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**Exploring Rear-End Roadway Crashes  
from the Driver's Perspective**

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16. Abstract  Rear-end crashes were examined from the driver's perspective to identify self-reported reasons and causes of rear-end crashes, to identify commonalities in the self-reported causes and locations and circumstances of the crashes, and to explore the merit of using this approach to develop countermeasures to the rear-end crash.			
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## TABLE OF CONTENTS

<b>INTRODUCTION</b> .....	<b>1</b>
Goals and Objectives .....	2
<b>METHODOLOGY</b> .....	<b>3</b>
Approach .....	3
Sampling .....	4
Subject Recruitment .....	5
Focus Groups .....	5
Telephone Interviews .....	6
Sample .....	7
Subjects .....	7
Crashes .....	7
<b>RESULTS</b> .....	<b>8</b>
Subject-Reported Crash Situations .....	8
Self-Reported Contributing Crash Factors .....	9
Question-Based Factors .....	9
Explanation-Based Factors .....	13
Cues About Imminent Crash .....	17
Perceptions of Countermeasures .....	17
<b>DISCUSSION</b> .....	<b>19</b>
Concepts for Potential Countermeasures .....	20
Normative Incorrect Driver Assumptions .....	20
Non-Normative Incorrect Driver Assumptions .....	20
Divided Attention .....	22
Unavoidable Crashes .....	23
Conclusions .....	24
<b>REFERENCES</b> .....	<b>26</b>
<b>APPENDIX A:</b>	
Moderator's Guide .....	27
<b>APPENDIX B:</b>	
Letter to Potential Subjects And Informed Consent Form .....	30
<b>APPENDIX C:</b>	
Demographic Questionnaire and Subject Demographics .....	34



## LIST OF TABLES

<b>Table 1. Number of drivers in sampling base</b>	<b>4</b>
<b>Table 2. Study Subjects by Age and Sex</b>	<b>7</b>
<b>Table 3. Self-Reported Main Factors Contributing to the Rear-End Crash</b>	<b>10</b>
<b>Table 4. Self-Reported Contributing Factors by Reported Maneuver of Lead Car</b>	<b>11</b>
<b>Table 5. Self-Reported Contributing Factors for the Rear-End Crash by Sex</b>	<b>11</b>
<b>Table 6. Self-Reported Contributing Factors for the Rear-End Crash by Age Group</b>	<b>12</b>
<b>Table 7. Self-Reported Contributing Factor by Location of Crash</b>	<b>12</b>
<b>Table 8. Self-Reported Contributing Factors by Traffic Condition</b>	<b>13</b>
<b>Table 9. Self-Reported Causes of the Rear-End Crashes</b>	<b>14</b>
<b>Table 10. Self-Reported Cause of Crash by Maneuver of Lead Vehicle</b>	<b>15</b>
<b>Table 11. Self-Reported Causes of Crash by Sex</b>	<b>15</b>
<b>Table 12. Self-Reported Causes of Crash by Age Group</b>	<b>16</b>
<b>Table 13. Self-Reported Cause of Crash by Location of Crash</b>	<b>16</b>
<b>Table 14. Self-Reported Causes of Crash by Traffic Condition</b>	<b>17</b>

## **INTRODUCTION**

Rear-end crashes are a very common type of vehicle crash and occur when a following vehicle strikes the rear of another vehicle that is in the same traffic lane and headed in the same direction. From the early days of motorized transportation, various countermeasures have been sought to reduce the frequency of this type of crash. Most of the countermeasures developed in response to this need are either part of the vehicle itself or part of the roadway system. The intent of most current in-vehicle systems is to increase the conspicuity of the lead vehicle or to inform the following vehicle that the lead vehicle is decelerating. Among such countermeasures are rear lights, reflective license plates, rear fog lights, brake lights, centrally high mounted third brake lights, hazard signals, and flashing brake lights. Signs such as the stop-ahead sign, the flashing signal-ahead sign, construction-expect-delay sign, and changeable message signs that warning motorists of congestion ahead act as countermeasures to rear-end crashes by informing drivers that there may be stopped vehicles ahead.

Although these countermeasures have done much to reduce the frequency of rear-end crashes, these crashes still occur and new ways to address the problem are constantly being sought. Intelligent transportation system (ITS) technology has introduced new countermeasures such as headway monitoring systems, collision warning devices, and sleep monitoring/warning systems that may have a positive effect on rear-end crashes. ITS has also introduced the possibility of electronic communication between the vehicle and the roadway. Systems that monitor traffic flow on roadways and inform drivers of the traffic status via changeable message signs or in-vehicle receivers are now being tested. Automated highway systems that move platoons of vehicles at high speeds and very short headways over long distances and various collision avoidance systems are in the research and development stages and it is very likely that such systems will eventually contribute to reducing the frequency of rear-end crashes.

When considering the problem of reducing the frequency of a certain type of crash, a

variety of solutions (i.e., countermeasures) may be generated by looking at the problem in a variety of ways. Some ideas come from examining statistical crash data to determine the prevalent types of crashes and patterns of occurrence. Other concepts are formed by examining individual crashes in great detail. Still other ideas come from solutions looking for a problem; that is, they result from the desire to apply a particular type of technology. Another approach to identify countermeasures for reducing crash frequency, suggested by staff at Honda R&D North America, is to look at the crash from the perspective of the driver. Honda staff wanted to know whether or not this approach could yield innovative solutions to the problem of motor vehicle crashes. Accordingly, they asked us to explore a specific crash type, the rear-end crash, from the perspective of the driver and to determine if this approach has merit for developing countermeasure ideas.

