40 km/h and maintain this velocity for some period of time (e.g., 30 seconds).

<u>Response Measures</u>

- o Time gap between the vehicles that the driver accepts prior to the lead vehicle initiating deceleration (also, some measure as to the variability of this time gap - does the driver maintain a relatively constant time gap or does it vary considerably?). The mean time gap and its standard deviation (prior to initiation of deceleration) may be appropriate measures.

- o Following lead vehicle deceleration (Quick Response Condition)

  - Reaction time to initiation of braking
  - Maximum deceleration
  - Simulated vehicles final position (stopped in road behind lead vehicle - number of meters separation, collision with lead vehicle, off the road to avoid a collision
  - Closest distance to lead vehicle (number of meters) during deceleration

- o Following lead vehicle deceleration (Normal Response Condition)

  - Reaction time to initiation of braking
  - Maximum deceleration
  - Closest distance to lead vehicle (number of meters) during deceleration

- Final time gap that driver maintains (mean, standard deviation) following deceleration of the lead vehicle

3. Dart-Out Situation

Qualitative Description of Scenario

In the dart-out situation, the driver will again be cruising at approximately 80 km/h on a dry roadway in clear weather. In one condition (NORMAL RESPONSE), there will be a bus parked along the curb, obstructing the driver's view of anyone behind the bus. A pedestrian will cross the street into the path of our subject driver, starting from a position which is hidden by the bus. This will occur when the subject driver is far enough from the bus so that he has to react to avoid hitting the pedestrian, but not in an emergency manner. In a second case, requiring a QUICK RESPONSE, a car will enter the right lane suddenly from the side of the road. In this situation, the driver will have to react very quickly to avoid a collision.

Response Measures

- Reaction time to initiation of deceleration
- Maximum deceleration
- Type of avoidance maneuver (none, swerved off the road to the right, swerved into the opposing traffic lane, decelerated to a stop)
- Collision with object (yes or no)

4. Snow on the Road Situation

Qualitative Description of Scenario

As in previous situations, the driver will be cruising at about 80 km/h. Road conditions will initially be dry. In this situation, the driver will eventually encounter a section of roadway that is covered with snow. This section of roadway will be colored white with some snow banks along the side of the road. The coefficient of friction on the snow covered portion will be reduced so that vehicle control is more difficult. However, the friction coefficient should not be so low as to simulate a sheet of ice.

Response Measures

- o Type of driver compensation for snow (none, accelerate, let up on accelerator pedal, apply brake, maximum amount of acceleration or deceleration)

- o Result of driver compensation for snow (stays in his traffic lane, slides off the road on right but maintains control, slides off road on right but loses control - accident, slides into opposing traffic lane but maintains control, slides into opposing traffic lane but loses control - accident).

5. Merge into Traffic Situation

Qualitative Description of Scenario

In this situation the driver is stopped at an intersection controlled by a 2-way stop sign. He is instructed to make a right turn and merge into crossing traffic. Two vehicles will be travelling down the crossroad that the driver must turn on to. The time gap between the first vehicle on the crossroad and the driver will be relatively short (e.g., 5 seconds) so that the driver would have to accelerate somewhat rapidly to safely make the turn and merge in front of the first crossing vehicle. The time gap between the first and second vehicle on the crossroad will be somewhat larger (e.g., 8 seconds) so that the driver does not have to accelerate as rapidly to successfully execute the turn and merge in between the crossing vehicles. The driver may also allow both crossing vehicles to pass before merging into crossing traffic.

Response Measures

- o Location of driver turn and merge - before the first crossing vehicle, in between first and second crossing vehicle, after second crossing vehicle
- o Time gap between driver and approaching crossroads vehicle when the turn is initiated
- o Maximum acceleration during the turn and merge maneuver
- o Collision with crossroads vehicle (yes or no)

6. Narrow Road Situation

Qualitative Description of Scenario

The driver will encounter a section of roadway where pylons are used to make the road much more narrow than normal. The driver will attempt to travel through these pylons without knocking any over.

Response Measures

- o Maximum change in vehicle velocity during pylon course
- o Number of pylons knocked over

7. Straight Road Situation

Qualitative Description of Scenario

At the end of the test ride the driver will drive along a straight section of road for some period of time. The objective here will be to look at the driver's ability to maintain lane position as an indication of the degree of fatigue he is experiencing.

Response Measures

- o Number of departures from traffic lane (off the road or into the opposing traffic lane)
- o Increase in weaving within driver's own traffic lane (yes or no)
- o Difference in average speed maintained in this situation from 80 km goal (plus or minus)

Post Simulator Drive Test Procedures

At the completion of the simulated drive, each subject will be asked to fill out a questionnaire. The questionnaire will include items asking how much driving experience the driver has had, and how long he has been licensed. A mood section will also be included along with items tapping basic demographic and personality information. Following completion of the questionnaire, each subject will be required to perform a number of laboratory psychomotor tasks, such as tracking, divided attention and reaction time tasks. It is hypothesized that the drugs taken will also influence performance in these cases, thereby serving as another measure of the drug effects on behavior. The effects of different drugs on performance on these separate activities will be compared to performance measures on the simulator.

Data Analyses

Regarding outcome data on the driving simulator, the relationship between driver performance and drug dose levels will be assessed for each scenario encountered. At a minimum, the response measures listed above for each driving scenario will be analyzed using appropriate statistical methodology to determine the nature and extent of performance changes associated with each drug and dose level. BASt will be responsible for the data analyses.