CHAPTER 6: CONCLUSIONS

Recapitulation

This study replicated one of the many rear end conflict scenarios that often occur in driving situations on U.S. roadways. This scenario involved a distracted driver following too closely to a lead vehicle just prior to a lane change which revealed a stopped vehicle in the roadway.

This situation was replicated to determine whether the addition of a flashing strobe to the back of a stopped vehicle in the roadway would improve perception response times and hence reduce the role of driver error in rear end crash causation. Recall that the most common category of driver error associated with rear end collisions is inattention to the driving task, and a second overlapping factor is following too closely. One or both of these factors are present in approximately 90% of rear end crashes according to Knipling et al. (1993). A breakdown of the apparent causes of driver error in the literature identified perceptual factors, following too closely, and inattention as key contributors. It was hoped that adding a flashing warning signal, in the form of a strobe, to a vehicle's design would help minimize driver error, as vehicle and/or highway design often interact to reinforce driver error (Dingus et al., 1998).

Strobe lights have been used increasingly in transportation to raise the conspicuity of vehicles or signs so that drivers are warned of presence to initiate an appropriate driving response. As flashing incandescent lights fail to attract a drivers' attention (Summala et al., 1998), a flashing strobe seemed to be a viable alternative due to its superiority at enhancing conspicuity (Howett, 1979). As it is very difficult to eliminate drivers' desire to follow too closely or be distracted while driving, this study aimed at primarily targeting perceptual factors as a way of reducing the potential for rear end crash causation.

This study measured many aspects of driver responses and these were divided into two categories, speed of response and severity of response. The results were mixed. Overall driver behavior was unchanged by the presence of the strobe (i.e., subjects were not more prone to steer or brake first nor did they prefer one type of maneuver to another).

Perception Time

The major finding of this study was the significant difference in the speed with which subjects perceived the stopped vehicle (i.e., the time it took drivers to initiate a first movement). Only younger drivers demonstrated improved perception time due to the strobe; no improvement was seen for older subjects. The signal seemed to be detected and comprehended as an imminent warning by both younger and older subjects. All subjects described the message conveyed by strobes in general as one of "warning," "be alert," and "danger." On seeing the strobe in this rear end conflict scenario, the descriptions were similar, as words such as "surprise," "stop," and "emergency" were used to describe the signal. Subjects had also described the signal as "very effective" as a warning.

One could argue that the strobe was not as conspicuous to older subjects because of degraded visual contrast. A more plausible explanation is that global changes in perceptual performance, due to general slowing of neural responses, were responsible for this lack of difference in perception time. Older subjects have difficulty with briefly presented stimuli (Hoyer and Plude, 1980), slower reaction times to stimulus onset (Stern, Oster and Newport, 1980), and have difficulty in identifying stimuli arriving in a rapid sequence (Birren, Woods, and Williams, 1980). When the perceptual tasks become more complex, slowing perceptual processing becomes even more apparent (Cerella, Poon, and Williams, 1980; Cunningham, 1980). The strobe light with its flashing warning, a display that had to be monitored, and a potentially dangerous situation displayed all the qualities that would slow perception (in terms of detection, identification, decision, and response) of the hazard presented to them.

Further impacting the perceptual process is the distribution of attention to perceptual tasks. Older people seem to have more difficulty dividing their attention between various stimuli (Craik and Simon, 1980). This finding has also become evident in the driving environment where older drivers have shown reduced performance compared to younger drivers during the performance of secondary automotive tasks (Monty, 1984, Dingus, Antin, Hulse, and Wierwille, 1989). The results of a study performed by Ponds et al. (1988) suggested that this degradation of dual task performance seemed to be restricted to persons over 60 years of age.

Potentially further impacting attentional resources was the observed reluctance of older subjects to follow at the shortest headway (24 feet) during the session whereas younger drivers seemed more comfortable at these shorter distances. Observations of subject behaviors and comments suggested that older subjects would not normally have placed themselves in a situation of such high anxiety requiring high attention to many factors. Wiacek and Najm (1999) suggest that drivers over age 64 are under-involved in rear-end collisions. This age group represents 13% of all licensed drivers, yet are involved in only 6% of all rear-end collisions. This finding suggests that older subjects are compensating for decreases in neural processing successfully by increasing following distance.