### **Goals and Objectives**

The goal of this research was to further understanding of roadway crashes by exploring the rear-end crash from the driver perspective and to determine if knowledge of the circumstances of the crash as perceived by the driver could offer insight into the characteristics of potential countermeasures for rear-end crashes. The objectives of the study were to:

- C Identify self-reported reasons why rear-end crashes occur;
- C Identify how these driver-reported reasons relate to certain situations and locations;
- C Identify crash hazard cues drivers recognized or failed to recognize;
- C Determine if this approach has merit for developing countermeasure ideas.

It is important to note that this was an exploratory (pilot) study. While it may provide some interesting and useful insights, it serves primarily as a test of methods and assumptions so that a full-scale study can be designed and conducted efficiently.

## **METHODOLOGY**

### **Approach**

A qualitative approach using focus groups was selected for this study. A focus group is a carefully planned discussion, guided by a moderator, among people who have something in common. It is designed to obtain perceptions on a defined topic in a permissive, nonthreatening environment and is conducted several times with similar types of participants. Typically there are 8 to 10 participants in a group. Careful and systematic analysis of the discussion provides the clues and patterns in the perceptions of the subjects. Results of focus groups cannot be generalized to the population from which the subjects were drawn but can be used to formulate ideas and hypotheses for further quantitative research. As an exploratory tool, focus groups initially seemed well suited for the purposes and pilot nature of this study.

The subjects for this study were drawn from the population in Michigan who had recently experienced a rear-end crash as drivers of the striking vehicle. Because of possible age differences in the perception of the circumstances surrounding a crash, subjects were initially divided into three age categories, 19-to-24, 25-to-64, and 65 or more years of age. These age categories were selected because overall crash involvement by drivers' age follows a distinct pattern which generally corresponds to these age categories. Two focus group sessions were planned for each age group.

The moderator's guide was developed that included a detailed outline of the topics and questions to be used in the focus group. The guide was designed to elicit information about the crash as perceived by the driver, including subjects' perceptions of the key contributing factors and causes of the crash. Subjects' ideas about what could have helped to prevent their crash, and rear-end crashes in general, as well as their acceptance of some potential crash-prevention systems were sought. The complete moderator's guide can be found in appendix A.

## Sampling

The State of Michigan Crash files for 1996 were used to develop the sampling base for the study. At the time of the study, 1966 was the most recent year for which a complete set of crash data was available. The files were filtered to retain the records of the striking vehicle in rear-end crashes that occurred in four Southeastern Michigan counties: Livingston, Oakland, Washtenaw, and Wayne. These counties were selected to keep the travel time of potential subjects to no more than 1 hour. The records were further filtered to exclude crashes that involved alcohol, animals, and fatalities. Alcohol and animal crashes were excluded at the request of the sponsor. Fatal crashes were excluded because these crashes were likely to have been very traumatic for involved drivers and it would, therefore, be extremely difficult to recruit these drivers for the study. Because the crash-involvement rate for men is higher than for women in all three age groups, it was possible that a random sample drawn for each age group might have few or even no women. To ensure that study subjects included women, men and women in each age category were sampled separately. Table 1 shows the number of potential subjects (sampling base) in each age and sex category.

<b>Age Group</b>	<b>Male</b>	<b>Female</b>
19-to-24	4,119	2,736
25-to-64	11,725	7,823
65 and over	1,055	637

Based upon previous experience recruiting subjects and the nature of the topic, we estimated that a 10 percent success rate in recruiting subjects was likely. Because we wanted a total of about 60 subjects (ten for each category), a random sample of 110 crash records from each age and sex category was drawn from the sampling base for a total of 660 records. Printed copies of the police crash reports (UD-10) for these 660 cases were obtained from State of Michigan microfiche files. Among other information, UD-10 reports

contain narrative descriptions of the crash and the names, addresses, and telephone numbers of the people involved.

### **Subject Recruitment**

Letters were sent to all 660 potential subjects describing the study, telling them that they would receive a call in the near future, and inviting them to participate in a focus group. The letters also informed them that they would receive a subject payment of \$35. A copy of the recruitment letter is presented in appendix B.

Recruitment began several days after the letters were mailed. An experienced project staff member telephoned potential subjects, explained the study, and invited them to participate in a focus group. If they agreed he scheduled them for a session. As the recruiting process got under way, it became obvious that a large majority of potential subjects were not interested in participating in focus groups on this topic and that obtaining the desired number of subjects would be difficult. Many potential subjects were irritated that we knew about their crash and several denied being in a crash. Approximately half way through the recruitment process we increased the subject payment to \$50 in order to provide additional incentive for participation. This increase in subject payment, however, did not result in an increased participation rate. In all, 30 people agreed to participate in the focus groups.

### **Focus Groups**

Focus groups were held in the last week of July and the first two weeks of August, 1998 and were moderated by a researcher. The sessions were videotaped, audio taped, and a research secretary took detailed notes. Five focus group sessions were held with a total of 16 subjects. There was a total of 10 participants in the two focus groups for drivers 65 years of age or older and a total of 3 participants in the two sessions for the drivers in the 19-to-24 year old age group. Only one focus group, with 3 participants, was held with drivers 25-to-64 years of age. Thus, a total of only 16 of the 30 people who agreed to participate actually showed up for the focus groups.

Before each session, subjects signed informed consent forms and filled out a demographic questionnaire. They received payment for participation at the end of the session. A copy of the informed consent form is in appendix B. The demographic questionnaire can be found in appendix C.

### **Telephone Interviews**

Recruitment calls to 660 potential subjects yielded only 16 actual participants. However, an additional 14 people had agreed to participate but did not come to the sessions. We therefore, decided to obtain the focus group information from each of these 14 people through a telephone interview using the moderator's guide from the focus groups as the interview instrument. Changing the method of data collection in the middle of this study was justified for two main reasons. First, this was a pilot study where assumptions and methods were being tested. As such, the focus group method was proving untenable and a different method was needed. Second, with one exception, the focus group sessions had a small number of subjects and took on a form more similar to an interview than to a focus group. Because of this we were confident that the information collected by each of the two methods was generally compatible and could be combined for analyses in a pilot study.

