

CHAPTER 4. METHODOLOGY

According to Knippling et al. (1993), approximately 70% of all rear end crashes are Lead Vehicle Stationary (LVS) collisions. A realistic rear end conflict scenario was developed. This involved a replication of a car following situation and presentation of a stopped stationary vehicle as a result of a lane change. The scenario was presented in an on road "proof-of-concept" study, where participants were presented with the scenario only once to retain the element of surprise. Had subjects anticipated the presence of the surrogate vehicle, responses would not have been valid as subjects would not have responded in a realistic way.

Experimental Design

This experiment used a 2 x 2 between-subjects design that originally involved 32 subjects. A between-subjects design was chosen in preference to a within-subjects design to retain the "surprise" element. If subjects were exposed to unexpected braking more than once, the scenario of unanticipated emergency braking would be lost. This would compromise validity and reliability of the results due to braking behavior being affected. Valid obstacle data were collected for all 32 subjects, but one more subject in the no strobe condition was added as a result of a miscalculation by the experimenter. As her data were valid, the experimenter decided to incorporate her data into the analysis resulting in analysis of 33 subjects, 16 in the strobe condition and 17 in the no strobe condition. The experimental design is shown in Table 4.1.

TABLE 4.1. Original experimental design*

		Type of Signal Presented	
		No Strobe	Strobe
Young (25-35 years)	Males	Subject 1	Subject 17
		Subject 2	Subject 18
		Subject 3	Subject 19
		Subject 4	Subject 20
	Females	Subject 5	Subject 21
		Subject 6	Subject 22
		Subject 7	Subject 23
		Subject 8	Subject 24
Older (60-70 years)	Males	Subject 9	Subject 25
		Subject 10	Subject 26
		Subject 11	Subject 27
		Subject 12	Subject 28
	Females	Subject 13	Subject 29
		Subject 14	Subject 30
		Subject 15	Subject 31
		Subject 16	Subject 32

*Note: An extra young female in the no strobe condition was added to make a total of 33 subjects

Independent variables. Two independent variables were evaluated in this study: age and signal presence. These factors are between-subject variables and are described in more detail below.

1) Age. Each treatment condition was blocked by age. Half of the drivers in each treatment condition were termed younger (25-35 years old) and the other half were termed older (60-70 years old). According to Campbell, Wolffe, Blower, Massie, and Ridella (1990), younger and older age groups are over represented in terms of rear end collisions (same direction, non-intersection types). These participants were recruited from a database of participants maintained by VTTI.

2) Signal presence. This was a proof of concept study and so only two levels of signal presence were tested: signal and no signal. The purpose was exploratory; it was not necessary to use any other configurations of the lighting system. The purpose was to explore the possibility of using a type of flashing signal and its effect on driving behavior when faced with a rear end conflict. Consequently, only the strobe light was displayed on the stationary vehicle at the time it was revealed to subjects (no standard brake lights were used). There was also a possibility that the standard brake lights would have interfered with the effects of the warning signal. In addition, not displaying brake lights reflects real life situations where stationary vehicles often do not display their taillights when stopped in traffic lanes. The flashing signal was triggered shortly before the surrogate vehicle came into the subjects' view. Subjects therefore were presented with the flashing signal and the surrogate vehicle at the same time.

Dependent variables. Dependent variables reflected the urgency and severity of driving behaviors exhibited by subjects in response to the rear end conflict. Therefore, it was possible for meaningful analysis and comparisons to be made between signal and no signal conditions. Multiple dependent measures assessed aspects of driving behavior by using variables related to perception, first response, steering, braking and stopping behavior. The speed or urgency with which subjects performed the aforementioned behaviors was assessed by using Perception Response Time (further separated into Perception Time and First Response Time components), Time to Brake, Brake Response Time, Brake Movement Time, Time to Steer, Steering Response Time, and Steering Movement Time. The severity of a subjects' response was assessed by using Maximum Brake Press, Maximum Steering Deviation, and Rate of Steering. All driver response times were measured with respect to frame number on the video tape and the data file recorded by the ICAR program. Velocity and Time-To-Collision variables were also captured and assessed to ensure the reliability of the measures to assess whether all subjects received identical conditions.

Figure 4.1 shows graphically the nature of response data in terms of a timeline for a subject who exhibits an accelerator release as a first movement and uses braking as an initial response. In this timeline example, a participant responds to the scenario by braking and steering around the

surrogate vehicle. This is simply an illustration to aid visualization of the types of dependent measures discussed previously, and not an actual representation of the timing of real life events.

