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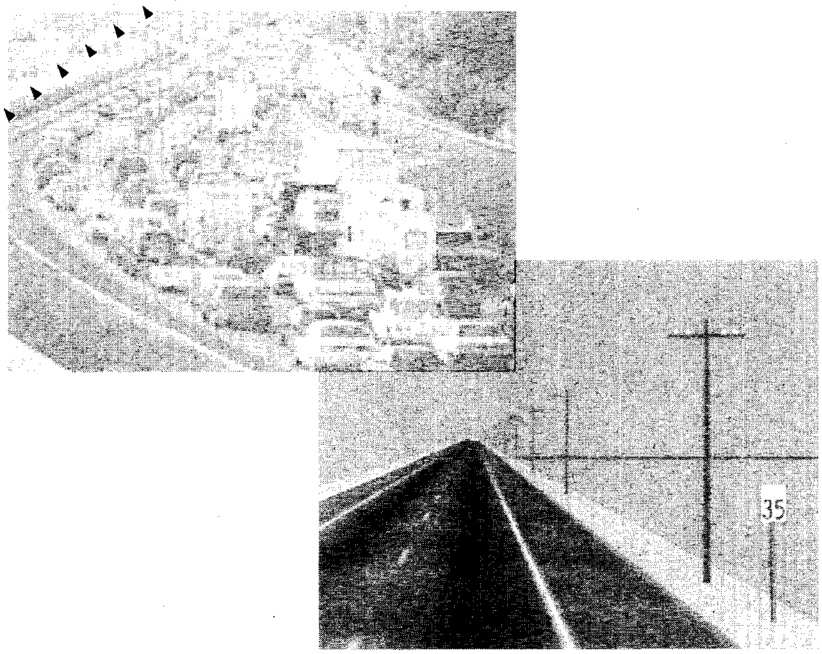

Simulation Validation: Evaluating Driver Performance in Simulation and the Real World

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16. Abstract (Limit: 200 words)

Simulation offers a cost-effective way to conduct research on collision avoidance and accident prevention. To be effective, simulated performance must be a valid measure of real world performance. This project sought to validate real world driving performance based on the performance of individuals driving in simulation.

The study presents performance data on 14 male and 12 female volunteer subjects who drove a route adjacent to the University of Minnesota campus and then performed in a similar computer-generated driving route. Generally, subjects reported the simulated driving test comfortable and realistic; performance and characteristics of driving in the simulator closely paralleled the real world; the qualitative pattern of driving was similar; and errors and the control parameters of driving performance suggested acceptable reliability between both driving worlds. Researchers concluded that the simulator performed reliably and provided a valid set of performance data that could be used to better understand driving behavior, especially as it related to accident prevention and collision avoidance.

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Simulation Validation:
Evaluating driver performance in simulation and the real world.

Final Report

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We also want to acknowledge the administrative help we received from Laurie McGinnis at the University of Minnesota's Center for Transportation Studies.

Finally, we are grateful for the funding support from the Minnesota Department of Transportation.

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Executive Summary

The project, Simulation Validation was sponsored by the Minnesota Department of Transportation and was performed at the University of Minnesota. The objective of this project was to better determine the relationship, reliability, and validity of driving performance in the wrap-around simulator (WAS), developed by the University of Minnesota's Human Factors Research Laboratory. The present study measured driving performance, selected kinematic variables, and perceptions and comments via a questionnaire, given to a group of volunteer subjects. These subjects drove the laboratory's on-road vehicle (Honda Accord) over a selected real driving world (RW), and then drove a similar vehicle in the WAS responding to a virtual driving environment (VE) with similar driving and structural characteristics as the RW. There is little published data available that directly compares real-world driving with simulated driving for on-road activities. It was therefore important to determine the degree of reliability and validity of the simulator, and thus its potential for future driving behavior research.

Development of the study was predicated on three elements: the selection of a real-world driving route (RW); the development of a computer generated virtual driving environment (VE) that shared similar characteristics to the RW driving world; and the development and distribution of a questionnaire asking volunteer subjects who participated in the study to provide us with their perceptions and feelings about driving in the simulator with respect to comfort level, motion sickness or other experiences.

The experimental portion of the study compared the lateral lane positioning (distance from center line) in the RW and the VE. The data (recorded in centimeters) compared the real-world driving scene with the virtual driving scene. The average differences between RW performance and VE performance appeared quite large e.g., 135 cm for the RW vs. 160 cm for the VE (a difference of 25 cm). However, it should be remembered that this represents a difference of only 1 foot, which is seen within the range of normal driving variance. More importantly, the qualitative pattern of driving exhibited by drivers in the real-world was similar to that in the virtual world. Thus, the

tracking of the vehicle over the VE driving course consistent with a driver's real-world performance.

In terms of driving behavior, when drivers proceeded from a stop position they tended to pull towards the center-line, proceed in essentially a straight line and then pull to the right again before stopping. At no time was this deviation greater than 38.10 cm, and at times, was as small as 12.70 cm, which again in real driving terms appears negligible. Standard deviations (s.d.) observed in the VE were larger due primarily to the lack of contact friction between a 'real' tire and a 'real road during vehicle turning maneuvers. This factor combined with no forward inertia and slightly delayed feedback to the steering wheel produced a greater degree of drift, especially immediately following turns. Once these 'in turn' oscillations subsided, deviations closer to RW values occurred.

The static phase of this project consisted of measurement of head motion in response to ambient optical stimulus; in this case an approaching Chevy Blazer (RW & VE). The primary question here was whether the VE produced a different visual stimulus resulting in amplified or muted response as measured by movement of the head. The head mounted accelerometer on the subjects responded to acceleration of the head in the plane of motion we would regard as medial/lateral & anterior/posterior. Output was recorded in hundredths of a volt (mV). These values were translated to accelerations from which actual displacement was derived (cm). Generally the values and patterns between head motion data taken in the RW and the VE were the same. Minor uncontrollable influences such as an object blowing in the wind, a sudden reflexive glance at a pedestrian, laughing, talking, sniffing, shifting in the seat, etc. produced large accelerations resulting in larger deviations.

Generally our participants found the VE to be comfortable, and the responses to the questionnaire data showed that factors such as comfort, realism, ease of use and expectation all fell slightly above the midpoint of a positive assessment (5-6 on an a 1-9 scale). Only the physical realism aspect scored below the midpoint on this scale (4.52). This was not surprising as we focused only on realism of the immediate environmental levels (road surface and vehicle). The VE contained no trees, houses or other physical environmental components.

Other experimenter observations between performance in the RW and VE were as follows: driving 'style' was consistent; aggressive drivers were consistently aggressive (i.e. hard acceleration/braking, speeding, etc.) in both RW and VE; one subject repeatedly ran or overshot stop signs in both environments, often at the same intersection. Other observations of note were anticipatory leaning back during VE stops, regularly looking left/right at intersections in the VE and reactions to VE vehicles as though damage would occur on impact. All represent a reliable degree of habitual or reflexive RW responses in a non-RW environment.

As one of the few studies to directly compare simulated driving performance with a real world driving scenario, we conclude that the simulator performed reliably and provided a valid set of performance data that reflected real world driving. The prognosis for utilizing the simulator for future driving research is promising.

I. INTRODUCTION

The now complete Human Factors Research Laboratory (HFRL) wrap-around simulator (WAS) has been used for a variety of transportation-related human factors research projects. Only rarely will a researcher be interested in just the simulation results. Instead, the intent would be to collect a large amount of data safely, timely, and inexpensively in the simulator; analyze the data, draw the conclusions, and infer that the simulated driving results may be valid in the real world of driving. Because the simulator is new, there is as yet no basis for making such inferences. The purpose of this project was to provide a basis for making inferences from the simulated to the real driving world.

Once this basis has been established, it will be reasonable to assume that the simulation results can be generalized to the real world. In previous work with the older simulator, at least a few data points were always checked against driving performance in the real world. The real world results have always agreed with the simulation findings.

The experience in the simulation community is that the higher the fidelity of the driving simulator, the greater the chance of simulator sickness. This problem of simulator sickness is, in large part, the centerpiece of this research project. The symptoms of simulator sickness are similar to car sickness or, more generally, motion sickness. However, the WAS is not a motion-based simulator, thus the cause of simulator sickness is equivocal. There are several attractive hypotheses, which may be wholly or partially correct.

Candidates for producing nauseogenic effects during simulation fall into one or more of the following categories:

1. The kinds of maneuvers subjects are asked to perform
2. The length of time that subjects are driving the simulator
3. The nature of the computer graphic display as a function of sampling rate used to generate the display

4. Other environmental factors such as ambient temperature in the simulator, the presence or absence of moving air, etc.
5. Display density of the simulated environment
6. Lag time between the subjects responses and changes in the display

It would seem that particular driving maneuvers evoke simulator sickness in a high percentage of the population. By avoiding such maneuvers, or limiting exposure to them, the likelihood of simulator sickness can be reduced. Pragmatically, subjects who begin to exhibit the symptoms of simulator sickness can simply be eliminated from studies--as long as the fraction of the population exhibiting these symptoms is small. However, if a large proportion shows these symptoms and are subsequently dismissed, data from simulated studies will be biased by sampling error and the validity of results would be in question, even if the same drivers reproduced the simulation results in the real-world. Seeking both a better understanding of the causes of simulator sickness, and a real-world validation of simulator performance with this as a background, is the central aim of this project.

OBJECTIVE

The objective of this project was twofold. First was to determine if, to what extent, and under what specific test conditions, the HFRL's wrap-around simulator induces simulation sickness. Second was how representative the simulator is of the actual on-road driving performance.

SCOPE

This project encompassed four elements. First consisted of a static evaluation of the simulator itself; this included computing hardware, the car's sensors, and the equation of motion for the car, the driving worlds, and the data handling software. Second, a simulation experiment employing selected, representative driving maneuvers. Data were recorded that measured driving performance and forcing functions (street width, parked cars, etc.) were used to vary the difficulty of the driving task. Third was the development and use of an opinion survey questionnaire for volunteer subjects driving in both the WAS and on-road protocols. Fourth was an on-road evaluation of driver performance, which shared the same demands as the simulation study.

The project required the development of several distinct entities which, taken together, provided a basis for comparing the validity of the HFRL simulator performance with real-world driving performance. These entities were as follows:

1. Identification and selection of a 'real-world' (RW) driving route that could be reproduced in the WAS
2. The development of a virtual environment driving world (VE) that was a scalar representation of the real-world driving route (RW)
3. Development of a questionnaire to be completed by volunteer subjects who participated in the study. The questionnaire was used to generate data about participant evaluation of the VE experience
4. An experimental study that compares driver responses in both the RW and the WAS (VE)

LITERATURE REVIEW

The draft final report for the Human Factors Evaluation for the Genesis program (Wade, et al., 1993) contains an extensive review and analysis of the literature partly on driving and multi-tasking's impact on driving safety. Since the HFRL simulator has not been validated there will be no directly relevant references. The literature search, which was conducted as part of the Genesis project, is presented below.

The key words for this search (courtesy of Minnesota Department Of Transportation Library Staff) were: Fidelity of Simulation, Simulation Validity, and Simulator Sickness. The relevant references follow:

Allen, R.W., Mitchell, D.G., Stein, A.C. and Hogue, J.R. (1991). *Validation of real time man-in-loop simulation.* Proceedings of the Conference, Strategic Highway Research Program and Traffic Safety on Two Continents, Part Four, Gothenburg, Sweden, September, 1991.

Drosdol, J., Panik, F. (1985). *The Daimler-Benz Driving Simulator: A Tool for Vehicle Development.* Society of Automotive Engineers, February 25-March 1.

Riccio, G.E. and Stoffregen, T.A. (1991). *An ecological theory of motion sickness and postural instability.* Ecological Psychology 3 (3), pp 195-240.

Riermersma, J.B.J., Van Der Horst, A.R.A., Hoekstra, W., Alink, G.M.M. and Otten, N. (1990). *The validity of a driving simulator in evaluating speed reducing measures.* Traffic Engineering and Control, 31, 7/8, pp 416-420.

Stapleford, R.L., Klein, R.H. (1980). *Recent developments in driving simulator hardware and sortware.* Systems Technology, Paper No. 273, October, 1994.

Stoffregen, T.A. and Riccio, G.E. (1991). *An ecological critique of the sensory conflict theory of motion sickness.* Ecological Psychology, 3 (3), pp159-194.

Szluk, J.P. (1995). *Relative effects of age and compromised vision on driving performance.* Human Factors, 37 (2), pp 430-436.

Törnos, J., Jansson, H., Laurell, H., Lindström, Morén, B., Nordmark, S. and Palmkvist, G. (1988). *The VTI driving simulator. Driver performance applications.* VTI sätryck, 1988, 122, 23P.

Voorhess, J.W. and Waddington, J.M. (1994). *Fidelity in human-in-the-loop driving simulation.* Traffic Technology International, Winter, 1994, pp 76-80.

Wade, M.G., Stackhouse, S.P. and Burrus, M. (1993). *Human factors aspects of The Genesis Program.* Minnesota Department of Transportation, GUIDESTAR, Winter, 1993.

No published references directly comparing simulator performance with real-world driving were found.

II. SELECTION OF THE REAL WORLD DRIVING ROUTE (RW)

The selection of the RW was based on criteria, which are both naturally occurring and manmade. Minnesota roads are notoriously difficult to maintain due to the extreme weather conditions during the winter. The effect this has on non-highway surface roads is pronounced. Large potholes, ruts and mounds are fairly common. These and other "naturally" occurring constraints, which would affect lateral road positioning of the real world (RW) vehicle played a role in the selection of the RW. Manmade constraints such as speed limits, road markings, lane widths, parking, and so forth were the other side of the coin. Lastly, logistic and human constraints played their part. Traffic congestion had to be avoided as was selecting a RW driving site too remote for reasonably quick trials.

The selection of the RW driving environment (15th Ave. SE to Como, to 19th Ave. SE to 20th Ave. SE) was made based primarily upon the following:

1. Near enough to parking lot test area to simplify logistics.
2. Far enough to allow some familiarization with the on road vehicle.
3. Roads were "true" with no curves.
4. Traffic was moderate (peak times were avoided).
5. No pronounced ridges or ruts.
6. Clear markings.
7. Parking conditions were consistent.
8. The sequence of roads offered varied test conditions.
9. Road sections were long enough to collect sufficient data and to get "up to speed".
10. Road sections were wide enough with and without parking to allow sufficient variation in position.

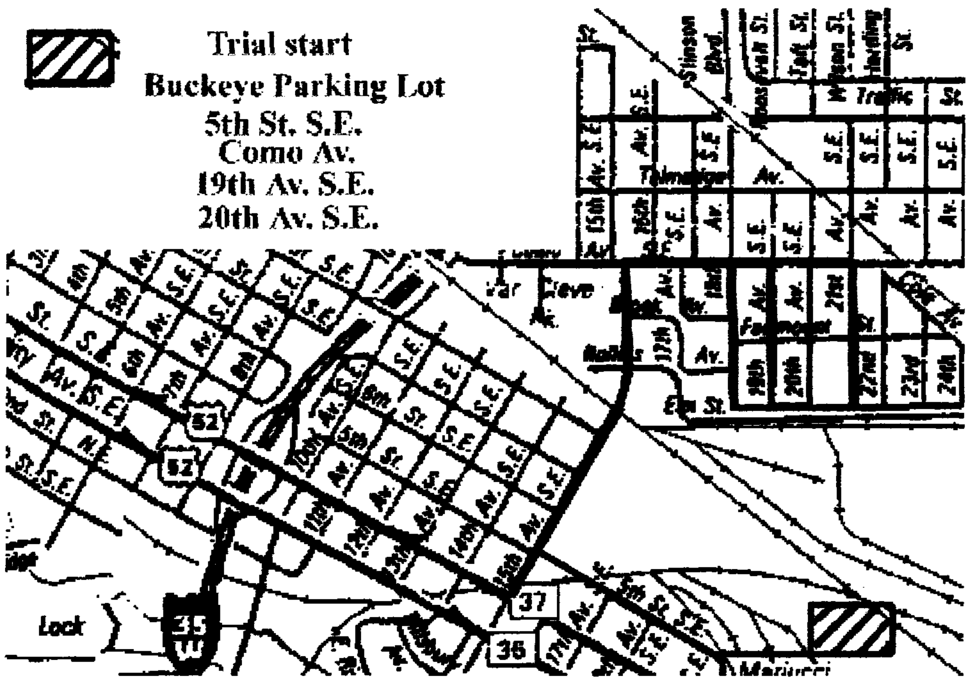


Figure 1. Real world driving environment.

The parking area pictured is an approximation of the RW location. The road running from the parking lot and NW (5th St. SE) comprises the 'familiarization' portion of the test road. The peripheral north / south residential non-test road sections (18th Ave. SE & 21st Ave. SE) other than the actual test roads (19th Ave. SE & 20th Ave. SE) are included in both the RW map and the VE map. Inclusion of these roads afforded the possibility to correct for missed turns or as alternative routes should unexpected traffic problems occur.

III. DEVELOPMENT OF VIRTUAL ENVIRONMENT DRIVING WORLD (VE)

1. Introduction

A virtual environment-driving world was produced for use in the wrap around simulator (WAS) to determine the validity of driver performance measures when compared to a real world-driving situation. The ability to elicit habitual and reflexive driving behaviors in a virtual environment allows research to be done in a safe environment without the threat of environmental hazards such as other vehicles. The virtual environment scenario developed can be repeated precisely each time for experimental control, or altered in order to change test variables or in order to update environmental or road conditions.

2. Methods and Procedures

(a) Limitations

The advantages of virtual environments have already been discussed. The two critical issues are those of safety and experimental control. The latter played the most critical role in the selection of the real world environment. The test road areas and trial times in the RW were chosen for their consistency of traffic flow, parking, and low number of potential confounding factors which may influence the test subjects performance. More importantly, it had to be reproducible in the VE.

Reproduction of the real world (RW) environment in the virtual environment (VE) is to scale except for some of the non-test road sections leading to the test area. Road side objects such as housing, trees, and other structures have been minimized in the VE to large texture mapped areas in order to reduce the computational load on the reality engine and thereby improving the human/machine feedback of the VE. Road conditions "curb to curb" were kept as accurate and realistic as possible since this was considered to be the critical test region (Appendix F).

(b) Environment Selection

The test environment was selected based upon four criteria. First, that the real world (RW) road have as few constraints and visual cues as possible; this was necessary to afford test subjects freedom for lateral positioning of the test vehicle while driving. Marked double lanes, heavy wear ruts, and road damage can easily constrain the driving behaviors to a set path. Second, daily traffic patterns along the test path needed to be low in traffic volume and consistent in parking density in order to maintain as consistent RW test conditions as possible. Third, road lengths were selected to allow the subjects enough time to attain a constant velocity after acceleration following a stop or turn. Fourth, roads with speed limits of 35 m.p.h. or less were selected for purposes of safety and to minimize the effect of acceleration in the RW vehicle and because of absence of acceleration in the virtual environment (VE).

(c) Road Types

Three basic road conditions were produced in order to duplicate RW conditions.

1. Lane 10.36 meters per side (20.7 meters total), no lane divider, little or no parking (Baseline).
2. Lane 10.36 meters per side (20.7 meters total), no lane divider, intermittent parking (C1/C3).
3. Lane 8.23 meters per side (16.5 meters total), no yellow line, intermittent parking (C2).

3. Real World and Virtual Environment Setup

(a) Test condition 1 (Static phase)

Parking lot - Test subjects began the trial in a large open parking area. This allowed the subjects to familiarize themselves with the vehicle and to acclimate to the test conditions before actually driving on the test road. The test vehicle was parked during this phase of the test. This was also one of the few times that the RW conditions were controlled and manipulated to match those of the VE.

(b) Test condition 2 (Dynamic phase)

(i) **On road.** - After the static trials, the test subjects proceeded to drive a short route through the parking lot, exiting onto a stretch of road, where the test vehicle drove to the first trial area. This stretch of familiarization road was repeated in both the RW and VE environments.

(ii) **Road 1.** - RW test road 1 (baseline) was approximately .8 km long with no stops. There was enough space in either direction to have parked cars (there were none on this stretch of road) and a slow and fast lane if there were, in fact, a lane divider. The surface was smooth and black and there were no significant visual clues as to lane position or the existence of two distinct lanes.

(iii) **Road 2.** - RW test road 2 (C1 / C3) was approximately .8 km long with no stops and was continuous and perpendicular to test road 1. It was the same width and appearance as road 1, with the exception of the existence of intermittent parking.

(iv) **Road 3.** - RW test road 3 (C2) was approximately .58 km long (1.15 km total). It was in a residential neighborhood. The road surface was neutral gray and consisted of large slabs divided by thin black tar lines. This line was the only visual clue as to road center. In the absence of oncoming traffic, this type of road by most drivers is usually considered as a large single lane. There was parking along this route as well as stop signs, which are incorporated in the experimental design.

The VE is limited by several physical factors. The most critical is the lack of acceleration since there is no actual motion within the chamber that would produce inertia. Stimuli such as wind and white noise (fan) was used in the chamber to improve the richness of the environment. Subjects were allowed to select radio stations in both the VE and RW.

Haptic feedback, such as gas/brake pressure and steering wheel torque, were matched as closely as possible to the RW test vehicle. Road feedback during turns and acceleration/deceleration was not of great concern since data was not acquired during these phases in the RW.

The VE vehicle performance has been tuned to perform as closely as possible in other aspects to emulate the RW vehicle. Low end drag, wind drag, roll, pitch, and other factors such as these have been tuned by Afeel@ in the software to produce a driving experience that mimics the real world as closely as possible sans the physics of motion found only in a moving vehicle.

IV. QUESTIONNAIRE DEVELOPMENT

Introduction

The purpose of this study was the validation of virtual environments in relation to real world scenarios. The specific areas of validity we were looking at in this study were lane positions and response to visual/physical presence stimuli (i.e. Parked vehicles, road width, etc). The pre-test survey (Appendix A) was designed to obtain our population demographics as well as any factors which might either exclude them from the study or affect the interpretation and analysis of the data. Other data we sought to obtain was a "demographic" of the normal driving world of our population (i.e. How often? What conditions? etc).

The two part questionnaire (Appendix A) was designed to obtain the level of agreement or dissonance between subject expectations of VE and the actual experience and as indicators of where improvements might be needed for future environment development and as a general de-briefing following the test. The second part served as an indicator of levels of nausea, if any.

Likert scales were used where possible for ease of subject use and data encoding. Most of the questions include an open ended comment section for the purpose of removing the constraints of Yes/No and Likert scale answers and allowing the subject to provide any information they may feel is pertinent to their answer. Other questions were strictly open ended in order to obtain qualitative assessments of the experience.

Methods

(a) Development

After the initial draft of the pre/post-test questionnaires was developed, the questionnaire was submitted to the *Minnesota Center for Survey Research* at the *University of Minnesota*. The questionnaire was reviewed and suggestions were presented and addressed as to the content, design and layout.

Once corrections and alterations were completed six "dummy" subjects were used to further assess the ease of completing the questionnaire and the clarity of the questions. These subjects were all city drivers and only took a short simulator (VE) drive. Comments from the subjects were addressed and changes to the questionnaire were made.

(b) Question Summary

Questionnaire Part I (see Appendix A)

Q1: Comfort level (physical).

Q2: Comfort level (mental).

Q3-4: Qualitative realism.

Q5-6: Ease of use.

Q7: Expectation vs. experience

Q8: Nausea Y/N and point of occurrence.

Q9: De-brief/ open ended comments.

Questions were Likert scaled (1-9) to allow a reasonable descriptive range and a numerical mid-point. Wherever possible the subjects were allowed space to explain answers should they feel it necessary. This was done both to ease the feel of "taking a test" and to provide valuable qualitative information for future refinement of VE research. Some open ended questions were prompted others were optional. The questionnaire itself was condensed from the original draft and kept as brief as possible to speed the test process while maintaining critical data as well as to make the experience as amiable as possible for the subjects.

Questionnaire Part II (see Appendix A)

This was a 16-item inventory that solicited subject's responses to both behavioral and physiological aspects of nausea, while in the simulator. Items were all Likert scaled items 0 – 3 (none, slight, moderate, and severe).

V. EXPERIMENTAL STUDY

Methods

The experimental design of this study was shaped primarily by a set of limitations found when comparing real world (RW) environments with virtual environments (VE).
A test track was not used for logistical reasons as well as the fact that it is inherently not a RW environment. The RW environment contained random stimuli and uncontrollable factors, which were impossible to reproduce from both a programming, processing, and logistical perspective. The study was designed to evaluate habitual driving behaviors and responses to specific stimuli.

Data acquisition occurs only during "low-acceleration" phases of the test. Acceleration phases would be stopping or slowing (negative acceleration), turning (lateral acceleration or vector change) and proceeding from a stop (positive acceleration). The low-acceleration phase was the period when the vehicle achieves a constant or nearly constant speed. Other data was acquired while the car is stationary (parked). Our VE emphasis relative to our RW was on car handling related to environment rather achieving an exact RW environment (houses, trees, skyline, clouds, etc.).

1. SUBJECTS

Subject population demographics.

Volunteer subjects were recruited from students attending classes and the population at large at the University of Minnesota during the fall quarter, 1997 (Appendix A).

The subject group comprised of 14 males and 12 females. Their ages ranged from 18-34 years of age with a mean age of 22. The average driving experience was 6.1 years with a range of 3-18 years. All subjects were free of visual impairment or wore corrective lenses. None of the subjects were taking any prescription medications, which might influence driving performance.