A researcher called each of the 14 people who had failed to show up for their scheduled focus group and either conducted the interview by following the questions in the moderator's guide or scheduled the interview for a more convenient time. The information covered in the informed consent form was read to the subject, and his/her consent was obtained verbally. The telephone interviews were audio taped with the permission of the subject. Demographic information was also collected. Subject payments were mailed to the subjects who completed the interview. In all 10 telephone interviews were completed.

## Sample

### *Subjects*

There were 26 subjects in the final sample. Of these 11 were male and 15 were female, 10 were in the 19-to-24 year old age group, five were in the 25-to-64 year old age group, and 11 were in the 65 years of age or older age group. Table 2 shows the distribution of the study subjects by age group and sex.

<b>Age Group</b>	<b>Male</b>	<b>Female</b>	<b>Total</b>
19-to-24	3	7	10
25-to-64	3	2	5
65 and over	5	6	11
Total	11	15	26

The overall average household income of the study subjects was \$42,000. The average household income for the three age groups was \$30,000, \$75,000, and \$37,000 from the youngest to the oldest age group, respectively. Other demographic characteristics of the sample of subjects can be found in appendix C.

### *Crashes*

Although the sample of subjects was selected from electronic crash records, the electronic crash data records for the specific rear-end crashes experienced by the 26 subjects were examined. In all 26 crashes, the vehicle was traveling straight ahead and the worst point of impact was the front-center of the car, confirming that the crashes were indeed rear-end crashes and that the subject was the driver of the striking vehicle. Ten of the crashes occurred on two-lane roads and the rest were on multilane roads or freeways. All but one of the crashes occurred during daylight. Precipitation in the form of rain or snow was present in four of the

crashes and the rest occurred in clear or cloudy weather. Most of the vehicles involved were passenger cars. No vehicle defects were noted in any of the crashes. In eight of the crashes the vehicle was in slow and stopped traffic. Moderate damage was noted in 11 cases, light damage in 14 cases and no damage in one case. In five cases there was an injury in the striking vehicle. Of these, two were minor injuries, three were non-incapacitating injuries, and one was an incapacitating injury. The review of these records showed that they were typical rear-end crashes.

## **RESULTS**

### **Subject-Reported Crash Situations**

The 26 crashes, as described by the subjects, occurred mostly during the day and were equally divided between peak traffic periods with heavy traffic conditions and off-peak periods with light to moderate traffic. Most subjects reported that their crash occurred in good weather and a few mentioned rain or snow. The majority of the crashes occurred on streets and only a few were on freeways. Of the crashes that occurred on the streets, more than one-half were reported to have occurred at intersections. In most cases, the subjects said that they were the only person in their vehicle and the vehicles they hit were in most cases occupied only by a driver.

Several subjects reported that their crash occurred in congested stop-and-go traffic, when the vehicle in front of them stopped because vehicles ahead had stopped. Two subjects reported that their crashes occurred when they reached down to pick up an item that fell to the floor in their car. Some subjects described crashes that occurred when a vehicle moved into their lane and stopped for some reason. A few subjects drove their vehicles into the car in front of them because they had incorrectly assumed that the car had started moving. There were also several cases where the subject crashed into a vehicle that was stopped in an unexpected location and was not visible to the subject until it was too late.

## **Self-Reported Contributing Crash Factors**

The analysis of driver responses to what caused their crash showed that the self-reported reason(s) for the a driver's crash was frequently different depending upon how the subject was asked the question. When questioned directly about their crash, subjects would report one or more reasons, called *question-based factors* here. However, when asked to explain what happened leading up to and during the crash, many subjects reported different factors than when asked directly. We have labeled these types contributing factors, *explanation-based factors*. For example, when asked directly, one subject stated that the crash was entirely because of road design (question-based). However, when she explained what happened during the crash, she reported that she mistakenly watched the wrong set of traffic signals and accelerated when the wrong signals turned green (explanation-based). On the one hand, road design was the cause and on the other, a personal error was the cause. Because these two ways of reporting perceptions of crash causation yielded different responses, we present them separately.

### *Question-Based Factors*

The subjects were directly asked what factors contributed to the crash and to indicate the relative contribution of each factor. Table 3 shows the overall allocation of contributing factors as reported by the subjects. Actions of other driver was the dominant contributing factor according to the subjects. The drivers described these actions as the other car stopped unexpectedly, the other car did not move when it should have, and the other car did "strange things." The next most frequent set of responses to this question included personal inattention or distraction. We grouped these into one factor which we called personal error. Other factors reported by the subjects as contributing to their crashes were road design, environment, and vehicle problems.

<b>Table 3. Self-Reported Main Factors Contributing to the Rear-End Crash (n = 26)</b>				
<b>Road Design</b>	<b>Environment</b>	<b>Actions of Other Driver</b>	<b>Vehicle Problems</b>	<b>Personal Error (inattention, distraction)</b>
7%	9%	49%	4%	31%

The following set of tables shows the number and distribution of the self-reported contributing factors for various groupings of subjects. It is important to remember that this is an exploratory study, the number of subjects is small, and that the results cannot be applied to the population of drivers. These tables simply provide a convenient way of looking at the information obtained from the study subjects. They also provide a starting point for formulating hypotheses and developing data analysis plans for any larger scale study that may follow. Furthermore, examining the information this way may offer insights into ways by which these crashes could have been prevented.

Table 4 shows the self-reported contributing factors for the crash by the maneuver of the lead vehicle as described by the subjects. In the majority of cases, subjects stated that the lead car either stopped because of actions of cars further ahead or the lead car was standing at an intersection. For cases where the lead car stopped because vehicles further ahead stopped, actions of the other driver was the factor most likely to be reported by the subjects. For cases where the lead car was standing at the intersection, the subjects were more likely to cite a personal error. There were two other less common maneuvers of the lead vehicle reported by the subjects: the lead car was standing in a lane of travel and the lead car pulled into the subject's lane and stopped. In these cases, the subjects were most likely to attribute the crash to the actions of the other driver.