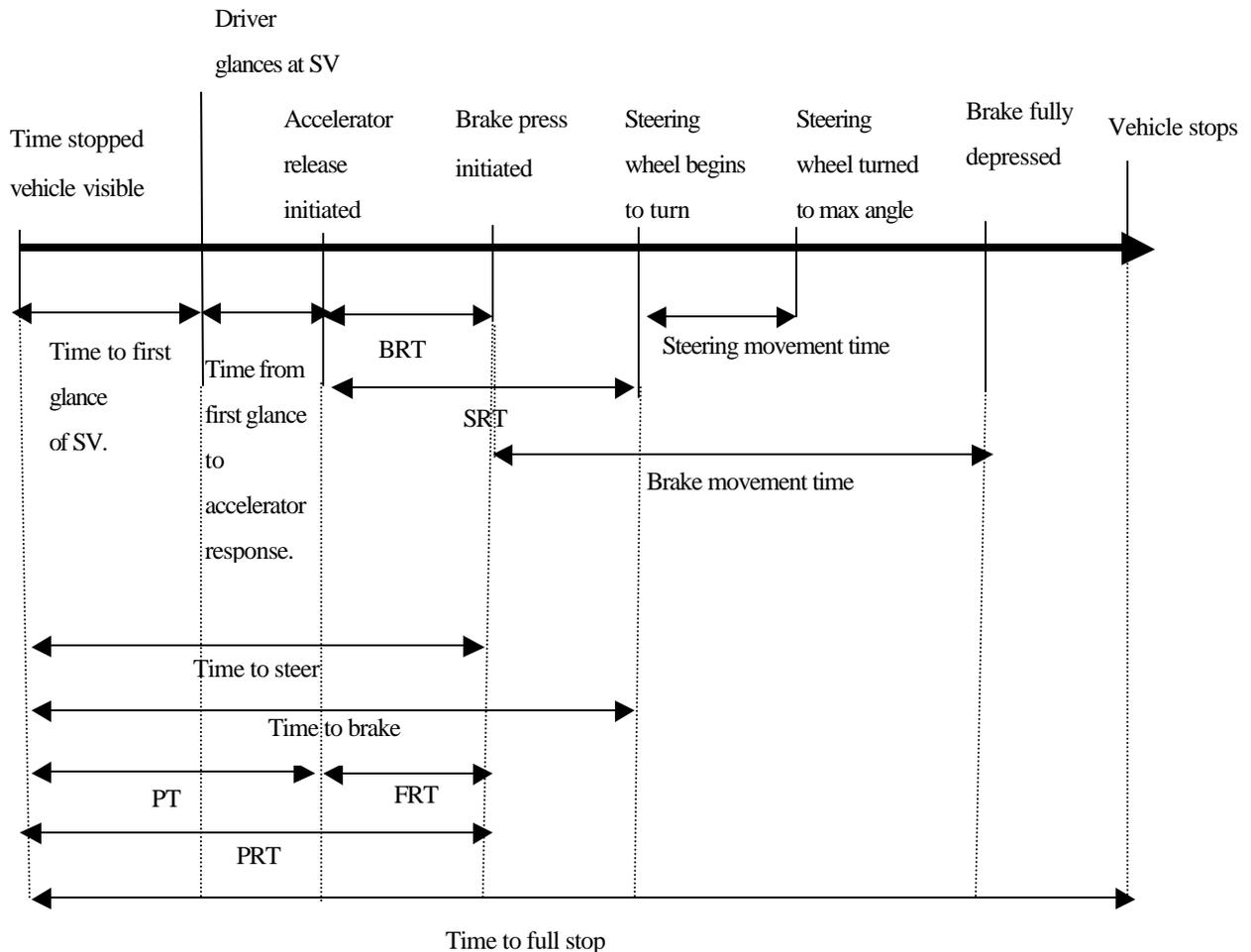


Figure 4.1. Timeline showing summary of dependent measures (response times only)

Figure 4.1 shows the behavior of a subject whose first movement is to release the accelerator. A few subjects did not have their foot resting on the accelerator as the constraints of the road forced subjects to coast down to the approach. For cases where subjects' first movement was to initiate a braking response (as their foot was resting over the brake pedal), there was no brake response. Steering response times would also begin at the moment of this first movement.

What follows are more detailed descriptions of the dependent variables that reflect the urgency of subjects responses (i.e., all response times as depicted in Figure 4.1). Time to First Glance

and Time from First Glance to Accelerator Response were originally proposed as dependent variables, but the majority of subjects were not looking down prior to perception of the stopped vehicle. As the majority were looking ahead, these dependent variables were not included in the analysis.

1) Perception Response Time (PRT). Hankey (1996), Lechner and Malaterre (1991), Lerner (1993), and Olson and Sivak (1986) conducted studies that measured reaction time in terms of PRT. PRT is defined as "the time between when an object or stimulus first becomes visible and when the subject responds." As such, PRT was calculated by summing perception and first response times (see detailed descriptions below) to determine whether overall reaction times were affected by the presence of the signal. The studies reviewed showed a difference in PRT depending on the urgency of a situation.

2) Perception Time (PT). Perception time was operationally defined as the time elapsed from the moment that the rear end conflict was "visible" to the point that the subject initiated their first movement (i.e., accelerator release or brake press if foot already over brake pedal). "Visibility" of the rear end conflict was determined using the frame on the front view videotape. The frame was used in conjunction with the data file recorded by the ICAR data collection program to determine the exact time that the stopped vehicle appeared. The surrogate vehicle was considered visible when the van had moved far enough across the lane to reveal any part of stopped vehicle on the video camera.

3) First Response Time (FRT). This dependent measure refers to the transition time from first movement to the initiation of the first collision avoidance response (e.g., braking or avoidance steering). Six subjects whose first movement was to press the brake were eliminated for this dependent variable, as they had no detectable transition between perception and first response. This category was also broken down into two subcategories (Brake Response Time and Steering Response Time) and whichever occurred first was analyzed as the FRT.

