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The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable Message Signs (CMS)

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16. Abstract (Limit: 250 words)

The *objectives* of this study investigating Changeable Message Signs (CMS) were to determine whether or not CMS messages really work, whether or not they cause traffic slow downs, and whether or not they have an impact on traffic flow. The participants were 120 licensed drivers from three age groups—18-24, 32-47, and 55-65 years old. Two experiments were conducted in a fully-interactive, PC-based STISIM driving simulator. Experiment One investigated the effectiveness of the following message, "CRASH/AT WYOMING AVE/USE THOMPSON EXIT." In Experiment Two, the final CMS message was: "AMBER ALERT/RED FORD TRUCK/MN LIC# SLM 509." *Results.* In Experiment Two, only 8.3% of the participants had Excellent AMBER Recall Scores, while 51.7% had Good scores. Gender significantly affected the AMBER Recall Scores—there were more females than males in the Excellent Category. A greater proportion of those who knew what AMBER Alert meant were in the Excellent and Good Categories. 21.7% of the participants slowed down by at least 2 mph. Whether or not traffic delays will result from drivers slowing to read AMBER Alerts in real life will depend on the extent of the slow downs and on current traffic density. In Experiment One, 55.8% of the participants took the Thompson Exit after seeing the Thompson Exit Message. Of the 53 participants who did not take the exit (1) 35.9% ignored the CMS message because they did not think that it applied to them; (2) 35.9% did not understand the CMS message; and (3) 22.5% did not notice the message. (It is not known why 5.7% of the 53 did not take the exit.) Changes to the wording of the messages are recommended.

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Executive Summary

0.1 Introduction

This report discusses two experiments investigating Changeable Message Signs (CMS). Although the Manual on Uniform Traffic Control Devices (1) states that CMSs "should not be used to display information other than regulatory, warning, and guidance information related to traffic control", other possible uses are being considered. These possible uses include presenting, safety, law enforcement, and travel quality messages, as well as Minnesota Department of Transportation (Mn/DOT) promotional messages. Also, whenever a request is received from the Minnesota Department of Public Safety, Mn/DOT will display AMBER Alerts on CMSs. Using CMSs to display non traffic-related messages in addition to traffic-related messages raises issues about effectiveness and traffic safety. The ***objectives*** of this study were to determine: (1) whether or not CMS messages really work; (2) whether or not CMS messages cause traffic slow-downs; (3) the likely impact of CMS messages on traffic flow; and (4) whether or not messages should be presented on CMSs only when necessary.

0.2. Method

Participants. The participants in the two experiments were 120 licensed drivers. They came from three age groups—18-24, 32-47, and 55-65 years old. Each age group had 40 participants (20 males and 20 females).

Simulator. Participants drove a fully-interactive, PC-based STISIM driving simulator, comprised of an automotive-style seat and three 17-inch computer monitors. They drove through a virtual environment presented on the computer monitors using a steering wheel, accelerator pedal, and brake pedal. The simulator adjusted speed and direction by registering the participant's inputs to these controls. The steering wheel was linked to a torque motor, providing forced-feedback, to add realism to the steering. There was a virtual speedometer at the bottom of the center display. Engine noise was provided by two small speakers located at shoulder height behind the CRT displays. The virtual environment was developed using STISIM's Scenario Definition Language. Additional modifications were made to the Test scenarios so that the lettering on the CMS Messages and Guide signs could be read when the participants were approximately 860 feet (262 meters) from them.

Experimental Design. Two experiments were conducted back-to-back. Experiment One investigated the effectiveness of a Category I (site-specific, time-critical) message, while Experiment Two focused on AMBER Alerts. (The CMS messages used in the experiments were provided by Mn/DOT.) In both experiments, participants drove approximately 20 miles on a four-lane freeway. While driving, they encountered a series of nine overpasses that occurred at irregular intervals along the freeway. CMS sites were located on five of these overpasses. There were also two guide signs along the route, advising participants of the distances to upcoming exits. Experiment One examined the effectiveness of the following Category I (site-specific, time-critical) message: "CRASH AT WYOMING AVE USE THOMPSON EXIT." This message was presented at the end of the drive. There were two experimental conditions. Half of the participants from each age group were randomly assigned to each condition. In Condition A, prior to reaching the Thompson Exit CMS message, participants encountered the four CMS sites which displayed the following Category III (non site-specific, non time-critical) message: "STAY WITH YOUR VEHICLE WHEN STALLED." In Condition B, the first four CMS sites did not display a message. Experiment Two examined the effectiveness of AMBER Alerts. Participants drove the same four-lane freeway as in Experiment One. However, in Experiment Two the final CMS message was: "AMBER ALERT RED FORD TRUCK MN LIC# SLM 509."

Procedure. After signing a consent form, participants took a practice drive in the simulator. Then they drove in Experiment One—half of the participants drove the Condition A scenario and half drove the Condition B scenario. At the end of the drive, after the participant had either taken the exit or driven past the Thompson Avenue exit, the experimenter noted whether or not the participant had taken the exit. Then, the participants drove in Experiment Two. In this experiment, when they passed the fifth CMS site, displaying the AMBER Alert message, the experimenter stopped the simulator and asked the participant "What was written on the last Message Board over the road?"

0.3. Effectiveness of Amber Alerts

In Experiment Two, on the basis of AMBER Recall Scores, the 120 participants were assigned to one of four categories: (1) Poor, for participants who obtained AMBER Recall Scores of zero or less, indicating they remembered nothing, or responded with incorrect information; (2) Fair, for those with scores between zero and 5.5, who could remember AMBER Alert and some vehicle information; (3) Good, for participants scoring between 6 and 10 points, who could remember "AMBER Alert," some vehicle information, and part of the license plate number; and (4) Excellent, for those participants scoring between 10.5 and 13, who could recall "AMBER Alert," vehicle information, and five or six alphanumeric characters on the license plate number. Only 8.3% (10/120) of the participants were in the Excellent Category. The Good Category included 51.7% (62/120) of the participants. The Fair and Poor Categories had 31.7% (38/120) and 8.3% (10/120) of the participants, respectively.

Chi-Square Tests showed that neither the Age of the participants nor Prior Exposure to Category III CMS messages affected the AMBER Recall Scores. In contrast, a Chi-Square Test showed that Gender did significantly affect the AMBER Recall Scores—there were many more females than males in the Excellent Category. After completing both experiments, participants were asked the meaning of AMBER Alert. Eighty-two (72%) of the participants knew its meaning; 32 (28%) did not. A Chi-Square Test showed knowledge of the meaning of AMBER Alert significantly affected the AMBER Recall Scores. A greater proportion of those who knew what AMBER Alert meant were in the Excellent and Good Categories, while a greater proportion of those who did not know its meaning were in the Poor or Fair Categories.

0 4. The Extent to Which Amber Alerts Caused Slow-Downs

Mean Speed on the Approach to the AMBER Alert. The mean speed of the participants in the 860-foot (262-meter) road segment before the AMBER Alert was compared with their speed in the 3,000-foot (984-meter) region immediately before this segment. An Analysis of Variance (ANOVA) showed the following statistically significant effects—(1) the Younger Group drove faster than the Middle Age Group who, in turn, drove faster than the Older Group; (2) in the 860-foot (262-meter) road segment before the AMBER Alert there was a small reduction in mean speed for the Middle Age Group and a more substantial reduction for the Older Groups; (3) the participants who had Prior Exposure to the Category III messages before encountering the AMBER Alert did not slow down in the 860-foot (262-meter) road segment before the AMBER Alert, while those who did *not* have Prior Exposure reduced their mean speed in the segment.

Participants who Slowed Down on the Approach to the AMBER Alert. Twenty-six of the 120 participants—i.e., 21.7%—slowed down by at least 2 mph (3.2 km/h) in the 860-foot (262-meter) road segment before the AMBER Alert; 16.7% slowed down by at least -4 to -5 mph (-6.4 to -8.0 km/h); and 1.7% slowed down by at least -10 to -11 mph (-16.1 to -17.7 km/h). Whether or not traffic delays will be caused by drivers slowing down to read AMBER Alerts in real life, will depend on the extent of the slow-downs and on the current traffic density. There was a significant effect of Age on the slow-downs that occurred as the participants approached the AMBER Alert: 42.5% of the Older Group slowed down—they were eight times more likely to slow down than the Younger Group. However, Gender, Prior Exposure to Category III CMS messages, knowledge of the meaning of AMBER Alert, and, surprisingly, obtaining higher AMBER Recall Scores did not affect the slow-downs.

0. 5. Effectiveness of the Thompson Exit CMS Message

In Experiment One, 67 participants took the Thompson Exit after seeing the Thompson Exit CMS Message, making the message 55.8% effective. Of the 53 participants who did not take the exit (1) 35.9% ignored the CMS message because they did not think that it applied to them; (2) 35.9% did not understand the CMS message; and (3) 22.5% did not notice the message. (It is not known why 5.7% of the 53 did not take the exit.). Age had a statistically significant effect on the response to the Exit Message—only 14 (35%) of the Younger Group took the exit, while 24 (60%) of the Middle Age Group and 29 (72.5%) of the Older Group took it. It is possible that Prior Exposure to Category III CMS messages affected the response to the Exit Message. Participants who were not exposed to the Category III CMS messages were more likely to take the exit. Gender did not have an effect.

0.6. Extent to which the Thompson Exit Message Caused Traffic to Slow Down

Mean Speed on the Approach to the Thompson Exit CMS Message. The mean speed of the participants in the 860-foot (262-meter) road segment before the Thompson Exit Message was compared with their speed in the 3,000-foot (984-meter) region immediately before this segment. An Analysis of Variance (ANOVA) showed the following statistically significant effects—(1) the Younger Group drove faster than the Middle Age Group who, in turn, drove faster than the Older Group; (2) there was a reduction in speed in the 860-foot (262-meter) road segment before the Thompson Exit Message for the Older Group but not for the Younger or Middle Age Groups; (3) participants who did not have Prior Exposure to Category III Messages reduced speed in the 860-foot (262-meter) road segment before the Thompson Exit while those who did have Prior Exposure did not.

Participants who Slowed Down on the Approach to the Thompson Exit CMS Message. Sixteen (13.3%) of the participants in the experiment, slowed down by at least 2 mph (3.2 km/h) for the kind of Category I (time-critical, site-specific) CMS message that is currently displayed by MN/DOT—13.3% (4/120) of the participants slowed down by at least -10 to -11 mph (-16.1 to -17.7 km/h), 8.2% (10/120) slowed down by at least -4 to -5 mph (-6.4 to -8.0 km/h). The higher the prevailing traffic density, the greater the impact of slower drivers on traffic flow. There were no effects of Gender, Age, or Prior Exposure to Category III CMS Messages on the slow-downs.

0.7.1 Recommendations

We recommend that the Minnesota Department of Public Safety increase its efforts to make the public more aware of the AMBER Alert system. We also recommend that the message be changed. It is particularly difficult to remember the license plate number. Instead, the AMBER Alert CMS Message should tell drivers to tune into an appropriate radio station, whose call sign will be easier to remember. When they tune into that station, the full AMBER Alert message, including the license plate number should be repeated frequently. This repetition will greatly aid drivers, making it more likely that the license plate number information will be moved from working (or short-term) memory to long-term memory, where it can be retained for a longer period of time. This will greatly increase the likelihood that if a driver encounters the vehicle mentioned on the AMBER Alert he or she will be able to recognize it. It is also likely that there will be fewer slow-downs than were found in this experiment. We also recommend changing the message in Crash CMS Messages so that they say "ROAD CLOSED"—this should greatly increase the number of drivers who take the exit—or "LANE CLOSED"—so that the information would be conveyed more clearly to drivers allowing them to make an informed choice about whether or not to stay on the freeway. The effect of previous exposure to Category III CMS messages was complex and remains a question for further research following an improvement in how easily the message content is understood.

Chapter 1
Introduction

1.1 Changeable Message Signs

Changeable Message Signs (CMS) are traffic control devices designed to display variable messages to motorists. [These signs are also known as Variable Message Signs (VMS) and as Dynamic Message Signs (DMS). For simplicity they are referred to throughout this proposal as Changeable Messages Signs (CMS)]. The Manual on Uniform Traffic Control Devices states that they "should not be used to display information other than regulatory, warning, and guidance information related to traffic control" (1).