<b>Maneuver of Lead Vehicle (n)</b>	<b>Road Design</b>	<b>Environment</b>	<b>Actions of Other Driver</b>	<b>Vehicle Problems</b>	<b>Personal Error</b>
Stopped because cars ahead stopped (8)	13%	16%	50%	0%	21%
Standing at intersection (10)	3%	8%	29%	10%	50%
Standing in travel lane (3)	17%	5%	45%	0%	33%
Pulled into lane and stopped (3)	0%	0%	100%	0%	0%
Other (2)	0%	0%	75%	0%	25%

Table 5 shows the distribution of the self-reported contributing factors by sex. The data show that, in this group of subjects, men were more likely than women to attribute the actions of the other driver as the reason for their crash. Women showed greater variability than men in their self-reported reasons for their crash.

<b>Sex (n)</b>	<b>Road Design</b>	<b>Environment</b>	<b>Actions of Other Driver</b>	<b>Vehicle Problems</b>	<b>Personal Error</b>
Male (11)	0%	10%	65%	0%	25%
Female (15)	12%	8%	38%	6%	36%

Table 6 shows the distribution of self-reported contributing factors by age group. The subjects in the oldest and youngest age groups tended to somewhat equally cite both personal errors and the actions of the other driver whereas those in the middle age group tended to attribute the cause of the crash to the actions of the other driver.

<b>Table 6. Self-Reported Contributing Factors for the Rear-End Crash by Age Group</b>					
<b>Age Group (n)</b>	<b>Road Design</b>	<b>Environment</b>	<b>Actions of Other Driver</b>	<b>Vehicle Problems</b>	<b>Personal Error</b>
18-to-24 (10)	8%	23%	37%	0%	32%
25-to-64 (5)	20%	0%	70%	0%	10%
65 and older (11)	0%	0%	50%	9%	41%

Table 7 shows the distribution of the self-reported contributing factors in the rear-end crash by the location of the crash. For crashes on the street system, either at intersections or on road segments, the study subjects cited the actions of the other driver and personal error about equally. For crashes that occurred on the freeways, however, the majority of subjects indicated that the actions of the other driver was the cause of the crash.

<b>Table 7. Self-Reported Contributing Factor by Location of Crash</b>					
<b>Location (n)</b>	<b>Road Design</b>	<b>Environment</b>	<b>Actions of Other Driver</b>	<b>Vehicle Problems</b>	<b>Personal Error</b>
Street - Intersection (12)	3%	7%	40%	8%	42%
Street - Non intersection (8)	0%	16%	48%	0%	36%
Freeway (6)	25%	3%	67%	0%	5%

Table 8 shows that among the subjects in this study there was little difference in self-reported contributing factors by the traffic conditions on the road.

<b>Traffic Condition (n)</b>	<b>Road Design</b>	<b>Environment</b>	<b>Actions of Other Driver</b>	<b>Vehicle Problems</b>	<b>Personal Error</b>
Heavy traffic/congestion (12)	6%	7%	44%	7%	29%
Light to moderate traffic (14)	8%	11%	54%	0%	26%

### *Explanation-Based Factors*

As mentioned earlier, when subjects explained what happened leading up to and during the crash, they frequently gave different reasons for the cause of the crash than they gave when asked directly. This section considers these explanation-based factors. Because of a problem with the recording of an interview, the explanation for one crash was deleted. This subject is not included in the analysis of explanation-based factors contributing to the rear-end crash.

The responses from the explanations suggested that there were *four* main self-reported causes for rear-end crashes in our sample of subjects. Two causes were related to an *incorrect assumption* about traffic movement made by the driver; that is, the driver thought a vehicle in traffic was going to do something that it did not do. We divided these self-reported incorrect assumptions into two types: normative and non-normative. Normative assumptions are those that a driver in a following vehicle makes about the driver's behavior in a lead vehicle that are based on social driving norms. For example, it is normal for a driver in a following vehicle to assume that the lead vehicle will not stop in the middle of a freeway ramp or stop at a signal-controlled intersection if the light is green. Thus, normative assumptions make sense and are necessary for safe driving. If the driver in a lead vehicle breaks a social driving norm, it increases the chance that a following vehicle will hit it. On the other hand, non-normative assumptions about the driver's behavior in the lead vehicle are those that do not

coincide with general driving norms. Examples of non-normative assumptions include assuming that the vehicles in a lane are moving because the vehicles in another lane are moving, or assuming that a lead vehicle is moving because the vehicles some distance ahead of the lead vehicle are moving. Thus, when a driver in the following vehicle makes a non-normative assumption about the actions of the lead vehicle, it is likely to be incorrect and chances of a rear-end crash increase.

A third self-reported cause of rear-end crashes was related to an inability of the driver to *divide attention* effectively. According to Bernstein et al. (1991), divided attention is “...devoting psychological resources to more than one task or stimulus at a time.” (pp 202). For example, in two of the cases studied, people had dropped something they were carrying and were try to pick it up when they crashed. The final self-reported reason, is that the crash was simply *unavoidable*. In these cases, subjects reported that their rear-end crash was unavoidable and resulted from the actions of drivers several vehicles ahead which they could not see or from other circumstances over which they had no control.

The Table 9 shows the distribution of the 25 crashes by the four categories of self-reported causes. The majority of the explanation-based causes of the crashes were related to problems with divided attention and incorrect assumptions about the actions of the lead vehicle, all personal error factors.