4) Time to Brake Press. This is defined as the time elapsed from the moment that the rear end conflict was visible to the moment a brake press was initiated. This dependent measure was

included to determine whether subjects overall initiation of a brake response was changed by the presence of the signal.

5) Brake Response Time (BRT). This was defined as the time elapsed from accelerator release to the point at which the foot first made contact with the brake pedal. This measure was also a component of “time to brake.” This dependent variable was calculated using a combination of frame numbers on the foot camera and the normalized brake pedal position. Subjects who did not have an accelerator release were excluded from the analyses of this dependent variable.

6) Time to Steer. This was defined as the time elapsed from the moment that the rear end conflict was visible to the moment a steering maneuver was initiated. This dependent measure was included to determine whether subjects' overall initiation of steering maneuvers was changed by the presence of the signal.

7) Steering Response Time (SRT). This is defined as extending from the time of first movement to the time a steering movement was initiated. This time was also a component of Time to Steer. This was captured from the video camera facing the steering wheel, or from the steering wheel sensor to detect any movement/deflection of the steering wheel after accelerator release. Those subjects who had no steering response were eliminated from the analyses of SRT.

8) Steering Movement Time. This was defined as the time elapsed from initial movement of the steering wheel to maximum steering deviation.

9) Brake Movement Time. This was defined as the time elapsed from initial contact of the participant's foot with the brake, to when maximum brake depression occurred.

10) Time to Full Stop. This was measured as the time elapsed from when the stopped vehicle became visible to the point when the car stopped.

11) Final Stopping Distance Behind Surrogate. This was the point at which subjects stopped behind the surrogate vehicle. Only subjects who had predominantly braking responses were

included. The information to determine stopping distance was obtained from the radar sensor. Measurements were also verified by physically measuring the distance from the surrogate periodically.

As mentioned, other dependent variables measured the severity of the subject's behavior. These include:

1) Maximum Brake Press. This was the maximum normalized brake press expressed as a percentage (100% corresponds to a fully depressed brake).

2) Maximum Steering Deviation. This was the maximum deviation from zero that a subject steered to avoid the stopped vehicle.

3) Maximum Rate of Steering. This was the maximum rate of steering achieved in the first second of a steering response. This was expressed as degrees per second.

Subjective Variables. A post-drive questionnaire facilitated the assessment of attitudes towards the warning signal during the rear end conflict scenario. The post-drive questionnaire for those subjects who received the signal can be found in Appendix B and the one for those who were exposed to the rear end conflict without the signal can be found in Appendix C. The aim of the subjective questionnaire was to target data that could not be objectively collected through instrumentation and was designed to elicit information regarding several areas of inquiry. These areas include:

1) Effectiveness of the methodology. This was assessed using free responses to questions concerning feelings of danger during the experiment. Other issues such as realism and distraction were elicited through a combination of free responses and rating scales.

2) Effectiveness of the signal as a warning. Free responses and rating scales were again used to elicit the subject's opinion concerning the signal as an understandable warning that conveyed a sense of urgency.

Controlled Variables. Some elements of the experimental design were controlled to avoid possible confounds to the experimental data. These were as follows:

- 1) All trials were run in dry, clear weather during daylight hours.
- 2) Use of the Smart Road facilitated a heavily controlled driving environment.
- 3) Each participant drove the same vehicle in each trial. This established a standardized driving environment for each participant.
- 4) The lead vehicle maintained approximately the same speed on approaching the surrogate vehicle (25-mph). Control of speed allowed for a consistent estimate of time-to-collision for stimulus presentation.
- 5) The position of the surrogate vehicle was the same. The vehicle was positioned over the crest of a hill on the Smart Road and pilot tests were run to determine the feasibility of proposed procedures to pull the stopped vehicle out from its original hiding position. Tape was affixed to the roadway to provide consistent positioning of the stopped vehicle.
- 6) The timing of the lane swap to reveal the surrogate vehicle was the same for each trial. A combination of tape and fluorescent markers was used to indicate to the driver of the lead vehicle where she should change lanes. The same experimenter was also used to drive the lead vehicle for each trial.
- 7) A standardized set of instructions was read to each participant prior to experimentation.
- 8) Each participant performed the same distracter task and was asked to relay their comfort level of the following distance and to read the distance reading just prior to the rear-end conflict.

Subjects

A power analysis was performed to determine the number of subjects needed to ensure significance from the results. A power analysis is robust enough not to be affected by the lognormal distribution displayed by reaction time measures (which form the majority of data collected).

Power Analysis. In order to perform the computation, a predicted baseline and treatment brake reaction time had to be estimated. This was derived from a study performed by Lerner (1993). He estimated a mean brake reaction time of 1.5 seconds for drivers to react to barrels rolled unexpectedly towards them during an on-road study. This was considered a baseline in that no signals were used, yet unexpected emergency braking was required, similar to the proposed baseline condition.

The predicted reaction time to the treatment condition was derived from research performed by Sivak, Olson, and Farmer (1982). Sivak et al. (1982) collected one of the largest samples of reaction times to brake lights in unexpected situations. Knipling et al. (1993) relied upon results from this study to model reaction times and collision avoidance algorithms. The strobe was anticipated to evoke reaction times faster than or equal to a mean of 1.21 seconds as obtained by Sivak et al. (1982).