Subject population history: Dizziness, nausea & phobias/driving behaviors

Three subjects reported some type of dizziness in the past 5 years. Of these, two reported dizziness in the past year and one in the past six months. All were related either to alcohol or rides (1 within 5 years, 1 within 1 year, and 1 within 6 months).

Ten subjects reported nausea from car, carnival or plane rides in the past (3 as car driver, 4 as car passenger, 3 as airplane passenger, 5 on carnival rides, 2 as other). Several subjects fell into multiple categories.

Only driving aggression scored below the "rarely" (3), and then only marginally (2.9). (1= always, 2= sometimes, 3= rarely, 4= never)(See Table 3, Fig. 16).
All subjects were regular drivers and their weekly driving environments (Appendix A) were similar. Responses to Q8 as to phobia were occasionally responded to as (paraphrased) "...I wouldn't categorize myself as claustrophobic...but tight spaces make me uncomfortable". This may have resulted in the low modal scores found in Table 3, Fig. 16 in the analysis section under "comfort" (Q1). The sub-questions (phobias) in Q8 were considered to be those relevant to driving in the VE.

2. DRIVING ENVIRONMENTS

The test environment was selected based upon several important criteria. These have been outlined in Part III of this report. To briefly reiterate they were: minimal constraints and visual cues as possible in the RW; daily traffic patterns along the test path needed to be low in traffic volume and consistent in parking density; road lengths were selected to allow the subjects enough distance to reach a constant velocity; and finally, roads with speed limits of 35 m.p.h. were selected for safety purposes and to minimize the effect of acceleration in the RW vehicle.

Three basic road conditions were chosen. (All roads were smooth, in good condition and had consistent coloration.) (Figure 2).

1. Lane 10.36 meters per side (20.7 meters total), no lane divider, little or no parking (bike lane) (Baseline).
2. Lane 10.36 meters per side (20.7 meters total), no lane divider, intermittent parking (C1/C3).
3. Lane 8.23 meters per side (16.5 meters total), no yellow line, intermittent parking (C2).

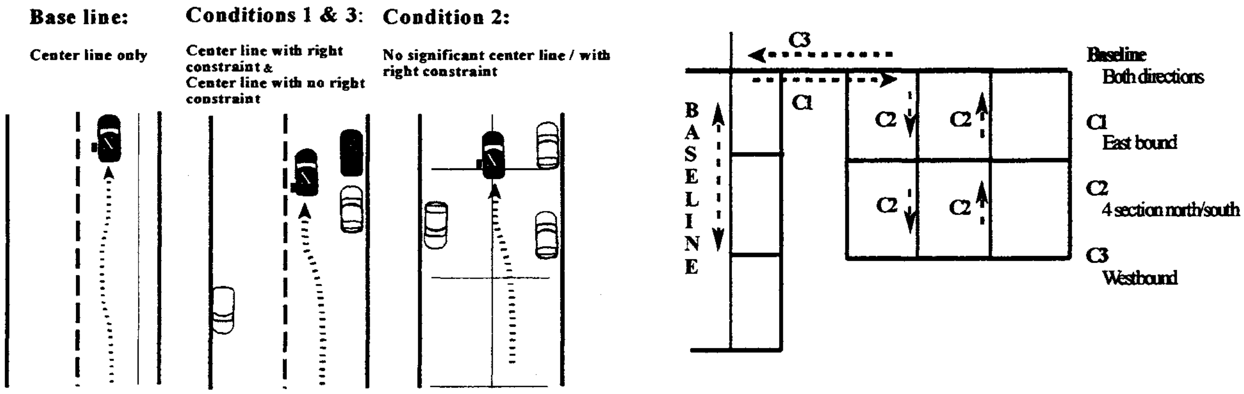


Figure 2. Driving environment road types.

Road 1. - RW test road 1 was approximately .8 km with no stops. There was enough space in either direction to have parked cars (there are none on this stretch of road) and a slow and fast lane if there were in fact a lane divider. The surface was smooth and black and there were no significant visual clues as to lane position or the existence of two distinct lanes.

Road 2. - RW test road 2 was approximately .8 km with no stops and was continuous and perpendicular to test road 1. It was of the same width and appearance with the exception of the existence of intermittent parking.

Road 3. - RW test road 3 was approximately .58km (1.15km total). It was in a residential neighborhood. The road surface was neutral gray and consists of large slabs divided by thin black tar lines. This line was the only visual clue as to road center. This type of road was usually considered as a large single lane by most drivers in the absence of oncoming traffic. There was parking along this route as well as stop signs, which were incorporated in the experimental design.

3. MEASUREMENT TECHNIQUES

a. RW/VE

Lane position / Affordances and constraints:

Both trials (RW and VE) included familiarization periods with the test vehicles. Data acquisition began as soon as a constant road speed was achieved after proceeding from a stop or turn in the test zones, and ended when braking to a stop or turn began. In the RW a green neon marker lamp signaled the start of data acquisition on the videotape (Fig. 4). In the VE the start point/endpoint was predetermined and set in the data-parsing program. Lane positions were described in terms of deviation from centerline (cm).

b. Real world

Real world (RW) data was acquired from the camera setup. Distance from centerline was measured on projection screen from a metered bar mounted out of view of the driver near the left front wheel well to the centerline. Trueness of the centerline was determined by a laser applied from point A to point B on a given section of test road (Fig. 3). Deviations were accounted for during analysis. Deviations from a straight line less than the width of the centerline itself were ignored. This method served as an "eyeball" estimate of trueness and eliminated any chance of optical illusions of curvature.

Figure 3. Centerline calibration

Regions of road width constraints or other variables (parked cars, slow traffic, illegally parked vehicles, etc.) were noted on film by a red neon marker lamp located on the meter bar (Fig. 4).

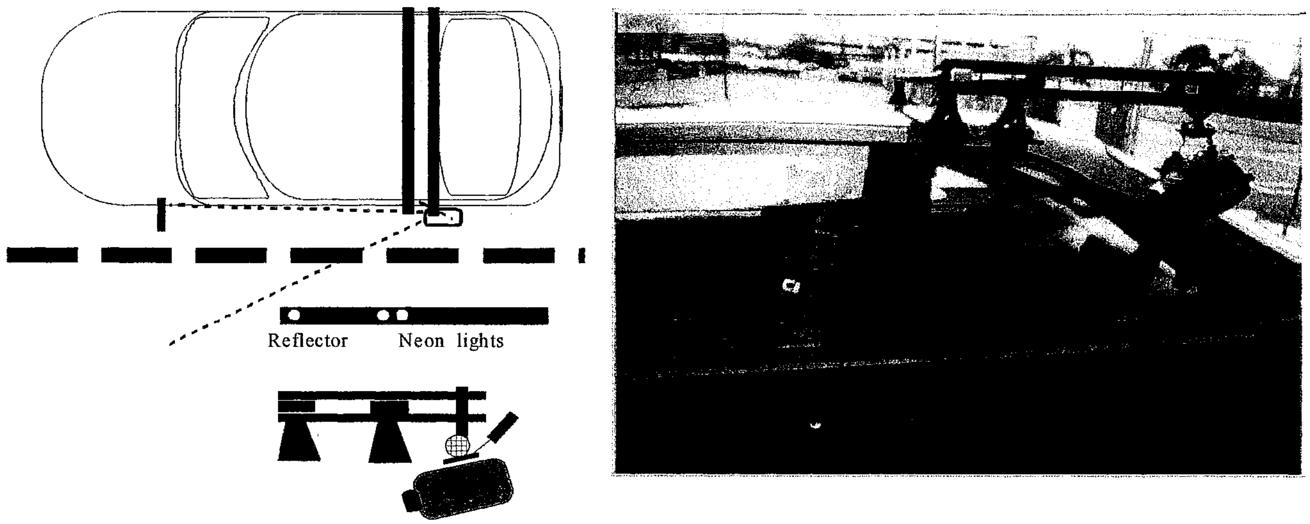


Figure 4. On road film data collection setup.

c. Virtual environment

The data acquired in the virtual environment (VE) was acquired directly via program software. Exact position was given at any given moment in time, and data was acquired under essentially the same conditions as the RW.

Analysis

Lane positions were analyzed by distance to centerline and lane category. Distance to centerline refers to the degree of positional compensation the driver executes when constraints are present (Figure 5).

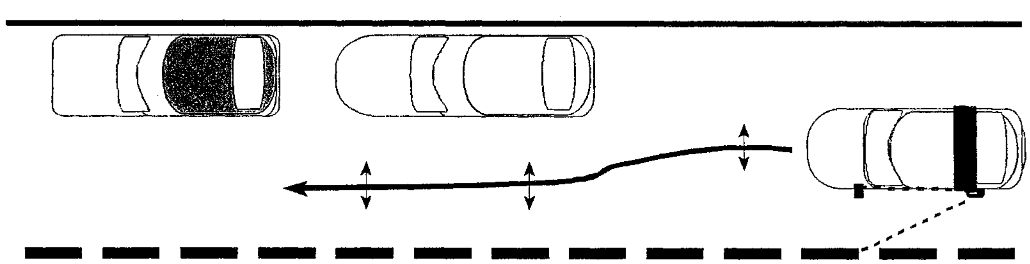


Figure 5. Response to constraints.

Trial one and two data for each subject for RW and VE was analyzed by t-test statistic in order to test for any learning effects, or significant variation. It was impossible to control all RW variables from trial to trial for our test subject population. Therefore, population data analysis consisted of a descriptive analysis of positional variance and constraint effect. This same random characteristic of the RW is why day to day trial reliability in the RW was not evaluated.

d. Static trial RW/VE

In both the RW and VE the optical flow patterns were produced by an automobile (Chevy Blazer) approaching at approximately 10-15 m.p.h. from directly ahead (~100 m) and slightly to the left and then again laterally from the right. Subjects had been instructed prior to the trial to remain focused on a target object placed at a distance of approximately 15 meters. In both cases (RW/VE) head motion data is derived from acceleration values generated by the accelerometer (in mV). The stimuli differed only in that one was 'real' and the other 'virtual'. Figure 6 illustrates the head harness used to position the accelerometer.

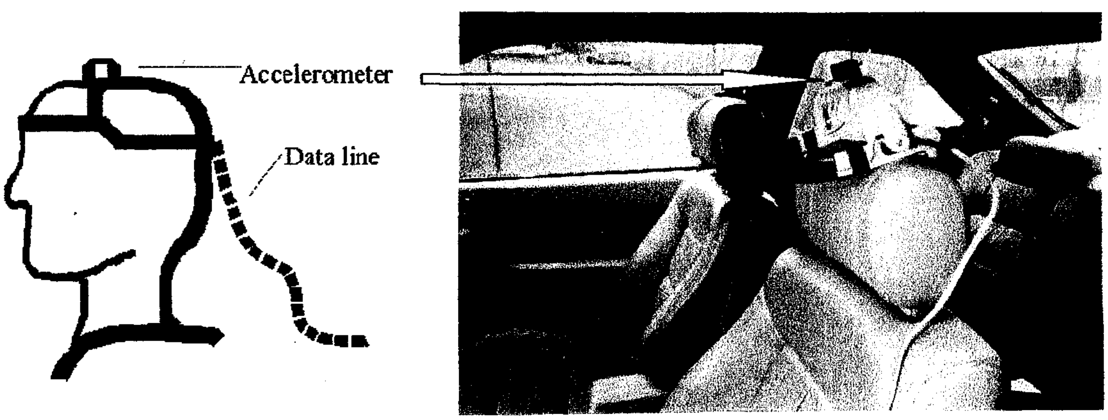


Figure 6. Accelerometer data acquisition.

e. Questionnaire responses

Part I and II of the survey sought responses regarding subjects feeling about driving in the simulator and issues of motion sickness. See Appendix A for both part I and II of the questionnaire.

Questionnaire data was analyzed by computing mean, mode, and variability (sd) scores of respondents. All questionnaire data (Part I and Part II) was completed by subjects who complete the VE condition.

4. TRIAL PROCEDURES

Table 1. Flow chart of test protocols for RW and VE

Trial Sequence	
RW trial	
Times	Stages
0:00 -0:05	Subject orientation: Subject proceeds to parking lot and trial car.
0:05-0:15	Subjects read design and qualification form, then reads and signs consent form. Subject proceeds to pre-trial questionnaire.
0:15-0:20	Subject is fitted with accelerometer head-gear. "In lot" initial run.
0:20-0:30	On road trial: Subject begins on road driving trial.
0:30-0:50	Subject returns and repeats "in lot" trial and road trial.
VE trial	
Times	Stages
0:00 -0:10	Subject orientation: Subject proceeds to "igloo" and trial car.
0:10-0:15	Subject reads design and qualification form, then reads and signs consent form. Subject proceeds to pre-trial questionnaire
0:15-0:20	Subject is fitted with accelerometer head-gear. VE "in lot" trial run.
0:20-0:30	VE on road trial: Subject begins virtual "on road" driving trial.
0:30-0:45	Subject repeats and VE "in lot" trial and road trial.
0:45-0:50	Subject completes post-trial questionnaire.

At the end of the VE trial, subject's completed the questionnaire. To guard against order effects subjects were randomized as to whether they drove the RW or VE condition first. A total of 14 subjects completed both trials under both RW and VE conditions.

Lane position / Affordances and constraints:

Both trials have a short period of familiarization with the test vehicles. Data acquisition begins as soon as a constant road speed is achieved after proceeding from a stop or turn in the test zones, and ends as soon as braking to a top or turn begins. A green neon marker lamp signals the start point of data acquisition on the videotape. Lane positions were described in terms of distance from the centerline (cm).

5. DATA ANALYSIS

Complex systems are not easily analyzed. In RW traffic conditions it is difficult to ascertain the impact specific stimulus components (lighting, road conditions, mood, color of the vehicle in front of you, etc.) have on the individual driver performance. Accounting for individual performance is somewhat more elusive. The data acquired from this study was interpreted from both and objective (empirical) and subjective standpoint. Driver performance was measured in terms of the distance the vehicle was traveling relative to the "center line". Where possible, those stimuli considered to be of "*obvious*" influence (large trucks, stop lights, etc.) were recorded.

The raw data produced in the VE portion generated values measured from center-line to the center of the virtual vehicle; the raw data produced from the film data (RW) was measured from center-line to a marker placed outside the wheel well of the road vehicle.

Figure 7 explains the derivation of the raw RW data presented in Appendix B. The data presented goes beyond simply presenting the numbers. The means and standard deviations are presented for an overview of the individual subject's performance. The graphs presented demonstrate some of the "raw" observations. The X-axis represents the road centerline. The line length along the X-axis represents data points as a function of the combination of road length and the rate at which the subjects drove (ergo, faster drivers = fewer data points). Scattered "liner" notes in the raw data (i.e. *car, lec, 4:19lbj*, etc.) are remnants from the road log and should generally be ignored.

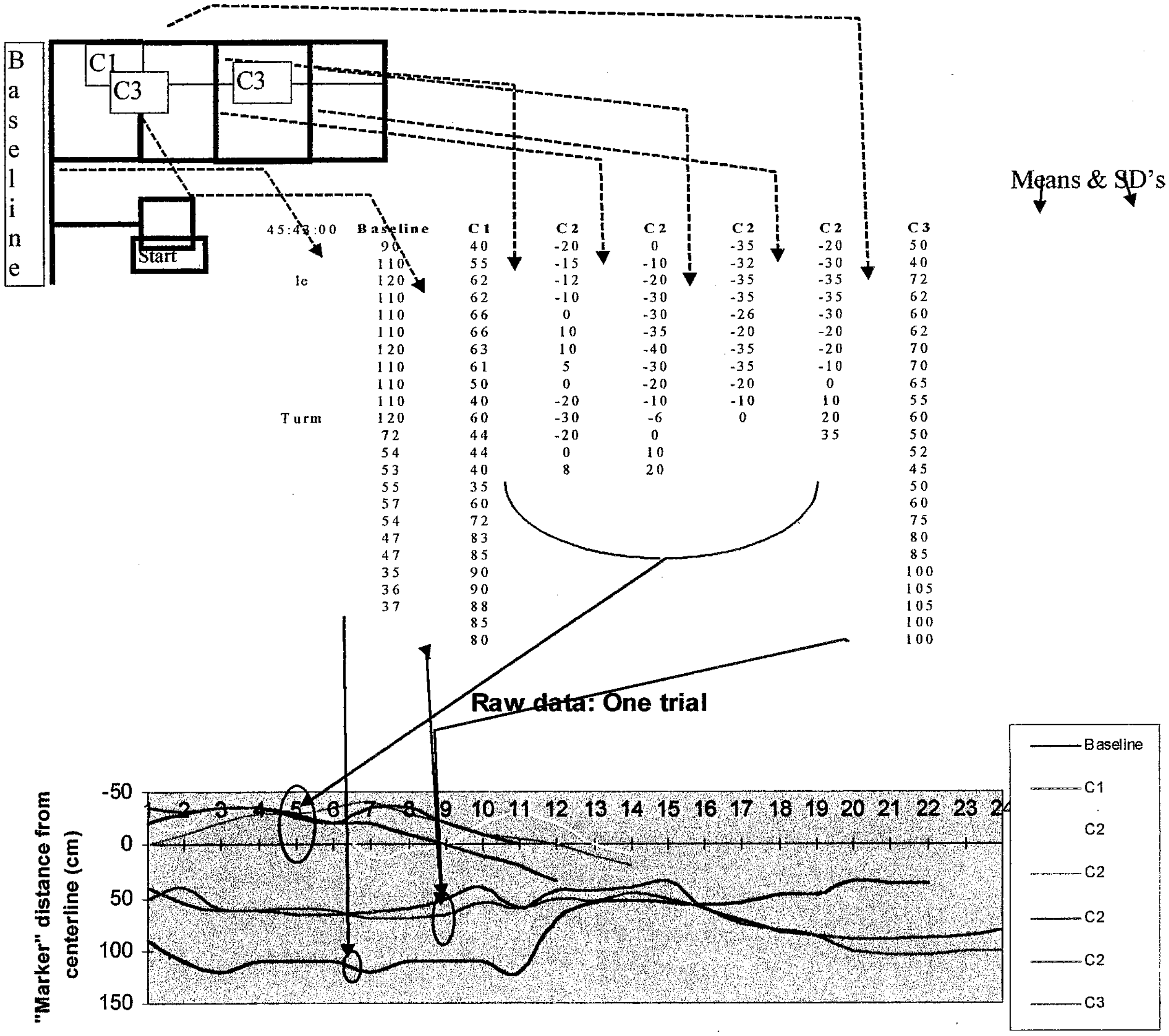


Figure 7. Overview of raw data layout (Appendix B).

Further interpretation of the *raw* data charts may be accomplished only in generalities. Of note are the repeated patterns found throughout many of the subjects such as the large "bump" found at the midway point of C1 and C3 (Fig. 8a). This is an artifact of stopping at a stoplight. This same pattern reoccurs at the residential stop signs of which there are four (x 2 trials = 8 total) (Fig. 8b). Also of note when viewing the presented charts is the effect a particularly long data set will have on the other data lines.

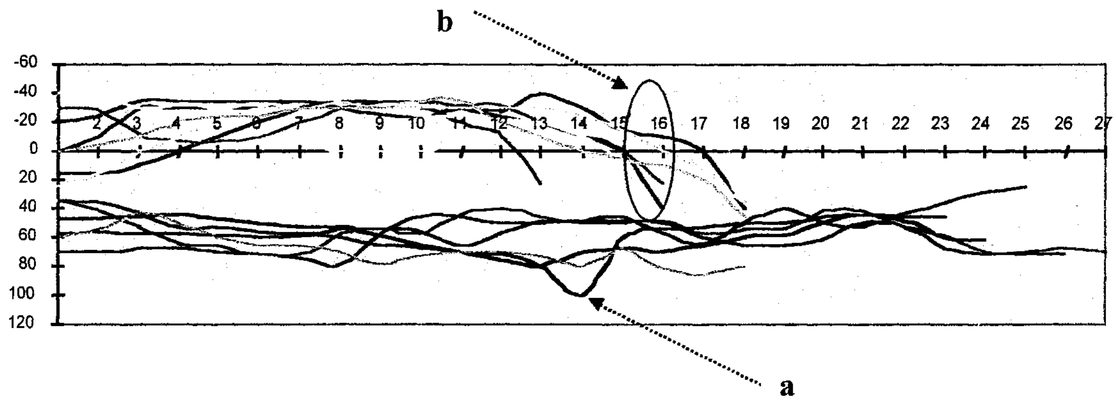


Figure 8. Raw data chart

Long data strings occur when the subject's driving speed is slow thus allowing a higher acquisition rate. Conversely, Short data strings are usually reflective of faster driving rates. Occasionally the residential portions (C2) appear compressed for this reason.

Data in the residential regions may appear flattened at -30cm on some RW trials. Subjects who tend to drive to the far left of center (sometimes completely to the left of centerline) exceed our ability to continue measurement. This caps out at about -35cm. Known ground references sometimes allow measurements to the left of approximately -50cm.

6. LIMITATIONS AND ASSUMPTIONS

(a) Limitations

1. Parking along the second and third test areas will vary day to day.
2. Traffic conditions vary significantly at specific times of day (morning & evening rush hours, lunch) and day to day.
3. The VE simulator used is a mid-level simulator and has no tilt/acceleration capabilities.
4. Exact duplication of RW environment is not possible with our current computational capacity.
5. Haptic (tactile) feedback is limited in VE (see Lim. #2 & #3).

(b) Assumptions

1. Our test subjects have been driving long enough to acquire habitual driving behaviors.

2. These behaviors are essentially the same from day to day.
3. The specific behaviors are somewhat unconscious and will not be unduly influenced by the test situation. (See subject instructions reassuring them results are in no way is reflected on their driving record, etc.)
4. Use of unfamiliar vehicles will not drastically alter normal driving behaviors.
5. Parked cars separated by less than several car lengths are perceived as a continuous constraint (obstacle) to a driver traveling 25-35 mph.

VI. RESULTS AND DISCUSSION

This section reports the results and appropriate discussion for the experimental study that compared the real world (RW) driving performance with the virtual environment (VE) performance of the volunteer subjects using the protocols and the questionnaires outlined in the earlier sections of this report. Four data based components and other observations of the experimental study were as follows:

1) Test / retest VE reliability
2) A comparison of driving performance between RW and the VE, measured as a deviation from the center line of the target road
3) The responses of the volunteer participants to the questionnaire information, soliciting their opinions regarding the utility, comfort, and ease of the simulated VE driving world and a second component of the questionnaire survey directed responses to feelings of nausea related to the VE simulator
4) A comparison of head motion in the stationary automobile in the RW environment with head motion in the VE environment in order to compare the relative impact of optical flow generated by the computer graphic display compared with optical information produced by a moving vehicle viewed by volunteer subjects sitting in the on-road vehicle
5) Other observations

   Behavioral and performance observations made during testing are included in this section. These observations were essentially notes and observations recorded by the experiment.

VE TEST / RE-TEST RELIABILITY

The consistency with which the volunteer subjects performed is evident from the observations presented in Figure 9 a, b, and c. The shape of the performance curves are similar in trial 1 and 2 with the higher values recorded early in the trial, produced by the execution of turns and by the muted feedback of the simulation test vehicle. Figures 9a-9c compares between trial 1 and trial 2 for the VE condition. Deviations are in cm (1cm = 2.54 inches).

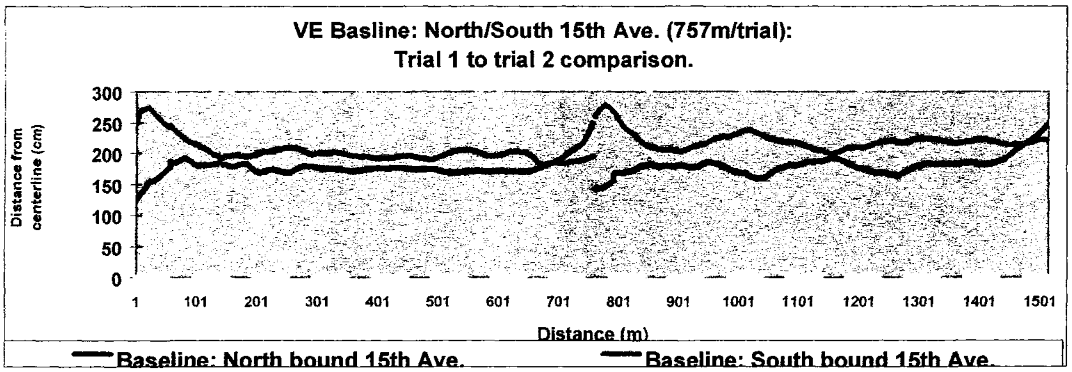


Figure 9.a

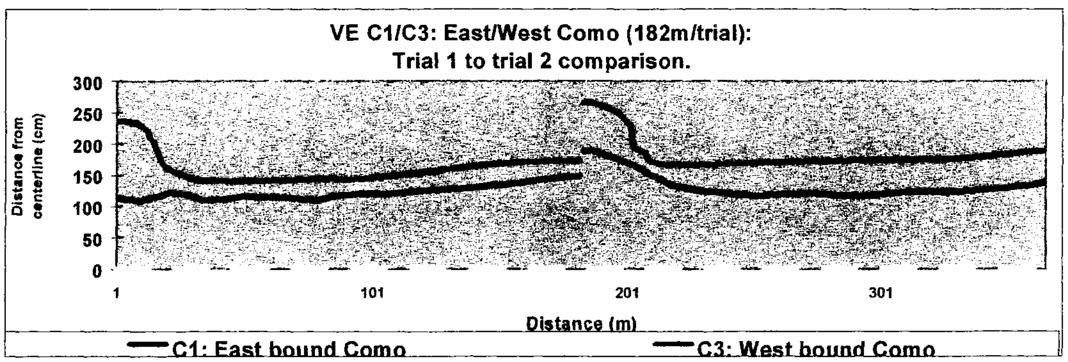


Figure 9.b

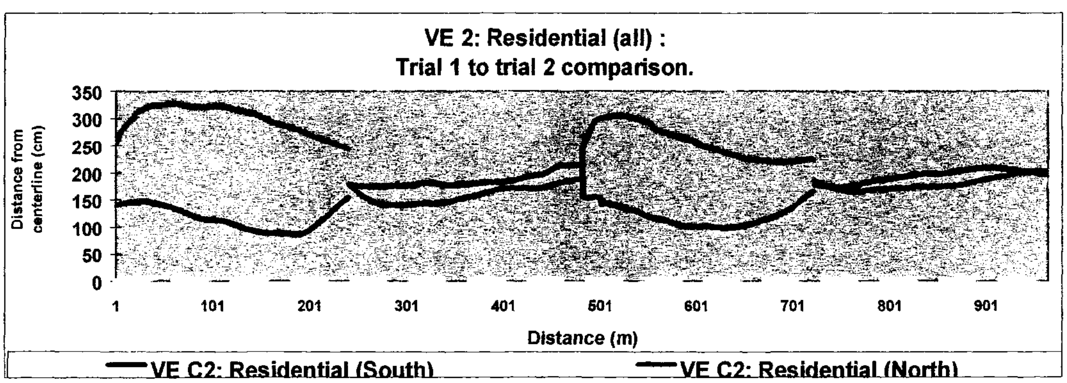


Figure 9.c

Figures 9.a, b, & c. Trial 1 vs. Trial 2 qualitative comparisons.