Rate of Steering

A second major finding was that the severity of subjects' response did change to a certain extent, but only for those subjects who steered. Although maximum brake press and steering deviation were not significantly different, initial steering rate was significantly faster for subjects in the strobe condition. As discussed in the results section, the fact that steering rate was significant but maximum steering deviation was not could be explained by the variations involved with the amount of steering required to avoid the surrogate. Subjects' positions varied somewhat with respect to the surrogate vehicle. For example, some subjects were further to the left and so any steering deviation to the left to avoid the obstacle would be much smaller than if he had steered to the right in the same situation. In this case, initial steering rate is a more accurate measure of severity of response.

A significantly faster steering rate suggests that the strobe conveyed a hazard warning that was easily comprehended by the majority of subjects who viewed the rear end conflict. Effective comprehension of the strobes in general was supported by subjects' impression of strobe lights in current transportation applications. As mentioned previously, subjects described the message conveyed by strobes as one of "warning," "be alert," and "danger." Subjects also described the signal as "very effective" as a warning.

Age Differences in Response Times

Interesting age range differences were found for perception time and brake response time in the no strobe condition (these differences were not present in the strobe condition) that could provide further information concerning the impact of the strobe signal. Older subjects had significantly faster perception times than their younger counterparts in the no strobe condition, yet brake response times for older subjects were significantly slower than their younger counterparts. It is possible that these two responses are related.

Older drivers expressed discomfort with the short following distance. This, combined with reduced ability to divide their attention during dual task performance (as observed by the experimenter and demonstrated in the literature, Ponds et al., 1988), could have contributed to greater alertness on the part of older subjects prior to the presentation of the surrogate vehicle. In addition, it has also been hypothesized that younger drivers take more time than older drivers to evaluate hazardous situations before responding, to ensure a more effective, controlled response (Lerner, 1993; Lerner, Huey, McGee, and Sullivan, 1995). Due to the longer perception time required to evaluate the situation, younger subjects then needed to initiate braking more rapidly. Although older subjects may have initiated an accelerator response earlier, Lerner (1993) suggests that older drivers respond to surprise braking situations in more reflexive stereotyped ways than do younger drivers, to compensate for degradation in neural processes. Since older drivers' perception times were quicker than those of younger subjects, older subjects were also faced with more time to respond, and therefore did not need to respond as quickly as younger subjects to avoid the surrogate vehicle. These factors were probably responsible for the significantly longer braking responses demonstrated by older subjects in the no strobe condition. This longer braking response effectively offset the shorter perception times, resulting in non-significant differences in PRT between older and younger subjects for the no strobe condition.

As mentioned previously, as a result of the strobe signal, younger subjects perception times improved while older subjects perception times did not change significantly.

Validity of the Methodology

The methodology used suggests that findings are valid and generalizeable to the general driving population. Time to collision values were consistent for all subjects, which meant that every subject was exposed to the same scenario. Subjective responses and observations provided compelling feedback concerning the level of surprise, level of realism, and degree of distraction experienced by subjects, which were also equal in both conditions. Recall that all subjects rated the experiment as very realistic or extremely realistic and that a median ranking of 5 (very surprised) was the response given by subjects in both conditions. Not one subject was aware of the stopped vehicle as it was parked just off the roadway prior to its presentation. Subjects also described their responses as “automatic,” and stated that the only unrealistic aspect of the experiment was that they did not have to check the rear view mirrors.

Threats to the external validity of the study may have been present, however. Visual distraction of subjects proved difficult. Hence, the impact of the strobe on attracting the attention of a visually distracted driver to the stimulus could not be as fully investigated as originally hoped. A more efficient distraction task, in which at least 50% of subjects are looking away from the roadway, would potentially provide greater benefits of the strobe signal for reducing crashes. Perception times on the whole would be longer, and the true effectiveness of the signal at attracting attention and conveying a sense of urgency would be more evident through facial expression and subjective responses. Response times would also reflect more urgent driver behavior, with a possible impact on brake and steering response times.