Finally, the standard deviation of 0.4 seconds was taken from Lerner (1993) to represent variation in reaction times exhibited by both young and old driver populations in unexpected braking situations. The results of the power analysis suggested a minimum of 15.98 drivers. Sixteen was selected to exceed this value while preserving experimental efficiency. These calculations can be found in Appendix D.

Participant population. The results from the power analysis suggested that a minimum of 32 participants (16 in each condition) was needed to increase the probability of finding statistically significant differences with a minimum number of participants. Thirty-three subjects were actually run in this study. Although an equal number of subjects was originally planned for each condition, an extra subject (a young female in the no strobe condition) was included. As

her data were valid, the experimenter decided to incorporate her data into the analysis resulting in the analysis of 33 subjects, 16 in the strobe condition and 17 in the no strobe condition. Participants were also divided into two different age groups.

The age ranges targeted were "younger" (25-35) and "older" (60-70) drivers. The mean ages of subjects in each age range group were 29 and 64 years for younger and older age range groups respectively. The overall mean age was 46 for both signal conditions.

The literature suggests a major difference in the accident rates of males and females. According to Dingus et al. (1998), men are three times more likely to be involved in driving accidents than women. However, in experiments such as this, only small, if any, differences are generally found between men and women on measures of driving performance. Nevertheless, to avoid any possible confounds, approximately equal numbers of male and female participants were recruited to run in the experimental sessions (there was one extra female in the experiment due to the addition of the extra subject).

Ability to participate in the experiment was determined by several criteria: 1) passing a visual acuity test with a score of 20/40 or better (as required by Virginia law), 2) passing appropriate health screening and pre-drive health questionnaires to ensure minimal risk (Appendix E), 3) presentation of a valid driver's license, and 4) signing an informed consent form (Appendix G). Anyone who did not fulfill these requirements did not participate. All those who did participate were instructed of their freedom to withdraw from the study without penalty. However, no subjects withdrew from the study. All data collected were handled with anonymity.

Each participant drove for approximately 40 minutes. It took approximately six minutes to complete a full lap. Subjects were given a practice lap and were asked to drive for just over five laps of the Smart Road prior to the conflict scenario, making the total amount of laps driven just over six. Then subjects were presented with the conflict and the session ended. The conflict was presented only once to prevent anticipation of future conflicts, which could confound results and undermine the realism of the scenario.

Apparatus

This section presents the apparatus required to reproduce the proposed conflict while collecting the relevant data in a safe and accurate way.

Surrogate vehicle (SV). The stopped vehicle, initially obstructed from the driver's view, was actually a full size simulated rear of a vehicle body. Figures 4.2 and 4.3 show the rear half of a production midsize automobile similar to the one used in this study. The body is constructed from fiberglass to allow compliance (deformation) on impact. The fiberglass body incorporated production taillights. This surrogate vehicle was attached to an aluminum frame and a 35-foot tongue assembly which was used to maneuver the surrogate vehicle into and out of position. The tongue included an 8-foot collapsible center for additional energy absorption. The vehicle also remained connected to a tow vehicle (a Crown Victoria) to allow the driver to accelerate forward to eliminate or reduce the possibility of a potential impact. However, the lead vehicle and experimenter effectively control led the participant's vehicle entry speed so that this was not an issue.



Figure 4.2. Surrogate vehicle: rear view.



Figure 4.3. Surrogate vehicle: side view

Strobe light. A 100 watt strobe light (7.75" x 7.75" x 8") that flashed at 4Hz was used as the flashing signal. Due to the attention value derived via the positioning of CHMSLs (Theeuwes and Alferdinck, 1995; Sivak and Flannagan, 1993; Sivak et al., 1986), the strobe light was positioned at the mid line of the car, just above the CHMSL (see Figure 4.4).



Figure 4.4. Positioning of strobe light on surrogate vehicle: rear view

Instrumented "following vehicle." A fully instrumented vehicle was also used to capture all data relevant to this study. Video images were used to capture vital data throughout the trials. The vehicle was instrumented with four miniature cameras including:

- A forward-looking camera mounted to the backside of the rearview mirror.

- A face/head/eye camera mounted in the rear view mirror and directed towards the driver.
- An over-the-shoulder camera mounted to the sunroof bezel, to provide views of the driver's hands and instrument panel.
- A foot camera to capture pedal movements.

These specific images provided the experimenters with a great deal of information. These images were combined and recorded as a quad-split image. Figure 4.5 shows a sample image with data overlays.



Figure 4.5. Typical quad-split image from the in-vehicle camera.

Sensors were installed into the participant's vehicle to measure the following:

- Steering position
- Accelerator position
- Brake actuation
- Lateral acceleration
- Longitudinal acceleration
- Vehicle velocity
- Inter-vehicle distance

Lead vehicle. The lead vehicle was a white 15-passenger van (see figure 4.6). This vehicle was chosen because of its size and ability to obstruct the view of the stopped surrogate

vehicle from the participant vehicle. This vehicle had no additional instrumentation other than the ability to communicate via radio with the experimenter in the subject vehicle and the experimenter controlling the stopped vehicle.