Table 2. Test re-test reliability.

(N = 16)	Trial 1 **means**/*sd*	Trial 2 **means**/*sd*	Pearson's **r** correlation: Trial 1 / Trial 2
Baseline North	**176.54** / *13.33*	**180.50** / *16.70*	**0.84**
Baseline South	**203.28** / *19.05*	**220.59** / *14.55*	**0.82**
C1 (corrected)	**118.98** / *12.82*	**119.77** /*16.26*	**0.94**
(C1 (uncorrected))		(127.94 / *16.81*)	(-0.14, see Discussion)
C3	**159.44** / *25.41*	**174.58** / *5.53*	**0.94**
C2	**189.80** / *70.19*	**187.44** / *52.34*	**0.94**

Discussion: VE test re-test validity.

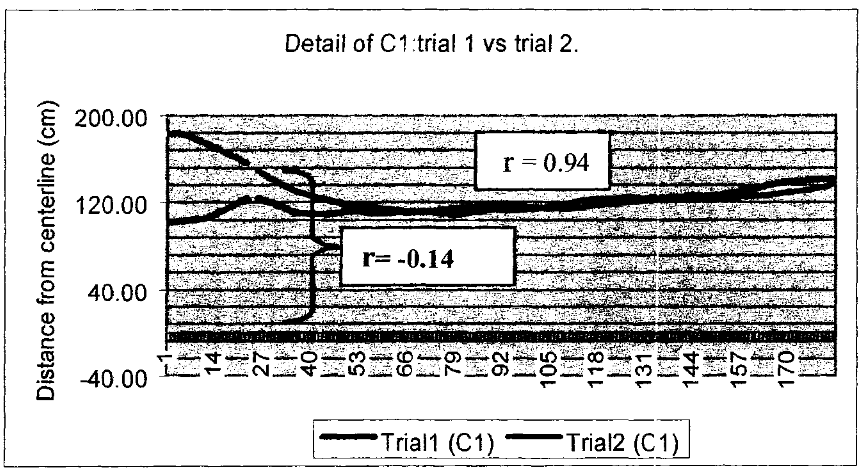


Figure 10. Detail comparison of C1 trial 1 and Trial 2.

The overall correlation (r) for the Baseline (C1) was -0.14. This low correlation was due to the increase in driver confidence with the VE vehicle resulting in an initial increase in speed and subsequently an increase in the overshoot demonstrated in Figure 10. When this overshoot is removed the overall correlation is .94. The data presented for the corrected and uncorrected C1 correlation is presented in Table 2.

PERFORMANCE COMPARISON BETWEEN RW AND VE

Chart interpretation (Baseline, C1/C3 & C2): As a guide to interpreting Figures 12, 13 & 14 it is important to note the following:

1. The data in the aerial view travels from right to left (green or top series) and left to right (blue or bottom series).
2. The Y-axis is scaled in centimeters whereas the X-axis is scaled in meters. This results in some visual distortion or shortening of the perspective.
3. The beginning and ends of the paths shown, sometime incorporate effects produced from turning on or off another road. This sometimes distorts the scale of the Y-axis.
4. The RW data series are distorted in length due to the nature of the collection of RW data. Varying road speeds produced different interval lengths between data points but the overall shape of the performance curve is still interpretable.

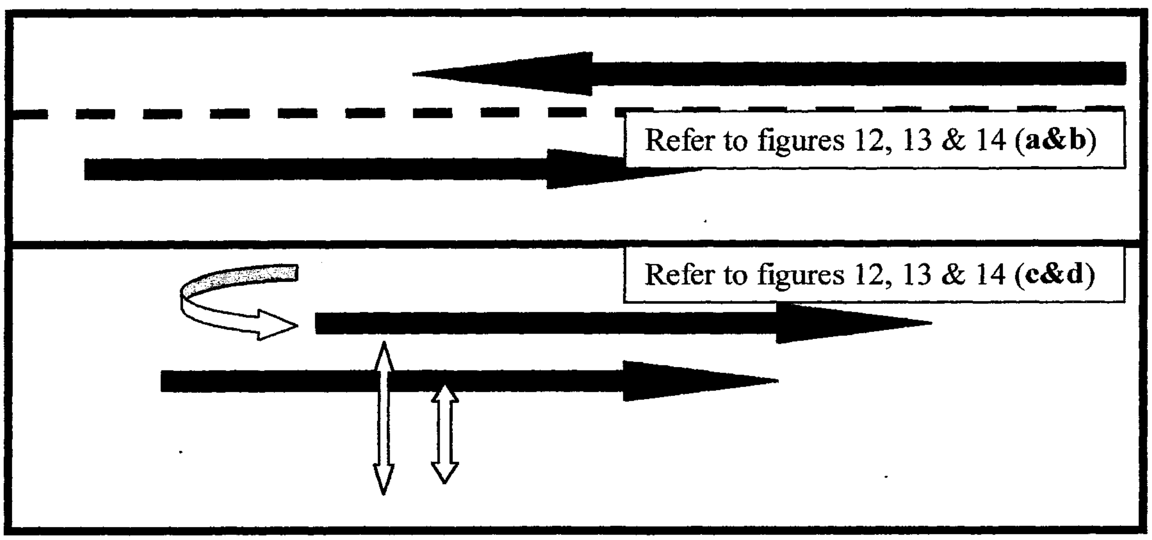


Figure 11. Relative direction of travel and comparative detail orientation.

The charts are arranged in the order of RW overhead or aerial view and then VE overhead or aerial view. These charts are then followed by a 'detail' set of charts in the same order but with the 'left-bound' or top set of data flipped 180 degrees (Figure 11) in order to compare the data along the same Y axis on a more detailed scale for comparison.

Discussion: RW / VE (Baseline)

Both environments (RW and VE) evidence similar patterns of driving under baseline conditions. Both conditions exhibited the deviations at the beginning and end of the trial area indicative of a turn or stop. The data series in Figure 12c has been artificially elongated by the addition of the mean value to the midsection to show a better comparison with the VE data. This was done only for graphic purposes and not for analysis.

Deviation from the centerline (the dependant variable) was an average 156.8cm for RW and 191.7cm for VE. This is a difference of about 12 inches. The lack of "feedback" via the steering column and other sources of haptic feedback account for this discrepancy. While this difference may be statistically significant we believe it is of no practical importance relative to the use of simulation (see Figure 15).

Results: RW / VE comparisons (Baseline)

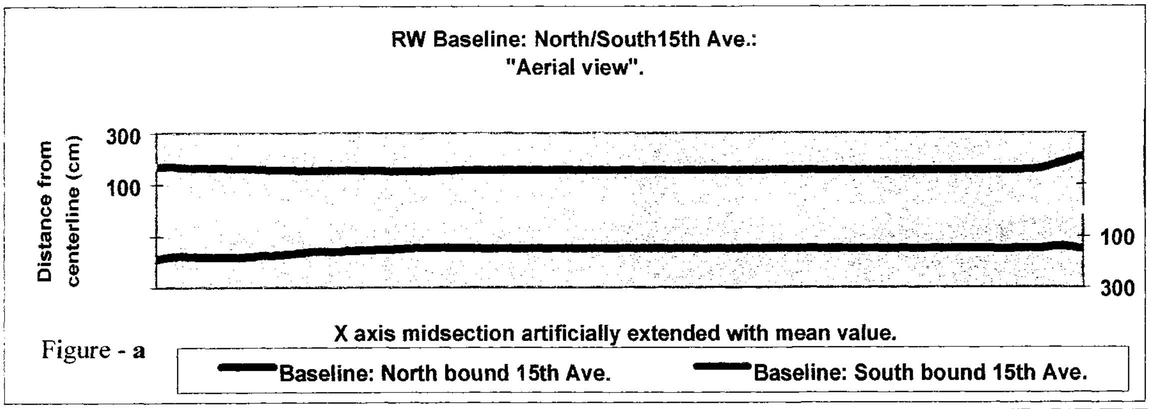


Figure - a

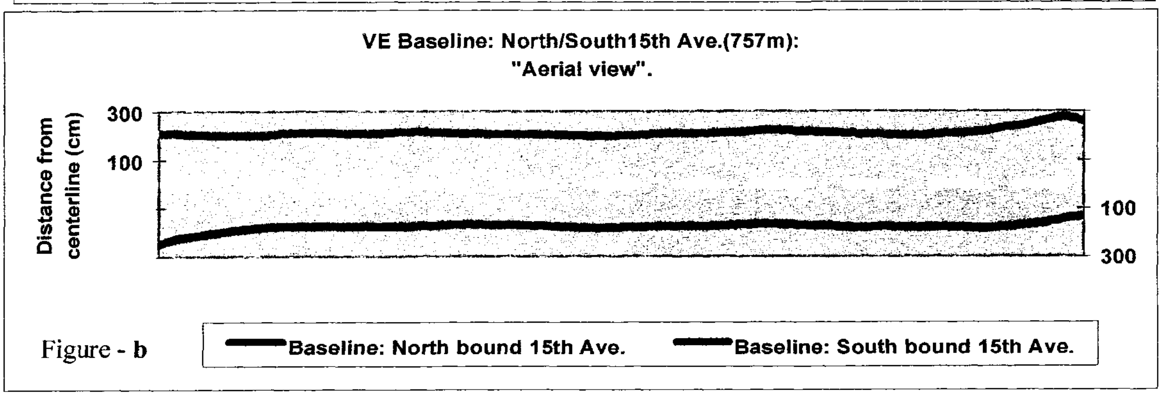


Figure - b

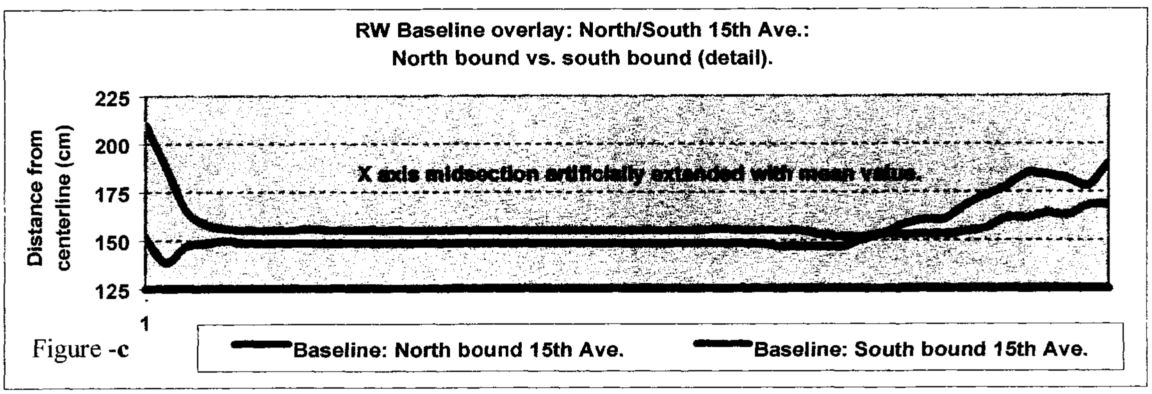


Figure -c

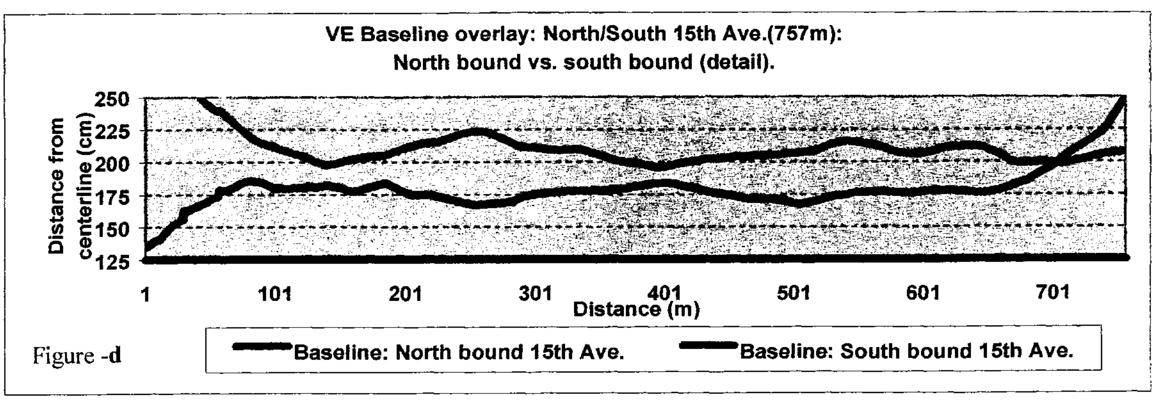


Figure -d

Figures 12.a, b, c and d. RW vs. VE for Baseline condition.

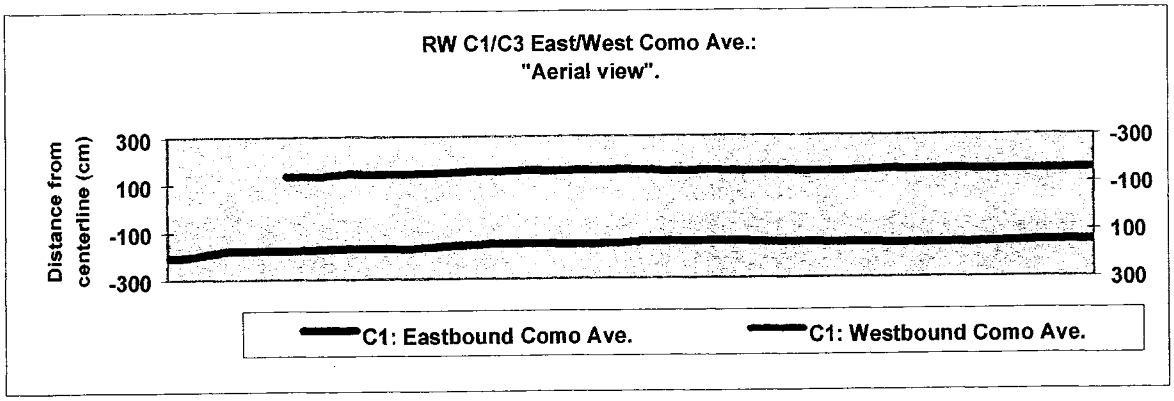
RW / VE C1-C3

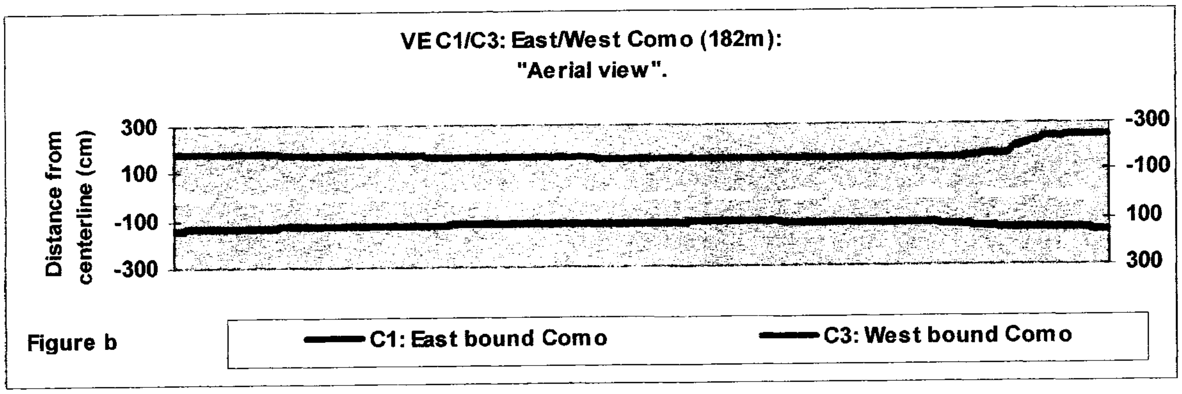
Results of driver performance in the C1 and C3 conditions were similar to the baseline conditions. Both conditions exhibit deviations at the beginning and end of the trial area indicative of a turn or stop.

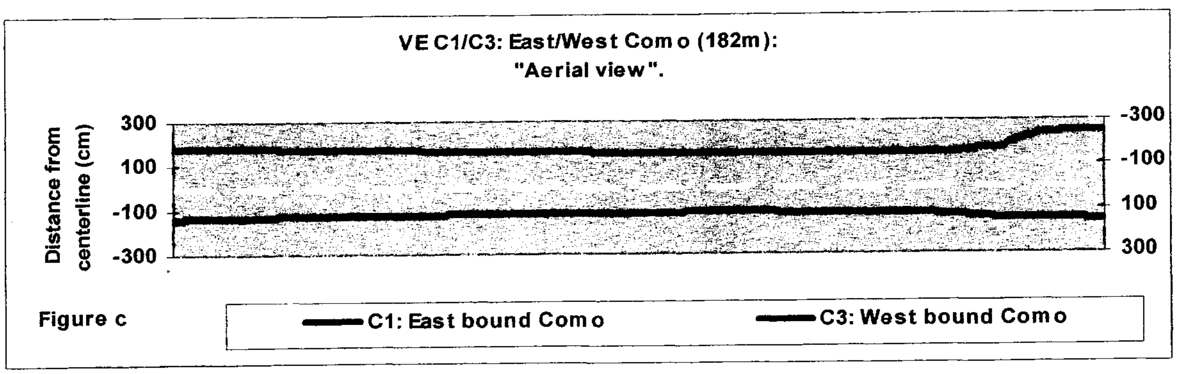
The RW condition (Figure 13a) demonstrates a small average difference in values between C1 and C3 (147cm vs. 148cm). This is possibly due to illegally parked traffic and / or traffic turning right off of the route forcing the test vehicle to the center of the road. Both of these conditions were noted by the experimenter in the test vehicle, but not on all subjects. However, this may have been adequate to alter the population means presented in Appendix C and Figure 15.

The VE trials produced values more in line with what might be expected from the two different conditions (C1 (parked vehicles, etc.) and C3 (no *legally* parked vehicles)). The large aberrant values found at the beginning of C3 are an artifact of the left turn from the residential area (C2) onto the C3 road.

Results: RW /VE comparison (C1 / C3)







[redacted]

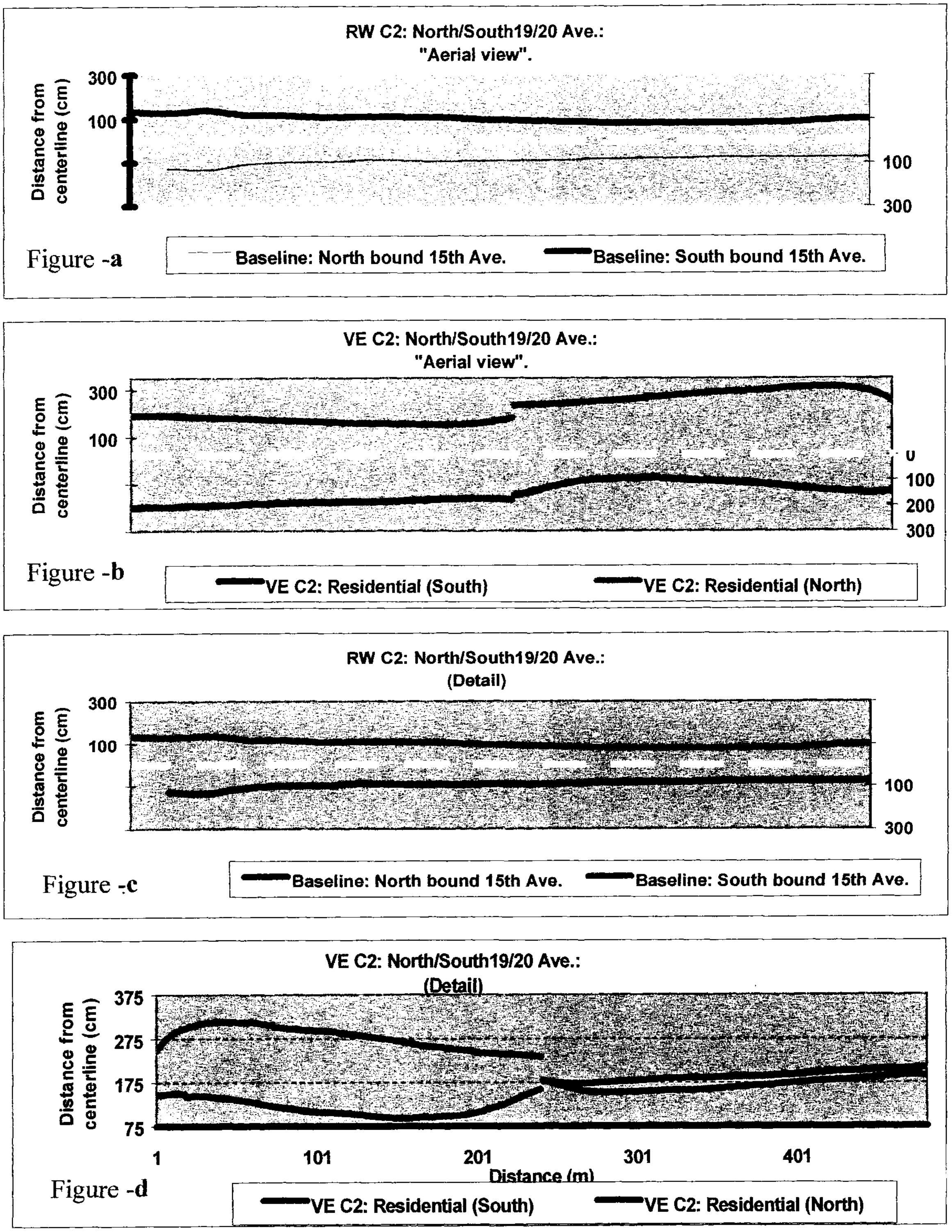
Figures 13.a, b, c and d. RW vs. VE for C1 and C3 conditions.

Discussion: RW / VE (C2)

In the C2 (residential area), both environments (RW and VE) produced similar average performance scores (112cm for VE vs. 91cm for RW). The break in the data series seen in Figure 14b is the intersection region where the data was not analyzed. The RW data (Fig. 14a) has the same break; it is just not apparent due to the removal of this gap on the spreadsheet.

Figure 14c clearly demonstrates the driver steering away from the centerline as the vehicle approaches stops and turns demonstrated repeatedly throughout the study.
Figure 14d demonstrates an atypical event on the return trip or "northbound" portion of C2. This may be an artifact of turning left from the street joining the two sections of C2. Under the conditions of turning right from Baseline onto C1, turning right from C1 onto C2 (south) and left from C2 north onto C3 there was sufficient time to compensate the vehicles position and prepare for the turn. Two subjects each passed this section of road in the VE and had to use the standby section of road designed into the VE map (21st Ave.).

Results: RW / VE comparison (C2, residential)



Figures 14.a, b, c and d. RW vs. VE for C2 condition.

Figure 15 provides a summary of driver performance in both the RW and VE driving route. The baseline is a summed averaged of north and south, C1 and C3 are east and west components of the Como Ave. section, and C2 is the residential component. Figure 15 is based only on subjects who completed all conditions (n=14).

The overall average difference of the performance scores illustrated in Figure 15 was subjected to an analysis of variance. The overall difference between the performance in the RW versus VE (135.9cm vs. 160.2cm) was significantly different. The overall effect of the four driving routes (BL, C1, C3, and C2) was also significant, but there was no reliable interaction.

The issue here is to determine the impact of the statistics versus the "effect" of these differences as it relates to the utility of simulation. The "real world" impact of the generally large scores in the VE world do not, in our judgement, diminish the value of using simulation to investigate driving performance.