<b>Table 9. Self-Reported Causes of the Rear-End Crashes (n=25)</b>			
<b>Divided Attention</b>	<b>Incorrect Assumption (non-normative)</b>	<b>Incorrect Assumption (normative)</b>	<b>Unavoidable</b>
32%	32%	8%	28%

Looking at the maneuver of the lead vehicle in our sample of rear-end crashes by the self-reported cause of the crash in Table 10 suggested that problems with divided attention were associated with crashes that occurred when a lead vehicle stopped because of cars

ahead stopping. This analysis also showed that an incorrect non-normative assumption was more likely in cases where the lead car was standing at an intersection. The table also shows that most of the crashes where the lead vehicle pulled into the subject's lane and stopped, were reported as unavoidable.

<b>Maneuver of Lead Vehicle (n)</b>	<b>Divided Attention</b>	<b>Incorrect assumption (non- normative)</b>	<b>Incorrect assumption (normative)</b>	<b>Unavoid-able</b>
Stopped because cars ahead stopped (7)	71%	15%	0%	14%
Standing at intersection (10)	20%	70%	0%	10%
Standing in travel lane (3)	34%	0%	33%	33%
Pulled into lane and stopped (3)	0%	0%	34%	66%
Other (2)	0%	0%	0%	100%

Table 11 shows that there was no consistent difference in the self-reported causes of the rear-end crash in this study between men and women.

<b>Sex (n)</b>	<b>Divided Attention</b>	<b>Incorrect assumption (non-normative)</b>	<b>Incorrect assumption (normative)</b>	<b>Unavoid-able</b>
Male (10)	40%	30%	0%	30%
Female (15)	27%	33%	13%	27%

Table 12 shows the distribution of the self-reported causes of the crash by age group. Incorrect non-normative assumptions were more likely among the youngest group of subjects.

This result is interesting because this type of error undoubtedly occurs from inexperience and the youngest age group would have the least driving experience of the age groups studied. The middle age group subjects most frequently described their crash as unavoidable. The oldest age group participants tended to report the cause as either divided attention or unavoidable about equally. This result is also interesting because it is known that in older adulthood, divided attention ability begins to decline (see, e.g., Eby & Molnar, in press).

<b>Age Group (n)</b>	<b>Divided Attention</b>	<b>Incorrect assumption (non-normative)</b>	<b>Incorrect assumption (normative)</b>	<b>Unavoidable</b>
18-to-24 (10)	30%	50%	10%	10%
25-to-64 (5)	20%	20%	20%	40%
65 and older (10)	40%	20%	0%	40%

Table 13 shows that among the subjects, incorrect non-normative assumptions were likely to be the self-reported cause of rear-end crashes at street intersections while problems with divided attention were more likely to be associated with crashes on street segments, away from intersections.

<b>Location (n)</b>	<b>Divided Attention</b>	<b>Incorrect assumption (non-normative)</b>	<b>Incorrect assumption (normative)</b>	<b>Unavoidable</b>
Street-intersection (12)	17%	58%	8%	17%
Street non intersection (8)	50%	13%	0%	37%
Freeway (5)	40%	0%	20%	40%

Table 14 shows the self-reported causes of crashes by traffic condition. We found that in heavy traffic, divided attention and non-normative incorrect assumptions were the most

frequently cited causes of the crash. In light traffic people were more likely to attribute the cause of the crash to all four factors with unavoidable circumstances being the most frequently cited factor.

<b>Traffic Condition (n)</b>	<b>Divided Attention</b>	<b>Incorrect Assumption (non-normative)</b>	<b>Incorrect Assumption (normative)</b>	<b>Unavoidable</b>
Heavy/traffic congestion (11)	36%	46%	0%	18%
Light to moderate traffic (14)	29%	21%	14%	36%

### **Cues About Imminent Crash**

We asked subjects if they remembered any cues that a crash was about to occur. Cues were defined as anything that let them know that a crash with the lead vehicle was imminent. Subjects either reported that they detected no clues or that there were no clues of an imminent crash. Most reported that the crash happened before they could think about or notice anything.

### **Perceptions of Countermeasures**

Subjects were asked what could have prevented their crash or rear-end crashes in general. Their suggestions are listed by frequency of response.

- C Drivers should pay more attention.
- C Having more time to avoid crash.
- C Drivers should leave more room between cars.
- C Better design of roads.
- C Device to let you know if car ahead is slowing down or not moving.
- C Move big vehicles to separate lane.
- C Better laws and enforcement.
- C Device that would not let you move if car immediately ahead was not moving.
- C Reduce the number of cars on the road.

Several subjects also brought up the topic of public information and education programs about following too closely and indicated that such programs would not reduce the number of rear-end crashes because most people know the rules about how far behind the car in front they should be but drive too closely anyway.

We were also interested in the subjects reaction to some countermeasure system concepts. We described two ITS systems presently under development, an in-vehicle headway monitoring/warning system and an in-vehicle sleep monitoring/warning system, as possible ways of reducing the number of rear-end crashes. The headway monitoring/warning system was described as a system that monitors the distance between a car and the car ahead of it and determines if the distance is safe for the current driving speed. If the distance between the cars is closing too quickly for the speed, the system warns the driver and, in some versions of the system, decelerates the car. The sleep monitoring/warning system was described as a system that tracks the steering motion of the car. We told the subjects that when a driver starts falling asleep the steering patterns becomes erratic. The sleep monitoring system would sense this and issue some type of warning to arouse the driver. No specific type of warning was described.

Subjects were asked what they thought of each system, if they would be willing to use them, and how much would they be willing to pay for them. The majority of the subjects thought the headway monitoring/warning system was a good idea and they would probably use it. Several others expressed concerns that a warning would not be enough, that people would ignore it, that it might help others, but that they do not need it. A few said that it would be a distraction and they would not use it.

About one-half of the subjects were willing to state how much they would pay for such a headway monitoring/warning system. The average amount these subjects were willing to pay for this system was approximately \$500 and ranged from \$25 to \$1000. Several subjects indicated that such a system should be standard equipment on vehicles. Several others said

they would like to see the system proven effective before they would put a monetary value on it.