Figure 4.6. Picture of passenger van to be used as lead vehicle in Conflict Scenario.

Radar sensor and headway display. Information about headway distance (in feet) was displayed by the headway display, so that subjects could monitor their headway distance. The headway distance display was positioned on the dashboard (see figure 4.7) so that the subject could comfortably perform the distracter task without compromising safety.



Figure 4.7. Headway display

The radar sensor that provided the information about headway was positioned in the center of the following vehicle's front bumper. However, problems were occasionally experienced when the sensor missed the van by directing the radar below the vehicle. To prevent this from happening, cardboard was positioned at the center of the van to ensure that the radar would hit the target more effectively. The headway display and radar sensor were also recalibrated periodically during the study to ensure accuracy.

Preliminary Testing of Experimental Procedures

Procedures and parameters were assessed in preliminary tests before actual testing began in order to refine the protocol.

Time-to-collision. Potential time to collision estimates were calculated in the lab prior to any testing. Proposed TTC criteria, for which each subject would be able to safely stop in time when presented with the rear end conflict while still eliciting an emergency response, were 2.99 (110 feet) seconds, 3.55 seconds (130 feet), and 4.09 seconds (150 feet) away from the rear of the surrogate vehicle. Calculation of these TTC utilized the formula provided by Knippling et al. (1993), which includes velocity of the following vehicle, deceleration rate of the following vehicle, and total time delay before the driver of the following vehicle initiates a full response (formula 1). These distances would essentially accommodate 75% of reaction times. These distances corresponding to the TTC values were broken down into their component lengths. The components included the length of the van (19 feet) and a 0.65 second (24 feet) headway (this is a headway at which 10% of Americans currently follow during real life car following situations according to Fancher et al., 1998). This resulted in distances at which the lead vehicle should make lane changes as 67, 87, and 107 feet, respectively

There were two objectives in running these preliminary tests on initially naive subjects. The first was to determine the point on the road at which the van should change lanes and the second was to practice the scenario. Fluorescent blocks were placed at the appropriate lane change positions prior to the subject entering the Smart Road. These tests involved use of a Chevrolet van, a Ford Explorer and/or Crown Victoria (as the tow vehicle), the surrogate vehicle (without the strobe attachment), and a subject vehicle (Ford Contour). On the first run, the driver of the van changed

lanes at the furthest distance away from the surrogate (resulting in presentation of the surrogate at the furthest TTC of 4.09 seconds). As the subject vehicle was not instrumented, the subject was asked to estimate their headway distance. Unfortunately, the subject had estimated these distances incorrectly causing the subject to follow too far behind the van. Following too far behind the lead vehicle resulted in the subject catching a glimpse of the conflict on her approach as well as providing her with a longer TTC. As a result, she expected the scenario. Having elicited feedback from the subject, the procedure was then practiced approximately four more times on the same subject, each time at a closer TTC. During these subsequent runs, the subject was also advised of her headway behind the lead vehicle by radio to ensure that she maintained the correct distance from the van. The driver of the van also practiced different methods of obstructing the view of the conflict scenario from the subject.

The shorter the TTC values were and the more practice the driver of the lead vehicle had at obstructing the subject's view of the surrogate vehicle, the more surprised the alerted subject became at the presentation of the scenario. In fact, on the last run, the subject was so surprised by the presentation of the conflict that her hard braking caused a radio to fall off the front seat. The distances of 107 and 87 feet were found to be too long (i.e., the element of imminence was lost). Sixty-seven feet was found to be too close even for subjects who anticipated the surrogate in subsequent runs. As a result, once the subject vehicle was instrumented, a compromise distance of 77 feet was chosen and later tested with three pilot subjects (one young and two older subjects). This distance and scenario worked so well that the data collected from these pilot subjects were included in the later analyses.

The final distances used in the procedure as a result of these preliminary tests are depicted in Figure 4.8.

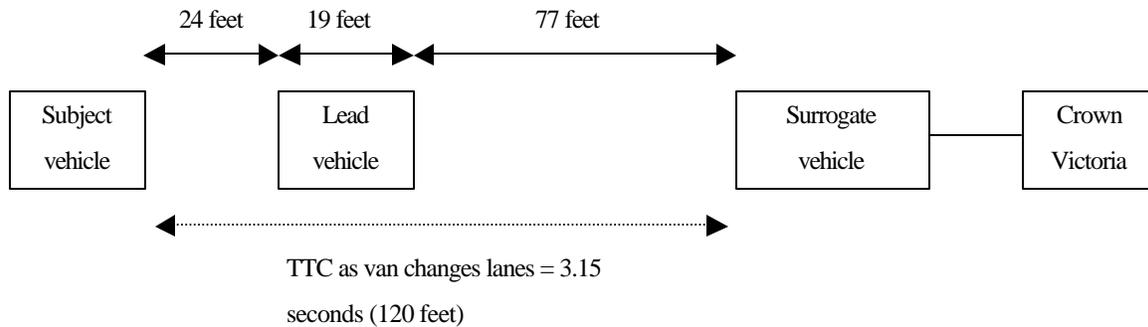


Figure 4.8. Final distances and TTC used in study

Experimental Procedures

Testing was delayed somewhat due to abnormally wet weather conditions and as a result the entire experiment took place over a period of approximately 6-8 weeks during the months of July and August at the Smart Road facility located at VTTI. Prior to testing, three pilot subjects were exposed to all procedures and those that were successful were included in subsequent data analysis.