Other possible uses of CMSs have been considered by the Minnesota Department of Transportation (Mn/DOT). In 1999, Mn/DOT's Traffic Management Center (TMC) sponsored a series of discussion groups dealing with CMSs. The results of the discussions were reported by MarketLine (2). Among other things, the discussants assessed possible new uses for CMSs. These possible uses included using CMSs to present Mn/DOT promotional, safety, law enforcement and travel quality messages.

Still more recently, in some states CMSs have been put to another use—to present AMBER Alerts as part of the AMBER (America's Missing—Broadcast Emergency Response) Plan. Mn/DOT will also present AMBER Alerts on CMSs, whenever they receive a request to do so from the Minnesota Department of Public Safety.

1.2 Objectives

The possible use of non traffic-related as well as traffic-related messages raises a number of issues about the effectiveness of CMSs and the safety impacts they may have on traffic. Because of this, Mn/DOT has posed the following questions (the **objectives** of the research presented here)—

- Should messages be presented on CMSs only when they are necessary, or should there always be some message on them?
- Do the messages presented on CMSs really cause slow-downs?
- Do the messages on CMSs really work?
- What is the impact of CMS messages on traffic flow?

These questions are considered further in the sections that follow.

1.3 Should messages be presented on CMSs only when they are necessary, or should there always be some message on them?

Initially in the USA, CMSs were designed to present traffic-related information—i.e., to report crashes or stalled vehicles ahead, whether they were in a traffic lane or on the shoulder; or to report traffic lanes that were shut down for roadwork. Further, the messages on the CMSs might suggest that the driver should prepare to slow down or take an alternative route. This kind of usage led Mn/DOT, and other State DOTs, to adopt a philosophy of only presenting messages on CMSs when they are necessary, and of not presenting any message on them when the road ahead is clear.

There are differences in the messages that are already being presented or are being considered for presentation on CMSs. The various messages can usefully be assigned to the following three categories.

Category I: Time-critical, site-specific, CMS messages.
The traffic-related messages that CMSs were designed to present are in this category—they are messages that contain information about current conditions occurring at specific locations and that may suggest how motorists deal with them. Depending on whether or not the messages in this category require a specific response, they can be further subdivided, as follows.
Category I (A) time-critical, site-specific CMS messages which give drivers information about traffic conditions *but which do not require a specific response*—examples are "TRAVEL TIME TO HIGHWAY 100, 20 MINUTES" or "TRAFFIC CONDITIONS POOR FOR THE NEXT TWO MILES."
Category I (B) time-critical, site-specific CMS messages which give drivers information about traffic conditions *but which suggest, or require, a specific response*—a message like "LANE CLOSED NEAR ST. CLAIR. ALTERNATE ROUTES SUGGESTED" suggests a specific response, whereas if the message was "ROAD CLOSED NEAR ST. CLAIR. USE OTHER ROUTES" a specific response would be required.

Category II: Time-critical, non site-specific, CMS messages.
At the moment only AMBER Alerts fall into Category II. AMBER Alerts are issued in cases of child abduction, when a child is in danger of serious bodily harm or death, and when descriptive information about the child, the suspect, or the getaway car is available. AMBER Alerts are time-critical because they are most effective in the first few hours of child abductions. In the cases where CMSs have been used to deliver AMBER Alerts, the messages have been issued state-wide—for example, the *San Francisco Chronicle* reports that five state-wide AMBER Alerts were issued in California in August 2002 (3).

Category III: Non time-critical, non site-specific, CMS messages.
In contrast to Category I and II CMS messages, Category III CMS messages are not time-critical. In addition, unlike Category I messages, they are not site-specific either. Examples of these messages include Mn/DOT promotional messages (e.g., "RAMP METERS REDUCE CRASHES 40%"), safety messages (e.g., "STAY WITH YOUR VEHICLE WHEN STALLED"), and law enforcement messages (e.g., "$77 FINE FOR WRONGFUL USE OF HOV LANE"). Although some Category III messages might refer to a particular time period, like the following law enforcement example—"EXTRA TROOPERS WORKING THIS WEEKEND"—they are not time-critical messages like AMBER Alerts.

Given the above categorizations, the question posed at the beginning of this subsection—
"Should messages be presented on CMSs only when they are necessary, or should there always be some message on them?"
can be refined as follows—
"When necessary, time-critical messages should be presented on CMSs, but when it is not necessary to present time-critical messages, should no messages be presented on CMSs or should non time-critical messages be presented?

If non time-critical messages are presented, then there would always be some message on the CMSs. In this case, we need to know whether or not motorists will become so used to non time-critical CMS messages that they do not pay attention to time-critical messages. If they do not pay attention to the time-critical messages, then they could be made more distinctive than the non time-critical messages. But if time-critical messages are made more distinctive will they then distract the motorist—so that driving performance deteriorates?

When non time-critical messages are not presented on CMSs (as is the case currently in Minnesota), are time-critical messages already so distinctive that they distract the motorist—with the result that driving performance deteriorates whenever messages are presented on CMSs?

These issues of attention and distraction are not easy to address. They have not been addressed in the large body of CMS message research that has been conducted. The following CMS research issues have been investigated:

- Attitudes of motorists toward the use of traffic and road information messages [Benson, (4); Lai and Wong, (5); Peeta, Ramos and Pasupathy, (6); Chatterjee, Hounsell, Firman, and Bonsall, (7)];
- Driver's ability to understand CMS messages [Marketline Research, (2); Dudek, Trout, Durkop, Booth, and Ullman, (8); Durkop and Dudek (9)];
- Differences in message use of peak, non-peak, and professional freeway users [Marketline (3)];
- Detection distances for messages presented on portable CMSs [Knoblauch, Nitzburg, Seifert, McGee, and Daly (10)];
- Photometric requirements for portable CMSs [Finley, Wooldridge, Mace, and Denholm (11)];
- Visibility and legibility of the messages presented on CMSs [Garvey and Mace (12)];
- Effect of fog on the visibility of CMSs [Colomb, Legoueix, Smith, Aston, and Williams (13)];
- Driver's ability to remember CMS messages [Metaxatos and Sööt; (14)];
- Differences between one-and two-phase CMS messages presented to both younger and older drivers [Guerrier, Wachtel, Budenz, (15)];
- Development of a CMS control heuristic framework dealing with the likelihood that motorists will take an alternative route when one is suggested by a CMS [Peeta and Gedela (16)].

In addition, the study conducted by Farby, Wochinger, Shafer, Owens, and Nedzesky addressing the safety effect of Electronic Billboards (EBB) is of relevance—Farby et al. consider the conspicuity and legibility of EBBs and the likely distracting effects they will have, as well as the effects of the age of the driver and of roadway characteristics (such as horizontal and vertical curves; interchanges and intersections; work zones) (17). These studies use the research tools listed by Bonsall—attitudinal research, stated preference methods, driving simulators, on-road trials, post-implementation (observational) studies (18). Some of these methods (e.g., attitudinal research and stated preference methods) are not amenable to addressing whether or not drivers actually do pay attention to particular messages or are distracted by them while they are driving. However, simulation, on–road trials and observational methods can be used. In this study, which pertains to issues of attention and distraction, we used a relatively low-cost driving simulator.

1.4 Do the messages presented on CMSs really cause slow-downs?

As mentioned in Section 2, it is possible that when non time-critical messages are not presented on CMSs (as they are not currently in Minnesota), time-critical messages may be so distinctive that they distract the motorist—with the result that current driving performance may deteriorate whenever messages are presented on CMSs.

A series of freeway guidance sign studies conducted by McNees and Messer indicates that the reading time required for these signs depends on the content of the signs (19). They also indicate that freeway guidance signs could be read in less than 6 seconds—which was what McNees and Messer suggest is the "desirable" reading time. Following McNees and Messer's lead, a number of investigators, including Farby et al. and Ram, Oppes, and Richards have assumed that 6 seconds is needed to understand CMS messages (17, 20). Guerrier, Wachtel, and Budenz allowed 8.86 seconds for their participants to read one- and two-screen simulated CMS messages (15).

As a part of this study we determined the time required for drivers to read typical Category I, II and III messages. Although time-specific, site-specific traffic-related messages may be read in 6 seconds or less, there are indications that the time-specific, non site-specific AMBER Alerts may require more time and could result in significant slow-downs. The *San Francisco Chronicle* reports that at 7:23 a.m. on Friday, August 30, a California Highway Patrol officer asked his superiors to turn off the AMBER Alert message on the CMS near the Cordelia truck scales on Westbound I-80 in Solano County (3). He made the request because too many drivers were slowing down to read the two-phase message.

1.5 Do the messages on CMSs really work?

Whether or not CMS messages really work is a more complex question than it seems at first. This is because the answer to the question depends on the details of each particular message. Some current and potential CMS messages require immediate responses, some suggest immediate responses, some suggest future actions, and for some no response is possible.

A mixture of responses is needed for the Category I CMS messages. A traffic-related message like “ROAD CLOSED NEAR ST. CLAIR AVENUE USE OTHER ROUTES” requires an immediate response. However, if the road is closed, the driver must use another route, whether a CMS message has been given or not.

If the message is “LANE CLOSED NEAR ST. CLAIR AVENUE ALTERNATIVE ROUTES SUGGESTED” no specific response is requested, and the driver may, or may not, take an alternative route. If the motorist is in the lane that is closed then it will be necessary to change lanes, or stop, or take an alternate route; on the other hand, if the motorist is not in the lane that is closed then, depending on the amount of traffic, he or she may be able to keep driving at the same speed in the same lane, or may have to slow down, or may take an alternate route. Responses of this kind can be investigated empirically.

If the message is “CRASH ON I-94 MAJOR DELAY” no immediate response is required or suggested, although the motorist is being given information that he or she may have to slow down soon.

Even though they are time-specific and site-specific, traffic quality messages like the examples given earlier, “TRAVEL TIME TO HIGWAY 100 20 MINUTES,” or “TRAFFIC CONDITIONS POOR FOR THE NEXT 2 MILES” do not require any response—they are informational messages.

The time-critical, non site-specific Category II AMBER Alert messages do not require a response. However, they do request a complex set of responses—(1) to remember the number plate of a hunted vehicle and a phone number; (2) to look at the number plates of other vehicles to see if they are the hunted vehicle; (3) if the hunted vehicle is spotted, then to report it using the remembered phone number. Responses of this kind can, at least partially, be investigated empirically.

Many Category III CMS messages do not require any response—e.g., “RAMP METERS REDUCE CRASHES 40%. Some give advice regarding appropriate responses if certain situations occur—e.g., “STAY WITH YOUR VEHICLE WHEN STALLED.” Other Category III CMS messages do not require particular responses, though they may suggest them—e.g., the message TROOPERS WORKING THIS WEEKEND” may suggest that driving with extra care would be prudent over the weekend.

The discussion above indicates that responses to only a limited set Category I (time-critical, site-specific) CMS messages can be investigated empirically.

With Category II AMBER Alerts it is possible—with a low-cost driving simulator—to determine whether drivers can remember the number plate of a hunted vehicle and a phone number. It is less easy to investigate the search for that number plate, or what might follow if it is spotted. For ethical reasons it would be difficult to investigate AMBER Alerts in the real world.

1.6 What is the impact of CMS messages on traffic flow?

The impact on traffic flow of CMS messages is directly related to the earlier question about whether the messages presented on CMSs really do cause slow-downs. Those CMS messages that do not cause slow-downs will not have an impact on traffic flow; while those CMS messages that do cause slow-downs will have an impact on traffic flow.

In order to address the questions discussed in the previous sections of this document, two experiments were conducted with the use of a driving simulator. In these experiments we investigated a number of time-critical Category I (B) CMS messages. The experiments and results are presented in the chapters that follow.

Chapter 2
Method

2.1 Participants

There were 120 participants in the experiment. Participants were licensed drivers from one of three age groups: 18-24, 32-47, and 55-65. Each age group had 40 participants. There were 20 males and 20 females within each age group. Participants were recruited from the Twin Cities metropolitan area, and reported regularly commuting on the Interstate highways in the metropolitan area. At the end of the experiment, participants were paid $40 for their participation.

2.2 Driving Simulator

Each participant drove in a fully-interactive, PC-based driving simulator provided by STISIM. The simulator was comprised of an automotive-style seat for the driver, which faced a bank of three 17-inch computer monitors. A photograph of the simulator can be seen in Figure 2.1.

The virtual environment through which participants drove was generated by three simulator PCs, and presented on the computer monitors. At the bottom of the center display, a virtual speedometer indicated the speed at which the participant drove through the virtual world. In the upper right corner of the center display, a small window provided a rear-view—this window can be seen in the center display in Figure 2.1. In the lower-right corner of the side displays, a window simulating a side-view mirror was provided— these windows can be seen in the two side displays in Figure 2.1.