Subjects' responses to the sleep monitoring system were generally positive. Several subjects reported that they themselves did not need such a system, but it was a good idea for other drivers. Several subjects mentioned that it was a good idea for truck drivers and some thought it should be standard equipment on trucks. About half of the subjects provided a monetary value for the sleep monitoring/warning system. The average amount they were willing to pay was about \$400 and the values ranged from \$25 to \$1200.

## **DISCUSSION**

This pilot study explored rear-end crashes from the perspective of the driver to ascertain whether or not this approach was useful for developing concepts for rear-end crash countermeasures. Recruiting subjects for the study proved to be difficult, primarily because the crash was a sensitive issue nearly all potential subjects. Many subjects were annoyed that we knew about their crash. The method of obtaining driver-reported information about the crash through focus groups was not effective. However, the same information was much more easily obtained through individual telephone interviews, suggesting a more promising avenue for this type of research in the future.

The study showed that drivers tended to attribute the causes of their crashes to different factors depending on how they were asked about contributing factors. Thus, it is important to assess driver perceptions of crashes by both asking people directly about the cause and having them explain the events leading up to and during the crash. The analysis of question-based factors showed that drivers most frequently attributed the cause of their crash to the actions of another driver. Unexpectedly, the second most frequently reported cause was personal error. Environmental conditions, road design, and vehicle problems were mentioned infrequently. Analysis of the explanation-based factors showed that the large majority of self-reported contributing factors were related to cognitive issues, with failure of

divided attention and incorrect assumptions about traffic movement accounting for about 70 percent of the reasons mentioned. For the purpose of generating new concepts for countermeasures to reduce the frequency of rear-end crashes, the explanation-based factors were more informative than the question-based factors.

### **Concepts for Potential Countermeasures**

One of the objectives of this study was to determine if information obtained by examining the driver's perception of the rear-end crash offered a way of conceptualizing potential countermeasure for these crashes. We reviewed the results and found that the classification of self-reported explanation-based contributing factors provided the best framework for the develop of countermeasure concepts. Each explanation-based contributing factor lent itself to at least one concept for countermeasure development. In this section we present each countermeasure as a function of the type of self-reported cause for the crash it is designed to counteract.

#### *Normative Incorrect Driver Assumptions*

Several of the crashes reported by the subjects in this study occurred when the driver was faced with a stopped vehicle in an unexpected location and made the wrong assumption about the motion of the vehicle. The drivers assumed that the car was moving. An unambiguous indication of the stopped status of the vehicle was clearly needed. Systems that convey this information could be useful in reducing this type of crash.

*Automatic Hazard Lights:* An easily implemented system is an automatic hazard light system that comes on when the car engine is running, the car is not moving, and the emergency brake is engaged or the car is in park. With this system, vehicles that have stopped for an unknown reason in a travel lane would be clearly identified as not moving. Since the system would only engage when the car is in park (or the emergency brake is applied), it would not function in stop-and-go traffic or at signalized or signed locations.

### *Non-Normative Incorrect Driver Assumptions*

Examining the self-reported reasons for these types of crashes, indicated that the crashes due to non-normative incorrect driver assumptions were most frequent among the youngest group of subjects, i.e., those 25 years of age or less. Numerous research has shown that many drivers in this age group are inexperienced with driving and engage in risky driving behavior. According to a recent cognitively-based model of risky driving (Eby & Molnar, in press), some of these young drivers may engage in risky driving behaviors because they are risk taking (i.e., they perceive the risk and do it anyway) and others engage in this behavior because they are risk ignorant (i.e., they do not perceive the risk in their behavior). Those who are risk ignorant, can become safer drivers by having a better understanding of the risk inherent in their driving behaviors. Thus, the results suggest that the non-normative incorrect assumptions made by drivers in our study may derive from inexperience with various traffic situations or from ignorance of traffic risks. If so, the results suggest that focused training could help to increase safe driving behaviors.

*Electronic Hazardous-Driving-Action Feedback:* The purpose of this system would be to provide individualized feedback to a driver at the end of a trip. The system would monitor a vehicle's headway over an entire trip and determine when the driver was following too closely for the speed and environmental conditions. At the end of a trip the system would provide the driver with some type of feedback about his/her driving. Example feedback might include the percent of the trip in which the driver was following too closely and an associated crash risk. The risk of injury during the trip might also be conveyed to the driver, based upon the crash risk, safety belt use, and driver age and sex. The crucial elements of the feedback are that it is accurate and individualized. The form, content, and timing of the feedback would need to be determined empirically using simulators and on-the-road experiments with subjects from various demographic populations.

*Do-Not-Accelerate-Now System:* Analysis of the self-reported, non-normative incorrect assumptions showed that in many of these cases the driver incorrectly assumed that the lead

vehicle had started to move when it had not. A system that would prevent the stopped following-vehicle from moving if there was a stopped lead-vehicle in front of it (at some specified short distance), might have helped to prevent some of the rear-end crashes reported in this study.

### *Divided Attention*

Problems with divided attention appeared to be the cause of a large portion of the crashes reported by the subjects in this study. Drivers were either preoccupied or were trying to do something else while driving. Systems that would eliminate some of the reasons that their attention was diverted from the driving task would help in this case, as would systems that reduced the effort that the driver had to devote to the second task. Systems that helped to teach drivers how to efficiently divide their attention would also be useful.

*Front-Seat Cargo Holder:* According to the subjects, some rear-end crashes occurred when the driver dropped an item they were carrying, either in their hands or on the front-passenger seat, and they reached down to pick it up. People often put items on the front seat or have to deal with beverage containers that are too big for the provided cup holders. Simply providing them with a device to safely and securely hold items that they do not want to put in the truck or back seat would reduce the need for them to bend down to pick up items when they are dropped or fall off of the seat. The device could be as simple as a package holder that can be quickly adjusted to hold various shapes and sizes of items and is attached to the front passenger seat. The device would, of course, need to be crash-tested and designed with safety in mind.