There also seem to have been potential threats to external validity associated with the approach of older subjects. It is proposed that based on subjective data and observations, older subjects’ arousal levels were higher than younger subjects due to the anxiety felt at following at a short headway while attempting to use limited attentional resources for dual task performance. Older subjects would not normally place themselves in this position of anxiety in a situation such as following too closely while distracted. During normal driving behavior they tend to compensate for their difficulty in sharing attentional resources and decrements in neural processing abilities. McKnight and McKnight (1993) found that older subjects would reduce their accident risk during attention-demanding conditions by avoiding use of distracting equipment such as cellular phones in vehicles. In addition, younger drivers are more likely to engage in risky behaviors, such as following too closely, than are older drivers (Dawson and Jonah, 1987). Furthermore, Wiacek and Najm (1999) suggest that drivers over age 64 are under-involved in rear-end collisions. This age group represents 13% of all licensed drivers, yet are involved in only 6% of all rear-end collisions. This finding suggests that older subjects are successfully compensating for decreases in neural processing. Alternative strategies for distraction that would not involve close following behavior are proposed in the next section.

Glare was also an issue during this experiment. Two subjects (subject 24 in the no strobe and subject 77 in the strobe condition) experienced specular reflected glare from the rear window of the surrogate vehicle. Looking back at the video and the graphs, there seemed to be no noticeable difference in their behavior as compared to others in the same conditions. Subject 24 (Appendix K, Figure K-3) was a younger female subject who had no steering movement and subject 77 (Appendix K, Figure K-14) was an older male subject who used a combination of steering and braking to avoid the vehicle. Their perception times were close to the overall mean perception time at 0.5 and 0.6 seconds, respectively. As there was only one individual in each group, and their scores were close to the mean, it is unlikely that the glare had much impact on the overall results.

CHAPTER 7 SUGGESTIONS FOR FUTURE RESEARCH

More effective distraction techniques need to be investigated to truly assess the potential of the strobe light to alert visually distracted drivers. A more efficient distraction task, in which at least 50% of subjects are looking away from the roadway, would provide a better indication of the benefit of the strobe signal at attracting attention, and thereby reducing crashes.

One suggestion for improving the distraction task would be to install the display lower on the console. Another suggestion concerns an increase in the amount of time subjects would be required to look at the display. In the current experiment, subjects only needed to make frequent, short eye glances at the display to monitor their distance and provide headway readings to the experimenter. An effective distraction task would require subjects to perform more complex tasks (e.g., navigation tasks that would take more of their visual attention away from the roadway). This would require rigorous testing to avoid compromises to subject safety.

If these changes were made to the distraction task alone, one would expect perception times to be longer. The true effectiveness of the signal at attracting attention and conveying a sense of urgency would become more evident through facial expression, subjective responses, and response times. Such a task should also be helpful for comparing the strobe light with conventional brake lights at attracting the attention of visually distracted drivers.

It would have been beneficial to collect information concerning information processing demands placed on subjects during the experiment (i.e., measures of mental workload). Increasing demands on mental workload are often reflected physiologically as changes in heart rate or feelings of fatigue. Subjective scales of mental workload (such as the NASA/TLX scale) would be more practical in an on-road study and would provide useful information regarding demand on attentional resources and correlation with coping strategies exhibited by younger and older people during the experiment.

If a similar study were to be repeated, changes could be made to the overall presentation of the surrogate vehicle. As mentioned previously, having older subjects engaged in dual task performance while following more closely than normal may not be representative of real world scenarios, due to high anxiety and hence arousal. Alternative strategies where older subjects are distracted and then are unexpectedly faced with another vehicle incursion (such as a vehicle incursion from the adjacent lane) may provide more externally valid results for this age group.

Finally, a few subjects had thoughts concerning the positioning and color of the light. While most subjects liked its current position, others suggested having the light positioned at the top of the rear window, placed at the top of the car, incorporated into the brake lights, placed in the centerline of the trunk, or located above the license plate. Most subjects liked the current color, although some suggested red as an alternative. White however is a preferable color since the visual system cannot distinguish colors in the periphery and colored filters would reduce the intensity of the light.

As the majority of subjects indicated satisfaction with the positioning of the light where the CHMSL is normally located, and research strongly suggests the benefit of the current position in attracting a driver's attention (Theeuwes and Alferdinck, 1995; Sivak and Flannagan, 1993; Sivak, Conn, and Olson, 1996), it would be beneficial to keep the position as is, and concentrate on manipulating color and flash rates. Shorter wavelengths have been found to be optimal for older drivers visual systems, and perhaps flash rate could also be adapted to meet the needs of a distracted elderly driver.