Engine noise for the simulator was provided by two small speakers located behind the computer monitors at the approximate shoulder height of the participants. A subwoofer located on the floor beneath the driver's seat provided low-frequency noise.

Participants drove the simulator through the virtual world using a steering wheel, accelerator pedal, and brake pedal. The simulator PC adjusted the participant's speed and direction by registering the participant's inputs to these controls. The steering wheel was linked to a torque motor, which provided forced-feedback, to add realism to the "feel" of the steering.

The virtual environment was developed using STISIM's Scenario Definition Language (SDL). Additional modifications were made to the test scenario so that the lettering on the CMS Messages and the guide signs could be read when the participants were approximately 860 feet (262 meters) from them.

Figure 2.1. The STISIM Driving Simulator used in this experiment.

2.3 Experimental Design

Two experiments were conducted back-to-back. Experiment One investigated the effectiveness of Category I (site-specific, time-critical) messages, while Experiment Two focused on AMBER Alerts (Category II time-critical, non site-specific CMS messages.). The design of the two experiments is discussed in the following subsections.

2.3.a. *Experiment One*. Experiment One examined the effectiveness of the following Category I (site-specific, time-critical) message. The message was chosen by Mn/DOT for use in the experiment and is identical in format to one they would use in a real world setting. The following message was presented at the end of the drive:

CRASH
AT WYOMING AVE
USE THOMPSON EXIT

There were two experimental conditions, Condition A and Condition B. Half of the participants from each age group were assigned to either Condition A or Condition B, using a counterbalanced design. In Condition A, prior to reaching the Thompson Exit CMS message at the end of the drive, the four CMS sites that the participants encountered displayed the following Category III (non site-specific, non time-critical) message (also selected by Mn/DOT):

STAY WITH
YOUR VEHICLE
WHEN STALLED

In contrast, in Condition B, the first four CMS sites did not display a message.

In both conditions, participants drove approximately 20 miles on a four-lane freeway. While driving, the participants encountered a series of nine overpasses that occurred at irregular intervals along the freeway. CMSs were placed on five of these overpasses. There were also two guide signs along the route, advising participants of the distances to upcoming exits. Table 2.1 gives the distance from the start of the scenario at which the overpasses that were not CMS sites (listed simply as bridges in the table), the overpasses that were CMS sites, and the guide signs occurred.

Table 2.1. Locations of overpasses, CMS sites, and Guide signs.

Structure	**Distance (ft)**
Bridge 1	5,432
CMS Site 1	10,632
Bridge 2	17,432
CMS Site 2	29,472
Bridge 3	49,432
CMS Site 3	55,872
Guide Sign 1	68,115
Bridge 4	69,432
CMS Site 4	82,272
Guide Sign 2	93,515
CMS Site 5	98,292

The following five pages show Figures 2.1 through 2.5. These figures show the central panel of the simulator that the participants saw as they approached the various structures listed in Table 2.1.

- Figure 2.2 shows the Category I message advising participants to use the Thompson Avenue Exit that was displayed on the final overpass (CMS Site 5).
- Figure 2.3 shows an example of one of the guide signs as it was presented to participants.
- Figure 2.4 shows one of the four CMS sites that displayed a Category III (non site-specific, non time-critical) message to the participants assigned to Condition A.
- Figure 2.5 shows one of the four CMS sites that were blank and that were seen by the participants assigned to Condition B.

Figure 2.2. Overpass with Category I CMS Message.

Figure 2.3. The First Guide Sign.

Figure 2.4. Overpass with Category III CMS Message.

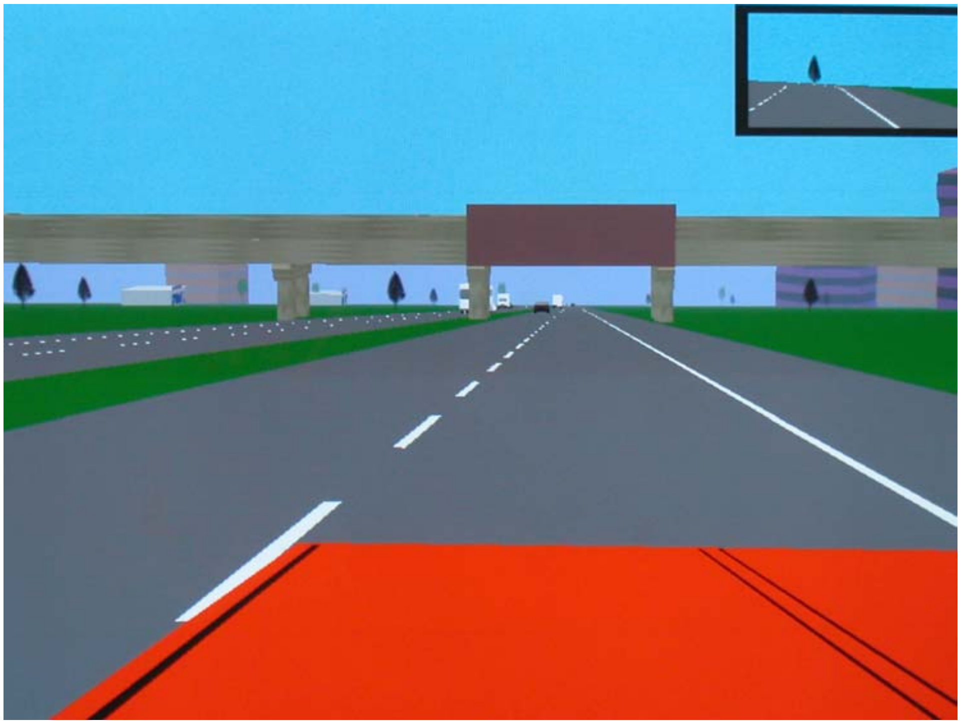
Figure 2.5. Overpass with No CMS Message.

2.3.b *Experiment Two*

Experiment Two examined the effectiveness of AMBER Alerts (Category II time-critical, non site-specific CMS messages). Participants were asked to drive along the same four-lane freeway that they drove in Experiment One. However in Experiment Two, the final CMS site did not display a Category I CMS message—instead it displayed the following AMBER Alert (also provided by Mn/DOT):

AMBER ALERT
RED FORD TRUCK
MN LIC# SLM 509

As in Experiment One, there were two experimental conditions, Condition A and Condition B. Prior to reaching the final CMS message (in this case the AMBER Alert) at the end of the drive, participants in Condition A encountered four CMS sites displaying the "STAY WITH YOUR VEHICLE WHEN STALLED" message shown in Figure 2.4, while participants in Condition B, encountered CMS sites, like the one shown in figure 2.5, that were not displaying a message.

The participants assigned to Condition A in Experiment One were also assigned to Condition A in Experiment Two. Similarly, the participants who were assigned to Condition B in Experiment One were assigned to Condition B in Experiment Two. This means that those participants who encountered the "STAY WITH YOUR VEHICLE WHEN STALLED" message on four CMS sites in Experiment 1 also encountered that message on four CMS sites in Experiment 2. And those participants who encountered four CMS sites that were blank in Experiment 1 also encountered four blank CMS sites in Experiment 2.

Figure 2.6 shows the final CMS site with the AMBER Alert message that the participants, in both Condition A and Condition B, saw on the central panel of the simulator at the end of the drive.

Figure 2.6. The Final CMS Site with AMBER Alert.

2.4 Procedure

When each participant arrived, the experimenter verified his or her age by examining his or her valid driver's license. Participants were then presented with a consent form. After the participant had read and signed the consent form, he or she was seated in the driving simulator.

Before the two experimental drives, participants had a practice drive to familiarize themselves with driving in the simulator. The practice drive was approximately 10 minutes, and was lengthened if the participant required additional training. During and at the end of the practice drive, the experimenter solicited questions from the participant and answered them.

Following the training session, general instructions were given for the experiment. The text of these instructions can be found in Appendix A. The experimenter then asked the participant if he or she had any questions, and answered them.

Then, Experiment One began. The participant drove the scenario for the condition to which he or she was randomly assigned—either Condition A (Category III CMS messages) or Condition B (no CMS messages). At the end of the scenario, after the participant had either driven past, or had taken the Thompson Avenue exit, the experimenter stopped the simulator, and noted whether or not the participant had taken the exit.

The scenario for Experiment Two was presented immediately after Experiment One. As mentioned above, participants who were in Condition A for the first experiment were in Condition A for the second experiment, and participants who were in Condition B for the first experiment were in Condition B for the second experiment.

Participants drove the second experimental scenario until they had passed the fifth CMS site, which carried the AMBER Alert message. Immediately after the participant had passed this CMS, the experimenter stopped the simulator and asked the participant the questions from the question sheet (Appendix B). After answering the questions, participants were asked to complete a post-experiment questionnaire pertaining to their driving habits. After answering the questions, participants were debriefed, paid for their participation, and released.

Chapter 3
The Effectiveness of Amber Alerts

3.1 Scoring Responses to AMBER Alert Messages

In the second experiment, immediately after passing under the bridge on which the CMS AMBER Alert was displayed, each participant was asked to pull over and stop. Then he or she was asked to tell the experimenter "what was written on the last Message Board over the road." The participant's response was written down by the experimenter. Subsequently, an AMBER Recall Score was determined for the participant, by scoring his or her response using the guidelines provided in Table 3.1.

Table 3.1. Guidelines for scoring the AMBER message

AMBER Message	Score
Line #1	AMBER—1 point ALERT—1 point
Line #2	RED—1 point FORD—1 point TRUCK—1 point If "PICKUP" instead of "TRUCK—1/2 point
Line #3	MN—1 point LIC #—1 point SLM—3 points (1 point for each correct letter in correct position in order) 509—3 points (1 point for each correct number in correct position in order)
Points subtracted	1 point deducted for each piece of incorrect information

Using the guidelines provided in Table 3.1, AMBER Recall Scores were determined for all 120 participants.

3.2 Overall AMBER Recall Scores

First, we examined the overall recall rates. There was considerable variation in the AMBER Recall Scores over the 120 participants—the scores ranged from a perfect score of 13, which was achieved by two of the 120 participants, to -9, which was also recorded for two participants who both produced nine pieces of incorrect information when asked, "What was written on the last Message Board over the road?"

On the basis of their AMBER Recall Scores, participants were assigned to one of four categories: (1) Poor, (2) Fair, (3) Good, or (4) Excellent. The definitions used for these categories were as follows:

- The Poor Category includes participants who obtained AMBER Recall Scores of zero or less. A score of zero or less indicates either that the participant remembered nothing, or that he or she produced information that was incorrect.
- The Fair Category includes participants whose AMBER Recall Score was between zero and 5.5. The participants in this category were typically able to remember the AMBER Alert term on Line 1 of the AMBER Alert message, and some of the vehicle information on Line 2.
- The Good Category includes participants who scored between 6 and 10. Typically, they were able to remember the AMBER Alert term on Line 1, some of the vehicle information on Line 2, *and* part of the vehicle's license plate number presented on Line 3.
- Finally, the Excellent Category includes those participants who scored between 10.5 and 13. These participants were able to recall the AMBER Alert term on Line 1, some of the vehicle information, *and* at least five of the six alphanumerics that made up the license plate number presented on Line3.

Table 3.2 shows how the 120 participants were distributed among these four categories

Table 3.2. Number (and percentage) of participants in each response category.

Range of AMBER Scores	**Response Category**	**Number (& Percentage) of Participants in Category**
Minus 9 to Zero	Poor	10 (8.3%)
+ 1 to + 5.5	Fair	38 (31.7%)
+ 6 to + 10	Good	62 (51.7%)
+10.5 to +13	Excellent	10 (8.3%)

The numbers presented in Table 3.2 are disturbing. Only 8.3% of the participants were in the Excellent Category, and although the Good Category included 51.7% of the participants, that leaves sizable numbers of participants in the Fair (31.7%) and Poor Categories (8.3%).

The next four sub-sections of this report discuss the effects on the AMBER Recall Scores of the following variables:

- The age of the participants.
- The gender of the participants.
- The presence or absence of Category III (non time-critical, non site-specific) CMS messages before the participant reached the AMBER Alert.
- Whether or not the participants knew what AMBER Alert meant.

3.3 The Effect of Age on the AMBER Recall Scores

The number of participants from the three age groups tested in the experiment who were in each of the four response categories is shown in Table 3.3.