*In-Vehicle Street Signs:* According to the subjects, some rear-end crashes occurred because driver was looking at street signs and not at the traffic flow. A system that brought this information into the vehicle would allow the driver not have to turn their head away from the traffic information to locate and read signage. An additional feature of a system such as this

is that it could also display the traffic control signs inside the vehicle-- another self-reported reason for rear-end crashes in this study.

*Neck Flexibility Training:* Several middle-age and older subjects reported that their rear-end crash occurred when they were looking over their shoulder to check their blind spot. Since it is well-known that flexibility declines in older adults (see, e.g., Eby & Molnar, in press), these subjects may have had difficulty performing this movement because of decreased flexibility. The direct solutions to this problem--mirror systems and proximity detection systems--are either currently available or are in development. A different approach to this problem would be to implement a flexibility training program that was designed specifically to improve flexibility and strength for the maneuvers needed for safe driving, such as neck turning.

*Hazardous Situation Detector:* Some of the younger subjects reported that they were thinking about other things at the time of their rear-end crash. Assuming that people of all ages are thinking about other things while driving, this self-reported factor in the crashes of young people may indicate that, because of inexperience, their driving task is less automated, thus requiring greater attention for safe operation of a vehicle. In addition it is well known that young drivers have greater difficulty than others in identifying hazardous traffic situations as they are developing. The slightly preoccupied younger driver would have less attention to devote to perceiving hazards, when even with full attention they have difficulty with this task. A solution to this problem is to obtain more experience in recognizing hazards. Again, the direct approach to this problem, to have the younger driver gain the experience in a setting that is relatively safe such as a simulator, have already been implemented. A different approach is to design an on-the-road system that identifies specific situations that have a high probability of being hazardous, and then warns the driver or asks if he or she sees it. This concept would have to be explored empirically before any specific recommendations could be made.

## *Unavoidable Crashes*

*Large Vehicle Lane Control:* As mentioned earlier, several of the subjects reported that their rear-end crash was unavoidable and resulted from the actions of drivers several vehicles ahead which they could not see. One reason mentioned for the inability to see the actions of vehicles more than one vehicle ahead was that the vehicle immediately in front of the driver was a van/minivan, large pick-up truck, or sport-utility vehicle. Requiring these vehicles to stay in certain lanes, perhaps in high traffic areas, would allow the more-common passenger vehicles to be able to see traffic movement more than one vehicle ahead. Lane restriction for large trucks is already implemented in many areas.

*Ban Darkened Rear Windows:* Another reason mentioned for the inability to see the actions of vehicles more than one vehicle ahead was that the vehicle immediately in front of the driver had a darkened rear window. An obvious countermeasure is to ban these types of windows.

*In-Vehicle Display of Traffic Patterns:* Another way to allow the driver to have information about the movement of vehicles more than one vehicle ahead is to bring this information into the vehicle electronically. It is possible that the systems that sense lane occupancy and speed of vehicles for freeway surveillance systems could be used to communicate lane occupancy and vehicle speeds to a device in the vehicle. Again, the type of system, algorithms, situations that constitute potential hazards, and message form, content and timing would need to be thoroughly researched.

## **Conclusions**

This pilot study has demonstrated that examining the crash from the point of view of the driver was a somewhat fruitful approach of coming up with concepts that could be developed into countermeasures. In this study, only rear-end crashes were investigated. The study approach could be applied to other crashes to develop countermeasure concepts for different types of crashes. However, it is important to note that many of the self-reported reasons for

the crashes (both question-based and explanation-based) could have been derived solely from the available crash statistics.

Given the study findings and the rear-end-crash-countermeasure concepts that have been proposed, the next step is to present these concepts to a group of experts for feedback and revision. The most promising and innovative concepts should then be selected and studied further. For example, the electronic hazardous-driving-action feedback system takes an approach to potentially reducing rear-end and other crashes that is unique from current approaches. This concept has to be tested with actual drivers. The concept could be quickly tested with a mock-up system using various types of available technology to see if the countermeasure has potential for further development. The effect of different feedback information on positively changing driving behaviors would also have to be empirically determined.

## REFERENCES

Eby, D.W. & Molnar, L.J. (in press). *Matching Safety Strategies to Youth Characteristics: A Literature Review of Cognitive Development. (Technical Report)*. Washington, DC: US Department of Transportation.

Bernstein, D.A., Roay, E.L., Scrull, T.K., & Wickens, C.D. (1991). *Psychology, 2<sup>nd</sup> Edition*. Boston, MA: Houghton Mifflin.

**APPENDIX A:**  
**Moderator's Guide**

## Moderator's Guide

### Introductions

lead-in: roles/rules in focus group

Research project for UMTRI looking the crash from the drivers perspective. Have looked at statistics, now we want to know what the drivers think happened. By knowing what the driver saw, heard, didn't see, didn't hear, we can think about features that may prevent such crashes in the future.

1. I'd like you to think back to the time of your crash,  
Tell us the circumstances and tell us what happened

### Points to be covered?

- C When your crash occurred - day, night, rush hour?
- C What was the purpose of your trip?
- C Where you in a hurry?
- C Where was the crash - city, suburbs, small town, mall, ramp, rural, speed limit?
- C Was your crash at an intersection - signal, stop sign, yield sign, no sign?
- C Was it the road (not at an intersection)? Type of a road was it? - grades, curves, how fast were you going? How close together were the cars?
- C What was the weather? - rain, snow, sleet, no weather problems
- C Did you have vehicle problems?
- C Who was with you in your car - what were they doing?
- C What you were doing?
- C Do you remember what you were thinking about? If yes, what?
- C What happened?
- C What were the actions of the other car?
- C What type of vehicle was it? Who was driving it? How many people were in it?
- C What was the damage?