Orientation and screening. Each subject underwent an orientation session, an experimental session, and a debriefing session. Each participant was told that they would be driving for an hour, when in reality each subject drove for approximately 40 minutes. Together with the orientation and debriefing session, the entire session lasted between 1.25 and 1.5 hours.

Prior to orientation, subjects were screened over the telephone regarding age, height (to minimize possible injury from the remote possibility of airbag deployment), driving experience, health, and demographics (the screening questionnaire can be found in Appendix E). Qualifying subjects were then scheduled for testing.

On arriving at VTTI, the orientation session began with the experimenter welcoming the subject and asking them to complete a vision test using a Snellen chart. Each subject was asked to take this vision test, show his or her driving license, fill out a pre-drive questionnaire (Appendix F), and complete an informed consent form (Appendix G). All subjects had 20/40-distance vision, a driving license, and fulfilled the health requirements.

Following completion of the paperwork, the participant was taken to the instrumented vehicle located in the parking lot at VTTI. The experimenter read a set of instructions to the subject (see Appendix H) and answered any questions posed by the subject. Subjects were asked to perform a practice run by driving around the Smart Road while maintaining a set distance behind the van. During the initial run the driver was asked to perform the distracter task so that he or she could become familiarized with the vehicle and the entire procedure. Once subjects felt comfortable with the vehicle (only one subject required two practice laps), the experiment began.

Testing Session. Subjects were asked to follow a lead vehicle (a Chevrolet van) in an instrumented vehicle (a Ford Contour) while concurrently performing a distracter task. The lead vehicle changed lanes periodically (6 times per lap), and the participant was asked to remain in their own lane while the lead vehicle continued to change lanes throughout the session. The van maintained a safe speed of 25 mph. This speed was selected after careful consideration of the following factors:

- 1) The National Highway Traffic Safety Administration (NHTSA) Human Use Review Panel approved trials, conducted by the Crash Avoidance Metrics Partnership (CAMP), which successfully investigated crash alert timing using a similar method. These trials used speeds of up to 60 mph without injury to participants or experimenters taking part in the study.
- 2) Twenty-five mph is the speed limit in most urban and some suburban areas where many rear end crashes occur.
- 3) This constant speed not only allowed more control of variables such as speed and headway distance, but it also enhanced safety. Participants were not at risk from other collisions due to taking turns too quickly or too slowly in an attempt to maintain a constant distance from the lead vehicle.

After considering these factors, a speed of 25 mph was thought to ensure the safety of participants and experimenters, while maintaining realism and control of experimental parameters.

Distracter task. The participants were told that, while following the lead vehicle at various headways, they needed to monitor an in-vehicle display, which depicted their headway (in feet). Twice every lap, the experimenter asked subjects to provide their headway by reading their distance aloud to the experimenter as well as rate their comfort levels using a comfort rating scale (Appendix I).

The use of the headway display and comfort rating scale facilitated many functions. These were as follows:

1) Deception. None of the subjects who took part in this study anticipated the occurrence of the rear end conflict. This was due to the consistency with which drivers were asked over a 40-minute period to maintain varying headways by monitoring this display as well as rating their comfort levels. The fact that the subject observed the van changing lanes 6 times per lap for 6 laps also ensured that even the most suspicious subjects were comfortable with the situation by the time the scenario was presented.

2) Distraction. The driving task often involves concurrent performance of many sub-tasks resulting in distraction. The purpose of exploring the feasibility of a strobe as a warning light was to assess whether it had the potential to attract the attention of a distracted driver. Subjects were purposely asked to read their headway just prior to the presentation of the signal to ensure that they would be looking away from the roadway. It was anticipated that about half of the subjects tested would be looking away from the roadway as the van changed lanes.

3) Realism. Unduly alerted subjects, in an on-road study such as this, may become over vigilant to the possibility of an incident. Subjects drove for a period of approximately 40 minutes, under uneventful circumstances, prior to the stimulus presentation, while performing the distraction task. This approach has proven sufficient on several occasions for reducing vigilance to realistic levels.

4) Time-to-collision. The use of the radar sensor input to the display allowed more effective calculation of TTC by ensuring the subject was at a certain distance from the surrogate vehicle at the beginning of the conflict scenario.

5) Obstruction. Having the subject perform the distracter task allowed the experimenter to more effectively block the participant's view of the stationary surrogate vehicle from the participant by averting the subjects' eyes.

On road sequence of events. After the practice lap, participants followed the lead vehicle at 3 headways: 2.99 seconds (72 feet), 1.32 seconds (48 feet), and 0.65 seconds (24 feet) respectively. These distances were chosen because they represented 90th, 50th and 10th percentile following headway exhibited by the U.S. population (Wasielewski, 1979; Fancher et al., 1998). Twice every lap, the experimenter asked subjects to provide their headway by reading their distance aloud to the experimenter as well as rate their comfort levels using the rating scale shown in Appendix I. The experimenter made sure that these questions were asked of subjects at approximately the same point in the road (once as he or she came out of the bottom loop, and once as the subject approached the point at which the surrogate vehicle would be presented). Subjects started to expect the question and so made extra effort to keep to the headway distance so that they could provide a correct reading. This ensured that at the approach to the presentation of the rear end conflict all subjects were making an effort to adhere to the 24 foot distance needed to provide the desired TTC value.