Table 3.3. Number of participants from the three age groups in each response category.

Response Category	**Younger Group (18 to 24 years old)**	**Middle Group (32 to 47 years old)**	**Older Group (55 to 65 years old)**	**Totals**
Poor	5	2	3	10
Fair	10	15	13	38
Good	21	19	22	62
Excellent	4	4	2	10
Totals	40	40	40	120

To determine whether there were differences in the distributions of participants from each of the three age groups across the four response categories, a Chi-Square Test (see Siegel and Castellan) was conducted (21). The χ^2 value obtained was 3.426. Since this value does not exceed 12.59, the critical value of χ^2 for 6 *df* and $\alpha = 0.05$, we can conclude that the age of the participants had no effect on the AMBER Recall Scores.

3.4 The Effect of Gender on the AMBER Recall Scores

The numbers of male and female participants tested in the experiment who were in each of the response categories is shown in Table 3.4.

Table 3.4. Number of male and female participants in each response category.
category.

Response Category	**Males**	**Females**	**Totals**
Poor	7	3	10
Fair	19	19	38
Good	33	29	62
Excellent	1	9	10
Totals	60	60	120

To determine whether there were differences in the gender distributions shown in Table 3.4, a Chi-Square Test (see Siegel and Castellan) was conducted (21). In this case, the χ^2-value obtained was 8.258. This does exceed 7.82, the critical value of χ^2 for 3 *df* and $\alpha = 0.05$. We can conclude that the gender of the participants did affect the AMBER Recall Scores.

Further inspection of Table 3.4, shows that the number of males and females in the Fair Category was equal, and that there were more males than females in the Poor and Good Categories. However, there were many more females than males in the Excellent

Category. The Binomial Test (see Siegel and Castellan) was used to compare the number of males and females in the Excellent Category (21). It showed that significantly more females were in this category (at the $p = 0.0107$ level). [It should be noted that when the Binomial Test was conducted for the Poor Category, the difference in the numbers of males and females in that category was not statistically significant.]

3.5 The Effect of Prior Exposure to Category III CMS Messages on the AMBER Recall Scores

The number of participants in each of the response categories that were exposed to Category III (non time-critical, non site-specific) CMS messages and the number who did not see Category III messages before reaching the CMS displaying the AMBER Alert are shown in Table 3.4.

Table 3.5. Number of participants who were, or were not, exposed to Category III CMS messages prior to reaching the AMBER Alert in each response category.

Response Category	**Exposed to Category III messages**	**Not exposed to Category III messages**	**Totals**
Poor	7	3	10
Fair	16	22	38
Good	32	30	62
Excellent	5	5	10
Totals	60	60	120

To determine whether there were differences between the distribution for participants who were exposed to Category III messages and the distribution for those who were not exposed, a Chi-Square Test (see Siegel and Castellan) was conducted (21). The χ^2 value obtained was 2.612. This does not exceed 7.82, the critical value of χ^2 for 3 *df* and $\alpha = 0.05$. Therefore, we can conclude that prior exposure to Category II CMS messages did not affect the AMBER Recall Scores.

3.6 The Effect of Knowing the Meaning of AMBER Alert on the AMBER Recall Scores

Following Experiment 2 one of the questions participants were asked was, “What does AMBER Alert mean?” Responses to this question were obtained from 114 of the 120 participants. Of these 114, 82 (72%) knew that it was an alert issued when there had been a kidnapping, while 32 (28%) did not know what AMBER Alert meant (although some of them had inventive guesses—e.g., that the alert might refer to terrorist activity).

Table 3.6 shows the number of participants who knew the meaning of AMBER Alert and the number who did not know the meaning in each of the response categories.

Table 3.6. Number of participants who did, and did not, know the meaning of AMBER Alert in each response accuracy category.

Response Accuracy Category	**Had prior knowledge of AMBER Alerts**	**No prior knowledge of AMBER Alerts**	**Totals**
Poor	6	4	10
Fair	20	16	36
Good	47	11	58
Excellent	9	1	10
Totals	82	32	114

To determine whether there were differences between the distribution for participants who knew what AMBER Alert meant and the distribution for those who did not, a Chi-Square Test (see Siegel and Castellan) was conducted (21). The χ^2 value obtained was 9.577. This exceeds 7.82, the critical value of χ^2 for 3 *df* and $\alpha = 0.05$, and we can conclude that knowledge of what AMBER Alert meant did affect the AMBER Recall Scores.

The number of participants who knew the meaning of AMBER Alert was more than double the number who did not know. Because of this, it may not be immediately clear from Table 3.6, exactly what effect this knowledge had on the AMBER Scores. The effect is made clearer in Table 3.7, which shows the proportions of participants who knew what AMBER Alert meant and of those who did not know.

Table 3.7. Proportion of participants who did, and did not, know the meaning of AMBER Alert in each response accuracy category.

Response Accuracy Category	**Had prior knowledge of AMBER Alerts**	**No prior knowledge of AMBER Alerts**
Poor	0.073	0.125
Fair	0.244	0.500
Good	0.573	0.344
Excellent	0.110	0.031
Total	1.000	1.000

Table 3.7 makes clear the statistically significant effect found when the Chi-Square test was conducted on the data in Table 3.6. A greater proportion of those with prior knowledge of what AMBER Alert meant were in the Excellent or Good Categories, while

a greater proportion of those who did not have prior knowledge of what AMBER Alert meant were in the Poor or Fair Categories.

3.7 Memory Loss and AMBER Recall Scores

In this experiment, the participants were asked to recall the AMBER Alert message within a few seconds of passing the CMS displaying it. At the time they were asked to recall it the information in the message would still have been in their short-term (or working) memory. Unfortunately, material does not stay in short-term memory very long. It is forgotten in seconds. Many investigators, including Reitman and Shiffrin, have indicated that rapid forgetting occurs because of two processes—decay and interference (22, 23).

Strategies for improving retention include rehearsal and repetition. When the Minnesota Department of Public Safety issues an AMBER Alert in real life, many drivers who see the Alert on a CMS will not be able to retain all the information for very long. The license plate number will be particularly difficult to retain. Public Awareness campaigns should suggest to drivers seeing AMBER Alerts that they tune into an appropriate radio station where the information will be repeated frequently. This repetition will greatly aid drivers, making it more likely that the AMBER Alert information will be moved from short-term memory to long-term memory, where it can be retained for a longer period of time. This will greatly increase the likelihood that if a driver encounters the vehicle mentioned on the AMBER Alert he or she will be able to recognize it.

Chapter 4
The Extent to which AMBER Alerts Caused Traffic to Slow Down

Chapter 4 deals with the effectiveness of the AMBER Alert tested in Experiment Two. This chapter focuses on the speed at which the participants drove as they approached the AMBER Alert. In the first subsection, the mean speed on the approach to the AMBER Alert is examined. Then, the second subsection of the chapter is concerned with the participants who slowed down as they approached the AMBER Alert—in particular focusing on the number of participants who slowed down, and the magnitude of the slow-downs.

4.1 Mean Speed on the Approach to the AMBER Alert

In Experiment Two, it was possible to read the message on the AMBER Alert when the participants were approximately 860 feet (262 meters) from the CMS on which it was displayed. We determined the mean speed of the participants over this distance.

In addition, the mean speed of the participants as they drove in the 3,000-foot (984-meter) region immediately before this 860-foot (262-meter) segment was examined. The region was divided into three 1,000-feet (328-meter) segments, and the mean speed of the participants in each of these segments was determined. The region was divided into three segments so that we could discover whether or not there were any changes in speed in the region.

Then, the mean speeds in each of these 1,000-feet (328-meter) segments were compared to the mean speed of the participants in the 860-foot (262-meter) section within which it was possible to read the AMBER Alert message. The segments are specified in Table 4.1.

Table 4.1. Segment specification (in terms of the distance from the AMBER Alert).

Segment	**Distance from AMBER Alert (in feet)**	**Distance from AMBER Alert (in meters)**
Segment 1	3,860 feet to 2,860 feet	1,246 meters to 918 meters
Segment 2	2,860 feet to 1,860 feet	918 meters to 590 meters
Segment 3	1,860 feet to 860 feet	590 meters to 262 meters
Segment 4	860 feet to 0 feet	262 meters to 0 meters

To determine whether there were differences in the mean speeds at which the participants drove through each of the four segments listed in Table 4.1, a four-way Analysis of Variance (ANOVA) was conducted. The ANOVA examined the effects of (1) the Gender of the participants; (2) the Age of the participants; (3) CMS Exposure—i.e., whether or not the participants were exposed to the Category III (non time-critical, non site-specific) message before they encountered the AMBER Alert; and (4) the Segments listed in Table 4.1. The summary of this four-way ANOVA is presented in Table 4.2.

Table 4.2. Summary of the ANOVA of the effects of Gender, Age, CMS Exposure and Segment on mean speed when approaching the AMBER Alert.

Source of variation	**Degrees of freedom**	**Sum of Squares**	**Variance estimate**	**F-Value**	**p-value**
Gender (G)	1	628.880	628.880	3.606	0.0602
Age (A)	2	7,768.160	3,884.080	22.270	<0.0001
CMS Exposure (C)	1	48.115	48.115	0.276	*Not significant*
G x A interaction	2	400.218	200.109	1.147	*Not significant*
G x C interaction	1	322.896	322.896	1.851	*Not significant*
A x C interaction	2	113.875	56.937	0.326	*Not significant*
G x A x C interaction	2	214.976	107.488	0.616	*Not significant*
Error Term 1 (Subjects within Groups)	108	18,836.441	174.411		
Segment (S)	3	82.057	27.352	3.508	0.0157
S x G interaction	3	3.656	1.219	0.156	*Not significant*
S x A interaction	6	136.869	22.812	2.926	0.0086
S x C interaction	3	64.028	21.343	2.737	0.0436
S x G x A	6	29.289	4.822	0.626	*Not significant*
S x G x C	3	20.831	6.944	0.891	*Not significant*
S x A x C	6	28.854	4.809	0.617	*Not significant*
S x G x A x C	6	23.309	3.885	0.498	*Not significant*
Error Term 2 (S x Subjects within Groups)	324	2,526.283	7.797		

Table 4.2 shows that the main effects of Age and of Segment were statistically significant, at the $p < 0.0001$ and $p = 0.0157$ levels, respectively. Also the effect of Gender approached significance, with $p = 0.0602$. In addition to these main effects, there were two significant interactions: between Segment and Age (at the $p = 0.0086$ level) and between Segment and CMS Exposure (at the $p = 0.0436$ level). These various effects are discussed below.

4.1.a *Effects of Age and Segment.* The main effects of Age and Segment, as well as the interaction between them are shown in Figure 4.1. It is clear from the figure that the effect of Age was that the Younger Group (ages 18 – 25) of participants drove faster than the participants in the Middle Age Group (ages 32 – 47) and that they, in turn, drove faster than the Older Group (ages 55 – 65) of participants—the average speeds were approximately 65 mph (104.6 km/h), 58 mph (93.3 km/h), and 55 mph (88.5 km/h), respectively.

Figure 4.1 also shows the Segment effect. There was little difference in the mean speeds in Segments 1 and 2. There were small reductions in mean speed in Segment 3—0.4 mph (0.6 km/h) for the participants in the Younger Group and 1.1 mph (1.8 km/h) for the Older Group. Then in Segment 4, there was a small reduction in mean speed of 0.4 mph (0.6 km/h) for the participants in the Middle Age Group and a second, more substantial reduction of 1.8 mph (2.9 km/h) for the participants in the Older Groups. The differences between the Age Groups in Segment 4—the more substantial reduction in speed for the Olders Group in contrast to the small reduction for the Middle Age Group and no reduction for the Younger Group—accounts for the significant interaction found between Age and Segment in Table 4.2.

4.1.b *Segment by CMS Exposure Interaction.* The interaction between Segment and CMS Exposure is illustrated in Figure 4.2. There was little difference in the mean speeds obtained in Segments 1 and 2 for the participants in both CMS Exposure Groups—it was approximately 60.3 mph (97.0 km/h) for both groups. However, there were differences between the Groups in Segments 3 and 4. While the Group who had prior Exposure to the Category III (non time-critical, non site-specific) message before they encountered the AMBER Alert continued to drive at approximately 60.3 mph (97.0 km/h) in Segments 3 and 4, the participants who did not have prior exposure reduced their mean speed to 59.3 mph (95 km/h) in Segment 3, and to 58.4 mph (94.0 km/h) in Segment 4.