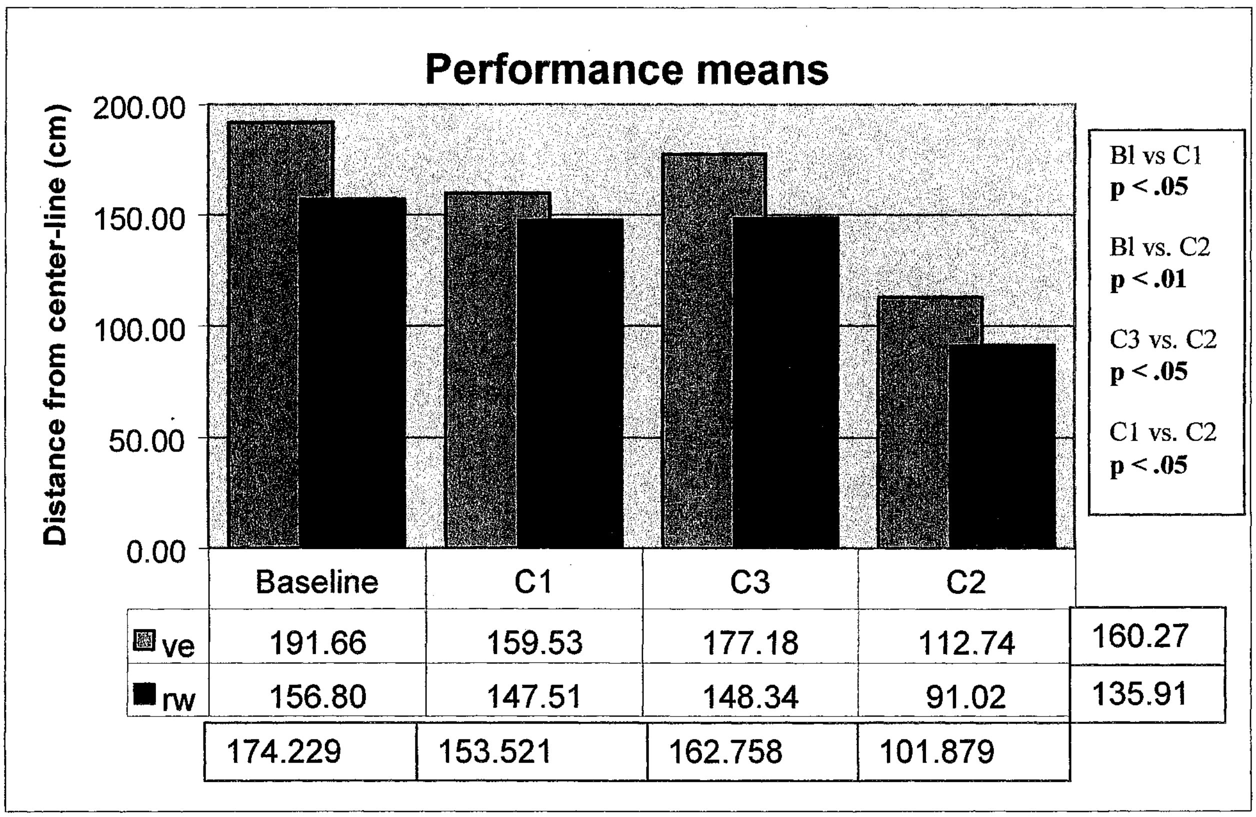


Figure 15. Performance means and marginal means.

The significant main effect for the driving route (Baseline, C1 / C3 and C2) was further analyzed using Newmann-Kuels post-hoc analysis. We systematically compared each of the six-paired mean differences according to the Newmann-Kuels procedure. These paired comparisons are displayed in Figure 15. Of the six possible comparisons, four were significant and these are included on the right side of Figure 15. The largest of these four was the Baseline and C2 (residential) and this was a difference of approximately 72cm (28.5 inches). The smallest of these was between C1 and C3 and this was 51.5cm (20 inches). Two of the four were not significant (BL vs. C3 and C1 vs. C3). Complete results of both the ANOVA and post-hoc test may be found in Appendix C.

ANALYSIS OF THE QUESTIONNAIRE DATA; RESULTS

Subjects driving in the VE simulated portion of the study were asked to complete a questionnaire. **Part I** recorded subjects feelings of arousal and comfort while driving in the simulator. Each question was a 1-9 Likert type item and the results are presented in Table 3. The questionnaire results are based on responses of the 26 subjects. As illustrated in Table 3, and Figure 16, responses fell on the midline with the lowest response being question 4 (**physical realism**) at 4.52 and the highest response being question 2 (**nervousness**) at 5.96. The average standard deviation of all responses was 1.95 with a range 1.72 – 2.0. This suggests that in terms of the general comfort level of subjects using the simulator, there were no high negative or high positive scores. The modal scores presented in the table range from 6-7, trending more towards the positive rather than the negative. Of the ten (10) subjects reporting some level of nausea during the VE condition, eight (8) reported a previous history of nausea (Appendix D).

Table 3. Comfort levels: Subject Population Averages, Mode and SDs. (N=26)

Question	Negative Assessment — Positive Assessment (1—2—3—4—5—6—7—8—9)	Mode	sd
Q1. Comfort	5.40	3	1.94
Q2. Nervousness	5.96	8	2.24
Q3. Visual realism	5.16	7	1.97
Q4 Physical realism	4.52	6	1.72
Q5. Ease of use.	5.36	6	2.00
Q6. Adaptation	5.72	7	1.87
Q7. Experience vs. Expectation.	5.68	6	1.95

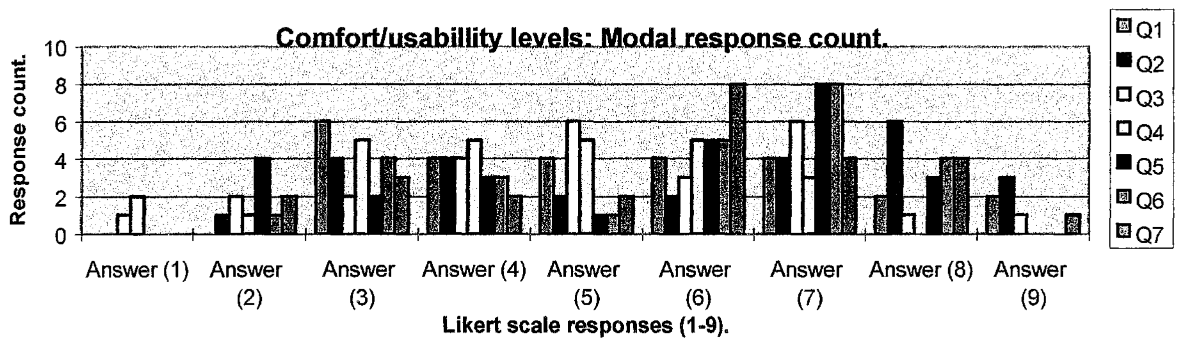


Figure 16. Response count to Likert scale (Post-test questionnaire Pt I.)

Part II of the questionnaire sought responses concerning any occurrences of nausea that may have been experienced by subjects while driving in the VE world. Table 4 presents responses to part II of the questionnaire, which focused on components of nausea. The 17-item questionnaire employed a Likert 0-3 scale. As can be seen, the mean responses ranged from .04 to 1.08. A scale of zero to 1 was designated as **slight** on the questionnaire and the only response greater than 1 was the symptom of **nausea (item #8)** at 1.08. Modal scores were 0 or 1, suggesting the overall set of responses represent essentially a benign impact of driving the simulator as it relates to nauseogenic effects. More detailed information about the questionnaire responses are included in Appendix D. Table 4 summarizes the subjects responses to questions designed to evaluate the level of nausea while using the simulator. All means fell below the mid-point of the Likert scale (1.5) and only one mean (Q8) exceeded 1.0 (slight) on the scale. The

modal scores indicate the most frequent response as none (0) with only Q1 (general discomfort), Q4 (eyestrain), and Q15 (stomach awareness) scoring 1 (slight) as the modal response.

Table 4. Physiologic responses: Subject Population Averages, Mode and SDs. (N=26)

SYMPTOM	None------------------Slight----------------Moderate--------------Severe 0------------I-------------1-------------I-------------2-------------I-------------3	Mode	sd
1. General Discomfort	0.92	1	.80
2. Fatigue	0.54	0	.71
3. Headache	0.62	0	.70
4. Eye Strain	0.69	1	.68
5. Difficulty Focusing	0.46	0	.65
6. Salivation Increased	0.38	0	.64
7. Sweating	0.92	0	.89
8. Nausea	1.08	0	.98
9. Difficulty Concentrating	0.46	0	.65
10. "Fullness of Head"	0.58	0	.76
11. Blurred Vision	0.38	0	.64
12. Dizzy (eyes open)	0.85	0	.92
13. Dizzy "eyes closed"	0.54	0	.65
14. Vertigo	0.42	0	.70
15. Stomach Awareness	0.85	1	.73
16. Burping	0.04	0	.20
17. Other comments	No Subjects commented.		NA

Questionnaire responses: Modal responses

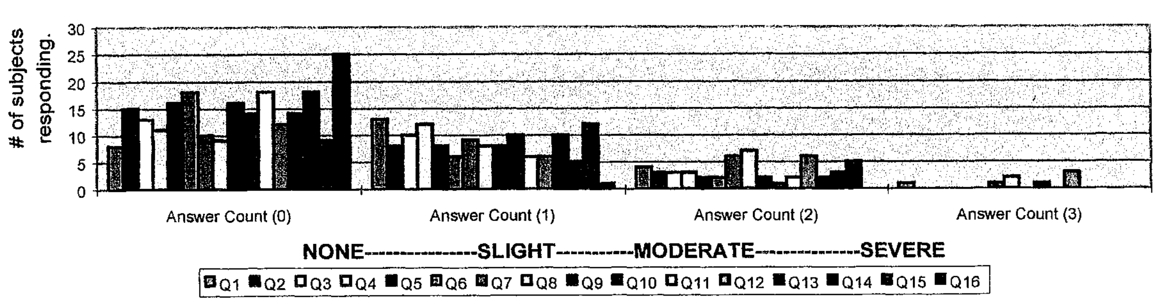


Figure 17. Modal response frequencies (Post-test questionnaire Pt. II).

SUMMARY DISCUSSION

Part I.

The participants generally found the environment comfortable. It is a closed-in dome which, especially when inhabited by three humans, reproduces relatively warm temperatures. These factors not withstanding, comfort and nervousness levels still scored fairly low. Visual realism scored on the mid-point of the scale. This was better than expected, as we did not attempt 'full environmental' realism and concentrated our efforts on the road itself. Physical realism scored slightly below the mid-point and this was perhaps not entirely surprising, as the simulator had minimal inertial and road contact friction. Comments most often made by subjects concerned the lack of realism in braking and acceleration. They reported that they had to apply the brakes too hard and that acceleration was sluggish at times. In actuality they were stopping and accelerating in the VE faster than an average automobile. Ease of use and adaptation to the VE scored on the positive side of the mid-point. Generally the comments from the subjects were that they felt much better about their driving performance during the second trial. Their performance in turns improved after the first few turns in the first trial. Experience vs. expectation (Q7) scored positive; a few subjects commented that they expected something more "Hollywood", but were generally impressed by the overall experience.

The occurrence of nausea was related to previous occurrences of nausea (Q7, Survey) to VE nausea (8 out of 10). Subjects already prone to motion induced nausea stand a reasonably high probability of experiencing it in the VE. For those subjects experiencing nausea in this study (n=10), it occurred early in the trial and subsequently faded. Strategies for dealing with these feelings varied but usually involved blinking or refocusing (see Appendix D). Turns (lamellar optical flow) were usually stated as the cause. Other comments and observations of note were that one shouldn't drive immediately following the test, it took time to regain one's "land-legs" and time to full recovery varied from minutes to several hours.

Part II.

Most subjects reported no significant nauseogenic effects in the VE, with few reporting slight effects; fewer yet reported moderate effects and very few reported severe effects (Q7, 8, 10, & 12; Table 4). The subjects also reporting past nausea reported these elevated scores. One subject in particular was admittedly nervous, somewhat claustrophobic and nauseous in both VE and RW environments. The subjects often responded with some confusion over the meaning of "stomach awareness" and often laughed when they got to question regarding burping (Q16). No subject responded to the open-ended question on this section of the questionnaire (Q17). Overall the environment proved benign even for those considered susceptible to motion sickness. A couple of comments were made as to the feeling that the road was "...on top of them". Otherwise the VE proved to be a comfortable experience.

STATIC TRIALS; OPTICAL FLOW AND INDUCED HEAD SWAY

Here we utilized a head-mounted accelerometer (Figure 6) to compare head motion for both the VE and RW environments. Under similar circumstances of visually induced information that would produce either forward and backward (anterior-posterior) or side to side (medial-lateral) motion of the head. Table 5 and the accompanying Figure 18 display the analysis for all trials (n=20) in the RW and VE world and a graphic illustration of the motion recorded in the two planes. An analysis of variance across the 20 participants showed no reliable differences between subjects for the motion displays irrespective of whether they were recorded in the RW or in the VE world. Direct comparison between head motion in the parked RW vehicle compared to the VE vehicle is small; thus we conclude that similar sets of head motion are produced in the RW and the VE.

COMPARISON OF THE HEAD SWAY DATA FOR THE RW AND VE WORLDS

Table 5. ANOVA- Across all trials and all conditions for both planes of motion.

ANOVA- X axis (antero-posterior)						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.8E-05	17	1E-06	0.01638	1	1.62616
Within Groups	0.19126	3018	6.3E-05			
Total	0.19128	3035				
ANOVA- Y axis (medial-lateral)						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9.5E-06	17	5.6E-07	0.01092	1	1.62616
Within Groups	0.15389	3018	5.1E-05			
Total	0.1539	3035				

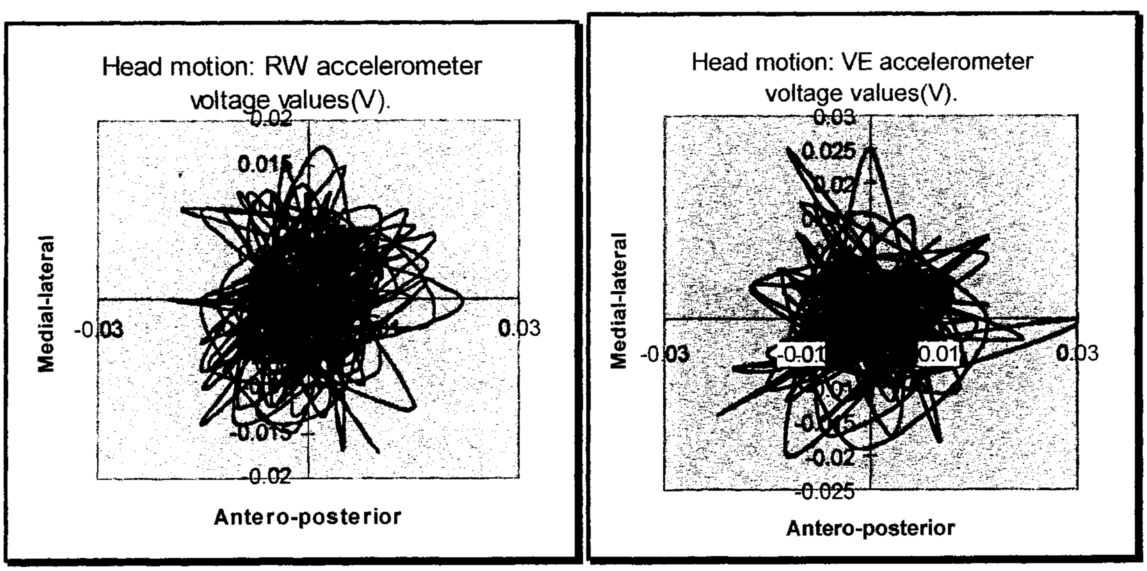


Figure 18. Example, typical single subject head sway response.

OTHER OBSERVATIONS

Much of the more interesting and possibly useful information from this study does not lend itself to either descriptive or statistical analysis. Several behaviors, common to many of the subjects, arise unexpectedly. Sometimes observation of these behaviors is purely hindsight and at other times it is sudden and possibly life threatening. Case in point:

One of our subjects (a fairly aggressive driver) while in the VE ran the southbound stop sign at the intersection midway down section C2. Fortunately this was not a critical issue in the VE trial. This driver demonstrated similar aggressiveness in the RW, and more critically, ran the same stop sign! While only one instance, it did generate questions as to the nature of the particular intersection. While perhaps merely coincidental, it did bring to light two of the inherent advantages to the VE, control and safety. Several other subjects exhibited similar aggressive driving in both the VE and RW.

A behavior common to many of our subjects was demonstrated at stop signs and rapid decelerations. Drivers, while stopping or slowing, invariably pulled away from the centerline and upon resuming normal speed, returned to their original lane position. We assume this was due entirely to the habitual response of avoiding any oncoming traffic or traffic making a turn. However it should be noted that this behavior was also demonstrated on straight-aways (midpoint C1) and in several locations in the VE where no obstruction of vision or threat of oncoming traffic was present. This supports our assumption that *habitual driving behaviors* are in fact just that, habitual, and they carry over to performance in the VE.

Another behavior observed was that of looking for cross-traffic with a "head bob", which was apparent for several subjects in both RW and VE worlds. Some drivers demonstrated a similar sequence and style (i.e. left-right-left-go, left-right-go, etc.). A critical observation here was that specific VE intersections prompted more cross traffic checks than others did. Those intersections producing these responses in the RW did so for obvious reasons such as a blocked view or high traffic volume. These checks occurred in the VE despite the absence of other traffic in the display.

Other minor behaviors of interest in the VE included: subjects asking whether they should buckle their safety belts; the release the parking break; anxiety over hitting VE stationary objects (cars); concern about speed limit; and not wanting to get out of the VE car until the projected display stopped.

Finally, a most interesting observation was that of driver behavior while decelerating. When we brake and decelerate in a RW scenario we press against the brake, put pressure on the steering wheel and flex the group of muscles (arms and shoulders) which prevent forward motion due to inertia. The VE was not actually moving, thus there was no inertia, yet nearly all subjects demonstrated an anticipatory or reflexive response to deceleration, which in the absence of inertia, resulted in the subjects leaning to the rear and pressing themselves into the back of the seat (Figure 20).

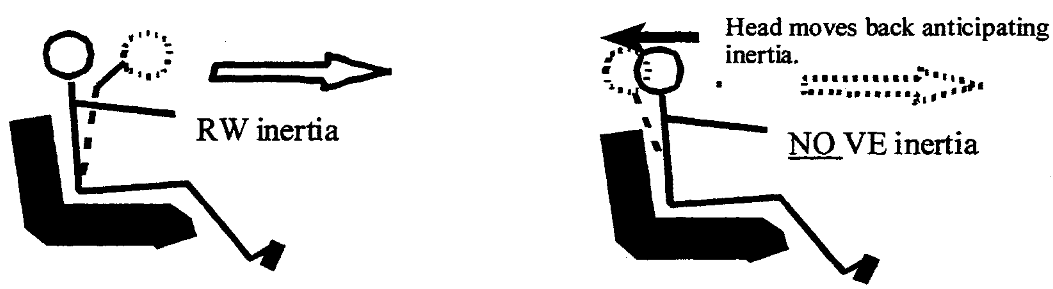


Figure 19. Inertial anticipation / compensation in the VE.

Other unsolicited comments from the subjects included (paraphrased): "I liked the telephone poles (Baseline north) and the low fence (C2), they helped me judge speed."; "Will it break anything (if I hit a parked car)?" and "It took me a second to get my land-legs back.". All of these comments indicate that an environment which is virtual (unreal) produces many of the stimuli we use in the real world. Some of these are physical, some psychological, some real (haptic input at the steering wheel and gas, etc.) but the responses appear real even if the environment is not. It is critical for the future use of the simulated VE to determine which stimuli produce what response or more precisely how much of each (intensity) produce the most reliable "real world" responses.

VII. CONCLUSIONS AND RECOMMENDATIONS

The results of our direct measures of driving performance, the survey of subject responses in using the simulated condition, and our descriptive and observational reports, support the effectiveness of employing the HFRL simulator for research on driving behavior, accident analysis, and collision avoidance. While there are differences in feedback provided from the simulated vehicle compared to the feedback drivers receive in a moving vehicle in the real-world exist, these differences are relatively small and not of any practical import to be of concern when studying driver behaviors in simulation circumstances.

Based on our results and this report, we conclude that the HFRL simulator at the University of Minnesota holds great potential for further analysis of a wide variety of issues that impact safe driving, collision avoidance, as well as the effects of road design on driving behavior. In terms of cost benefit analysis, there is no question that the use of the simulator is both cost and time effective, and appears to have sufficient validity to expect that driver performance measured in the simulator will generally reflect what will actually transpire in real-world driving.

In closing, we urge Mn/DOT to seek a closer cooperative arrangement with the Department of Public Safety, because the opportunity for simulation research in driving for the citizens for Minnesota clearly cross the boundary of what is the responsibility of Mn/DOT and the responsibility of the DPS. It would be in everyone's interests to seek ways in which collaborative research can be carried out between these two departments of state government.

Appendix A

Survey
&
Questionnaires

University of Minnesota Human Factors Driving Simulation Study
Pre-test Survey/Questionnaire

As stated in your instructions, all data are confidential.

Q1.

Name	
Age	
Gender	**M / F**
Phone Number	

Q2. Do you currently have a valid drivers license? (Circle one.)

1. **Yes**
2. **No**

Q3. Years driving experience (likely to be age-16=_). Number of years ____________.

Q4. Do you have any visual impairments?

1. **Yes** If Yes, please describe.-______________________________
2. **No**

Q5. Are you currently taking any medications?

1. **Yes** If Yes, please describe.-______________________________
2. **No**

Q6. Have you experienced dizziness in the past (whether driving or not)(circle one.)

	Yes	**No**	(If you answered yes , what caused the dizziness?)
a. 5 years?	1	2	____________________
b. 1 year?	1	2	____________________
c. 6 months?	1	2	____________________

Q7. Please answer Y or N and the frequency (Circle one response for each item.)

Do you experience nausea in any of the following situations?	YES	NO	If YES describe situation (where, how often, etc.).
Driving a car.	1	2	
Riding in a car as a passenger.	1	2	
During plane trips.	1	2	
Carnival rides.	1	2	
Other.(Watching TV, movies, etc.)	1	2	

Q8. (Circle one response for each item.)

Do you experience-	always	sometimes	rarely	never
Claustrophobia (fear of closed spaces)	1	2	3	4
Acrophobia (fear of heights)	1	2	3	4
Driving fatigue	1	2	3	4
Panic attacks while driving.	1	2	3	4
Driving aggression. (Anger while driving)	1	2	3	4

Time on Road

Q9. How often do you drive a car under the following conditions (circle one response for each item).

	5 - 7 days /week	2-5 days/week	Once/week	Once/month	Rarely
a. Under 35 m.p.h.	1	2	3	4	5
b. 35 - 55 m.p.h.	1	2	3	4	5
c. 55 m.p.h. +	1	2	3	4	5
Q10. a. Heavy traffic	1	2	3	4	5
b. Moderate to light traffic	1	2	3	4	5

POST-test Questionnaire: Part I

Please rate your simulator experience (circle one number).

Q1. How would you rate the physical comfort of your simulator experience?

Not at all comfortable. Very comfortable.

1 2 3 4 5 6 7 8 9

Q2. How nervous did you feel during your simulator experience?

Very nervous. Not at all nervous.

1 2 3 4 5 6 7 8 9

Q3. How realistic did you find the visual display?

Not at all realistic. Very realistic.

1 2 3 4 5 6 7 8 9

Q4. How realistic did the simulator feel physically?

Not at all realistic. Very realistic.

1 2 3 4 5 6 7 8 9

Q5. How difficult or easy was it for you to learn to use the simulator?

Very difficult. Very easy.

1 2 3 4 5 6 7 8 9

Q6. How well did you adapt to the simulator?

Never got use to it Quickly became use to it.

1 2 3 4 5 6 7 8 9

Q7. How closely did your simulator experience meet your expectations?

Not very closely Very closely

1 2 3 4 5 6 7 8 9

Please feel free to explain any extreme scores (1,2 or 8,9) you may have had:

____

____

____

Q8. Did you experience any nausea during the experiment?

1. **Yes**
2. **No** (If *No*, skip to **Q9**)

a. If *Yes*, at what point during the experiment did it occur (early, midway, late)?

____

b. If *Yes*, was it caused by a specific situation that you can remember?

____

c. If *Yes*, what (if anything) did you do to ease the sensation?

____

Q9. Describe the general experience or any other comments you may have about your simulator experience (if any).

____

____

____

____

____

POST-test Questionnaire

Please rate your simulator experience.

	LOW								HIGH
Comfort (physical) - Low: nausea, bad seat, etc. - High: felt good, good driving position, etc.	1	2	3	4	5	6	7	8	9
Comfort (mental) - Low: nervous, etc. - High: at ease, relaxed, etc.	1	2	3	4	5	6	7	8	9
Realism (Visual/display)	1	2	3	4	5	6	7	8	9
Realism (Physical/feel)	1	2	3	4	5	6	7	8	9
Familiarization: -Low: never got use to it. -High: became easier as trial went on.	1	2	3	4	5	6	7	8	9
Expectation: -Low: It wasn't what you thought Virtual reality would be. -High: It was what you expected.	1	2	3	4	5	6	7	8	9

Please explain any extreme scores:

____

____

____

____

Did you experience any nausea during the experiment? Y / N
If yes, at what point during the experiment did it occur (early, midway, late)?______________________________

Was it caused by a specific situation that you can remember?