2. Why do you think your crash occurred? What do you think the reasons are? Why do you think so?

Do you think any of the following contributed to the crash? - how much?

- C Vehicle problems
- C The weather - visibility
- C Road surface - slippery, wet, icy, snow covered
- C The road itself - curves, hills, couldn't see
- C road signs - confusing
- C the traffic signal
- C actions of the other driver (Did you assume that the driver of the car was going to do something that he/she did not do?)

- C passenger interference
- C personal error
- C Other Distraction - what kind
- C other

3. Were you aware of the other car you before the crash?  
Did you see it? Did you hear it?

4. Did you have any clues that there was a problem? What were they? Did you hear, see, sense anything unusual?

5. What was going through you mind at the time of the crash?

6. Do you think this type of crash if unusual or fairly common? Why do you think so?

7. Think about your crash and crashes like it. What do you think would help you and others avoid crashes of this type.

8. If you had more time to react - could you have avoided the crash? How much more time?

Do you think a warning system of some type would help to avoid such crashes? What kind of warning do you think would help?

What about a system that lets you know that there is a vehicle within some distance of your vehicle? - do you think that would help?

What do you think of a system that monitored the distance between cars and gave you a warning if the space between your car and the one in front was closing too rapidly for the speed at which you were traveling - would you consider using it.

How about a system that monitored whether you were falling asleep? Do you think it would have helped you or others that experienced similar crashes?

9. Would you be willing to try out such warning systems. Would you consider buying any of these systems as options on your car? How much would you be willing to pay such systems? Proximity warning system, closing distance warning system, sleep monitoring system?

**APPENDIX B:**  
**Letter to Potential Subjects And Informed Consent Form**

**The University of Michigan  
Transportation Research Institute**  
2901 Baxter Road, Ann Arbor, Michigan 48109-2150

July 13, 1998

John Smith  
100 Main Street  
Some City, MI 48100

Dear Mr. Smith:

The University of Michigan Transportation Research Institute is studying ways to help prevent rear-end crashes. As part of this study we want to talk to drivers who have recently experienced such a crash. We received your name from the State of Michigan Vehicle Accident Records and would like to invite you to participate in a focus group of drivers who have had a similar experience. In about a week, one of our researchers will call to see if you would like to participate in this study.

A focus group is a structured group interview of people who have something in common. If you take part in this study, you will participate in one focus group session for approximately 1 hour you will be asked to talk about your experience in the rear-end crash, for example, what you, what you heard, what clues you had or did not have that something was wrong, and so on. The atmosphere will be friendly and congenial and you will receive a payment of \$35 for your participation. You will also be asked to sign an informed consent form, a copy of which is enclosed for your review.

Any information you provide will be considered strictly confidential and will be used only for the purposes of this study. Your name will never appear in any study publication. If you have any questions about this study, please call Dr. Lidia Kostyniuk, the project director, at 734-763-2466. She will be happy to assist you.

Sincerely yours,

Carl Christoff  
Research Associate

Enc. Informed Consent Form





Name:

Date:

**APPENDIX C:**  
**Demographic Questionnaire and Subject Demographics**



## Subject Demographics

How Many Years Have You Driven?	Age Group		
	18-to-24	25-to-64	65 and over
Mean	7.1	27.4	53.6
SD	2.2	14.4	9.8
N	9	5	11

How Many Miles Do You Drive in a Year?	Age Group		
	18-to-24	25-to-64	65 and over
Mean	16,550	17,000	13,590
SD	1,232	7,079	6,964
N	10	5	11

What Type of Car Do You Drive?			
Vehicle Type	Age Group		
	18-to-24	25-to-64	65 and over
Passenger	7	3	6
Sport Utility	2	0	1
Pickup Truck	0	0	0
Minivan	0	0	0
Station Wagon	0	0	1
Full Size Van	1	0	0
Other	0	2	3
<b>TOTAL</b>	10	5	11

<b>Are You Male or Female?</b>			
<b>Sex</b>	<b>Age Group</b>		
	<b>18-to-24</b>	<b>25-to-64</b>	<b>65 and over</b>
<b>Male</b>	3	3	5
<b>Female</b>	7	2	6

<b>How Old Are You?</b>	<b>Age Group</b>		
	<b>18-to-24</b>	<b>25-to-64</b>	<b>65 and over</b>
<b>Mean</b>	23.4	43.0	73.7
<b>SD</b>	1.9	14.5	5.7
<b>N</b>	10	5	11

<b>What is the Highest Level of Education you Have Completed?</b>			
<b>Education Level</b>	<b>Age Group</b>		
	<b>18-to-24</b>	<b>25-to-64</b>	<b>65 and over</b>
<b>Less than High School</b>	0	0	0
<b>High School Diploma/Equivalent</b>	0	0	2
<b>Some College</b>	7	3	4
<b>College Degree</b>	2	0	1
<b>Some Graduate Education</b>	1	0	1
<b>Graduate Degree or Higher</b>	0	2	3
<b>TOTAL</b>	10	5	11

<b>What Best Describes Your Annual Household Income?</b>			
<b>Annual Household Income</b>	<b>Age Group</b>		
	<b>18-to-24</b>	<b>25-to-64</b>	<b>65 and over</b>
<b>less than \$14,999</b>	1	0	0
<b>\$15,000 - \$29,999</b>	5	0	3
<b>\$30,000 - \$49,000</b>	3	1	6
<b>\$50,000 - \$64,999</b>	1	0	0
<b>\$65,000 - \$79,999</b>	0	2	1
<b>\$80,000 - \$94,999</b>	0	1	0
<b>\$95,000 - \$109,999</b>	0	1	0
<b>more than \$110,000</b>	0	0	0
<b>missing</b>	0	0	1
<b>TOTAL</b>	10	5	11