As mentioned above, it only became possible to read the message on the AMBER Alert when the participants were approximately 860 feet (262 meters) from the CMS on which it was displayed. However, it was possible to see that something was on the CMS (even if it was not yet readable), and the participants who did not have prior exposure to the Category III (non time-critical, non site-specific) message may have reduced their mean speed to 59.3 mph (95 km/h) in Segment 3 in anticipation of being able to read the message on the AMBER Alert CMS.

4.1.c *The Effect of Gender*. As mentioned above the effect of Gender approached significance, with $p = 0.0602$. Over the four segments the mean speed for males was 61.1 mph (98.3 km/h), while the mean speed for females was 58.8 mph (94.6 km/h)

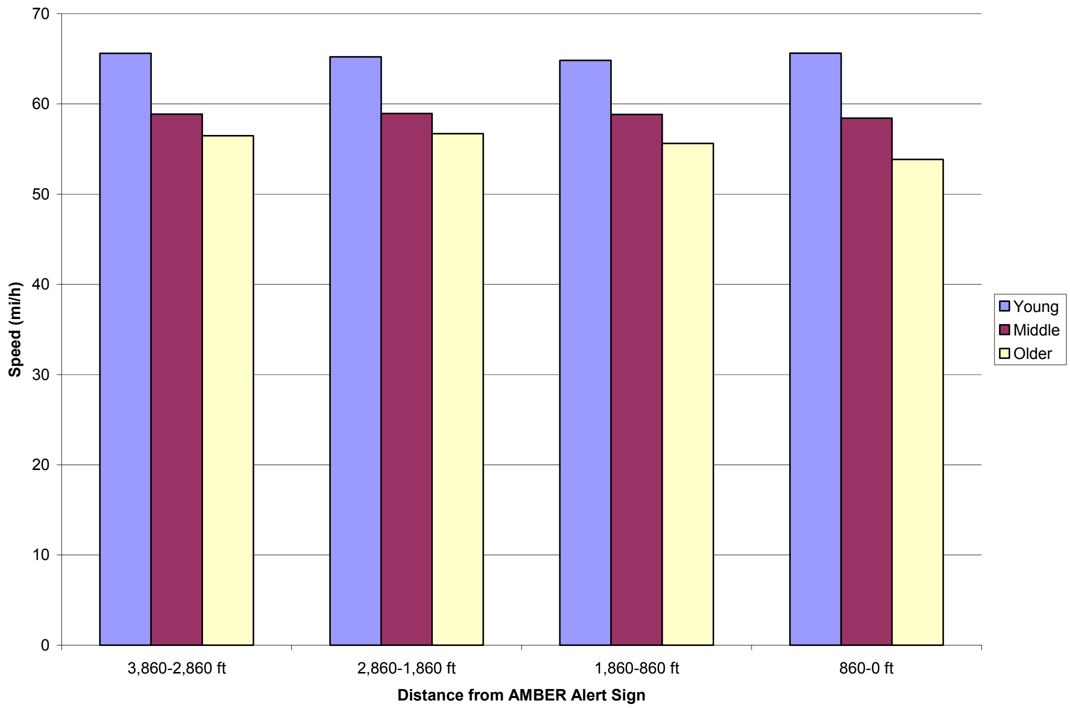

Figure 4.1. The change in speed from segment to segment for each age group as the participants approach the AMBER Alert.

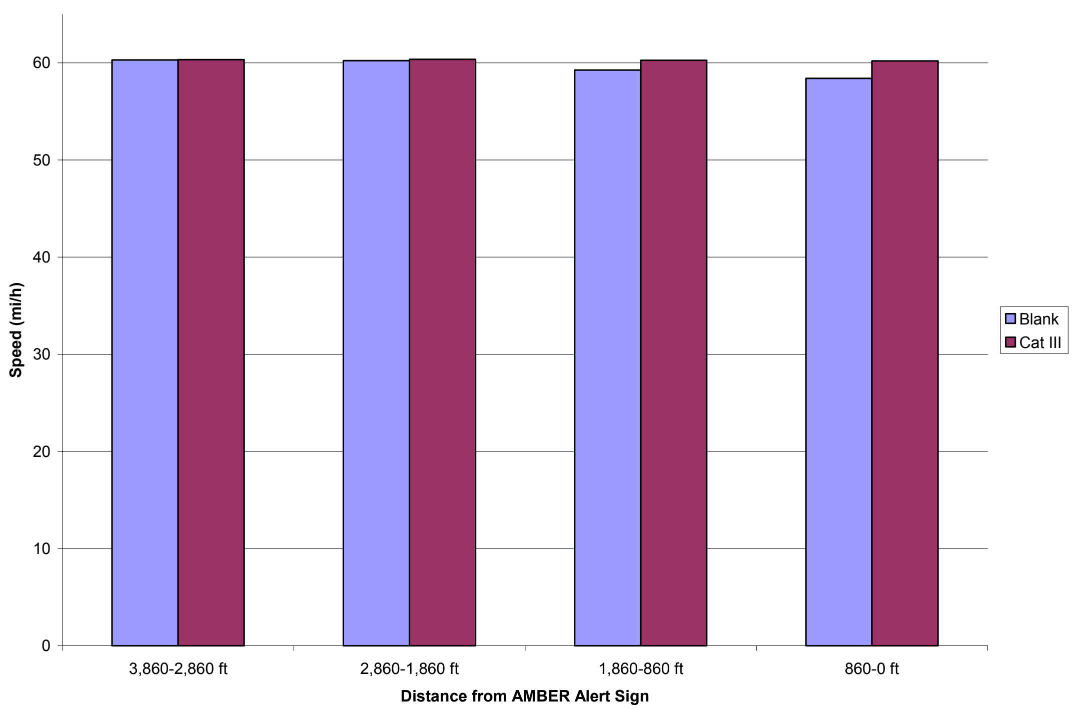

Figure 4.2. The change in speed from segment to segment for each CMS Exposure group as the participants approached the AMBER Alert.

4.2 Examination of Participants who Slowed Down on the Approach to the AMBER Alert

This subsection focuses on individual participants who slowed down at least 2 mph (3.2 km/h) as they approached the AMBER Alert.

4.2.a *Number of Participants who Slowed Down*. Of the 120 participants in the experiment, there were 26 who slowed down by at least 2 mph (3.2 km/h). Therefore, 21.7% of the participants slowed down. If this percentage of drivers were to slow down on freeways in real life, they would be likely to cause traffic delays.

4.2.b *Range of Slow-downs.* Whether or not traffic delays will actually be caused by drivers slowing down to read AMBER Alerts in real life, will depend on the extent of the slow-downs and the current traffic density. Table 4.3 presents the extent of the slow down for the 26 participants who did reduce speed by at least 2 mph (3.2 km/h) as they approached the AMBER Alert. It also presents cumulative percentages—for example, while only 1.7% (2/120) of the participants slowed down by at least -10 to -11 mph (-16.1 to -17.7 km/h), 16.7% (20/120) slowed down by at least -4 to -5 mph (-6.4 to -8.0 km/h). The higher the prevailing traffic density, the greater the impact of the slowing drivers.

Table 4.3. The extent of the slow-downs of participants approaching the AMBER Alert.

Range	Number of Participants in Range	Cumulative Number of Participants	Cumulative Percentage of Participants I Experiment
-13 to -14 mph (-20.9 to -22.5 km/h)	1	1	0.8%
-12 to -13 mph (-19.3 to -20.9 km/h)	0	1	0.8%
-11 to -12 mph (-17.7 to -19.3 km/h)	0	1	0.8%
-10 to -11 mph (-16.1 to -17.7 km/h)	1	2	1.7%
-9 to -10 mph (-14.5 to -16.1 km/h)	0	2	1.7%
-8 to -9 mph (-12.9 to -14.5 km/h)	2	4	3.3%
-7 to -8 mph (-11.3 to -12.9 km/h)	2	6	5.0%
-6 to -7 mph (-9.7 to -11.3 km/h)	5	11	9.2%
-5 to -6 mph (-8.0 to -9.7 km/h)	2	13	10.8%
-4 to -5 mph (-6.4 to -8.0 km/h)	7	20	16.7%
-3 to -4 mph (-4.8 to -6.4 km/h)	2	22	18.3%
-2 to -3 mph (-3.2 to -4.8 km/h)	4	26	21.7%

4.2.c *Effect of Gender*. The effect of Gender on the slow-downs that occurred as the participants approached the AMBER Alert is shown in Table 4.4.

Table 4.4. Number of male and female participants who slowed down while approaching the AMBER Alert.

	Males	**Females**	**Totals**
Number of Participants who Slowed Down	12	14	26

As Table 4.4 shows, the numbers of males and females who slowed down were almost the same. Therefore, it is no surprise that, when the Binomial Test (see Siegel and Castellan) was used to compare them, the difference between them was not statistically significant (21). The test indicated that the probability of obtaining values shown in Table 4.5 was 0.423. We can conclude that gender did not affect the number of participants who slowed down.

4.2.d *Effect of Age*. The effect of age on the slow-downs that occurred as the participants approached the AMBER Alert is shown in Table 4.5.

Table 4.5. Number of participants in each age group who slowed down.

	Younger Group (18 to 24 years old)	**Middle Group (32 to 47 years old)**	**Older Group (55 to 65 years old)**	**Total**
Number of Participants who Slowed Down	2	7	17	26

To determine whether the differences in the number of participants from each of the three age groups who slowed down as they approached the AMBER Alert were significant, the Chi-Square Goodness-of-Fit Test (see Siegel and Castellan) was conducted (21). The χ^2 value obtained was 13.41. Since this value exceeds 9.21, the critical value of χ^2 for 2 *df* and $\alpha = 0.01$, we can conclude that the age of the participants did have a statistically significant effect on number of participants who slowed down. Observation of Table 4.5 shows that the participants in the Older Group were more than eight times more likely to slow down than the participants in the Younger Group.

Further it is worth noting that while 26 of 120 (21.7%) of the participants slowed down by at least 2 mph (3.2 km/h) as they approached the AMBER Alert, in the Older Group 17 of 40 (42.5%) of the participants slowed down.

4.2.e *Effect of Prior Exposure to Category III CMS Messages*. The effect of Category III (non time-critical, non site-specific) CMS messages on the slow-downs that occurred as the participants approached the AMBER Alert is shown in Table 4.6.

Table 4.6. Number of participants in the two Exposure Groups who slowed down.

	Exposed to Category III messages	Not exposed to Category III messages	Total
Number of Participants who Slowed Down	10	16	26

The Binomial Test (see Siegel and Castellan) was used to determine whether or not the difference in the number of participants in the two Prior CMS Exposure Groups who slowed down as they approached the AMBER Alert was significant (21). The test indicated that the probability of obtaining values shown in Table 4.6 was 0.163. Therefore there is not sufficient evidence to conclude that prior exposure to Category III CMS messages affected the number of participants who slowed down.

4.2.f *Effect of Knowing the Meaning of AMBER Alert.* As already mentioned in Chapter 3, following Experiment 2 one of the questions the participants were asked was, "What does AMBER Alert mean?" Responses to this question were obtained from 114 of the 120 participants. Of these 114, 82 (72%) knew the meaning of the term, while 32 (28%) did not know its meaning. Table 4.7 shows the distribution in the two AMBER Alert knowledge categories of 24 of the 26 participants who slowed down. (Please note that responses were not obtained from two of the 26 participants who slowed down.)

Table 4.7. Number of participants who slowed down that did, and did not, know the meaning of AMBER Alert.

	Had prior knowledge of AMBER Alerts	No prior knowledge of AMBER Alerts	Totals
Number of Participants who Slowed Down	18 of 82	6 of 32	24 of 114

To determine whether there were differences in the proportion of participants who slowed down and knew what AMBER Alert meant and the proportion of participants who slowed down and did not know the meaning of the term, a z-Test for two proportions (see Ferguson) was conducted (ref 24). The z-value obtained was 0.0376—the p-value associated with this is 0.484, so we can conclude that knowledge of what AMBER Alert meant did not affect the number of participants who slowed down.

4.2.g *Relationship with AMBER Recall Scores*. It is also of interest to know whether or not those participants who slowed down as they approached the AMBER Alert obtained higher AMBER Recall Scores. Table 4.8 shows the relationship between the AMBER

Recall Accuracy Response Categories for the participants and whether or not they slowed down.

Table 4.8. Number of participants who did, and did not, slow down in each AMBER Recall Accuracy Response Category.