After every 2 laps the subject was asked to follow at the next shortest headway (from 2.99 - 0.65 seconds). Throughout the session, the lead vehicle changed lanes 6 times per lap at approximately the same points in the road and subjects were asked to remain in their lane. This was done to ensure the reliability of the data. Periodic lane changes familiarized the subjects with the driver of the lead vehicle making the lane change maneuver. As a result, a final lane change by the lead vehicle to reveal the stopped surrogate would not unduly alert the subject to the presence of a roadway obstacle.

The distracter task had multiple purposes, one of which was to deceive subjects concerning the real reason for their participation in the study. An extended period driving on the road performing this distracter task was necessary to avoid subject's suspicion concerning the true purpose of the study. As a result, subjects drove on the Smart Road for 40 minutes (practice lap included) and for about 30 lane changes by the lead vehicle. Just prior to the rear end conflict, the participant was asked to rate their comfort for a final time and to provide the experimenter with the display reading. As the participant was distracted, the conflict scenario was presented. The lead vehicle quickly changed lanes, from the right lane to the left, revealing the stopped surrogate vehicle blocking the participant's lane (Figure 4.9 provides a top-down view of the rear end conflict scenario). Depending on the experimental condition, the strobe light was or was not present as the surrogate vehicle came into view. The light was triggered by the driver of the tow vehicle just prior to the lane change.

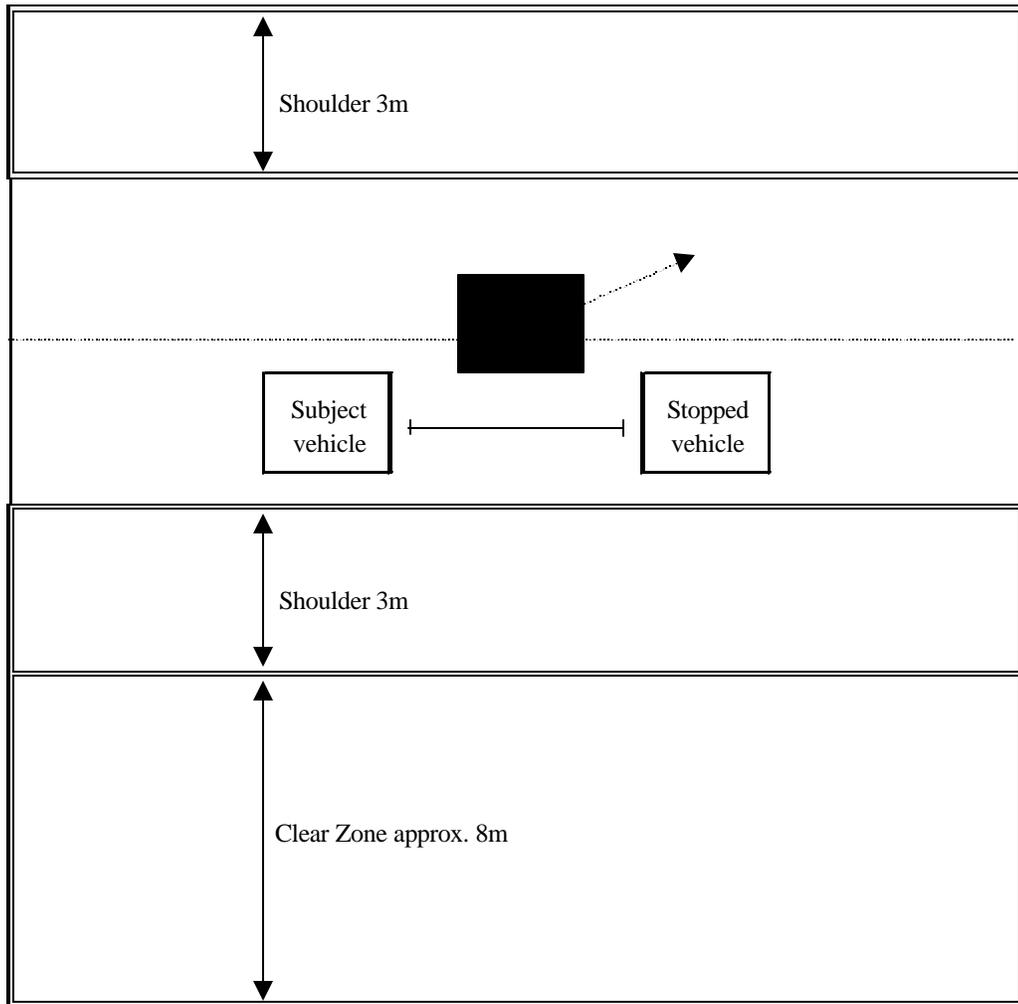


Figure 4.9. Rear-end conflict scenario

The surrogate vehicle. To avoid suspicion during the session, the surrogate vehicle was located out of the subject's view for the first 40 minutes. The surrogate vehicle was effectively hidden from view by placing it (while still attached to a tow vehicle) alongside a trailer. This trailer was parked to the side of the Smart Road (see Figure 4.10).