____

If yes, what (if anything) did you do to ease the sensation?

____

Describe the general experience.

____

____

____

____

____

Instructions: Circle the items that apply to you RIGHT NOW.

SYMPTOM			RATING	
1. General Discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye Strain	None	Slight	Moderate	Severe
5. Difficulty Focusing	None	Slight	Moderate	Severe
6. Salivation Increased	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty Concentrating	None	Slight	Moderate	Severe
10. "Fullness of the Head"	None	Slight	Moderate	Severe
11. Blurred Vision	None	Slight	Moderate	Severe
12. Dizzy (eyes open)	None	Slight	Moderate	Severe
13. Dizzy (eyes closed)	None	Slight	Moderate	Severe
14. Vertigo	None	Slight	Moderate	Severe
15. Stomach Awareness**	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

17. Other: Please describe ____

____

** "Stomach Awareness" usually is used to indicate a feeling of discomfort that is just short of nausea.

Appendix B

Raw Film Data
&
Charts

VE1 Start	Baseline	C1	C2	C2	C2	C2	C3
	47	34	-40	0	-20	15	70
BN	47	36	-35	-10	-25	15	70
	45	43	-30	-30	-35	10	68
bn	44	53	-20	-30	-35	0	67
	47	53	-18	-30	-35	-10	70
	50	56	-12	-30	-35	-20	72
	52	57	-6	-35	-35	-30	74
	52	55	0	-30	-30	-35	79
	59	55	0	-30	-26	-35	57
	65	56	0	-30	-24	-35	45
	70	66	-6	-20	-30	-30	46
turn	75	57	-8	-10	-28	-25	50
	80	49	-10	22	-40	-20	50
	70	48	-15		-30	-10	48
	68	49	-25		-15	0	46
	69	50	-25		-10	40	57
	65	60	-30		0		64
	60	65	20		40		50
	58	66					40
	50	61					50
	44	50					52
	48	52					43
	60	67					36
	62	72					28
		72					25
		72					

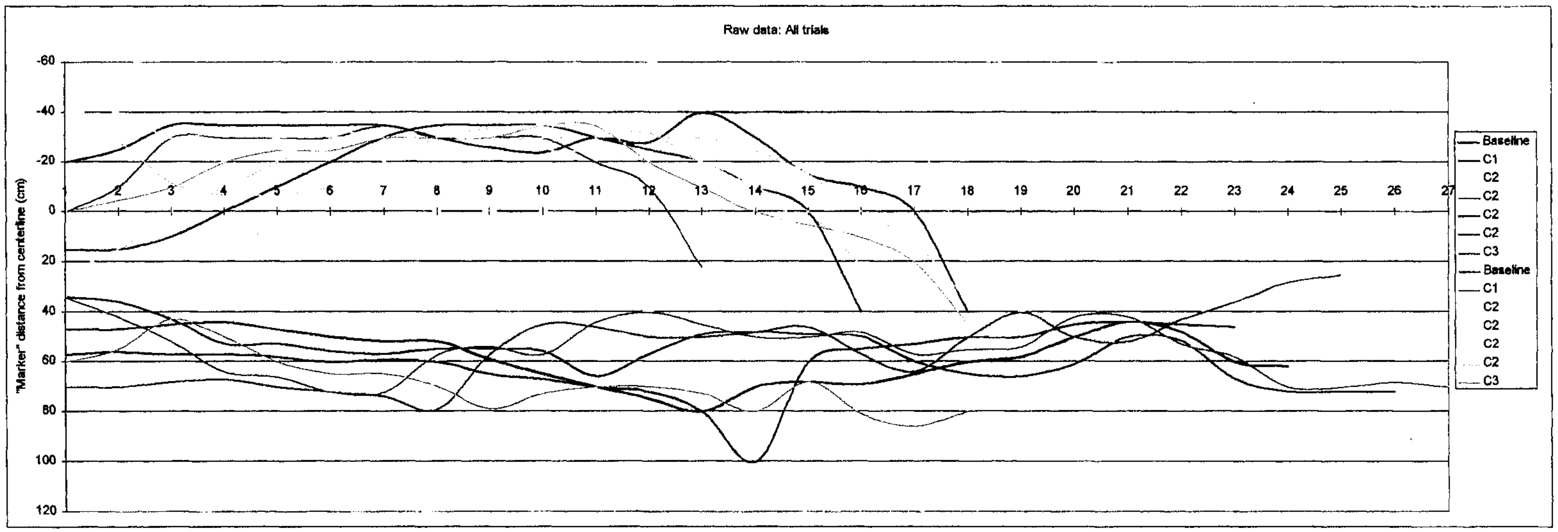
VE1 Start	Baseline	C1	C2	C2	C2	C2	C3
T2	57	34	-30	24	-40	0	60
	56	42	-28	15	-40	-5	55
	57	52	-12	0	-30	-10	43
	57	64	-7	-10	-33	-20	50
	58	66	-7	-20	-30	-25	60
	60	72	-10	-30	-33	-25	65
	59	72	-20	-30	-30	-30	65
	60	57	-30	-34	-30	-30	70
	65	54	-34	-30	-30	-30	79
	67	57	-35	-30	-25	-35	73
	70	44	-32	-30	-25	-35	70
	72	40	-32	-30	-23	-20	70
	80	45	-20	-30	-20	-10	73
(turn)	100	50	-10	-25	-10	0	80
	60	50	0	-15	8	5	68
	55	48	22	0		10	81
	53	57		12		20	86
	50	55		36		45	80
	50	54					
	45	42					
	44	42					
	45	53					
	46	58					
		70					
		70					
Como 14th		68					
		70					

Means

Baseline	C1	C2	C3
58.57	54.82	-16.70	38.66

SD's

Baseline	C1	C2	C3
11.60	9.55	18.75	14.90



31:56:00	Baseline	C1	C2	C2	C2	C2	C3
	40	50	-30	0	-26	-28	24
	40	43	-20	-30	-26	-30	23
	40	35	-15	-35	-30	-30	10
rm	38	39	-30	-35	-34	-35	20
	37	40	-32	-30	-30	-35	25
	34	43	-20	-20	-30	-30	35
	30	30	-10	-15	-30	-34	35
	27	30	0	-10	-30	-30	33
	25	38	10	0	-30	-30	30
	27	30	10	10	-25	-35	56
	30	30		20	23	-20	60
	40	60		36		-15	67
	45	60		40		-10	47
	47	62		45		0	56
	52	57				30	45
	47						35
	42						20
	38						15
	34						15
turn	38						26
	48						
	45						
	43						
	44						
	45						
	44						
	42						
	41						
	40						
	35						
	33						
	35						
	44						
	47						
	50						
	60						
	65						
	63						
	63						
	61						
	60						

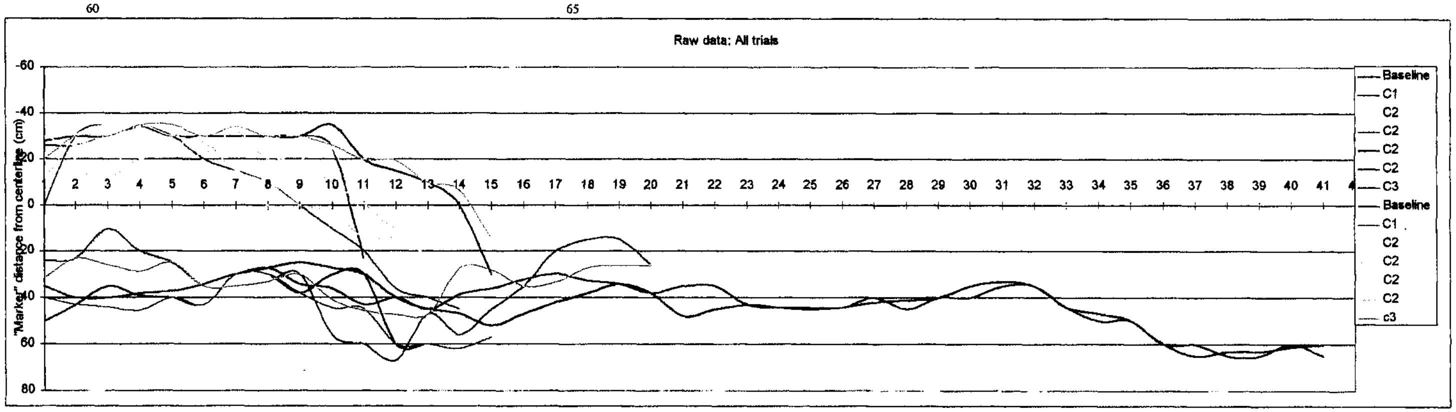
?	Baseline	C1	C2	C2	C2	C2	c3
	35	40	-15	-10	-30	-20	31
	40	43	-15	-30	-26	-30	23
	40	44	-12	-35	-30	-30	26
	38	46	-20	-35	-34	-35	29
	37	40	-21	-30	-26	-35	25
	34	43	-22	-27	-30	-30	35
	30	30	-32	-15	-23	-34	35
	27	30	-20	-10	-30	-30	33
	34	38	-21	0	-30	-30	30
	36	44	-10	3	-25	-26	41
	43	45	-1	14	7	-20	46
	40	60	10	14		-20	47
	45	60	10	22		-10	47
	38	62		26		-7	27
	36	57				14	28
	32						35
	30						33
	33						27
	34						26
	38						26
	35						
	35						
	43						
	44						
	44						
	44						
	40						
	45						
	40						
	40						
	35						
	35						
	44						
	50						
	50						
	60						
	60						
	65						
	65						
	60						
	65						

Means

Baseline	C1	C2	C3
42.41	44.29	-16.14	22.31

SD's

Baseline	C1	C2	C3
6.12	10.91	19.32	12.82



45:43:00	Baseline	C1							
	90	40	C2	C2	C2	C2	C3		?
	110	55	-20	0	-35	-20	50	c3	film stop??
le	120	62	-15	-10	-32	-30	40	cirex	
	110	62	-12	-20	-35	-35	72		
	110	66	-10	-30	-35	-35	62		
	110	66	0	-30	-26	-30	60		
	120	63	10	-35	-20	-20	62		
	110	61	10	-40	-35	-20	70		
	110	50	5	-30	-35	-10	70		
	110	40	0	-20	-20	0	65		
Turm	120	60	-20	-10	-10	10	55		
	72	44	-30	-6	0	20	60		
	54	44	-20	0		35	50		
	53	40	0	10			52		
	55	35	8	20			45		
	57	60					50		
	54	72					60		
	47	83					75		
	47	85					80		
	35	90					85		
	36	90					100		
	37	88					105		

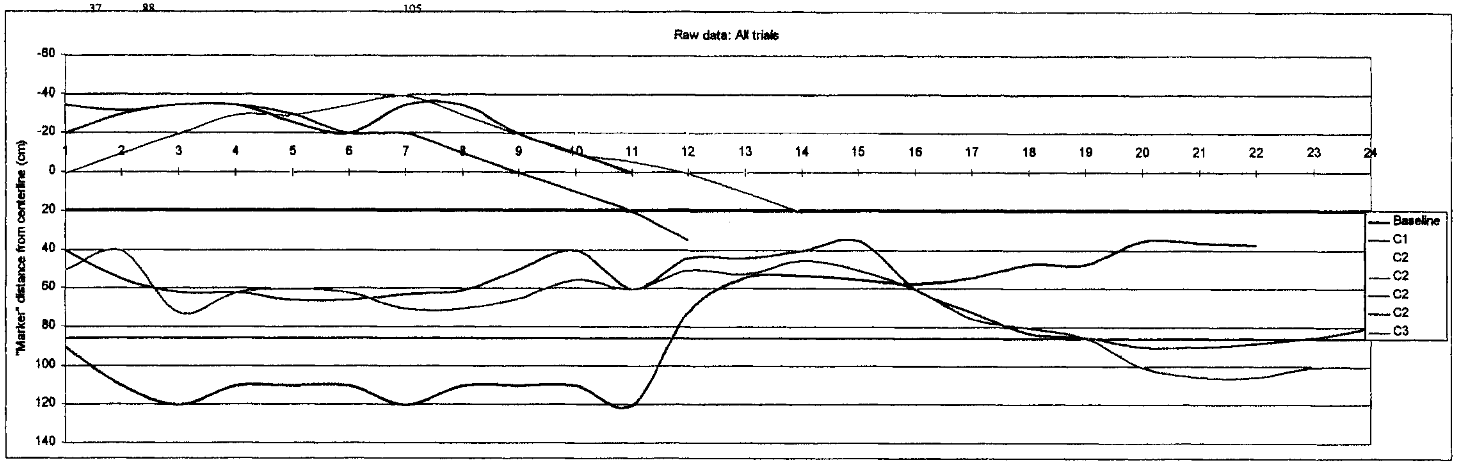
Baseline C1 c2 C2 C2 c2 C3

Means

Baseline	C1	C2	C3
80.32	63.38	-13.98	69.71

SD's

Baseline	C1	C2	C3
32.72	17.68	17.86	20.03



2:30	Baseline	C1					
	82	52	C2	C2	C2	C2	C3
	72	42	-25	0	0	-20	80
	70	30	-25	-30	-35	-30	85
djand	74	30	-30	-30	-35	-35	90
	66	39	-20	-30	-30	-35	80
	65	50	-20	-20	-30	0	80
	60	54	-20	-25	-35	10	60
	80	60	-25	0	-20	18	40
turn	100	50	-30	10	0	35	50
	56	48	-25	20	25		60
	45	48	-10	30	25		58
	50	62	0		20		80
	48	57	10				60
	44	55	32				58
	70	50					60
	70	49					82
		50					80
		55					64
		60					60
		60					(turn)

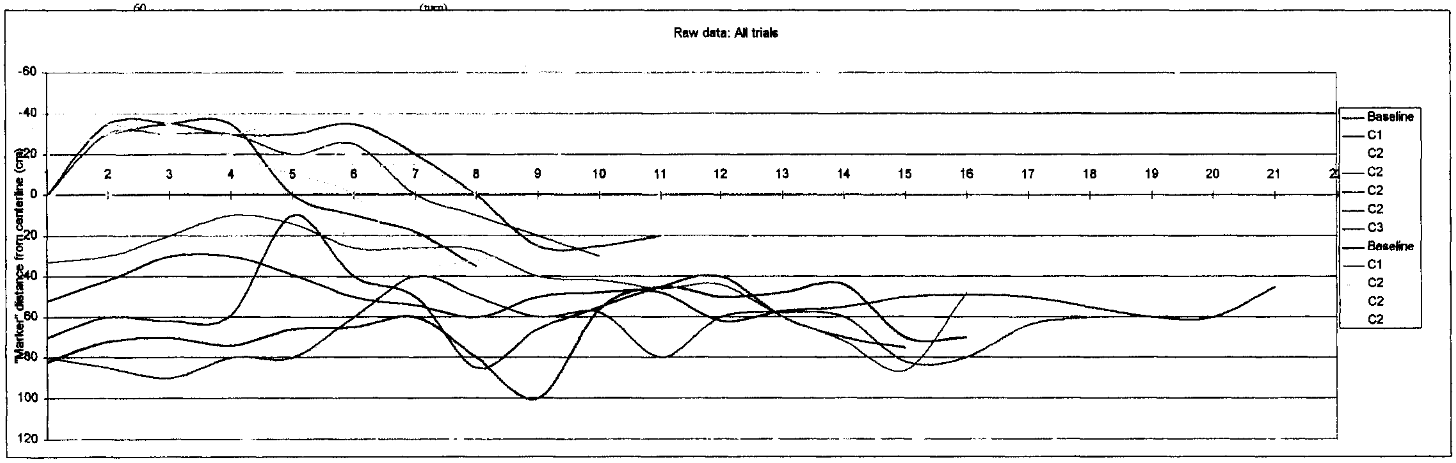
?	Baseline	C1	C2	C2	C2	C2	C3
	70	33	-30	-35	-20	0	
	60	30	-35	-35	-30	0	
	62	20	-20	-30	-35	-10	
•	59	10	-10	-30	-20	-15	
cargo truc	10	14	-15	-34	-10		camera stop
	40	26	-15	-15	0		
	50	26	0	-15	32		
turm	85	27	-20	0	32		
	66	40	-10		25		
	55	42	0				
	45	46	20				
	40	44	32				
	60	60					
	70	72					
	75	86					
		48					

Means

Baseline	C1	C2	C3
65.75	45.14	-10.44	68.17

SD's

Baseline	C1	C2	C3
15.05	15.79	21.27	14.00



	19:29 Baseline	C1						
	32	57	C2	C2	C2	C2	C3	
	30	36	0	0	-40	-20	20	
	30	29	-30	20	-35	-30	28	
as	34	10	-30	-28	-35	-20	40	
	34	16	-22	-35	-35	-20	40	
	46	26	-24	-10	-30	-15	33	
	48	29	-25	-5	0	0	28	
	55	25	-20	0	10	10	26	
	49	39	-2	0	15	15	48	
	50	35	0	0		30	26	
turn	80	29	15	-4			26	
	34	27		5			28	
	30	27		10			30	
	23	30		10			35	
	16	28						turn
	27	25						
	30	38						
	44	36						
	44	36						

19:29	Baseline	C1	C2	C2	C2	C2	C3	
	47	57	0	0	-35	-15	20	
	45	36	-30	0	-22	-20	28	
	40	29	-30	-28	-26	-30	40	
	35	10	-22	-35	-28	-20	40	
	30	16	-24	-10	-30	-20	33	
	34	26	-25	-5	10	-15	28	
	32	29	-14	-5	10	-10	26	
	46	25	-16	0	0	0	48	
	48	39	0	5	10	10	26	
	40	35	10	2		10	26	
	55	29	10	8		15	28	
	55	27		-1		20	30	
	60	27		5		30	35	
	59	30		10				turn
turn	59	28		10				
	34	25						
	30	38						
	23	36						

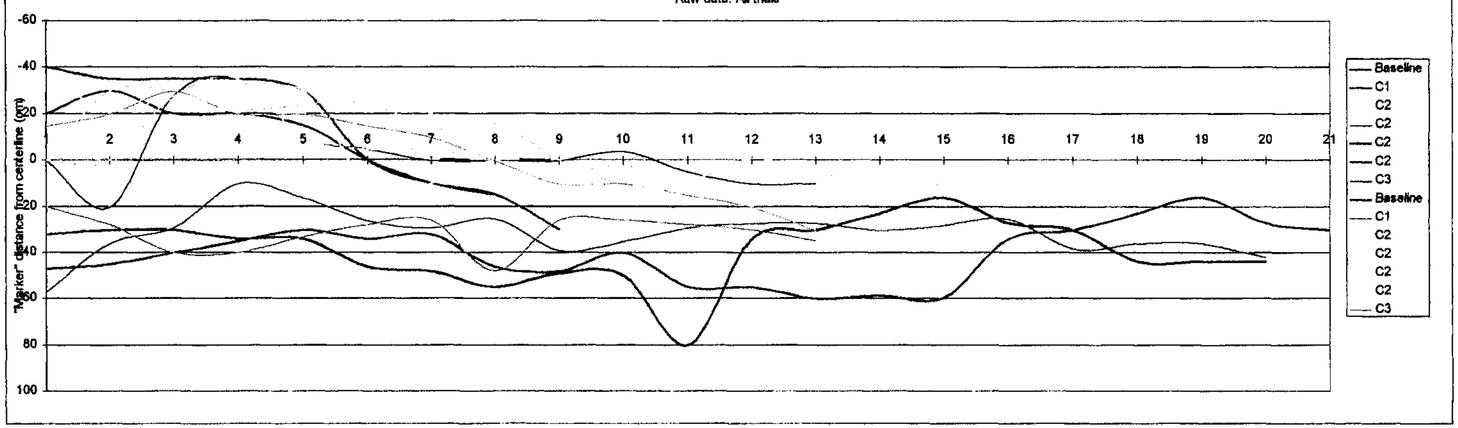
Means

Baseline	C1	C2	C3
39.63	31.00	-8.14	31.38

SD's

Baseline	C1	C2	C3
13.22	9.66	17.45	7.45

Raw data: All trials



	Baseline	C1	C2	C2	C2	C2	C3	
			0	-10	-25	-10	77	
			-15	-25	-30	-20	78	
	63	65	-20	-25	-25	-25	78	
	55	64	-25	-28	-22	-25	74	
rev	53	64	-28	-28	-25	-23	69	
	53	61	-30	-15	-20	-30	66	
	54	61	-25	-13	-10	-10	59	
	57	56	-15	-10	5	0	55	
	55	54	-10	3	18	10	58	
	61	43	0	10	10	25	58	
	70	40	0	10	10	40	64	
	75	35	5	15	15	40	65	
	73	35		20	15	40	68	
	80	34		25			68	
	88	39		30			59	
turn>>	40	43		40			57	
	43	43		45			54	
	33	40		48			54	
	30	40					60	
	37	43					67	
	42	45					67	
	50	50					51	
	50	55					50	
	58	61					48	
	61	68					55	
	64	75					55	
	68	75					53	
	70	80					55	
	68	80					53	
	65	82					55	
	65	78					53	
	100	80					56	
	100	100					57	
	100	110					61	
							40	

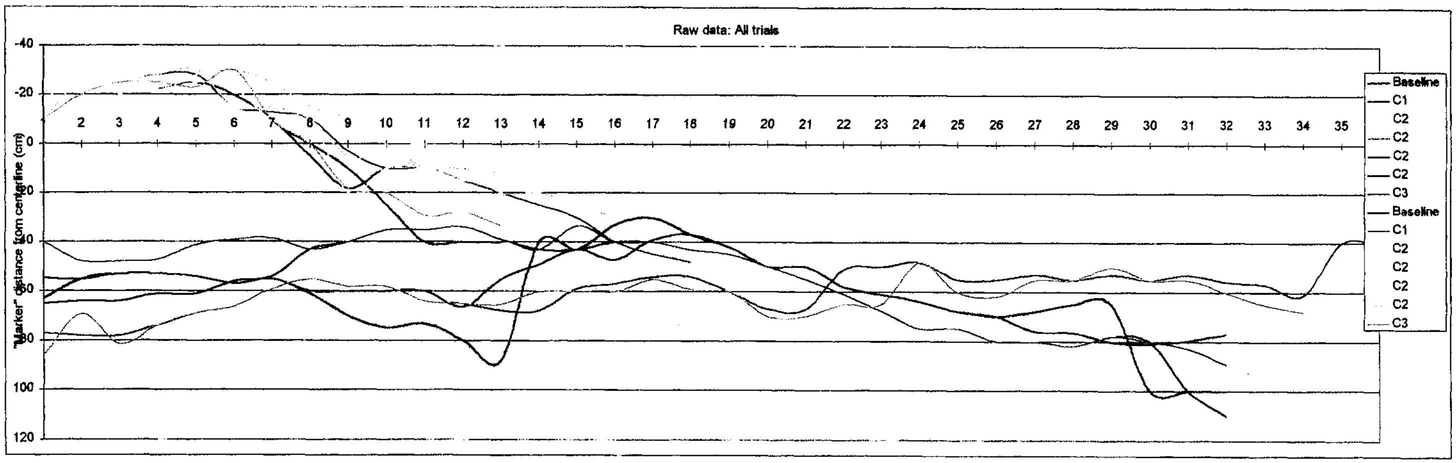
t2	Baseline	C1	C2	C2	C2	C2	C3
	55	40	-22	-10	-25	-10	86
	55	48	-15	-25	-30	-20	69
	53	48	-20	-25	-25	-25	82
	53	47	-25	-28	-22	-25	74
	54	41	-28	-30	-25	-23	69
	57	39	-30	-15	-23	-30	66
	55	38	-25	-15	-10	-10	59
	60	43	-15	-10	-10	0	55
	60	40	-10	5	20	18	58
	60	35	0	5	10	20	58
	60	35	10	10	10	29	64
	66	34	10	10	15	28	65
	55	39	12	20	15	33	65
	49	43		20			60
	43	33		25			60
	47	40		30			60
	39	40					55
	37	43					59
	42	45					60
	50	50					70
	50	55					70
	58	61					65
	61	68					65
	64	75					48
	68	75					60
	70	80					62
	76	80					55
	77	82					55
	80	78					50
	81	80					55
	80	83					55
	77	89					60
							65
							68

Means

Baseline	C1	C2	C3
60.51	56.67	-4.04	60.92

SD's

Baseline	C1	C2	C3
15.39	18.95	21.32	8.78



sm

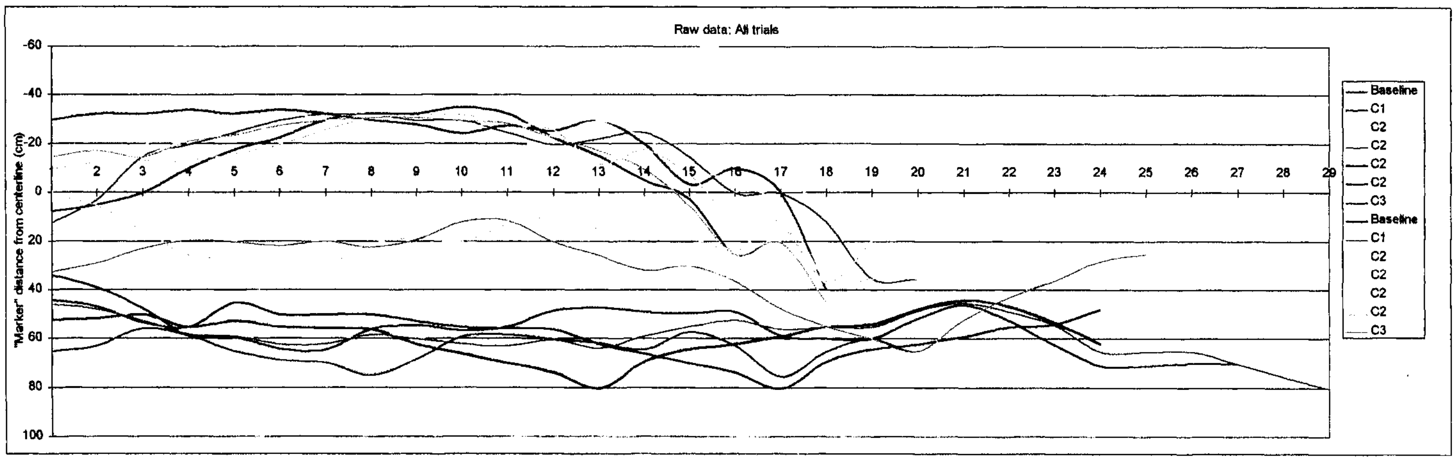
Baseline	C1	C2	C2	C2	C2	C3
52	34	-35	12	-30	8	65
52	39	-32	3	-33	5	63
50	48	-21	-15	-33	0	56
55	59	-14	-20	-34	-10	59
53	60	-13	-25	-33	-18	65
55	64	-11	-30	-34	-23	69
56	65	-13	-33	-33	-30	70
56	56	-15	-32	-30	-33	75
62	55	-17	-30	-28	-33	68
66	57	-18	-30	-25	-35	59
70	55	-19	-25	-28	-33	58
74	49	-20	-20	-26	-23	60
80	47	-15	-22	-30	-15	62
69	49	-13	-25	-20	-5	64
64	50	-13	-15	-4	3	57
62	49	-13	0	-10	25	63
59	59	-9	0	0	20	75
55	60	10	12	40	45	65
54	60	20	35			60
48	52		35			65
44	46					52
47	53					43
53	63					36
62	71					
	71					
	70					
	70					

t2

Baseline	C1	C2	C2	C2	C2	C3
44	46	0	-10	0	-15	33
47	48	5	-13	-10	-18	29
53	52	16	-14	-15	-15	23
55	58	25	-14	-22	-22	19
45	59	27	-16	-26	-24	20
50	62	31	-20	-32	-28	22
50	62	30	-26	-31	-30	20
50	58	21	-31	-32	-31	22
53	60	19	-32	-29	-31	19
55	62	20	-33	-27	-30	12
56	63	13	-29	-29	-29	12
56	60	10	-26	-28	-23	20
62	64	15	-12	-30	-18	26
66	59	19	-18	-23	-10	32
70	55	19	-8	-10	5	30
74	52	23	11	-5	25	36
80	56	14	12	6	20	48
69	55	38	36	38	45	55
64	55	35	20			60
62	48	35				65
59	45					52
55	49					43
54	54					36
48	65					28
	65					25
	65					
	70					
	75					
	80					

	Baseline	C1	C2	C3
Means	57.71	57.21	-9.07	45.63
SD's	9.07	8.88	21.73	19.28

car pass
on C2/1



B7

DJ Nov 2	Baseline	C1	C2	C2	C2	C2	C3
	12	40	-30	-20	0	-20	100
	15	35	-30	-20	-5	-20	80
	15	35	-25	-30	-10	-30	75
dj	15	45	-30	-20	-20	-30	75
	14	50	-40	-30	-20	-20	86
	18	65	-30	-30	-20	0	86
	19	47	-20	-10	-20	-10	76
	36	47	-10	-10	-30	-10	63
	50	44	-10	-10	-20	0	63
	50	30	0	0	-10	10	69
	60	10	0	0	-10	20	66
	100	5			0	30	45
	120	0			0		36
	130	10					36
	140	0					40
	140	0					37
	140	0					56
Turn	150	5					54
	54	8					53
	34	30					40
	20	38					33
	18	32					32
	17	33					31
	20	44					30
	25	36					28
	26	40					30
	26	60					38
	22						

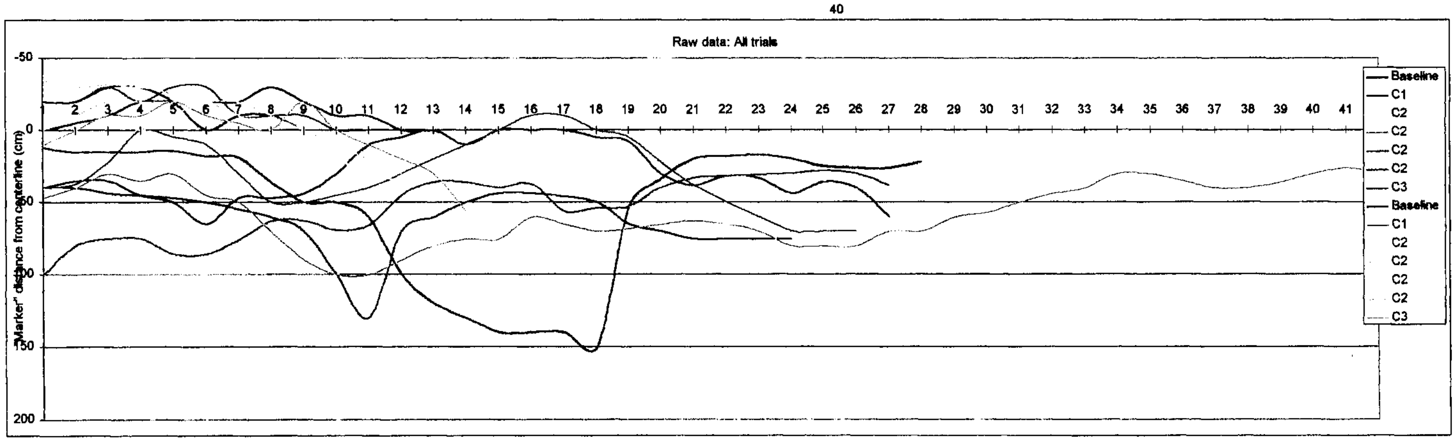
Trial 2	Baseline	C1	C2	C2	C2	C2	C3	
	40	40	-35	0	0	10	47	
	40	37	-30	-10	-9	0	40	
	44	22	-32	-20	-10	-10	30	
	45	0	-30	-20	0	-10	35	
	47	5	-25	-20	-10	-20	30	
	50	10	-20	-20	-20	-10	45	
	55	30	-10	-20	-10	-5	50	
	60	50	0	-10	0	0	70	
	70	50		0	10	-20	90	
	100	45		10	20	0	100	
Turn	130	40		20	30	10	100	light
	70	30		30	35	20	90	
	60	20				30	80	
	50	10				56	75	
	44	0					75	
	44	-10					60	
	46	-10					65	
	50	0					70	
	65	5					68	
	70	22					65	2cars in lead
	75	38					63	
	75	50					65	
	75	60					70	
	75	70					80	
		70					80	
		70					80	
							70	
							70	
							60	
							57	
							50	
							44	
							40	

Means

Baseline	C1	C2	C3
57.04	29.11	-8.66	56.07

SD's

Baseline	C1	C2	C3
38.19	22.27	17.88	21.05



MC	Baseline	C1	C2	C2	C2	C2	C3
	54	50	-20	0	-25	0	70
	55	45	-30	-10	-25	-10	80
	65	47	-28	-20	-30	-10	80
	75	50	-25	-20	-30	-10	80
	65	50	-30	-25	-30	-15	85
	65	60	-30	0	-25	-20	90
	70	60	-20	5	-20	0	80
	73	62	-10	0	-10	10	70
	75	52	0	5	0	20	68
	70	50			10	30	60
	75	45					60
	90	40					60
	100	30					55
	90	25					58
	100	22					60
	110	30					65
	0	40					70
	-5	45					68
Turn	5	50					65
	10	52					60
	20	55					62
	30	50					70
	45	50					80
	50	50					84
	60	52					82
	62	60					70
	62	70					66
	65	75					80
	65	80					80
	60	80					75
	50	82					70
	40	78					60
		80					60
		100					50
		110					52
							50
							56
							40
							30

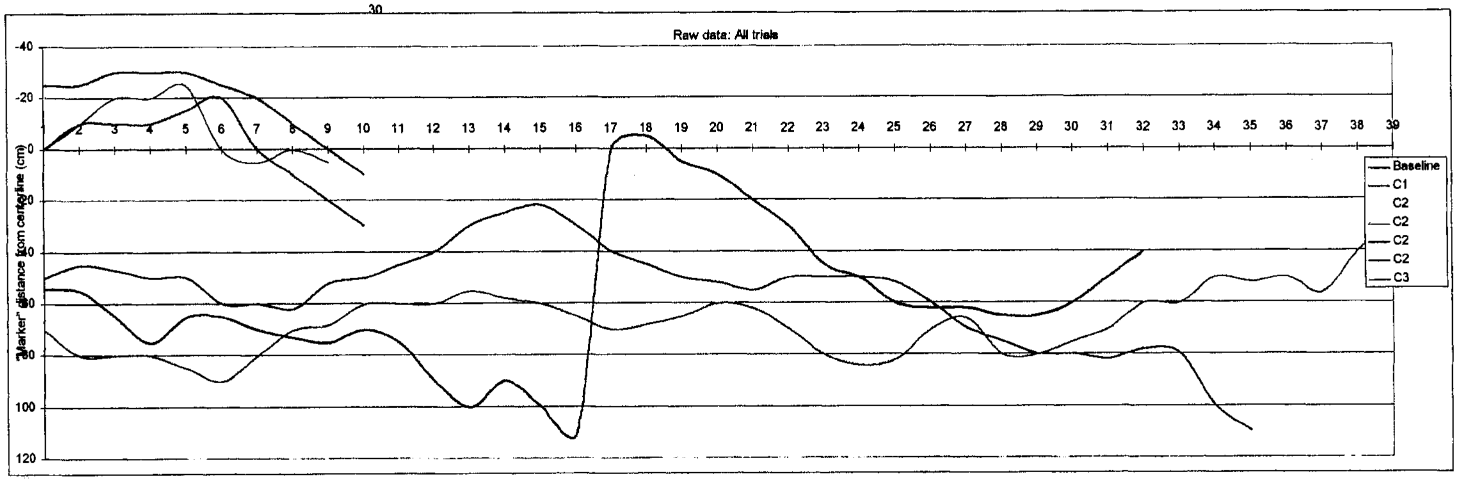
Trial 2	Baseline	C1	C2	C2	C2	C2	C3
?							

Means

Baseline	C1	C2	C3
57.84	56.49	-11.79	66.69

SD's

Baseline	C1	C2	C3
28.55	19.65	15.42	12.87

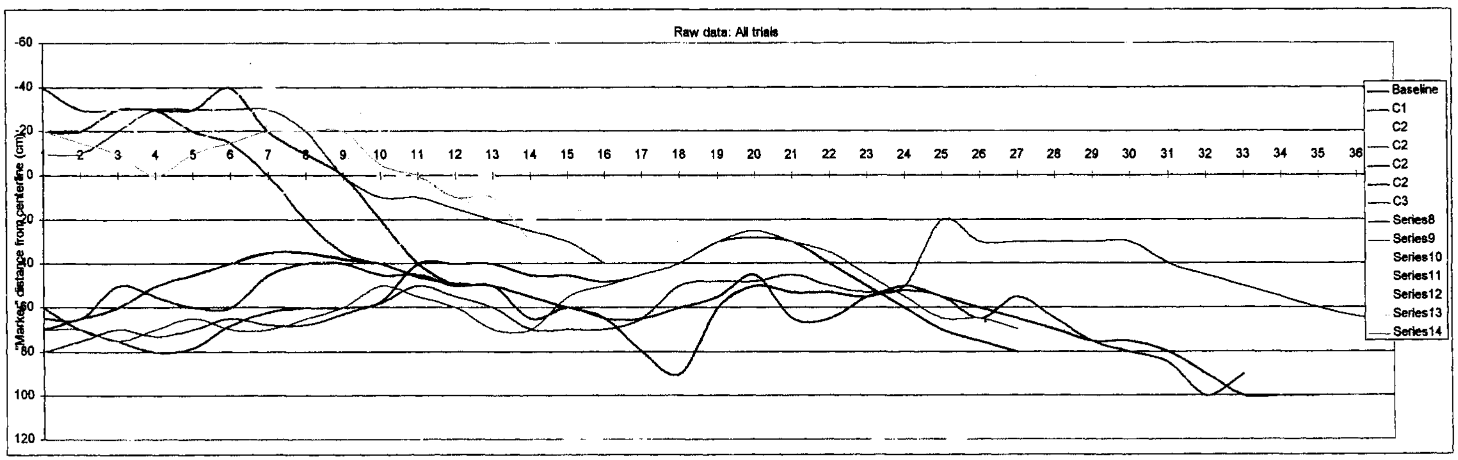


	Baseline	C1	C2	C2	C2	C2	C3	
	70	60						
	65	70	-33	-10	-40	-20	80	
MB	60	75	-30	-10	-30	-20	75	
	50	80	-28	-20	-30	-30	70	
	45	78	-30	-30	-30	-30	73	
	40	68	-30	-30	-20	-30	70	
	35	62	-30	-30	-15	-40	65	
	35	60	-40	-30	0	-20	68	
mb	38	60	-35	-20	20	-10	68	
	40	57	-30	0	35	0	63	
	46	40	-20	10	40	20	58	
	49	40	-10	10		40	50	
	50	40	0	15		50	55	
	55	45	0	20			60	
	60	45	5	25			70	
	65	48		30			70	
	80	45		40			70	
	90	40					65	
	60	30					50	
	50	28					48	
Turn	53	30					48	
	53	40					45	
	55	50					50	
	50	60					53	
	55	70					50	
	60	75					20	truck parked ill.
	65	80					30	
	70						30	
	75						30	
	75						30	
	80						30	
	90						40	
	100						45	
	100						50	
	100						55	
							60	
							64	
							66	

Trial 2	Baseline	C1	C2	C2	C2	C2	C3
	65	70	-20	-10	-30	-20	78
	65	70	-25	-10	-25	-15	68
	50	75	-30	-15	-25	-10	62
	55	70	-22	-15	-15	0	60
	60	65	-24	-15	-15	-10	60
	60	70	-35	-25	-10	-15	57
	45	70	-40	-30	5	-20	40
	40	65	-35	-25	10	-20	40
	40	60	-30	-10	15	-20	40
	45	50	-25	0	30	-5	45
	45	55	0	0	30	0	45
	50	60	10	10		10	48
	50	70	10	15		10	45
	65	70	15	20		30	40
	60	55	15	15			30
	65	50		20			28
	65	45		30			30
	60	40		30			40
	55	30					50
	45	25					60
	65	30					70
	65	35					70
	55	45					65
	52	55					50
	55	65					48
	65	65					48
	55	70					45
	65						50
	75						53
	80						50
	85						20
	100						30
	90						

Means			
Baseline	C1	C2	C3
61.12	55.67	-7.88	52.01

	SD's			
80	Baseline	C1	C2	C3
	16.32	15.35	22.13	14.71



VE1 Star	Baseline	C1	C2	C2	C2	C2	C3
	47	34	-40	0	-20	15	70
xx	47	36	-35	-10	-25	4	70
mp	45	43	-30	-30	-35	-5	68
xx	44	53	-20	-30	-35	-8	67
	47	53	-18	-30	-35	-10	70
	50	56	-12	-30	-35	-20	72
	52	57	-20	-35	-35	-30	74
	52	55	-21	-30	-30	-35	79
	59	55	-20	-30	-26	-35	57
	65	56	-20	-30	-24	-35	51
	70	66	-15	-20	-30	-30	46
turn	75	57	-8	-10	-28	-25	50
	80	49	-10	22	-31	-20	50
	70	48	-15		-30	-10	48
	68	49	-25		-26	0	46
	69	50	-25		-17	10	57
	65	60	-19		0	15	64
	60	65	20		40	35	50
	58	66				40	40
	50	61					50
	44	50					52
	48	52					43
	60	67					36
	62	72					39
							36

Como 14th

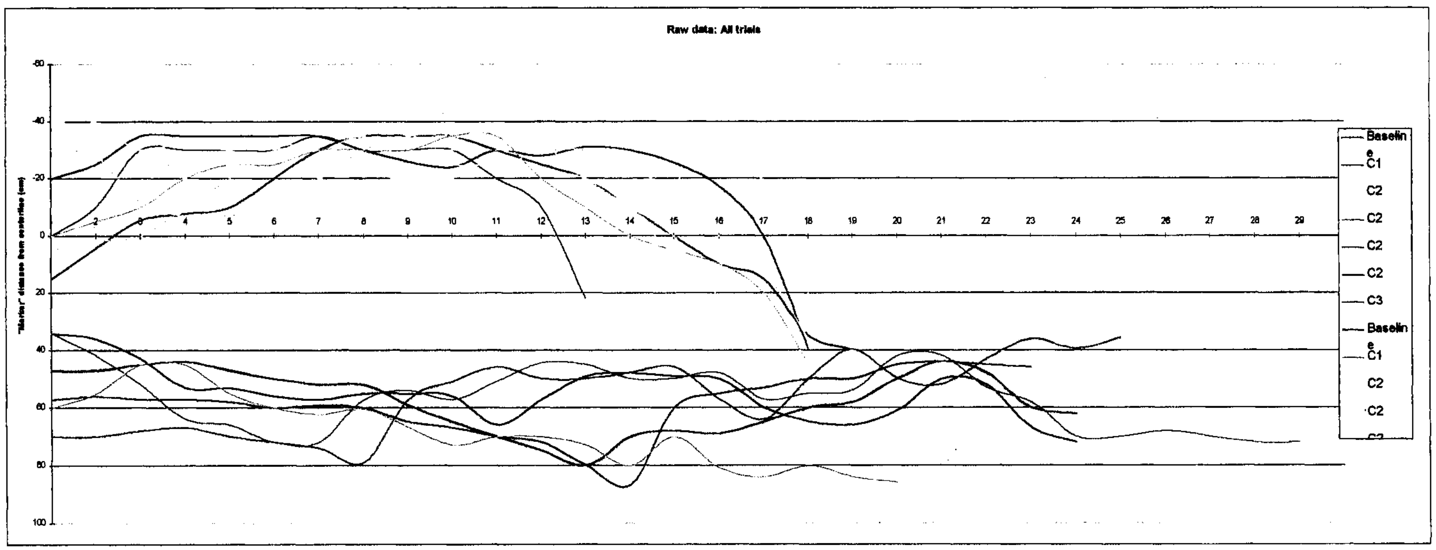
VE1 Star	Baseline	C1	C2	C2	C2	C2	C3
T2	57	34	-30	5	-40	0	60
	56	42	-28	2	-40	-5	55
	57	52	-12	0	-30	-10	45
	57	64	-7	-10	-33	-20	45
	58	66	-7	-20	-30	-25	55
	60	72	-10	-30	-33	-25	60
	59	72	-20	-30	-30	-30	62
	60	57	-30	-35	-30	-30	60
	65	54	-35	-30	-30	-30	67
	67	57	-35	-30	-25	-35	73
	70	51	-32	-30	-25	-35	70
	72	44	-32	-30	-23	-20	70
	80	45	-20	-30	-20	-10	73
(turn)	87	50	-10	-25	-10	0	80
	60	50	0	-22	8	5	70
	55	48	22	0		10	81
	53	57		12		20	84
	50	55		36		45	80
	50	54					84
	45	42					86
	44	42					
	45	53					
	46	58					
		70					
		70					
		68					
		70					
		72					
		72					

Means

Baseline	C1	C2	C3
58.29	55.37	-17.47	37.83

SD's

Baseline	C1	C2	C3
10.70	9.33	17.89	13.38



VE1 Star	Baseline	C1	C2	C2	C2	C2	C3
	40	40	-35	0	-20	-12	55
xxx	47	36	-35	-10	-25	4	70
cn	45	43	-30	-30	-35	-5	68
xxx	44	53	-20	-30	-35	-8	67
	47	53	-18	-30	-35	-10	70
	50	56	-12	-30	-35	-20	72
	52	57	-20	-35	-35	-30	74
	55	52	-21	-30	-30	-35	60
	55	59	-20	-30	-26	-35	57
	56	65	-20	-30	-24	-35	51
	66	70	-29	-20	-30	-30	46
turn	57	75	-33	-10	-28	-25	50
	49	80	-10	-10	-31	-20	50
	48	70	-15	-10	-30	-10	48
	49	70	-25	-15	-26	0	46
	50	69	-25		-17	10	57
	60	65	-19		0	15	64
	65	60	20		8	17	50
	66	58			35	19	40
	61	50			40		50
	50	50					52
	48	52					43
	60	67					
	62	72					

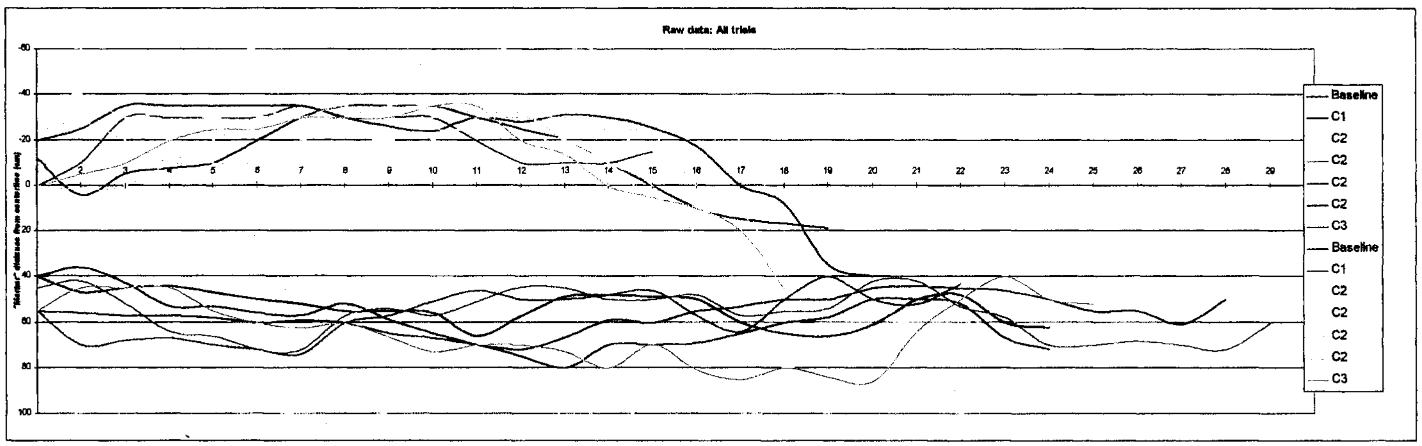
VE1 Star	Baseline	C1	C2	C2	C2	C2	C3
T2	55	45	-24	0	-35	0	55
	56	42	-28	2	-40	-5	45
	57	52	-20	0	-30	-10	45
	57	64	-10	-10	-33	-20	45
	58	66	-10	-20	-30	-25	55
	60	72	-10	-30	-33	-25	60
	59	72	-20	-30	-30	-30	62
	60	57	-30	-35	-30	-30	60
	65	54	-35	-30	-30	-30	67
	67	57	-35	-30	-25	-35	73
	70	51	-32	-30	-25	-35	70
	72	44	-32	-30	-23	-20	70
	67	45	-20	-30	-20	-14	73
(turn)	59	50	-10	-25	-10	0	80
	60	50	0	-22	8	5	70
	55	48	22	0		10	81
	53	57		12		20	85
	50	55		36		45	80
	50	54					84
	45	42					86
	44	42					64
	45	53					50
	46	58					40
	50	70					50
	55	70					52
Como 14th	55	68					
	61	70					
	50	72					
		60					

Means

Baseline	C1	C2	C3
55.04	57.73	-18.53	36.96

SD's

Baseline	C1	C2	C3
7.78	10.47	16.12	12.15



	Baseline	C1	C2	C2	C2	C2	C3
t1	35	40	-35	0	-20	-20	55
xxxx	40	36	-35	-10	-25	0	59
pp	45	43	-30	-30	-35	-37	68
	44	53	-35	-30	-35	-40	67
	45	53	-35	-30	-35	-40	70
	50	56	-35	-30	-35	-40	72
	45	57	-20	-35	-35	-30	74
	40	52	-35	-35	-30	-35	60
	42	59	-35	-30	-30	-35	57
	50	65	-35	-30	-30	-35	51
	56	70	-35	-42	-35	-30	46
	57	75	-33	-30	-30	-25	50
	52	80	-20	-20	-30	-20	50
turn	48	70	-15	-10	-30	-10	48
	45	70	-25	-15	-26	-10	46
	45	69	-25		-6	0	57
	42	65	-19		-10	10	47
	45	60	10		0	15	50
	55	58	10		-2	20	40
	55	50	20		6		50
	50	50			2		52
	50	52					43
	60	67					
	62	72					
	65						
	70						
	72						

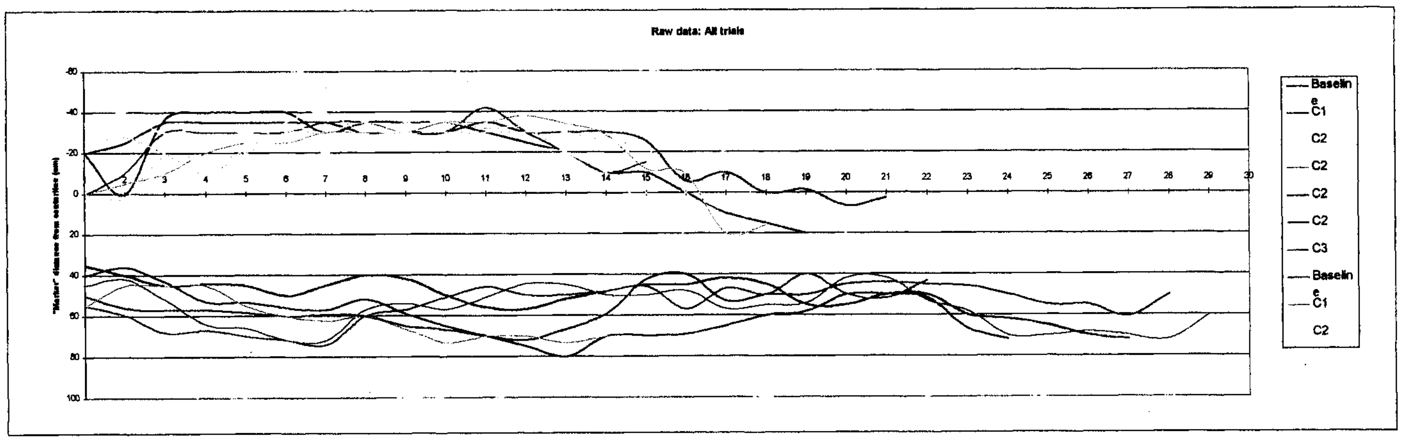
	Baseline	C1	C2	C2	C2	C2	C3	
T2	50	45	-24	0	-35	0	55	
	56	42	-28	2	-40	-5	45	
	57	52	-20	-19	-30	-10	45	
	57	64	-10	-17	-33	-20	45	
	58	66	-22	-20	-30	-25	55	
	60	72	-35	-30	-33	-25	60	
	59	72	-40	-30	-30	-30	62	
	60	57	-30	-35	-30	-30	60	
	65	54	-35	-30	-30	-30	67	
	67	57	-35	-30	-25	-35	73	
(turn)	70	51	-32	-30	-25	-35	70	
	72	44	-32	-30	-23	-38	70	sped
	67	45	-20	-30	-20	-34	73	clipped red light
	59	50	-10	-25	-10	-29	70	
	42	50	0	-22	8	-12		chatt.
	40	48	22	0		-9		
	53	57		12		20		
	50	55		36		16		
	50	54						
	45	42						
	44	42						
	45	53						
	46	58						
	50	70						
	55	70						
	55	68						
	61	70						
	50	72						
		60						

Means

Baseline	C1	C2	C3
51.93	57.73	-22.75	32.67

SD's

Baseline	C1	C2	C3
8.72	10.47	15.06	10.26



t1	Baseline	C1	C2	C2	C2	C2	C3	
wc	40	43	-20	-30	-26	-30	23	
	40	40	-15	-35	-30	-30	10	
	38	40	-30	-35	-34	-35	20	
cwwc?	37	40	-32	-30	-30	-35	25	
	34	43	-20	-20	-30	-30	· 35	
	30	30	-10	-15	-30	-34		camera stop[
	27	30	0	-10	-30	-30		<<<<<
	25	38	10	0	-30	-30		
	27	30	10	10	-25	-35		
	30	30		20	11	-20		
	40	60		30		-15		
	45	60		30		-10		
	47	62		30		0		
	52	55				20		
turn	47	45				30		
	42							
	38							
	34							
	38							
vc driver	48							
	45							
	43							
	44							
	45							
	44							
	42							
	41							
	40							

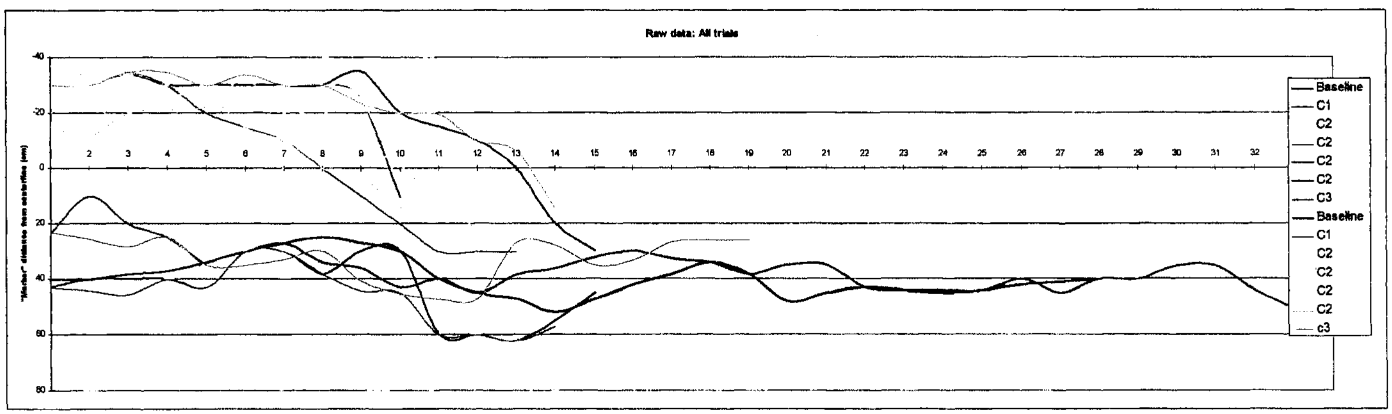
t2	Baseline	C1	C2	C2	C2	C2	c3	
	40	43	-15	-30	-26	-30	23	
	40	44	-12	-35	-30	-30	26	
	38	46	-20	-35	-34	-35	29	
	37	40	-21	-30	-26	-35	25	
	34	43	-22	-27	-30	-30	35	
	30	30	-32	-15	-28	-34	35	
	27	30	-20	-10	-30	-30	33	
	34	38	-21	0	-30	-30	30	
	36	44	-10	3	-25	-24	41	
	43	45	-1	14	7	-20	46	
	40	60	10	14		-20	47	stop on C2
	45	60	10	22		-10	47	
	38	62		26		-7	27	
	36	57				14	28	
	32						35	
	30						33	
	33						27	
	34						26	
	38						26	
	35							
	35							
	43							
	44							
	44							
	44							
	40							
	45							
	40							
	40							
	35							
vc driver	35							
	44							
	50							
	50							

Means

Baseline	C1	C2	C3
38.11	44.40	-15.93	16.41

SD's

Baseline	C1	C2	C3
6.24	10.82	19.03	9.10



t1	Baseline	C1	C2	C2	C2	C2	C3
	60	65	0	-10	-20	-10	77
	55	60	-15	-20	-30	-20	78
	53	60	-20	-20	-20	-25	78
	53	60	-20	-30	-20	-20	74
zBs	54	60	-20	-20	-25	-20	69
	57	55	-20	-15	-20	-30	66
	55	55	-15	-15	-10	-10	59
	61	45	-15	-10	5	0	55
	70	40	-10	0	20	10	60
	75	35	0	10	10	25	60
	73	35	0	10	10	25	65
	80	34	5	15	10	35	65
	76	39		20		35	68
	40	43		25		25	68
	43	43					59
	33	40					57
	30	40					54
	37	43					54
	42	45					60
turn>>	50	50					67
	50	55					67
	58	60					51
	61	70					50
	64	75					48
	68	75					55
	70	80					55
	68	80					53
	65	82					55
	70.8	78					53
	100	80					
	100	100					

t2	Baseline	C1	C2	C2	C2	C2	C3
	55	40	-20	-10	-25	-10	86
	55	48	-15	-25	-30	-20	76
	53	48	-20	-25	-25	-25	82
	53	47	-25	-28	-22	-25	74
	54	41	-28	-30	-25	-23	69
	57	39	-30	-15	-20	-25	66
	55	38	-25	-15	-10	-10	59
	60	43	-15	-10	-10	0	55
	60	40	-10	5	20	18	58
	60	35	0	5	10	20	58
	60	35	10	10	10	29	64
	66	34	10	10	15	28	65
	55	39	12	20	15	33	65
	49	43		20			60
	43	35		25			60
	47	40		30			60
	39	40					55
	37	45					59
	42	45					60
	50	50					70
	50	55					70
	58	60					65
	61	68					65
	64	75					48
	68	75					60
	70	80					
	76	80					
	77	82					
	80	78					
	81	80					
	80	83					
	77	89					

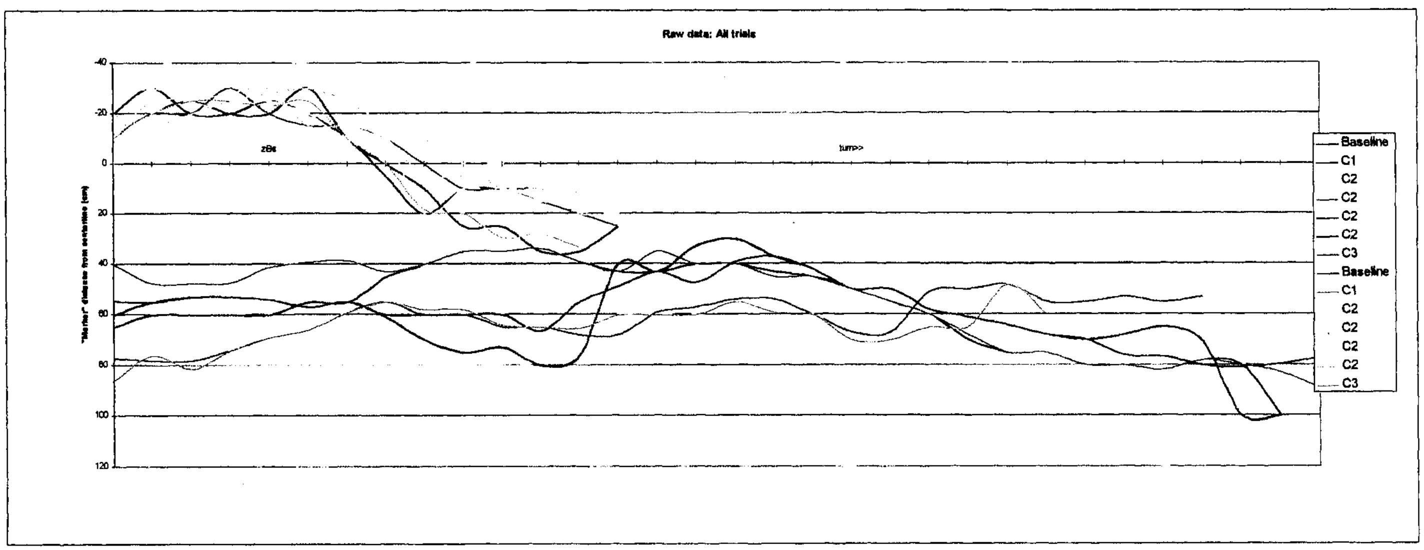
lw straddle on all? C2's

Means

Baseline	C1	C2	C3
51.69	27.09	6.42	38.16

SD's

Baseline	C1	C2	C3
12.41	32.26	30.89	8 75



	Baseline	C1	C2	C2	C2	C2	C3	
ebt1	52	34	-25	12	15	8	65	
	52	39	-20	3	10	5	63	
zzeb	50	48	-10	-15	0	0	56	
	55	59	-10	-15	10	-10	59	
	53	60	0	-15	5	-18	65	
	55	64	2	-10	0	-15	69	
	56	65	5	-10	-10	-15	70	
	56	56	0	-15	-10	-20	75	
	62	55	2	-12	-15	-20	68	
	66	57	2	-8	-15	-15	59	
	70	55	10	0	-14	-10	58	
	74	49	5	0	-10	-10	60	
	80	47	0	0	-10	-15	62	
	69	49	-13		0	-5	64	
	64	50	-13		0	3	57	
	62	49	-10		-10	14	63	
	59	59	20		0	20	75	
	55	60			20	45	65	<appr.ca
	54	60					60	onC2
	48	52					65	<<
	44	46					52	
	47	53					43	
	53	63					36	
	62	71						
		71						
		70						
		70						

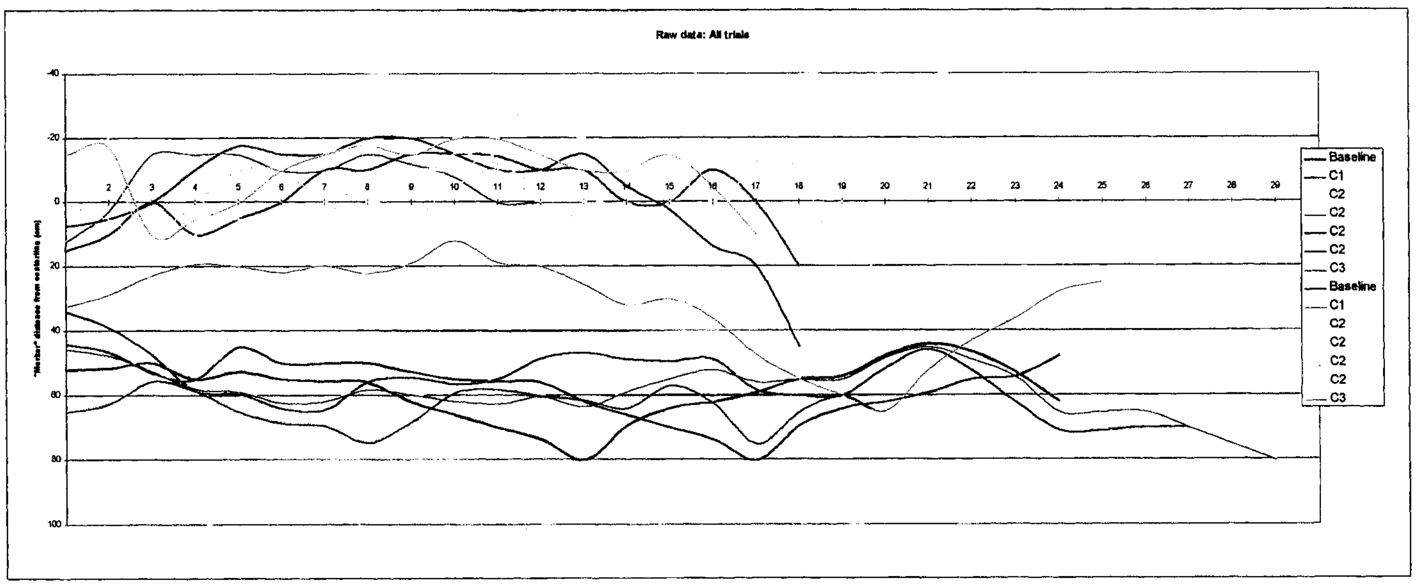
t2	Baseline	C1	C2	C2	C2	C2	C3
	44	46	0	-10	0	-15	33
	47	48	5	-13	-10	-18	29
	53	52	10	12	15	10	23
	55	58	0	3	10	5	19
	45	59	-10	-10	5	0	20
	50	62	-10	0	8	-10	22
	50	62	0	0	5	-15	20
	50	58	5	-5	0	-18	22
	53	60	5	-5	-10	-15	19
	55	62	-5	-15	-10	-20	12
	56	63	-10	-12	-15	-20	19
	56	60	0	-5	-15	-15	20
	62	64	5	0	-20	-10	26
	66	59	5	0	-10	-10	32
	70	55	0	10	-10	-15	30
	74	52	-13		0	-5	36
	80	56	-13		-10	10	48
	69	55	-10		-10		55
	64	55	25		0		60
	62	48			30		65
	59	45					52
	55	49					43
	54	54					36
	48	65					28
		65					25
		65					
		70					
		75					
		80					

Means

Baseline	C1	C2	C3
57.54	28.89	-1.13	31.58

SD's

Baseline	C1	C2	C3
7.65	28.32	14.23	8.87



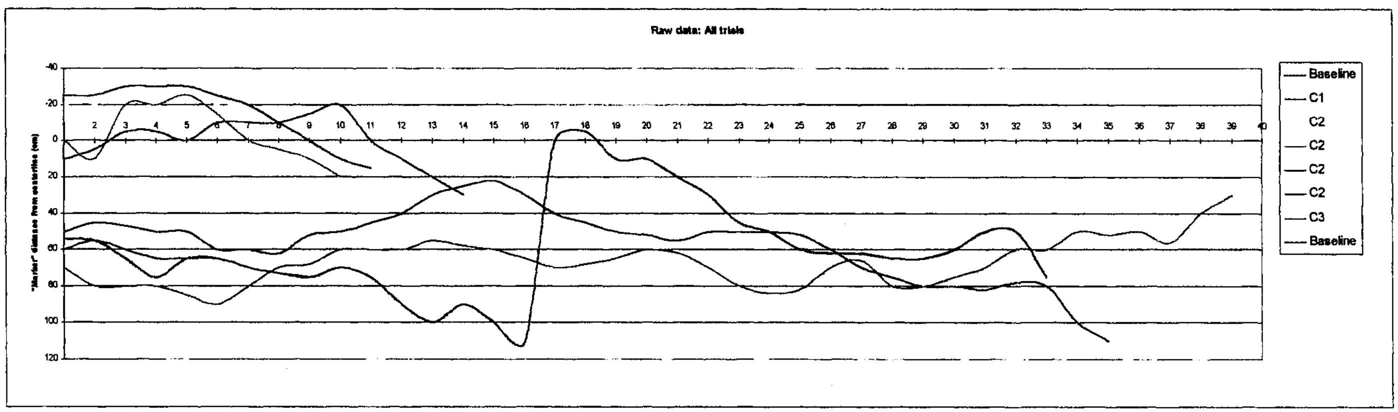
zHPt2	Baseline	C1	C2	C2	C2	C2	C3	t2	Baseline
	54	50	-20	0	-25	10	70		60
	55	45	-20	10	-25	5	80		55
	65	47	-28	-20	-30	-5	80		60
	75	50	-30	-20	-30	-5	80		65
	65	50	-30	-25	-30	0	85		65
	65	60	-20	-15	-25	-10	90		65
	70	60	-20	0	-20	-10	80		70
	73	62	-10	5	-10	-10	70		73
	75	52	0	10	0	-15	68		75
	70	50	10	20	10	-20	60	C.Stop	
	75	45	15		15	0	60		
	90	40				10	60		
	100	30				20	55		
	90	25				30	58		
	100	22					60		
Turn	110	30					65		
	0	40					70		
	-5	45					68		
	10	50					65		
Very	10	52					60		
slow	20	55					62		
traffic	30	50					70		
	45	50					80		
both	50	50					84		
trials	60	52					82		
	62	60					70		
sped	62	70					66		
on	65	75					80		
C2	65	80					80		
	60	80					75		
	50	82					70		
Ran	50	78					60		
stop	75	80					60		
		100					50		
		110					52		
							50		
							56		
							40		
							30		

Means

Baseline	C1	C2	C3
58.35	46.09	-7.78	70.00

SD's

Baseline	C1	C2	C3
33.14	10.70	16.33	10.03



DJA Nov	Baseline	C1	C2	C2	C2	C2	C3	
	40	90	15	20	-50	10	80	
	45	60	10	15	-50	0	80	
	50	50	6	10	-50	-10	70	
DJA Nov	50	40	4	0	-50	-10	65	
	55	30	0	-10	-40	-20	65	
	60	30	-10	-10	-30	-30	70	
	90	35	-10	0	-30	-30	70	
	100	35	-10	10	-10	-30	72	
	100	40	0	20	0	-20	72	
	100	45	15	20		-10	70	
	110	55	25	40		0	60	
Turn	120	55		50		20	50	
	100	54		40		30	47	
	90	50				40	40	
	80	48					40	
	70	50					40	
	60	50					48	
	55	50					50	
	50	52					55	
	45	53					40	
	50	50					35	
	50	50					30	
	45	40					35	
	60	45					35	
	65	20					35	
	70	30					30	
	50	40					30	traffic on c3
		45					35	<<<
		55					40	
		53					40	
		60					40	
		70					30	
							20	
							20	
							22	
							24	
							24	
							26	
							22	

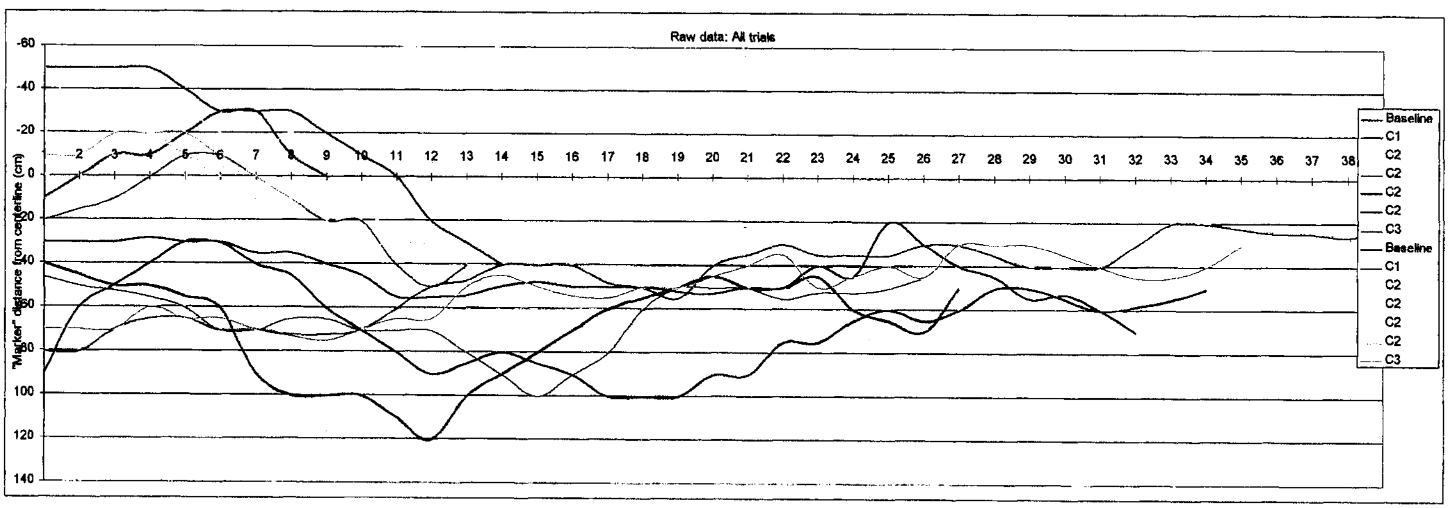
Trial 2	Baseline	C1	C2	C2	C2	C2	C3
	30	46	-20	0	-50	-10	70
	30	50	-25	0	-30	-10	70
	30	52	-25	-10	-30	-20	70
	28	55	-20	-20	-30	-20	60
	30	60	-10	-10	-30	-20	65
	30	70	-5	0	-20	-10	65
	40	70	0	10	-10	0	70
	45	65		10	-20	10	73
	60	65		20	-10	20	75
	70	70		30	-10		70
	80	70		30			65
	90	70		30			65
	85	80					50
	80	90					45
	85	100					50
	90	90					54
turn	100	80					55
	100	60					50
	100	50					50
	90	50					45
	90	50					40
	75	55					35
	75	52					50
	65	52					45
	60	50					40
	65	45					45
	60						30
	50						30
	50						30
	55						35
	60						40
	58						45
	55						45
	50						40
							30

Means

Baseline	C1	C2	C3
65.92	54.78	-5.12	48.03

SD's

Baseline	C1	C2	C3
23.12	15.82	22.47	16.63



AS Nov 2	Baseline	C1	C2	C2	C2	C2	C3
	70	50	-20	20	-40	10	50
	70	45	-20	10	-30	-15.1	45
	75	45	-30	-8	-30	-17.5	50
	75	50	-30	-14.4	-30	-10	45
	76	50	-30	-8	-30	-20	60
as2	70	45	-30	-8.9	-10	-30	70
	70	50	-30	10	0	-20	70
	75	55	-20	20	10	-10	65
	80	55	-10	30	50	0	50
	85	55	0			20	60
	90	60	10			30	50
	100	60	15			24.5	60
Turn	110	55				21.4	60
	45	55					55
	50	50					55
	60	40					50
	65	48					45
	70	55					40
	70	45					45
	60	60					40
	70	60					53
	80	70					60
	90	80					70
		90					70
							75
							80
							70
							65
							50
							40
							40
							45
							45
							30

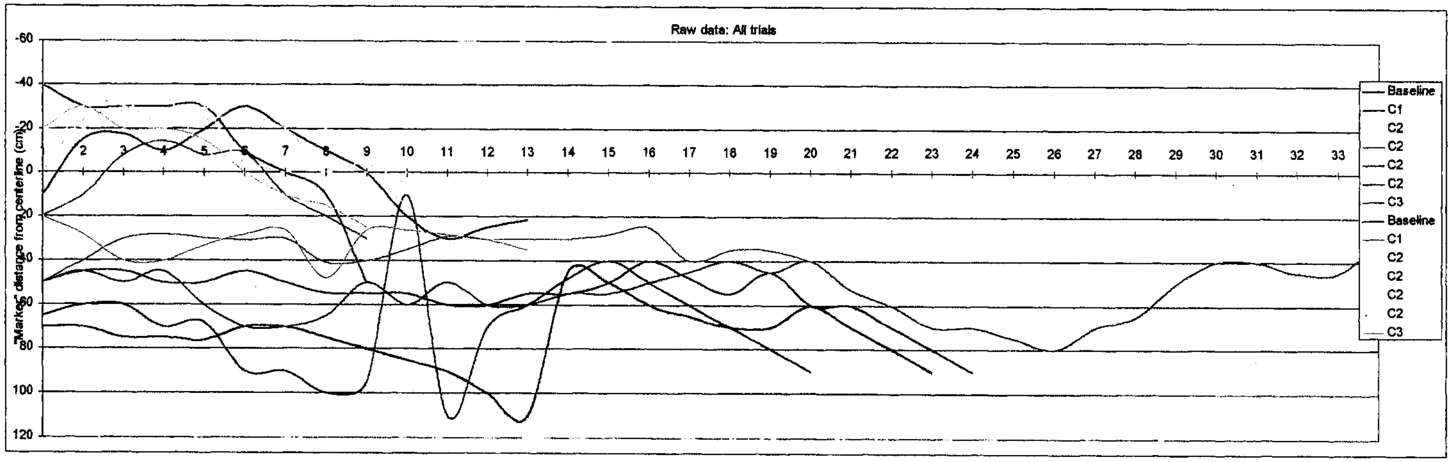
Trial 2	Baseline	C1	C2	C2	C2	C2	C3
	65	50	0	0	-40	-20	20
	60	40	-30	-24	-35	-30	28
	60	30	-30	-28	-35	-20	40
t2cirex	70	28	-22	-35	-35	-20	40
	68	30	-24	-10	-30	-15	33
	90	31	-25	-5	0	0	28
	90	30	-20	0	10	10	26
	100	41	-2	0	15	15	48
	95	40	0	-4		25	26
	10	35	15	5			26
	110	29		10			28
	70	30		10			30
	60	30					35
	48	30					
	40	28					
	50	25					
	60	40					
	70	35					
	80	35					
	90	40					

Means

Baseline	C1	C2	C3
71.91	45.55	-8.48	48.21

SD's

Baseline	C1	C2	C3
19.00	14.27	19.93	15.13



Dec 19 E	Baseline	C1	C2	C2	C2	C2	C3
	50	26	-30	10	-40	30	60
	50	30	-20	0	-40	3	60
	50	30	-10	-10	-30	-23	60
Rev	50	35	0	-10	-30	-23	65
	60	40	0	-20	-30	-30	70
	70	45	-10	-30	-20	-20	75
	70	50	-20	-40	-20	-30	80
	65	50	-30	-30	-30	-30	80
	75	53	-30	-30	-20	-40	85
	60	54	-20	-20	-20	-25	80
	90	50	-10	-10	-10	-10	70
	110	50	0	0	0	0	60
	120	50	20	10	10	10	55
turn	130	57		20	20	20	50
	30	45			30	30	45
	55	50			35		45
	50	57					45
	50	60					45
	50	60					50
	55	55					60
	60	50					60
	65	60					60
	70	70					65
	70	70					50
	70	67					45
	65	70					40
	65	80					45
	60	90					50
	65	110					50
	55						40
							40
							30
							25
							20
							20
							10

Trial 2	Baseline	C1	C2	10	C2	C2	C3	
	75	30	-30	0	-40	5	50	
	75	40	-20	-10	-30	0	60	
	70	45	-10	-20	-30	0	60	
	65	45	-10	-30	-30	-10	50	
	60	50	-20	-30	-30	-20	50	
	65	60	-30	-30	-20	-30	50	
	70	65	-35	-30	-25	-30	60	
	70	50	-35	-20	-30	-30	70	
	75	50	-30	-10	-20	-30	75	
	80	55	-20	0	-10	-30	80	
	90	55	0	10	0	-20	85	
	100	40	30	10	5	0	90	
	110	35				10	80	
	120	50				40	75	
	130	50				40	75	
	140	55					70	
turn	140	50					70	
	70	55					80	
	60	55					85	
	50	50					75	
	55	50					65	
	60	55					65	
	60	40					70	
	55	45					80	
	50	50					80	
	55	65					85	
	55	70					50	
	55	70					50	
	55	65					45	
	60	70					40	follow truck
		90					40	
		100					40	
		120					40	
							40	
							40	
							45	
							45	
							40	
							40	
							35	

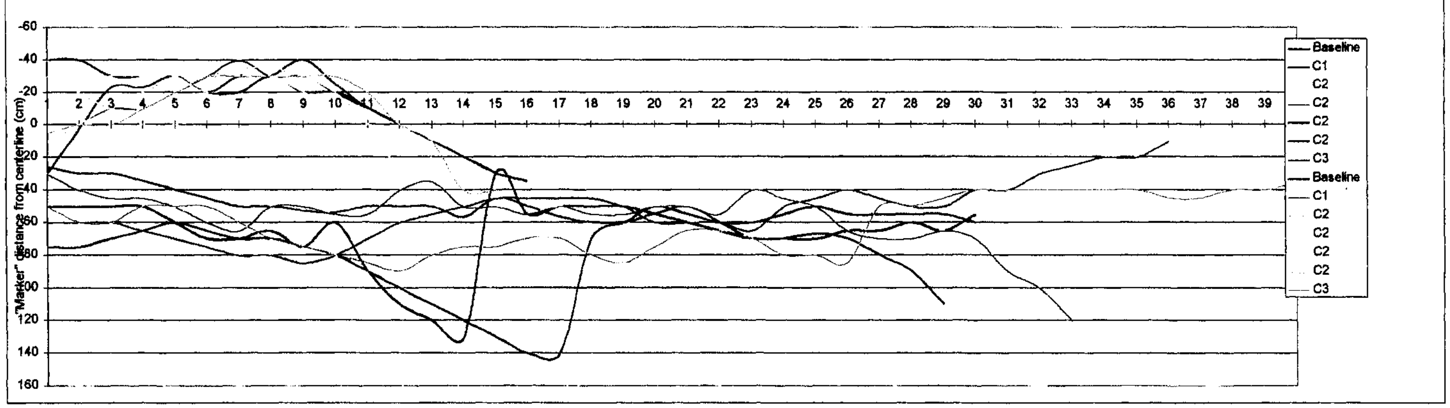
Means

Baseline	C1	C2	C3
71.00	56.27	-12.73	56.78

SD's

Baseline	C1	C2	C3
24.47	17.87	19.59	17.75

Raw data: All trials



Appendix C

ANOVA Table

Analysis of Variance: RW / VE all conditions.

Anova: Two-Factor With Replication

SUMMARY	Baseline	C1	C3	C2	Total
VE					
# of subjects	14	14	14	14	56
Mean	**191.66**	**159.54**	**177.18**	**112.74**	**160.28**
Variance	803.34	1124.42	1456.03	940.59	1921.03
RW					
# of subjects	14	14	14	14	56
Mean	**156.79**	**147.50**	**148.34**	**91.02**	**135.92**
Variance	89.15	169.68	257.58	52.64	831.97
Grand means					
Grand mean	**174.23**	**153.52**	**162.76**	**101.88**	
Variance	744.83	660.58	1040.78	600.45	

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
RW vs VE	16618.1	1	16618.1	27.1678	9.5E-07	3.93243
Driving route	85773.4	3	28591.1	46.7418	3.3E-19	2.69198
Interaction	2026.76	3	675.587	1.10447	0.35081	2.69198
Within	63614.9	104	611.682			
Total	168033	111				

Post Hoc Analysis (Newman-Keuls)

Conditions compared	Means	Difference (cm)
Baseline vs. C3	174.23 vs. 162.76	11.47
Baseline vs. C3	174.23 vs. 153.52	20.71*
Baseline vs. C3	174.23 vs. 101.88	72.35**
C3 vs. C1	162.76 vs. 153.52	9.24
C3 vs. C2	162.76 vs. 101.88	60.88*
C1 vs. C2	153.52 vs. 101.88	51.64*

*p < .05
**p < .01

Appendix D

Q7, Q8 & Q9
From Subject Survey

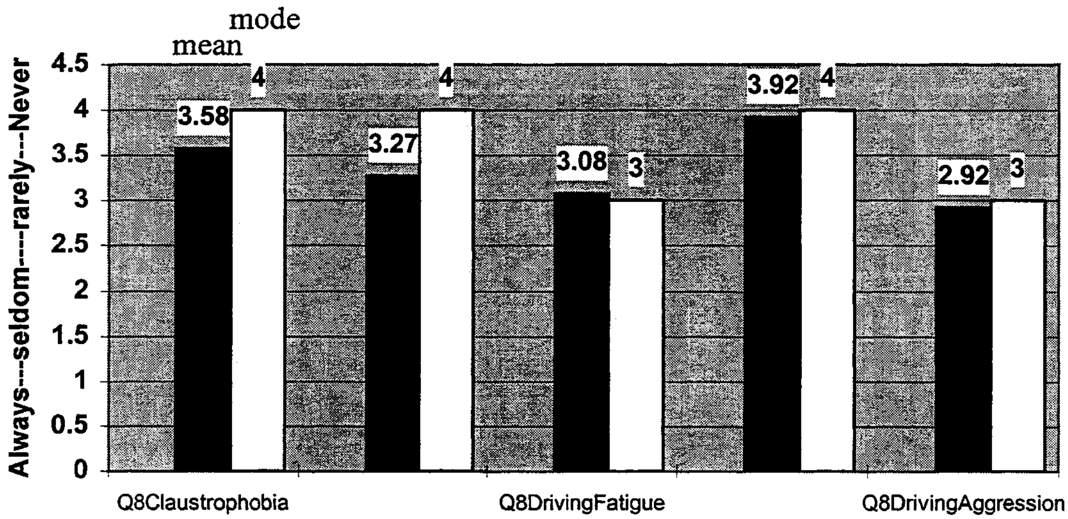
Q7. Nausea during test.

Occurrence, description and correction of nauseogenic effects.

Sub. #	YES	NO	When?	Why?	Correction.	Previous nausea? from pre-test)
1	X		early	turns		
2		X				
3		X				
4	X		late	after standing		
5		X				
6	X		midway			
7		X				
8	X		early		it passed	X
9	X		early		it passed	X
10		X				
11	X		early	turns & stops	focus on distant object	
12		X				
13	X		end	turns	blink/close eyes	X
14	X		early	non-specific	focus on distant object	X
15	X		early	turns	chewing gum	X
16	X		early	non-specific		X
17	X					
18		X				
19	X		after test	non-specific		
20		X				X
21	X			turns		X
22	X		after test			
23	X			turns & stops		X
24		X				
25		X				X
26		X				

Q8 Phobias & driving behaviors

Means and Modal responses to Q8 (pre-test).



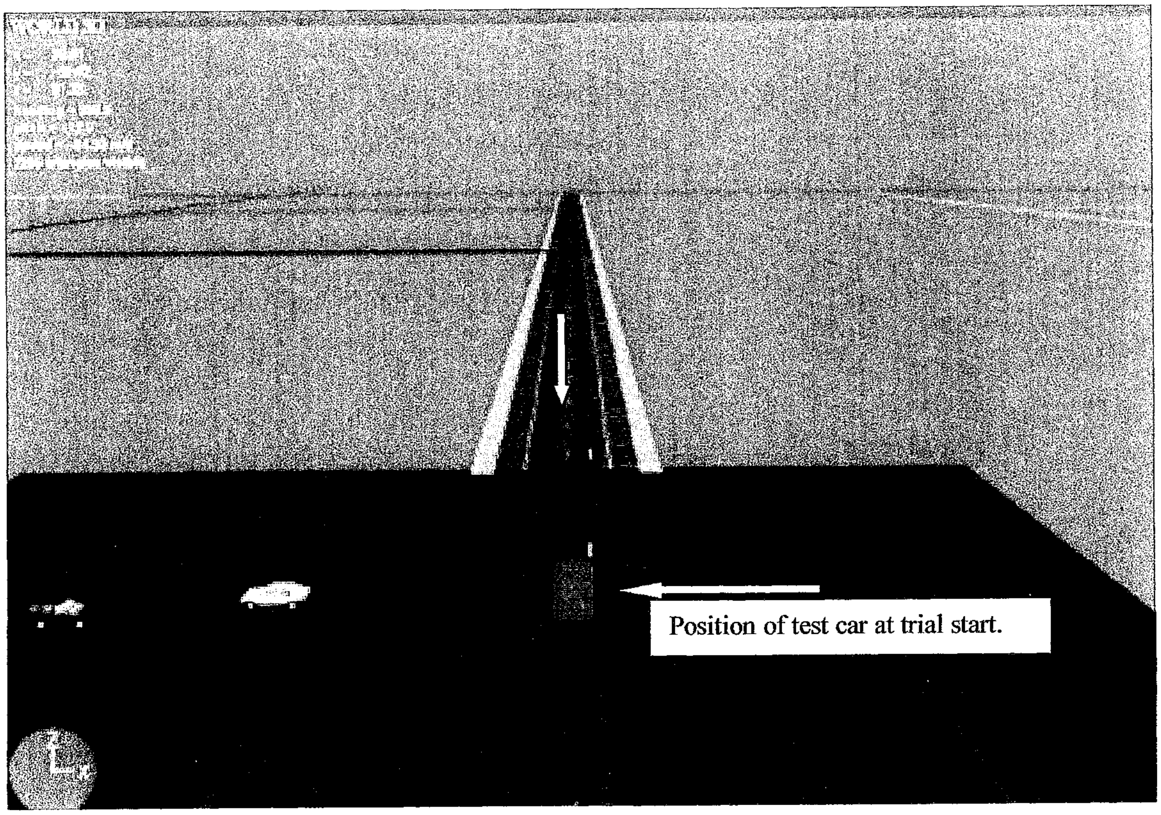
Q9 Driving conditions/frequency: Population Averages, Mode and SDs. **(N=26)**

General driving conditions.	5-7 days/week-----2-5 days/week-----1/week------1/month or less 1 -------------------2 ------------------3 -------- ----------4	Mode	sd
Under 35 mph	2.00	2	.97
35-55 mph	1.81	1	1.02
55+ mph	2.08	1	1.01
Heavy traffic	2.46	2	1.02
Moderate to light traffic	1.92	1	1.13

Appendix E

Virtual Environments:
Screen Shots and Descriptions

Parking lot: Static trials and vehicle familiarization.

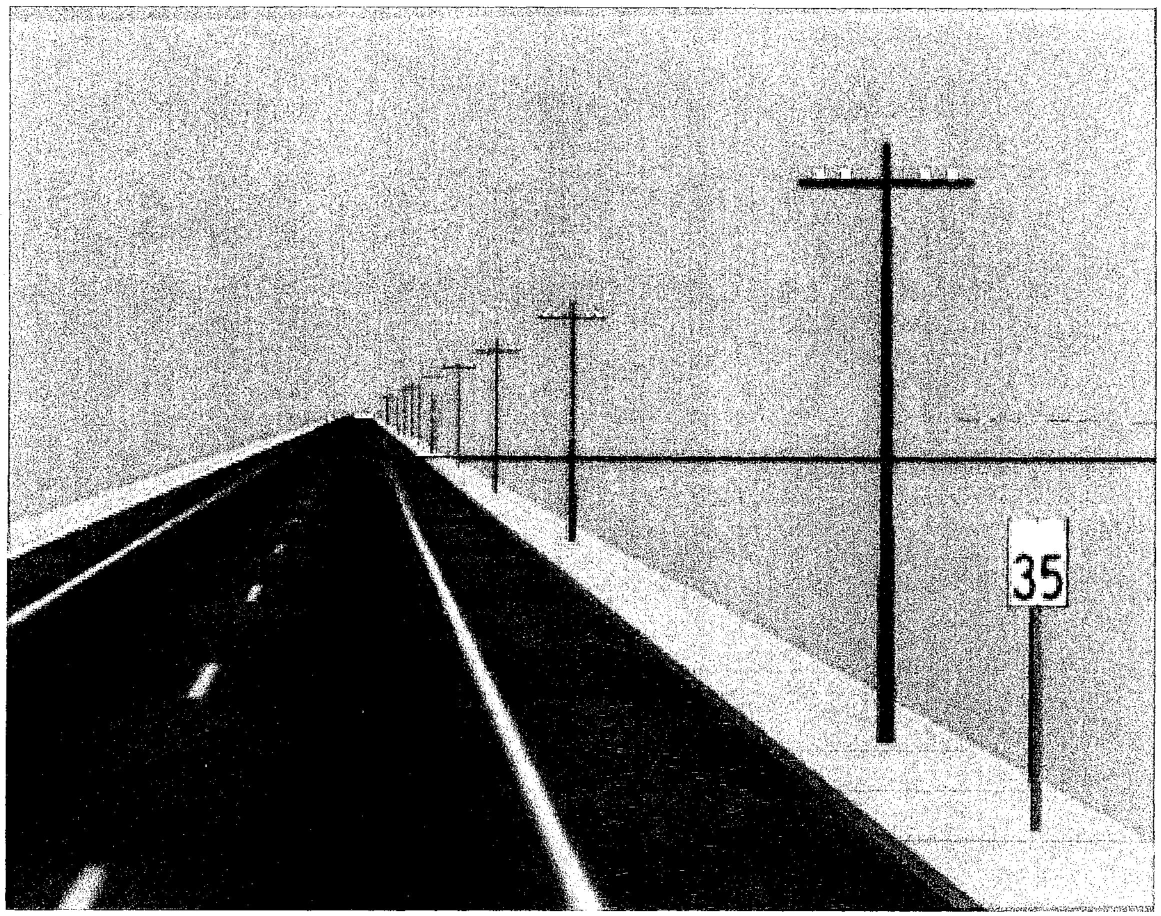


Parking lot.

Parking Lot, north view.

This is a frame shot of the Parking lot from an altitude of 31 meters in the VE. C2 can be seen as thin gray lines (different road surface) in the upper right of this image. The horizontal line in the distance is C1 and C3. The other roads are not test areas. The two small marks (one in the parking lot and one at the start of the road) are the test car marker and the visual "focus" target used for the optical stimulus trials. The optical stimul vehicles approach the test car from the right (off screen) and from directly ahead.

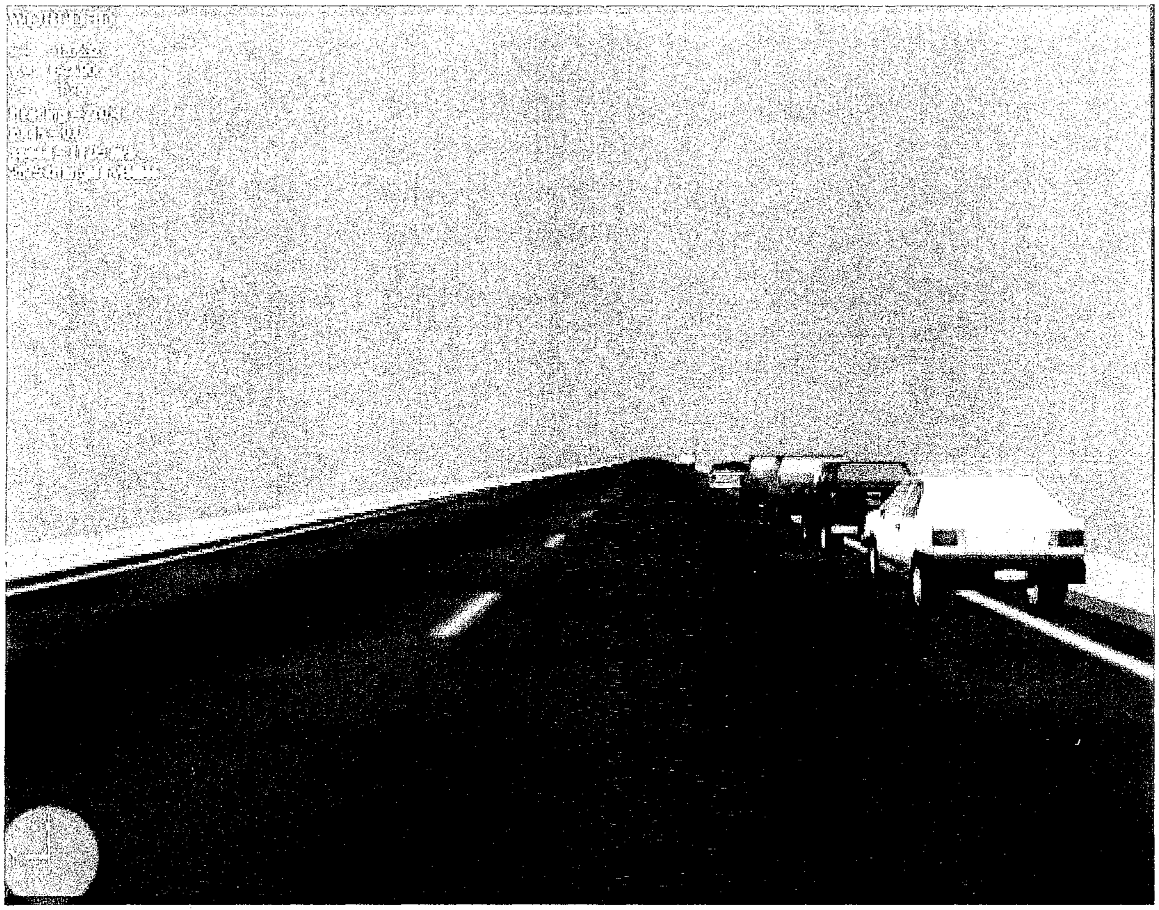
Baseline



Baseline, north view.

This is a screen shot of the north and south bound sections of the baseline condition in the VE. The only difference is the absence of visual stimuli near the edge of the road. The intersection of the road just ahead and to the right is approximately where data acquisition for baseline begins. The turn onto C1 is at the vanishing point of the baseline road. This view is from a higher perspective than that of the subjects in the VE vehicle.

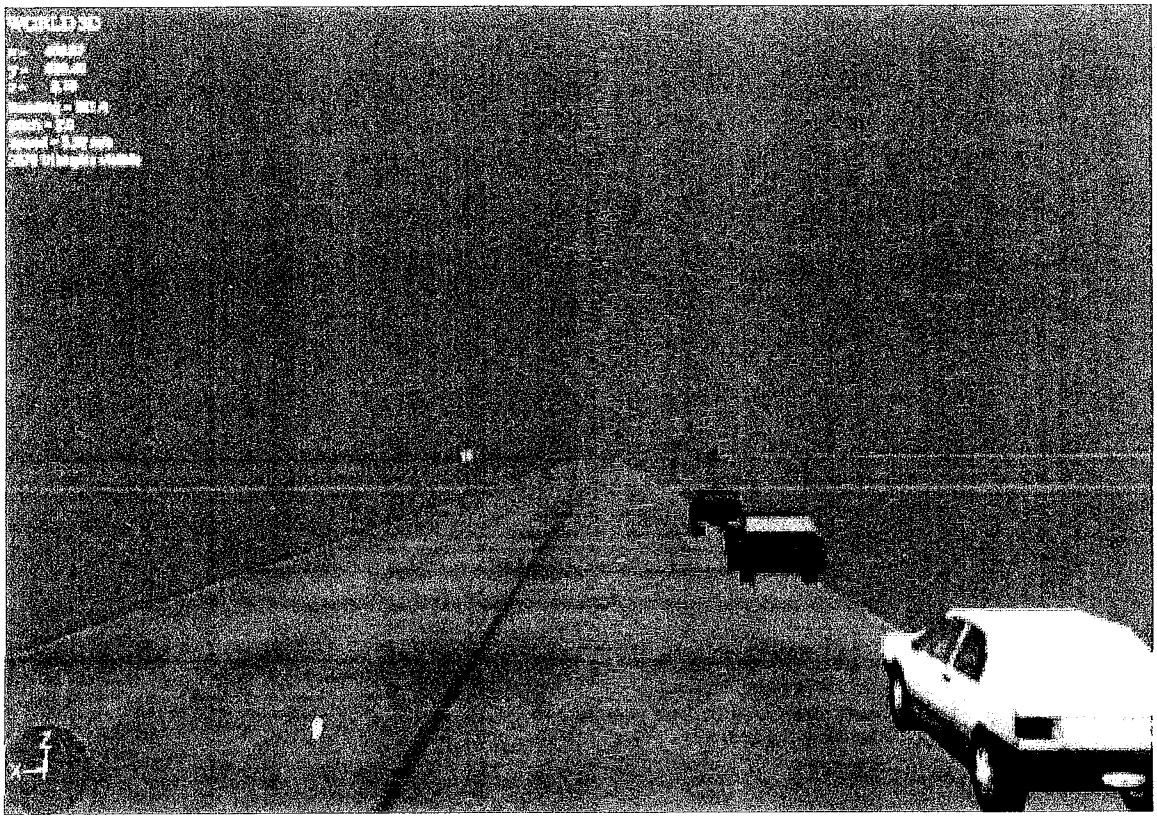
C1 / C3



C1 / C3, east view.

This is a screen shot of the east and west bound sections of the C1/C3 condition in the VE. The only difference is the absence of visual stimuli near the edge of the road on C3-westbound. This view is from a higher perspective than that of the subjects in the VE vehicle.

Residential: C2



C2, south view.

This is a frame shot of the south bound section of the C2 condition in the VE. The VE vehicle passes through this intersection and executes a left turn at the T-intersection two blocks ahead. The turn onto C2-northbound is one block after this left turn. This view is from a higher perspective than that of the subjects in the VE vehicle.