Range of AMBER Scores	**Response Accuracy Category**	**Number of Participants who Slowed Down**	**Number of Participants who Did Not Slow Down**	**Total Number of Participants in Response Category**
Minus 9 to Zero	Poor	1	9	10
+ 1 to + 5.5	Fair	8	30	38
+ 6 to + 10	Good	12	50	62
+10.5 to +13	Excellent	5	5	10
Total		26	94	120

A Chi-Square Test (see Siegel and Castellan) was conducted to determine whether there were differences between the distributions of the participants who slowed down when approaching the AMBER Alert and those who did not slow down with regard to the AMBER response accuracy categories (21). The χ^2 value obtained was 5.694. This does not exceed 7.82, the critical value of χ^2 for 3 *df* and $\alpha = 0.05$. Perhaps somewhat surprising, we cannot conclude that slowing down when approaching the AMBER Alert resulted in obtaining higher AMBER Recall Scores.

Chapter 5
The Effectiveness of the Thompson Exit CMS Message

5.1 Overall Effect of the Thompson Exit CMS Message

Towards the end of the first experiment, the participants encountered a CMS sign with the following message:

CRASH
AT WYOMING AVE
USE THOMPSON EXIT

This is a Category I (time-critical, site-specific) CMS message. The participants saw the message approximately one mile before the Thompson exit. Our primary measure of the effectiveness of this sign was the number of participants who took the Thompson Exit. As shown in Table 5.1, 67 of the 120 participants took the exit and 53 participants did not. So, in this study the Category I (time-critical, site-specific) CMS message was 55.8% effective.

Table 5.1. Number and percentage of participants who took, and did not take, the exit.

Outcome	Number of Participants	Percentage of Participants
Took Exit	67	55.8%
Did Not Take Exit	53	44.2%

During the questioning that occurred following completion of the second experiment, the participants who did not take the Thompson Exit were asked why they did not take it. This information was collected from 50 of these 53 participants. Their responses fell into three main categories:

- Those who saw the CMS message, but ignored the information on it because they did not think that it applied to them. They said that neither Wyoming Ave. nor Thompson Ave. was their destination.
- Those who saw the CMS message, but did not understand the sign. This category included people who thought that the sign meant that there was a crash on the Wyoming exit, and people who thought that there was a crash on the freeway, but that a lane was still open. If the CMS message had been “ROAD CLOSED AHEAD, USE THOMPSON EXIT the people in this category would have exited at the Thompson Exit.
- There were also some participants who failed to notice the CMS message.

The breakdown of the participants into these categories is shown in Table 5.2.

Table 5.2. Number of participants who did not take the exit in each explanation category.

Response Category	Number of Participants in Category
Saw CMS Message But Ignored It	19/53
Did Not Understand CMS Message	19/53
Did Not Notice CMS Message	12/53
Unknown	3/53

The overall effect of the Category I (time-critical, site-specific) CMS message is illustrated in Figure 5.1.

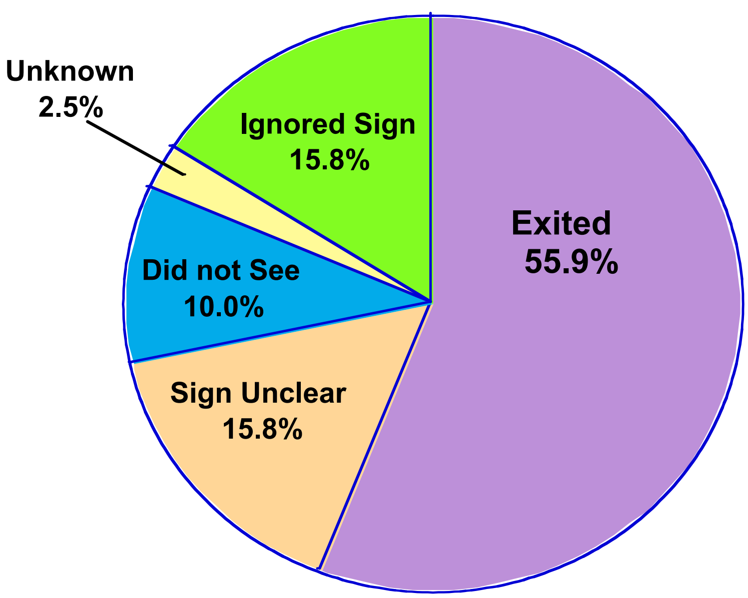

Figure 5.1. Pie chart illustrating the effectiveness of the Category I (time-critical, site-specific) CMS message telling drivers to use the Thompson Exit.

In the next three sub-sections of this report, we discuss the effects on the response of the participants to the Category I (time-critical, site-specific) CMS message telling drivers to use the Thompson Exit of the following variables:

- The age of the participants.
- The gender of the participants.
- The presence or absence of Category III (non time-critical, non site-specific) CMS messages before the participant reached the Category I (Time-critical, site-specific) CMS message.

5.2 The Effect of Age on the Response to Thompson Exit CMS Message

The number of participants in each of the three age groups tested in the experiment who took, or did not take, the Thompson Exit is shown in Table 5.3.

Table 5.3. Number of participants from the three age groups in each outcome category.

Outcome	**Younger Group (18 to 24 years old)**	**Middle Group (32 to 47 years old)**	**Older Group (55 to 65 years old)**	**Totals**
Took Exit	14	24	29	67
Did Not Take Exit	26	16	11	53
Totals	40	40	40	120

To determine whether there were differences in the distributions of participants from each of the three age groups across the two outcome categories, a Chi-Square Test (see Siegel and Castellan) was conducted (21). The χ^2 value obtained was 11.828. This value exceeds 11.34, the critical value of χ^2 for 3 *df* and $\alpha = 0.01$. We can conclude that the age of the participants did have an effect on their response to the Thompson Exit CMS Message.

Further inspection of Table 5.3 shows that only 14 (35%) of the participants in the younger group took the exit while 26 (65%) did not. This effect was reversed in the middle age and older groups where 24 (60%) and 29 (72.5%), respectively took the exit, while 16 (40%) and 11 (27.5%) did not. The effect of age on the response to the Thompson Exit CMS Message is illustrated clearly in Figure 5.1. The older the participant the more likely he or she was to take the exit.

This result is all the more interesting in that age did not emerge as a factor influencing the response of the participants to the AMBER Alert CMS Message (discussed in Chapter 3 of this report).

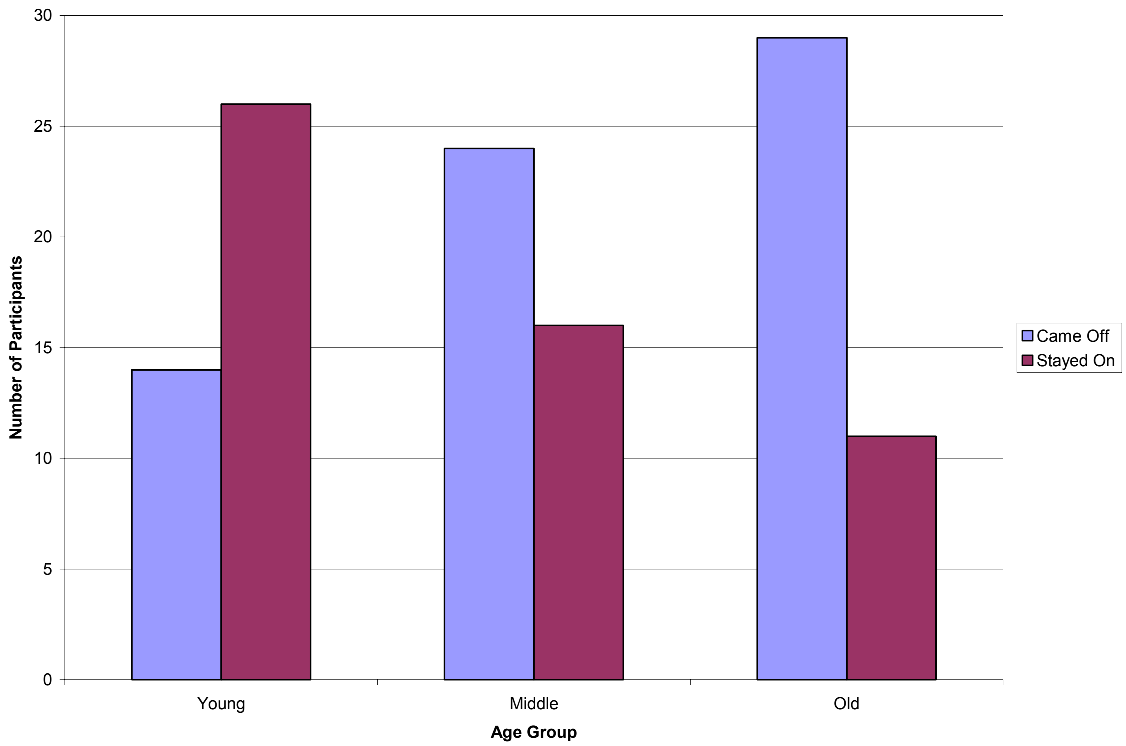

Figure 5.2. Number of participants from each age group that either took the exit or did not take the exit.

5.3. The Effect of Gender on the Response to Thompson Exit CMS Message

The number of male and female participants tested in the experiment who were in each of the response categories is shown in Table 5.4.

Table 5.4. Number of male and female participants in each outcome category.

Outcome	**Males**	**Females**	**Totals**
Took Exit	34	33	67
Did Not Take Exit	26	27	53
Totals	60	60	120

Inspection of Table 5.4 shows that the number of males and females in each outcome category is virtually identical. Unlike age, the gender of the participants had no effect on their response to the Thompson Exit CMS Message.

5.4 The Effect of Prior Exposure to Category III CMS Messages on the Response to Thompson Exit CMS Message

The number of participants in each of the outcome categories who were exposed to the Category III (non time-critical, non site-specific) CMS messages and the number who did not see Category III messages before reaching the CMS displaying the Thompson Exit CMS Message are shown in Table 5.5.

Table 5.5. Number of participants who were, or were not, exposed to Category III CMS messages prior to reaching the AMBER Alert in each outcome category.

Outcome	Exposed to Category III messages	Not exposed to Category III messages	Totals
Took Exit	30	37	67
Did Not Take Exit	30	23	53
Totals	60	60	120

To determine whether there were differences between the distribution for participants who were exposed to Category III messages and the distribution for those who were not exposed, a Fisher Exact Probability Test (see Siegel and Castellan) was conducted (21). The resultant probability was 0.0644. This suggests that prior exposure to the Category III (non time-critical, non site-specific) CMS messages may have affected the response of the participants to the Thompson Exit CMS Message.

Inspection of Table 5.5 shows that participants who were not exposed to the Category III (non time-critical, non site-specific) may be more likely to take the exit. In other words, there is a suggestion (at the $p = 0.0644$ level) that the presence of Category III messages may diminish the response to Category I (time-critical, site-specific) CMS messages like the one tested in this experiment.

Chapter 6
The Extent to which the Thompson Exit CMS Message Caused Traffic to Slow Down

Chapter 5 deals with the effectiveness of the Thompson Exit CMS Message tested in Experiment One. This chapter focuses on the speed at which the participants drove as they approached the Thompson Exit CMS Message. First, the mean speed on the approach to the Thompson Exit CMS Message is examined. Then, the second subsection of the chapter is concerned with the participants who slowed down as they approached the message—in particular it is concerned with the magnitude of the slow-downs, and the number of participants who slowed down.

6.1 Mean Speed on the Approach to the Thompson Exit CMS Message

In Experiment One, it became possible to read the Thompson Exit Message when the participants were approximately 860 feet (262 meters) from the CMS on which it was displayed. As with the AMBER Alert, the mean speed of the participants over this distance was determined. And again, their mean speed in the 3,000-foot (984-meter) region immediately before this 860-foot (262-meter) segment AMBER Alert was examined, with the region divided into three 1,000-feet (328-meter) segments. The mean speed of the participants in each of these segments was determined.

Then, the mean speeds in each of these 1,000-feet (328-meter) segments were compared to the mean speed of the participants in the 860-foot (262-meter) section within which it was possible to read the Thompson Exit Message. The segments are specified in Table 6.1.

Table 6.1. Segment specification (in terms of the distance from the Thompson Exit Message).