Figure 4.10. Hiding position of the surrogate vehicle prior to the rear end conflict scenario

Figure 4.11 and 4.12 provide views of the hiding position from both directions on the Smart Road (i.e., as subject drives away from top loop and as subject drives towards the top loop). As can be seen from these images, the angle at which the tow vehicle parked also aided in blocking the subject's view of the surrogate. Subjects were asked after the session whether they had seen the surrogate or suspected its presence on the Smart Road at the time of testing. Although subjects could see the Crown Victoria, none of the subjects could see the surrogate, nor did they suspect the presence of the vehicle.



Figure 4.11. View of the surrogate behind the trailer as subject drives away from top loop



Figure 4.12. View of the surrogate and tow vehicle behind trailer on approach to top loop

In the time it took the subject and lead vehicles to drive around the top loop and ascend a slight hill, the surrogate vehicle was moved into position on the road without being seen (due to the crest of the hill obstructing the view). Preliminary tests showed the proposed sites to be effective and it took only 15-20 seconds to position the surrogate at a predefined point on the road. The procedure involved radio communication between the drivers of the lead and tow vehicles to determine at what point the driver of the tow vehicle could move without being seen. The

experimenter's radio communication was switched off throughout the session so that the subject could not hear the preparations.

The driver of the lead vehicle was trained in how to drive the van at an appropriate speed and in an appropriate manner to effectively obstruct the subjects' view of the upcoming rear end conflict. Preliminary tests showed that the driver of the lead vehicle should slow to an approximate speed of 10 mph as the van rounded the top loop and ascended the slight incline on the Smart Road. On cresting the slight hill, the driver of the lead vehicle then consistently reached an approximate speed of 25mph without using the brakes excessively, if at all, as the van traveled down the incline towards the surrogate vehicle. It was important that the van traveled as close to 25 mph as possible to ensure constant TTC values for all participants. To further ensure a low speed on approach, subjects were asked to change into second gear as they entered the top loop on each lap. Also, it was important that the driver of the lead vehicle keep to the left to effectively obstruct the subjects' view, as most subjects drove to the far left when rounding the top loop. As some subjects had a tendency to drift across the lane, the driver of the lead vehicle was guided by the driver sitting in the tow vehicle concerning their road position. The subject was also told to keep the midline of their vehicle as close to the midline of the van as possible to ensure accuracy of headway display readings. These instructions ensured that the view of the surrogate vehicle was blocked as the participant approached the scenario. Despite the precautions, six subjects out of the 39 run were eliminated due to seeing the surrogate vehicle stopped in the road prior to the rear end conflict.

Post drive and debriefing session. Immediately after the rear end conflict was presented, all subjects were asked if they were all right and whether they needed any assistance. All subjects who participated were fine, but just very surprised by the appearance of the vehicle. Then subjects were asked whether or not they saw the surrogate vehicle prior to the lane change made by the van. Data from any subjects who answered yes to this question were eliminated. After the conflict scenario presentation, the participant was debriefed about the true purpose of the study, and was asked to sign another informed consent form allowing use of the data collected (the debriefing and second consent form can be found in Appendix J). Finally, the participant was asked to complete a post-drive questionnaire (Appendix B for those presented

with the strobe and Appendix C for those subjects not presented with the strobe). The experimenter then answered any questions posed by subjects.

Safety precautions. The risk in this study centered on the risk of potentially hitting the stopped surrogate vehicle. Careful thought was taken to ensure that the subjects did not hit the stationary surrogate vehicle, and that if this were to have happened, that no injury or undue stress would be caused to either subject or experimenter. The following precautions were taken:

- 1) The entrance speed to the scenario was limited to a low speed (25 mph) by the lead vehicle and the experimenter.
- 2) The experiment was conducted on a closed, controlled test track
- 3) The “safety zone” portion of the Smart Road was used, which had an 8-meter wide area beyond the shoulder for approximately 300 ft. of travel distance.
- 4) A paramedic was on duty in the observation tower in case of any emergency.
- 5) Each subject was offered a place to rest following the experiment although all subjects were fine and did not require assistance following the presentation of the rear end conflict.
- 6) The experimenter insured that the driver and the experimenter were wearing their seatbelts properly.
- 7) The experimenter adjusted headrests so that they were positioned as well as possible, in the unlikely event that a collision did occur.
- 8) Both the driver/subject and passenger/experimenter-side airbags remained connected. Subjects were also screened for height and weight criteria to ensure that no injury would be caused to a smaller participant in case of air bag deployment.

9) A collapsible surrogate was used as the stationary vehicle. The body was constructed from fiberglass to allow compliance (deformation) if it was hit from the rear. The surrogate vehicle was also lightweight (approximately 120lbs) and attached to a 35 foot collapsible “boom.” The vehicle and boom would give way if hit, causing minimal damage to the subject vehicle and no injury to the participant.

10) The 35-foot boom assembly was attached to another vehicle and used to maneuver the surrogate vehicle into and out of position. The boom included an eight foot collapsible center section for additional energy absorption. The vehicle also remained connected to the tow vehicle. The driver of the tow vehicle was prepared to accelerate away from the scenario if it appeared that a collision was imminent, which would reduce the crash force.