Segment	Distance from Exit Message (in feet)	Distance from Exit Message (in meters)
Segment 1	3,860 feet to 2,860 feet	1,246 meters to 918 meters
Segment 2	2,860 feet to 1,860 feet	918 meters to 590 meters
Segment 3	1,860 feet to 860 feet	590 meters to 262 meters
Segment 4	860 feet to 0 feet	262 meters to 0 meters

As with the AMBER Alert, a four-way Analysis of Variance (ANOVA) was conducted to determine whether there were differences in the mean speeds at which the participants drove through each of the four segments listed in Table 6.1. The ANOVA examined the effects of:

- the Gender of the participants;
- the Age of the participants;

- CMS Exposure—i.e., whether or not the participants were exposed to the Category III (non time-critical, non site-specific) message before they encountered the Thompson Exit Message;
- the Segments listed in Table 6.1. The summary of this four-way ANOVA is presented in Table 6.2.

Table 6.2. Summary of the ANOVA of the effects of Gender, Age, CMS Exposure and Segment on mean speed when approaching the Thompson Exit Message.

Source of variation	**Degrees of freedom**	**Sum of Squares**	**Variance estimate**	**F-Value**	**p-value**
Gender (G)	1	334.647	334.647	2.170	*Not significant*
Age (A)	2	7,260.976	3,630.488	23.538	<0.0001
CMS Exposure (C)	1	162.745	162.745	1.055	*Not significant*
G x A interaction	2	504.255	252.127	1.635	*Not significant*
G x C interaction	1	385.153	385.153	2.497	*Not significant*
A x C interaction	2	36.413	18.207	0.118	*Not significant*
G x A x C interaction	2	276.106	138.053	0.895	*Not significant*
Error Term 1 (Subjects within Groups)	108	16,658.204	154.243		
Segment (S)	3	19.847	6.616	1.306	*Not significant*
S x G interaction	3	1.844	0.615	0.121	*Not significant*
S x A interaction	6	105.331	17.555	3.466	0.0025
S x C interaction	3	60.220	20.073	3.963	0.0085
S x G x A	6	10.119	1.686	0.333	*Not significant*
S x G x C	3	1.259	0.420	0.083	*Not significant*
S x A x C	6	2.155	0.359	0.071	*Not significant*
S x G x A x C	6	32.327	5.373	1.061	*Not significant*
Error Term 2 (S x Subjects within Groups)	324	1,640.940	5.065		

Table 6.2 shows that the main effect of Age was statistically significant, at the $p < 0.0001$. Also the effect of Gender approached significance, with $p = 0.0602$. In addition, there were two significant interactions: between Segment and Age (at the $p = 0.0025$ level) and between Segment and CMS Exposure (at the $p = 0.0085$ level).

6.1.a *Effects of Age and Segment*. Figure 6.1 shows the main effect of Age, as well as the interaction between Age and Segment. As with the AMBER Alert speed data, it is clear from the figure that the effect of Age was that the Younger Group drove faster than the Middle Age Group and that the participants in this group, in turn, drove faster than the Older Group. The average speeds were approximately 65 mph (104.6 km/h), 58 mph

(93.3 km/h), and 55 mph (88.5 km/h), for the Younger Group, the Middle Age Group, and the Older Group, respectively.

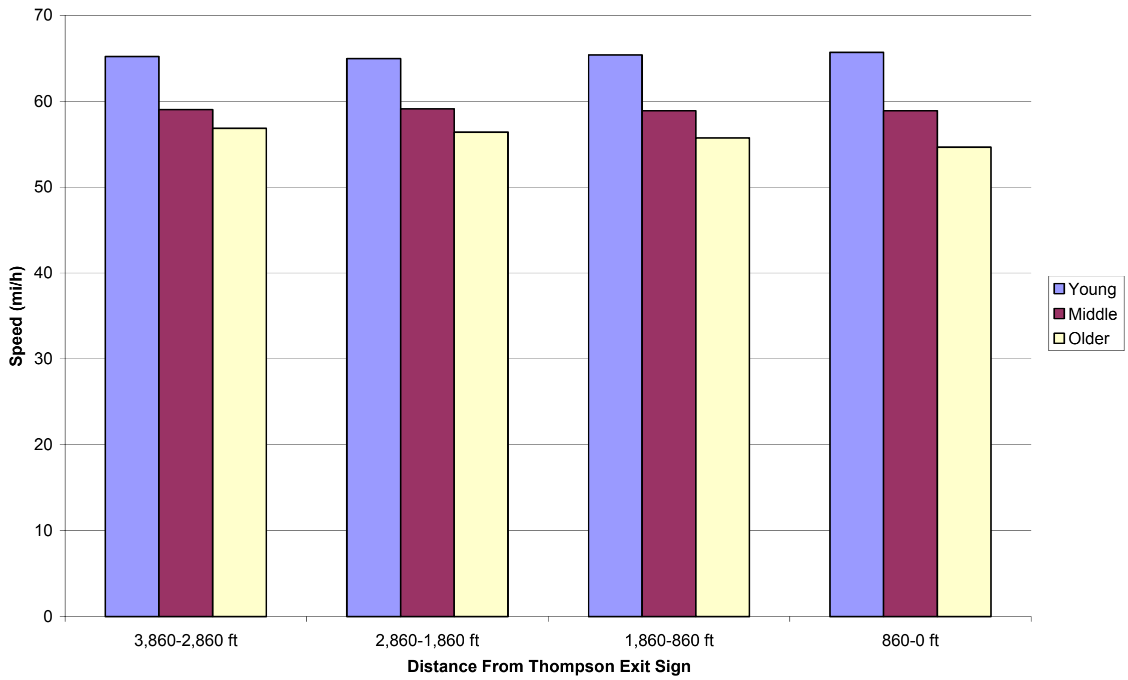

Figure 6.1. The change in speed from segment to segment for each age group as the participants approach the Thompson Exit Message.

It should be noted that these average speeds were virtually the same for Experiment One (with the Thompson Exit CMS Message) and Experiment Two (with the AMBER Alert). This indicates that there was a great deal of consistency in the way that the participants drove in both experiments.

Figure 6.1 also shows the interaction between Age and Segment. There was little difference in the mean speed in Segments 1 and 2 for all three Age Groups. And there were no reductions in mean speed in Segments 3 or 4 for either the Younger or Middle Age Groups. However—and this is what accounts for the significant Age by Segment interaction indicated in Table 6.2—there are reductions in mean speed of 0.7 mph (1.1 km/h) in Segments 3 and a further 1.0 mph (1.6 km/h) in Segment 4 for the participants in the Older Group.

6.1.b *Segment by CMS Exposure Interaction.* The interaction between Segment and CMS Exposure is illustrated in Figure 6.2. The effect is quite striking. Both CMS Exposure Groups had similar mean speeds in Segments 1 of approximately 60.3 mph (97.0 km/h). But over Segments 2, 3 and 4, there was a small but systematic decrease in the mean speeds of the participants in the Group who did not have prior exposure—in Segment 4 their mean speed dropped to 58.7 mph (94.5 km/h). In contrast, there was a very slight increase in mean speed over Segments 2, 3, and 4 (up to 60.8 mph, or 97.8 km/h, by Segment 4) for the Group who did have prior exposure to the Category III (non time-critical, non site-specific) message.

As mentioned in the similar discussion about AMBER Alerts in Chapter 4, although it only became possible to read the message on the CMS when the participants were approximately 860 feet (262 meters) from it, the participants in the Group who did not have prior exposure to the Category III (non time-critical, non site-specific) message may have reduced their mean speed in the earlier segments in anticipation that they may see a message on the CMS displaying the Thompson Exit Message.

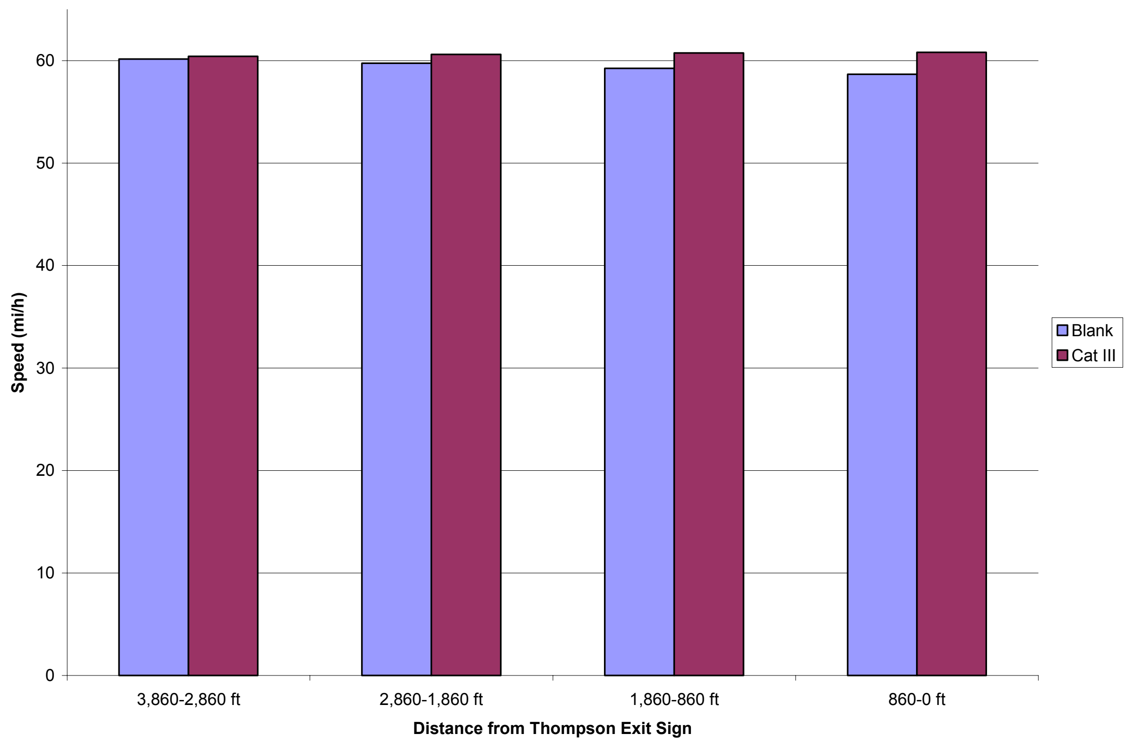

Figure 6.2. The change in speed from segment to segment for both CMS exposure groups as the participants approached the Thompson Exit CMS message.

6.2 Examination of Participants who Slowed Down on the Approach to the Thompson Exit CMS Message

This subsection focuses on individual participants who slowed down at least 2 mph (3.2 km/h) as they approached the Thompson Exit CMS Message.

6.2.a *Number of Participants who Slowed Down*. Of the 120 participants in the experiment, there were 16 who slowed down by at least 2 mph (3.2 km/h). Therefore, 13.3% of the participants slowed down for the kind of Category I (time-critical, site-specific) CMS message that is currently displayed by MN/DOT. If this percentage of drivers were to slow down on freeways in real life, they could cause traffic delays.

6.2.b *Range of Slow-downs.* Whether or not traffic delays will actually be caused by drivers slowing down to read Category I (time-critical, site-specific) CMS message in real life, will depend on the extent of the slow-downs and the current traffic density. Table 6.3 presents the extent of the slow down for the 16 participants who did reduce speed by at least 2 mph (3.2 km/h) as they approached the Thompson Exit CMS Message. It also presents cumulative percentages—for example, while only 3.3% (4/120) of the participants slowed down by at least -10 to -11 mph (-16.1 to -17.7 km/h), 8.2% (10/120) slowed down by at least -4 to -5 mph (-6.4 to -8.0 km/h. The higher the prevailing traffic density the greater the impact of the slower drivers will be.

Table 6.3. The extent of the slow-downs of participants approaching the Thompson Exit CMS Message.

Range	**Number of Participants in Range**	**Cumulative Number of Participants**	**Cumulative Percentage of Participants I Experiment**
-12 to -13 mph (-19.3 to -20.9 km/h)	2	2	1.7%
-11 to -12 mph (-17.7 to -19.3 km/h)	1	3	2.5%
-10 to -11 mph (-16.1 to -17.7 km/h)	1	4	3.3%
-9 to -10 mph (-14.5 to -16.1 km/h)	0	4	3.3%
-8 to -9 mph (-12.9 to -14.5 km/h)	0	4	3.3%
-7 to -8 mph (-11.3 to -12.9 km/h)	2	6	5.0%
-6 to -7 mph (-9.7 to -11.3 km/h)	0	6	5.0%
-5 to -6 mph (-8.0 to -9.7 km/h)	0	6	5.0%
-4 to -5 mph (-6.4 to -8.0 km/h)	4	10	8.3%
-3 to -4 mph (-4.8 to -6.4 km/h)	0	10	8.3%
-2 to -3 mph (-3.2 to -4.8 km/h)	6	16	13.3%

6.2.c *Effect of Gender*. The effect of Gender on the slow-downs that occurred as the participants approached Thompson Exit CMS Message is shown in Table 6.4

Table 6.4. Number of male and female participants who slowed down on approaching the Thompson Exit

	Males	**Females**	**Totals**
Number of Participants who Slowed Down	8	8	16

As Table 6.4 shows, the numbers of males and females who slowed down were identical. Therefore, we can conclude that Gender did not affect the number of participants who slowed down.

6.2.d *Effect of Age*. The effect of Age on the slow-downs that occurred as the participants approached the Thompson Exit CMS Message is shown in Table 6.5.

Table 6.5. Number of participants in each age group who slowed down.

	Younger Group (18 to 24 years old)	**Middle Group (32 to 47 years old)**	**Older Group (55 to 65 years old)**	**Total**
Number of Participants who Slowed Down	4	3	9	16

The Chi-Square Goodness-of-Fit Test (see Siegel and Castellan) was conducted (21) to determine whether the differences in the number of participants from each of the three age groups who slowed down as they approached the Thompson Exit CMS Message were significant. In this case, the χ^2 value obtained was 3.90. Because this value does not exceed 5.99, the critical value of χ^2 for 2 *df* and $\alpha = 0.05$, we cannot conclude that the age of the participants had an effect on the number of participants who slowed down.

6.2.e *Effect of Prior Exposure to Category III CMS Messages*. The effect of Category III (non time-critical, non site-specific) CMS messages on the slow-downs that occurred as the participants approached the Thompson Exit CMS Message is shown in Table 6.6.

Table 6.6. Number of participants in the two Exposure Groups who slowed down.

	Exposed to Category III messages	**Not exposed to Category III messages**	**Total**
Number of Participants who Slowed Down	5	11	16

To determine whether the differences in the number of participants in the two CMS Exposure Groups who slowed downs as they approached the Thompson Exit CMS Message were significant, the Binomial Test (see Siegel and Castellan) was conducted (21). The test indicated that the probability of obtaining values shown in Table 6.6 was 0.105. Therefore we cannot conclude that prior exposure to Category III CMS messages had an effect on the number of participants who slowed down.

6.2.f *Relationship to response to Thompson Exit CMS Message*. We also investigated whether or not those participants who slowed down as they approached the Thompson Exit CMS Message were more or less likely to take the exit. Table 6.7 shows the relationship between the outcomes at the Thompson Exit and whether or not the participants slowed down.

Table 6.7. Number of participants who did, and did not, slow down in each AMBER Recall response category.

Outcome	**Number of Participants who Slowed Down**	**Number of Participants who Did Not Slow Down**	**Total Number of Participants in Response Category**
Took Exit	11	56	67
Did Not Take Exit	5	48	53
Total	16	94	120

A Chi-Square Test (see Siegel and Castellan) was conducted to determine whether or not there were differences in the outcomes at the Thompson Exit for those participants who slowed down when approaching the CMS Exit Message and those who did not slow Down (21). The χ^2 value of 1.289 that was obtained falls short of 3.84, the critical value of χ^2 for 1 *df* and $\alpha = 0.05$. We cannot conclude that slowing down when approaching the Thompson Exit CMS Message increased the likelihood that the participant would take the Thompson Exit.

Chapter 7
Recommendations

7.1 AMBER Alert

7.1.a *Experimental Findings.* Experiment Two used AMBER Recall Scores to measure the effectiveness of AMBER Alerts. The results were not impressive. Only 8.3% (10/120) of the participants were in the Excellent Category, which included participants who could recall AMBER Alert, vehicle information, and five or six alphanumerics on the license plate number.

There were 51.7% (62/120) participants in the Good Category. They recalled AMBER Alert, some vehicle information, *but* only part of the license plate number. Further, the 31.7% (38/120) in the Fair Category did not recall any part of the license plate number and, worse, the 8.3% (10/120) in the Poor Category either remembered nothing or produced information that was incorrect.

Also after completing both experiments, participants were asked the meaning of AMBER Alert. Eighty-two (72%) of the participants knew its meaning while 32 (28%) did not.

7.1.b *Need for Public Awareness*. These results suggest that the Minnesota Department of Public Safety should increase its efforts to make the public more aware of the meaning of AMBER Alert if the AMBER Alert system is to be effective.

7.1.c *Changing the AMBER Alert message.* The AMBER Alert currently used by the Department of Public Safety was tested in this experiment. The participants were asked to recall the AMBER Alert message within a few seconds of passing the CMS displaying it. At the time they were asked to recall the message, the information in it would still have been in their working (or short-term) memory. It has long been known that, unfortunately, material does not stay in working memory very long. It is forgotten in seconds.

When the Minnesota Department of Public Safety issues a real AMBER Alert, like the one tested in this study, it is to be expected that drivers will not be able to retain all the information for very long. In particular, the license plate number is particularly difficult to retain. However, as the experiment revealed, the participants in the Excellent Category, Good Category, and even most of those in the Fair Category realized that the CMS had displayed an AMBER Alert.

Many investigators, for example Reitman and Shiffrin, have indicated that rapid forgetting occurs because of two processes—decay and interference (22, 23). There are strategies for improving retention: They include rehearsal and repetition. AMBER Alerts should omit the license plate number, which is hard to remember, and instead tell drivers to tune into an appropriate radio station, whose call sign will be easier to remember. When they tune into that station, the full AMBER Alert message, including the license plate number should be repeated frequently. This repetition will greatly aid drivers, making it more likely that the AMBER Alert information will be moved from working memory to long-term memory, where it can be retained for a longer period of time. This will greatly increase the likelihood that if a driver encounters the vehicle mentioned on the AMBER Alert he or she will be able to recognize it.

If this is done it is also likely that there will be fewer slow-downs than were found in this experiment. Fewer slow-downs are likely because rather than asking drivers to focus on a long message with a vehicle description and license plate number, instead drivers will be asked to tune to a dedicated radio station which communicates public safety alerts and traffic safety warnings.

It is also recommended that the message CHILD ABDUCTION be displayed on CMSs rather than AMBER ALERT. The words "child abduction" immediately communicate the meaning of the message displayed on the CMS. Conversely, drivers who see the words AMBER ALERT will have to search their memory for the meaning until they translate the words into the real meaning underlying AMBER ALERT: child abduction.

Our recommended AMBER Alert is:

CHILD ABDUCTION
TUNE TO
RADIO FM XX.X

If it is politically impossible to use CHILD ABDUCTION in the CMS, then our recommended AMBER Alert is:

AMBER ALERT
TUNE TO
RADIO FM XX.X

7.2 Category I CMS Messages

7.2.a *Experimental Findings.* In Experiment One, on seeing the Thompson Exit CMS Message, the participants were supposed to take the Thompson Exit. Only 67 (55.8%) of them did that. Of the 53 participants who did not take the exit (1) 38% ignored the CMS message because they did not think that it applied to them; (2) 38% did not understand the CMS message; and (3) 24% did not notice the message.

7.2.b *Changing the Thompson Exit Message.* In some cases, the participants who did not understand the message thought that the message which said

CRASH
AT WYOMING AVE
USE THOMPSON EXIT

meant that there was a crash on the exit and that because they were not planning to take that exit, the message did not apply to them. We believe that crash information of the kind indicated on the Thompson exit sign should say:

ROAD CLOSED
BEFORE WYOMING AVE
USE THOMPSON EXIT

This would be clearer and should greatly increase the number of drivers who take the exit.

We also recommend that if there is still a lane open on a two-lane freeway, the message should read as follows:

LANE CLOSED
BEFORE WYOMING AVE
USE THOMPSON EXIT

Presenting the information in this format would convey the message more clearly and would allow drivers to make an informed choice about whether or not to stay on the freeway.

7.3 Prior Exposure to Non traffic-related CMSs

In Experiment One in which the Thompson Exit Message appeared in the last CMS, the effect of prior exposure to Category III (non time-critical, non site-specific) CMSs was complex. Participants who did *not* have prior exposure were more likely to take the exit. However, those same participants were also more likely to slow down as they approached the Thompson Exit Message.

Similarly, in Experiment Two participants who did *not* have prior exposure to Category III (non time-critical, non site-specific) CMSs were more likely to slow down as they approached the AMBER Alert. The presence of the Category III Messages did not, however, affect the AMBER Recall Score of participants.

If the recommendations, outlined in Section 7.2, are adopted, then slow-downs should be less likely. Whether or not Category III (non time-critical, non site-specific) CMSs should be displayed remains a question for further research following an improvement in the clarity of the message content.

With shorter public message signs (e.g., DON'T DRIVE DROWSY or BUCKLE UP) we recommend using the bottom line of the CMS. This will likely make the message easier to distinguish from traffic-related time-specific signs and AMBER Alerts. Further, placing an action message on the bottom line will remain consistent with the standard practice of placing the action portion of a CMS message on the bottom line of CMSs.

7.4 Concluding Remarks

The questions addressed in this study and the findings that relate to them are presented below:

- Do CMS Messages really work?
  Answer: For AMBER Alerts, the CMSs worked to the following extent—8.3% (10 of 120) of the participants had Excellent AMBER Recall Scores and 51.7% (62 of 120) of the participants had Good AMBER Recall Scores. The Thompson Exit CMS Message also worked to some extent—55.8% (67 of 120) of the participants took the exit.

- Do CMS Messages cause slow-downs?
  Answer: Yes, they did cause slow-downs in this study. With AMBER Alerts, 21.7% (26 of 120) of the participants slowed down by at least 2 mph (3.2 km/h) and up to as much as 13.9 mph (22.6 km/h) as they approached the AMBER Alert. And with the Thompson Exit CMS, 13.3% (16 of 120) of the participants slowed down by at least 2 mph (3.2 km/h) and up to as much as 12.7 mph (20.4 km/h) as they approached the exit CMS.

- What is the likely impact of CMS Messages on traffic flow?
  Answer: Slow-downs were observed in the two experiments that comprise this study. Whether or not traffic delays will actually be caused in the real world will depend on the state of the traffic density and the extent of the slow-downs at a particular point in time. Table 4.3 for AMBER Alerts and Table 6.3 for the Thompson Exit CMS shows the cumulative slow down effects for the range of slow-downs observed in both Experiment One and Experiment Two. These tables should be used in conjunction with traffic density data to predict the possible effects of slow-downs on traffic flow.

- Should messages be presented on CMSs only when necessary?
  Answer: As mentioned in Section 7.3, in both experiments the effect of prior exposure to Category III (non time-critical, non site-specific) CMSs was complex. Participants who did *not* have prior exposure were more likely to take the exit, but they were also more likely to slow down as they approached both the Thompson Exit CMS and the AMBER Alert CMS. As a result, whether or not Category III (non time-critical, non site-specific) CMSs should be displayed remains a question for further research following an improvement in the clarity of the message content.

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Appendix A

General Instructions for Experiment

We would like you to drive twice in the simulator. Each time you drive you will be on the same segment of freeway. At the start of each drive your car will already be on the freeway. The speed limit is 55 mph on this road. Please drive as you normally would if you were driving on this freeway in the real world. Each drive will be for about 20 miles. At the end of the drive the experimenter will ask you to stop.

Appendix B

Question Sheet

Questions asked by experimenter immediately after the subject completes the second drive.
Subject #________________

Question #1: Can you please tell me what was written on the last Message Board over the road?

____
____
____

Question #2: Can you remember any other signs that you saw during the drive?

Question #3: [If yes to Question #2…] Can you please tell me what they said?

____
____
____
____
____
____

Question #4: [If in answer to Question #3, subject remembers only "Direction" signs, ask…] Did you see any signs giving any other information?

Question #5: [If yes to Question #4…] Can you please tell me what they said?

____
____
____

Question #6: [If in answer to Question #3, subject only mentions "Stalled vehicle" signs, ask…] Did you see any signs giving directions?

Question #7: [If yes to Question #6…] Can you please tell me what they said?

____
____
____

Question #8: What does Amber Alert mean?

____

Question #9: What would you do if you saw an Amber Alert?

____

____

____

Questions about the first scenario (Crash Ahead):

If the subject did not take the exit, ask them this question:

Question #10: Did you notice the sign at the end of the first test scenario? ________

If yes, ask him or her:

Question #11: What was the reason you did not take the exit?

____

____

____

Write comments you gather during the debriefing here: