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Laboratory Evaluation of Crash Cushion Delineation

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Alternative means of delineating crash cushions in gore areas were investigated in laboratory evaluations. A variety of passive delineation methods, including nose panels, back panels, side treatments, and combinations of these, was evaluated. The laboratory experiments used driver's-eye-view photographic slides of road scenes, only some of which contained crash cushions. A high-resolution computer graphics and digitization system was used to convert the original photographs to computerized images, so that any desired delineation could be inserted into, or removed from, the scene. Two experiments were carried out to investigate different aspects of the "conspicuity" of the markings. In one, viewers quickly searched a scene to determine if a crash cushion was present. Detection time, and the apparent distance of the crash cushion, were recorded. The other experiment provided only a brief fixed viewing time (1 sec), and the viewer was required to answer a series of questions about the scene; detecting crash cushions was a low priority, and crash cushions had no special relevance to the viewer. The results indicated differences between delineation and no delineation, as well as among alternative means of delineating, in terms of reliability of detection, speed of detection, and apparent distance of crash cushions. The findings suggest that Type 1 object markers may be less effective than other alternatives and that back panels may be an especially promising means of delineating crash cushions. There were also age-related deficits in viewers' ability to detect crash cushions.

Crash cushions (also called impact attenuators) are commonly used at freeway gores and other areas to protect motorists in run-off-the-road accidents. Typically, crash cushions guard some fixed-object hazard, such as a bridge pier or a railing end in an elevated gore area. These devices provide recognized highway safety benefits by substantially reducing the severity of accidents (*1*, *2*). However, they do not reduce the frequency of collisions and, indeed, may even result in an increase of "nuisance" collisions. This increase may result from the reduced area of the recovery zone, perceptual confusion, or simply the presence of an additional object to strike.

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Most collisions with crash cushions result in only minor injury or vehicle damage (reducing crash severity is, after all, the purpose of a crash cushion). However, these collisions still result in occasional serious injury or death as well as significant maintenance costs. Collisions with crash cushions can lead to secondary accidents and can disrupt traffic flow because elements of the barrier, or its contents (sand, water), or the impacting vehicle itself, obstruct the roadway. There is risk as well for the highway crews that must do the repair work at high-accident-risk sites with limited work space. Thus, for reasons of both safety and cost, it is important to reduce the frequency of collisions with crash cushions. One means of doing this is through effective delineation of crash cushions. Unfortunately, what constitutes "effective" crash cushion delineation, how well it works, and how cost-effective it may be are not known.

Crash cushion delineation has been recommended by the FHWA as well as by manufacturers of the devices. Marking practices differ widely. Some jurisdictions have implemented extensive programs of standardized marking practices for their crash cushions; others may only spot-treat extreme problem sites. Many varied delineation elements, which differ in size, color, shape, markings, and reflectorization and occur in numerous combinations, have been encountered.

Under contract to the FHWA, COMSIS Corporation is evaluating crash cushion delineation as a means of reducing collisions with these devices at gore areas. The interest is in passive marking treatments rather than more elaborate powered treatments such as flashing lights or illuminated barrels. Laboratory research evaluations of alternative delineation treatments are described in this paper. Some field evaluation is planned for the future.

COLLISIONS WITH CRASH CUSHIONS

There is relatively little information on the nature of accidents involving crash cushions. This is due in part to the minor nature of most collisions, which may go unnoticed for some time. One 5-year study (*3*) found that 88.5 percent of collisions with crash cushions were hit and run. Thus accident circumstances are often unknown. Furthermore, most accident studies done to date have focused on hardware performance, injury reduction, or maintenance and repair costs. These do not shed light on problems that relate to the effective use of delineation in preventing the collision in the first place. Nevertheless, there are some accident data of interest.

The majority of collisions occurs in darkness, and the early morning hours may be particularly overrepresented (*4, 5*). Most hits are to the nose of the cushion and generally strike at a flat angle (*1, 6*). Brown et al. (*7*) used a videotaping method. Although they only captured 13 hits during a 4-year period, accident descriptions are available for these. They too found most collisions to occur at night (8 of 13), including all four of their injury accidents. Alcohol use was reported involved in three cases, not involved in one, and unreported for the remaining nine. Accident diagrams suggest that a last-minute change of course contributed to three collisions; this was the most frequent accident cause reported by Corum (*4*) in his study. However, diagrams for five other cases reported by Brown et al. appear to show the vehicle driving straight into the gore area (including all three of the known alcohol-involved cases). Brown et al. concluded that "no single cause can be identified as contributing abnormally to crash cushion collisions."

A review of sources revealed that a number of different accident "causes" have been identified, but the relative frequency of each is unknown. These causes include last-second changes of course, "inattention," confusion at the gore, and other vehicles (forcing the victim into the gore or obscuring the view of the road). Other causes were loss of vehicle control due to skidding on ice or tire blowouts; however, these are not of concern here because delineation could have little effect on loss-of-control accidents.

PREVIOUS STUDIES

There have been few formal evaluations of crash cushion delineation. Some spot-treatment improvements have been reported, but typically these involve multiple improvements to the site in addition to crash cushion delineation (e.g., signing, lane lines). Only three relevant studies have been identified. Of these, one (*7*) evaluated only a single unusual and extensive treatment that consisted of a battery-powered, illuminated orange plastic barrel and an array of reflective delineator posts. The authors concluded that the display was effective, but no data were reported. They also acknowledged that maintenance was prohibitively expensive.

The remaining two studies used more realistic delineation treatments. Both were conducted in Texas. Wunderlich and Dudek (*8*) investigated 10 sites in the Houston area using frequency of repair (based on district maintenance records) as the measure of effectiveness. Four different levels of delineation, along with control sites, were compared. The most extensive treatment, which included amber flashers, appears to have led to some reduction in collisions. This treatment was used at the two sites with the highest pretreatment accident rates. The other three treatments, which used static delineation elements only, were located at sites with lower accident rates, and the results were ambiguous.

In another study in the Fort Worth area, Wunderlich (*9*) videotaped three sites and used vehicle encroachments into the gore area, rather than actual collisions, as the measure of effectiveness. At each site, a yellow and black high-intensity reflective back panel was added to the existing delineation; other aspects of the existing delineation were also modified at some sites. The existing pretreatment delineation differed for each site, but all included a striped nose panel. At all three sites, this study found a 42 percent drop in nighttime encroachments and a 21 percent drop in daytime encroachments. Thus extensive passive delineation, in the form of reflectorized nose and large back panels, appears to be effective in reducing erratic driving through the gore area. Gore encroachments are presumed to be related to actual crash cushion collisions, but the nature of this relationship is unknown.

In summary, delineation apparently can help reduce collisions with crash cushions. How extensive delineation needs to be, what treatments are most effective, and how great a reduction in collisions may be expected are unknown.

LABORATORY EXPERIMENTS ON CRASH CUSHION PERCEPTION

The laboratory study investigated people's ability to detect crash cushions imbedded in roadway scenes. Two experiments, employing somewhat different procedures, used photographic slides that portrayed behind-the-wheel views of the road ahead. Some of these scenes contained crash cushions; these photographs were modified so that different delineation treatments could be incorporated into scenes that were otherwise identical. The images were modified by photodigitizing the original photographs and then using a high-resolution computer graphics system to modify the image.

The two experiments were directed at somewhat different aspects of detection of crash cushions by motorists. "Conspicuity" (the property of an object that causes it to be conspicuous, or easily noticed) has been recognized as having two different aspects. Cole and Hughes (*10*) have labeled these as "attention conspicuity" and "search conspicuity." The former refers to the ability of an object to attract attention when it is not expected; the latter refers to how readily the object is identified when it is being searched for. Both types of conspicuity are relevant for crash cushion collisions. The primary experiment described in this paper addresses search conspicuity. In the second experiment, concerning attention conspicuity, similar, though less extensive, results were obtained.

Search Conspicuity Experiment

This experiment focused on the rolè of delineation in helping the driver to detect the presence and proximity of a crash cushion at a glance. It was designed to model the condition in which a driver makes a last-second decision to change course and must quickly decide if any object hazards are in the path and, if so, at what distance. Therefore the important measures are how long it takes the subject to detect the presence of a crash cushion and, in this brief view, how close the device appears to be.

Photographic Stimuli

Crash cushions located in the greater Washington, D. C., area were photographed from a driver's-eye position at distances of from 100 to 300 ft. The camera was mounted facing directly ahead of the vehicle, so that the picture was centered on the uproad path. The location of the crash cushion itself might therefore be anywhere from central to peripheral in the picture. Both day (using Kodacolor 200 ASA film) and night (using Kodacolor 1000 ASA film) shots were taken. The photographic prints were then converted to digitized computer images (1024 × 780 pixels) using a high-resolution computer graphics system (New England Technologies Graphics System, incorporating a Jupiter graphics generator, a hard disk system, a color graphics recorder, the digitizing controlling unit, and a Panasonic TV camera for input to the digitizer). After they had been converted to computer images, the scenes containing crash cushions could be modified in any manner desired. The modified images were rephotographed for presentation as slides.

The use of a digitizer-computer graphics system permitted excellent experimental control of the stimuli used for the experiment. The same site could be presented with alternative delineation treatments inserted into the scene. Perhaps the most important advantage was that undesired aspects of the scene could be easily and convincingly eliminated. Most of the crash cushions photographed already contained some sort of marking, and this could be readily eliminated in the computerized image. Extraneous signage, signals, warning flashers, and other hardware or distracting features could be removed. This method provided an alternative to the more difficult, time-consuming, less flexible (and sometimes unsatisfactory) photo-composite and photo-retouch method.

Delineation Treatments

In selecting delineation treatments to evaluate in this study, the emphasis was on passive markings, already in use by some states or jurisdictions and in conformance with the Manual on Uniform Traffic Control Devices (MUTCD) (*11*). The delineation treatments selected represent the devices typically used. Thus alternatives differ not only in shape and marking but also in size. The experiment on search conspicuity used six different delineation treatments, shown in Figure 1. Figure 2 shows a crash cushion with delineation elements added.

Experimental Design

The research subjects viewed a series of slides of road scenes, fewer than half of which contained crash cushions. Therefore the subject had to study the scene to determine if any crash cushion was present. Each of the 36 slides containing crash cushions (18 daytime and 18 night) were modified so that each site was portrayed with each of the six delineation treatments. Each research subject viewed each scene only once; different versions of the scene were viewed by different subjects. Thus there were six groups of subjects, each of which viewed a different delineation treatment for a given scene. Comparisons among treatments could be made on the basis of performance for all 18 day and 18 night slides, so that site-specific factors became less important. The design was counterbalanced so that each research subject saw each treatment three times in the set of 18 crash cushion slides, and each version of a site was viewed by one-sixth of the subjects.

Research Participants

Thirty paid research participants, 14 males and 16 females aged 18 to 35, were recruited through local advertising. All reported normal or corrected-to-normal vision and held valid driver's licenses.

Procedure

The general procedure was for the subject to view a slide and press a button as soon as he was able to determine that there was, or was not, a crash cushion somewhere in the scene. If a crash cushion was seen, its distance ahead was also estimated.

Subjects participated one at a time. They viewed rear-projected slides from a distance of 8 ft; the slide subtended a visual angle of 26 degrees horizontally and 18 degrees vertically. This reproduced the crash cushion image at approximately the same visual angle that it subtended in the field. The initial instructions informed the subject that his task would be to determine as rapidly as possible whether there was a crash cushion in a scene and then to estimate its distance; however, there would be a training period.

Training covered three elements: distance estimation, familiarization with crash cushions, and practice with the response time procedure.

The purpose of the distance training was to reduce the variability of the distance judgments and to make the task less distressing for the subject. The concern in collecting distance judgments was not with the absolute accuracy of the estimates but with the relative differences in the apparent distances of cushions with alternative delineation treatments. The training provided the subjects with some benchmarks and feedback. Slides that portrayed the same car at different distances from the camera were shown, and the subject was informed of the

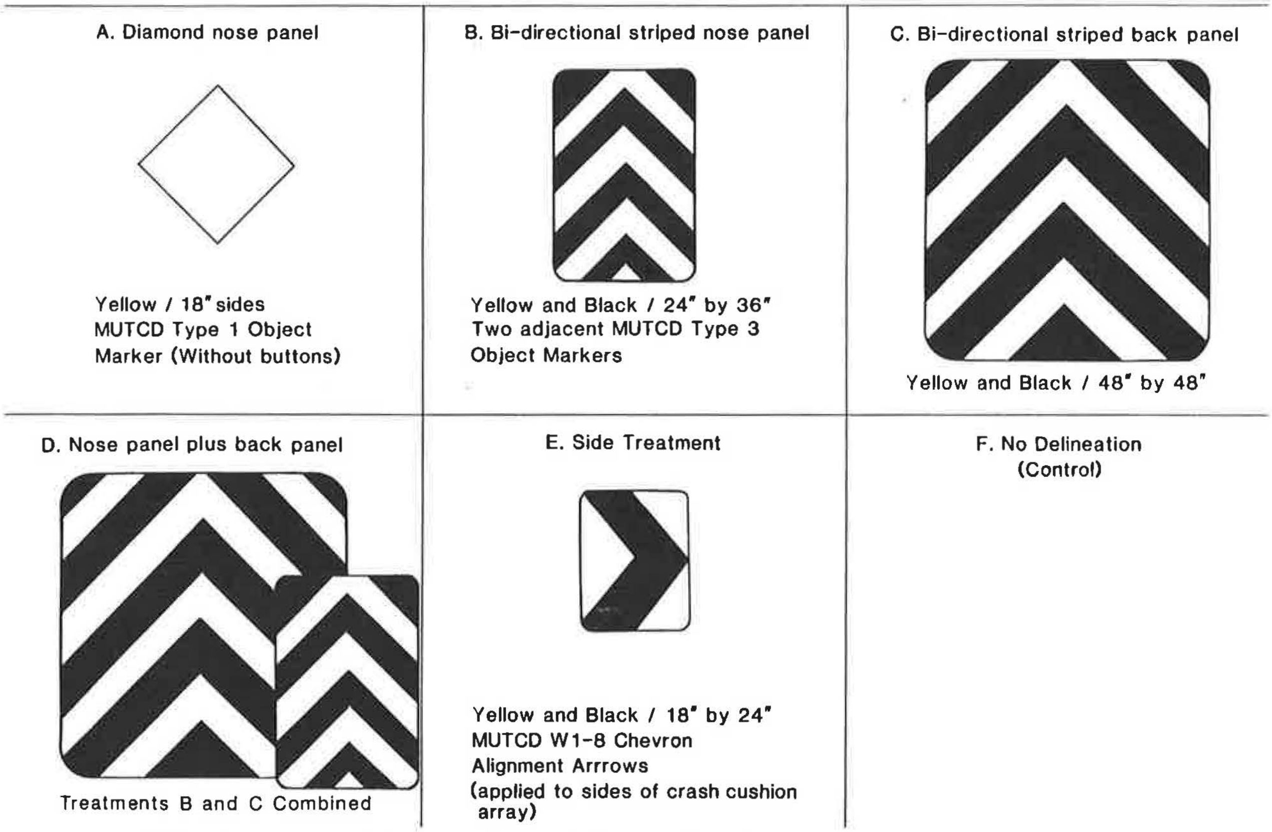

FIGURE 1 Delineation treatments for search conspicuity experiment.

distance. Following this, the same car was shown in different settings, at various distances. The subject estimated the distance, and then the experimenter informed him of the actual distance. The actual distances employed in training ranged from 75 to 268 ft.

Next, the subject was familiarized with the appearance of crash cushions. First he viewed (nondigitized) slides of a sand barrel array and two perspectives of a hydrocushion. Then he viewed a digitized scene that contained another hydrocushion and was told that this was typical of the scenes he would see. The cushion in this scene contained a nose panel, which was pointed out, with the comment "sometimes the highway department puts markers on or near the crash cushion. We put

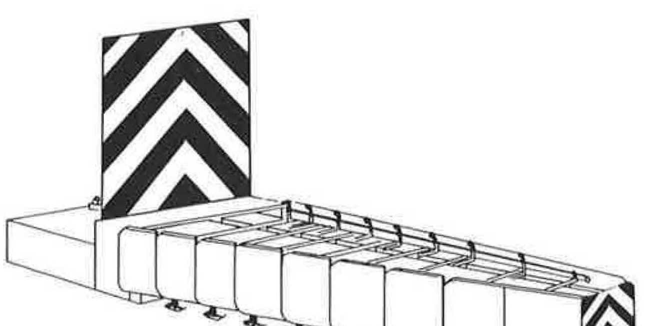

FIGURE 2 Illustration of a crash cushion with nose panel and back panel.

several different kinds of markers on this crash cushion, to give you some idea of what they look like." The subject then saw slides that portrayed the crash cushion with each of the delineation elements that would be encountered during the session (striped nose panel, diamond nose panel, striped back panel, and side alignment chevrons).

Finally, the subject practiced the response time procedure. The instructions emphasized the need for making a decision as rapidly as possible. First, four slides were presented, and the subject was only to determine if there was a crash cushion and operate the button appropriately. If a response time was slow (more than 2 sec), the experimenter coached the subject to respond more rapidly. Then, four more slides were presented, and the task of providing the distance estimate was added.

During actual data collection, the subject viewed a screen with a dot pattern projected on it. This provided a fixation point as well as a masking stimulus to minimize visual aftereffects of the actual scenes. The subject pressed a hand-held button to present the slide of the scene and activate a timer. As soon as the subject was able to determine that there was, or was not, a crash cushion in the scene, he again pressed the button. This stopped the timer and presented the dot pattern in place of the scene. The subject then informed the experimenter "Yes" (there was a crash cushion) or "No" (there was not a crash cushion), and, if there was one, how far away it appeared to be. The experimenter then recorded this information as well as the response time to the nearest millisecond.

First, a block of 42 daytime slides, 18 of which contained crash cushions, was viewed. After a brief break, a block of 42 night scenes, 18 of which again contained crash cushions, was

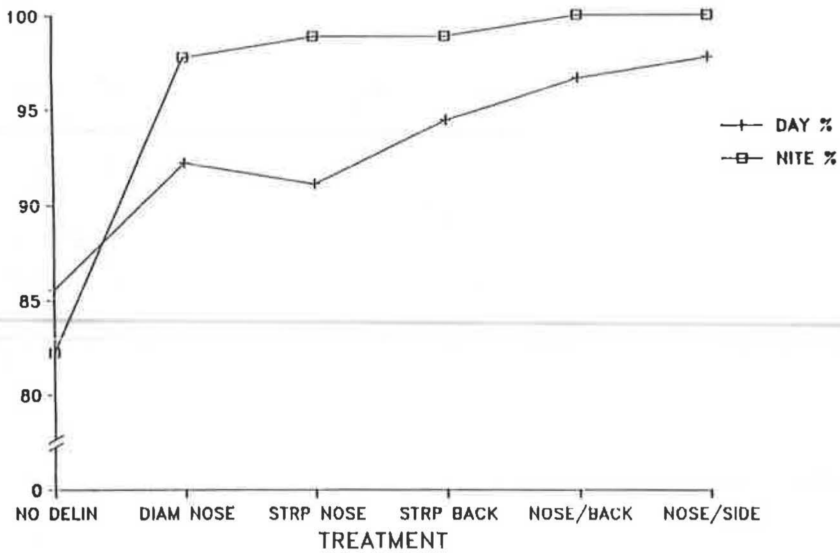

FIGURE 3 Percentage of crash cushions detected.

viewed. The order of the slides was random and was the same for all subjects. The subjects differed only in what delineation treatment they saw in each of the slides that contained a crash cushion.

Results

Overall, the "hit" rates (correctly reporting a crash cushion when there was one in the scene) were high (95 percent); the false alarm rate (incorrectly reporting a crash cushion when there actually was none in the scene) was low (2.7 percent); and the six groups of subjects were closely comparable. Mean detection times were uniformly rapid (well under 1 sec for all delineation treatments), as desired. Thus the procedure was successful, and comparisons of detection time and estimated distance may be readily made among treatments.

There were three dependent variables of primary interest: the percentage of time a crash cushion was correctly detected, the mean time it took to detect the presence of the crash cushion, and the apparent distance of the crash cushion. All three of these measures were significantly related to the delineation treatment.

As expected, because the subject was free to search the scene until he could decide whether a crash cushion was present, the detection rates were quite high. Figure 3 shows the percentage of time a crash cushion was detected as a function of the delineation treatment used. For both night and day scenes, fewer crash cushions were detected when no delineation was used (82 percent for nighttime, 86 percent for daytime). At night, a ceiling effect limited comparisons among the alternative markings: all delineation alternatives led to greater than 97 percent detection. For day scenes, the trend was for greater detection as delineation became larger and more extensive. Again, however, the magnitude of these differences was constrained because all delineation alternatives led to detection rates greater than 91 percent.

Figure 4 shows the geometric mean time required to detect

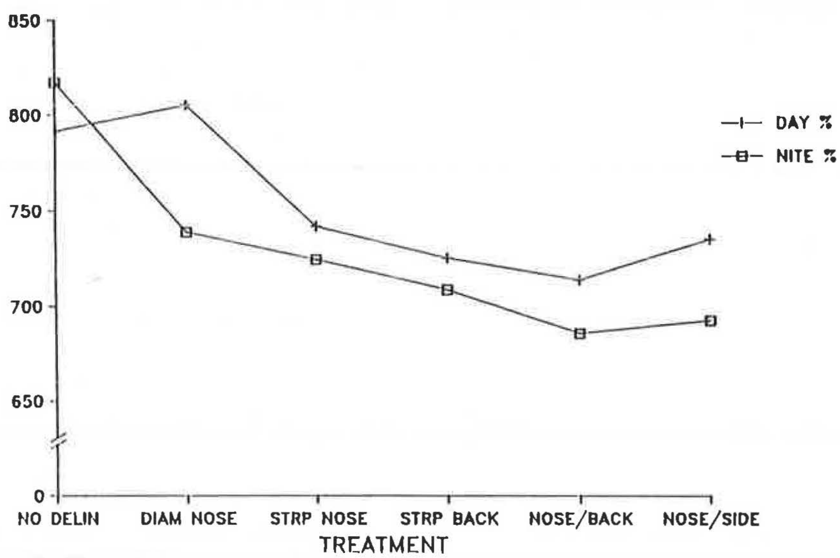

FIGURE 4 Geometric mean time to report cushion.

crash cushions for each delineation condition (geometric mean was used because the logarithm conversion corrects for positive skew when there are occasional long reaction times). As the figure makes clear, delineation generally produced faster detection of the crash cushion than did no delineation. The exception was for the diamond nose panel, which produced no benefit for the daytime simulation and a smaller benefit for the nighttime simulation. The trend in the detection time data was for faster times as the delineation became larger in area or more extensive in treatment. However, these effects were small and cannot be statistically confirmed. The fastest mean detection times for both day and night conditions occurred with the combination of the striped nose and back panels.

Figure 5 shows the mean distance at which subjects perceived the crash cushion to be. Although distances were estimated as somewhat farther for day scenes, this should be cautiously interpreted because the set of sites and actual distances was not the same for day and night slides. The more important point is that the same pattern was evident for both day and night conditions: the perceived distance was strongly dependent on how the crash cushion was marked. Crash cushions with nose panels, but no back panel, appeared farther away than if no delineation was used; crash cushions with only a back panel appeared nearer than if no delineation was used. The combination of nose plus back panel led to an intermediate perceived distance. The difference between the judged distances for the extreme conditions was quite substantial: 41 ft (a 39 percent difference) at night and 39 ft (a 32 percent difference) in day. The implication of these findings is that some treatments may help reduce the likelihood of the driver making a last-second change of course through the gore because, at a glance, the crash cushion will appear to be much closer to the vehicle than it really is. It is possible that this finding could be related to some tendency of the viewer to assume some "standard" sized delineation and then interpret the differences in size as differences in distance. Such a process could occur on the road as well as in the laboratory. An attempt was made to minimize any artifactual tendency of this kind by (a) providing all distance judgment training using a target other than crash cushions and (b) showing examples of delineation that included different sized markers.

Taken together, the results from this experiment clearly show that delineation can improve the probability and the speed of detecting a crash cushion in the context of a roadway scene. There are also meaningful differences between alternative delineation candidates.

Attention Conspicuity Experiment

The objective of this experiment was to compare the conspicuity of markings for the situation in which the driver is not concerned primarily with the detection of crash cushions. The key difficulty in devising a meaningful study of attention conspicuity is getting sufficient information on the subject's response to the object without having that object become the focus of his attention. Unfortunately, if the subject is constantly viewing crash cushions, and especially if he is making judgments about them, his attention will certainly come to be directed to these devices. If the subject rarely encounters a crash cushion, the problem is mitigated, but few data are collected. The solution to this problem was to force the subject to visually process multiple aspects of a scene (as in real driving), controlling the priority that various aspects of the scene received and being sure that crash cushions were not typical aspects of every scene. Thus, although subjects were required to indicate when they saw a crash cushion in a scene, identification of these objects was designed to be a relatively low attentional priority for them.

Temporal constraints on viewing were also designed to parallel certain features of real driving conditions. Crash cushion collisions often involve a driver who is devoting his attention, under time stress, to problems such as determining the proper route, seeking a gap for lane changing, or other problems. In the course of evaluating these other problems, the driver may fail to notice a crash cushion until it is too late to avoid it. In this experiment, each scene was visible to the subjects for only 1 sec. This was long enough to permit normal visual search and

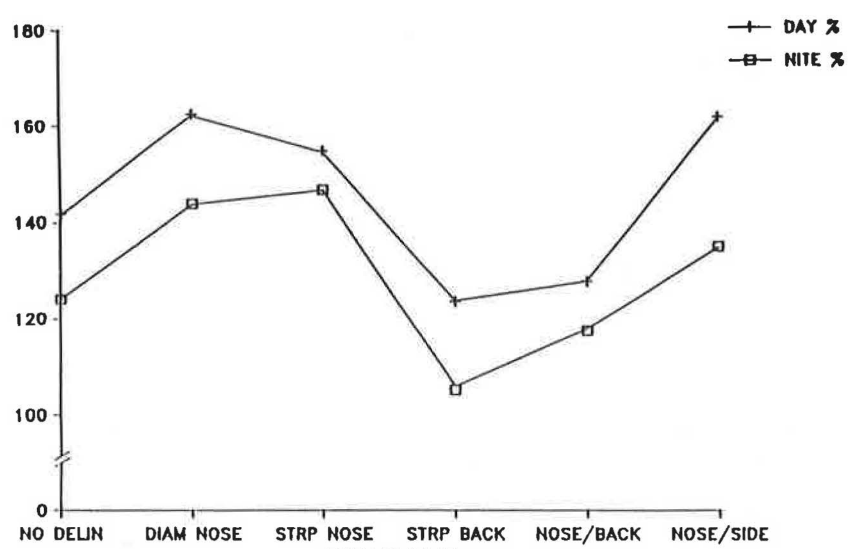

FIGURE 5 Mean estimate of distance.

visual information processing. However, it was brief enough to produce some temporal stress and to force rapid simultaneous processing of diverse elements of roadway-related information. In this way, the visual demands of scene interpretation during driving were approached without distorting normal visual acquisition processes.

The measure of effectiveness of delineation for this type of study is the percentage of time that subjects were able to detect the presence of crash cushions in scenes. This dependent variable does not provide a measure for each observation, as was done for response time and distance in the search conspicuity experiment. This is therefore a much less sensitive measure, although a necessary one given the objective of the experiment. Because the results of this experiment generally parallel those of the previously described experiment, though not always with statistically significant findings, only the general method of the rather complex detailed design and procedure will be described here. It would have been prohibitively long to evaluate every treatment at every site using this method; the actual design evaluated three related treatments at each site.

Delineation Treatments

Ten delineation treatments were included. There were three nose panel treatments: the diamond and striped panels as used in the search conspicuity experiment plus a novel treatment. The novel treatment was a modification of the bidirectional striped marker, in which the sign was essentially inverted and arrowheads were placed on the ends of the yellow stripes. This was included as an attempt to emphasize the directional information in the markings. There were also three back panel treatments, each of which was evaluated only in combination with a striped nose panel. The back panels included the bidirectional striped back panel described for the other experiment. It also included a Type 1 object marker (MUTCD 3C-3), which is the same as the diamond nose panel. Finally, it included a double arrow sign (MUTCD W12-1). There were three side delineation treatments, again used only in conjunction with the striped nose panel. The side treatments included the alignment chevrons, Type 3 object markers (diagonal striping), and a horizontal reflective yellow band. The tenth and final treatment was a combination of the striped nose panel, striped back panel, and side alignment chevrons.

Experimental Design and Procedure

As in the previous experiment, scenes containing crash cushions were modified so that different versions contained different delineation treatments. Different subjects viewed different versions of the same scenes. In all, each person viewed 60 scenes, 21 of which contained crash cushions. All were daytime scenes.

Each slide was shown for 1 sec. The subject then answered six questions about the scene. Only the last question asked about the presence of a crash cushion. The other questions served the function of ensuring that the viewer acquired the complete range of information relevant to driving; questions related to path, other vehicles, environment, and the like were included. These questions also served to keep the subjects from paying special attention to crash cushions. The crash cushions had no special status to the subject. A training and practice period assured that subjects understood the questions and served to emphasize the priority given to each of the questions. The instructions emphasized that the first questions were the most important and that the questions should be answered in order; however, every question had to be answered, with a guess if necessary. The crash cushion question, because it was last, was given low priority. This method was designed to force the viewer to fully process the visual scene for the many aspects of importance while driving, intentionally giving low priority to the task of identifying crash cushions. It was subjectively a demanding task, and it was not possible to fully attend to all aspects of the scene during the 1-sec presentation.

Each of the 21 scenes containing a crash cushion was presented with one of three delineation treatments. Thus not all treatments were compared at every site, nor were all possible pairs of treatments directly compared with one another. Rather, the design permitted comparison of triads of related treatments at the same location.

Research Participants

This experiment employed participants whose ages covered a much wider range than the previous experiment. This made it possible to evaluate age-related differences in perception. Seventy-seven research subjects were recruited through local advertising and paid to participate. All held valid driver's licenses and reported normal, or corrected-to-normal, vision. The group included 28 males and 49 females whose ages ranged from 18 to 78 years (mean of 40.2).

Results

Overall, crash cushions were correctly identified 55 percent of the time. False alarms were infrequent, occurring at an overall rate of less than 5 percent. The low false alarm rates for crash cushions indicate that guessing and confusion are not important factors and that the number of correct crash cushion identifications may be readily compared.

Effects of Age and Sex Performance was strongly related to the age of the subject. Figure 6 shows a scatterplot of the percentage of crash cushions missed versus the age of the subject. The figure shows much greater variability in performance as age increases. This effect appears to begin around age 40, with continuing decline thereafter. Nonetheless some older subjects did quite well. This experiment was not designed to identify the underlying cause of this age effect on conspicuity. However, it is clear that the ability to identify a crash cushion embedded in a realistic scene declines with age, perhaps becoming significant as early as age 35 to 40. Males detected somewhat more crash cushions than females (63 versus 51 percent). An age-by-sex analysis of variance, where age was classified into three categories (18 to 35, 36 to 50, and 51 years and older), found a statistically significant effect of the age

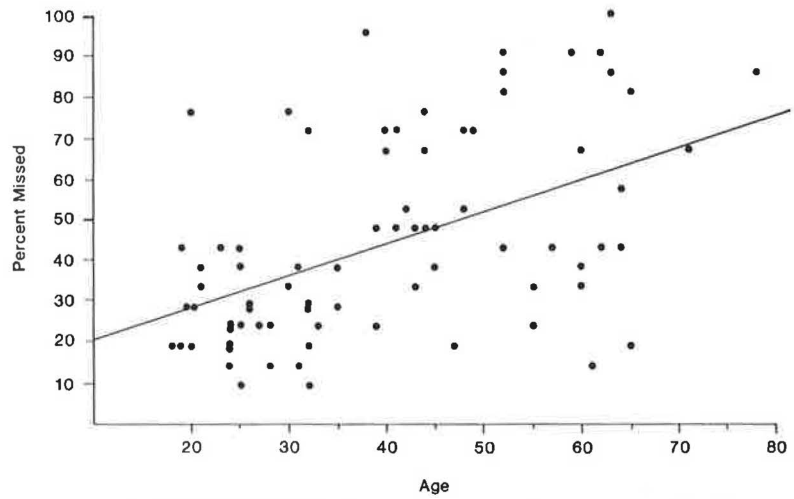

FIGURE 6 Percentage of crash cushions missed versus age of subject.

variable and the sex variable. The age-by-sex interaction was of borderline significance.

Conspicuity of Delineation Treatments Large site-to-site differences, the lesser sensitivity of simple detection data, and possibly the lesser statistical power of nonparametric analyses resulted in fewer clear-cut and statistically significant differences. Chi-square analyses were used to evaluate the differences in detection rates for each treatment at a given site. The most apparent result was that some delineation provides significantly better detection than no delineation. At three sites where nose panels were compared with no delineation, the crash cushion was detected only 34 percent of the time with no delineation versus 53 percent with a striped nose panel and 44 percent with a diamond nose panel. At three sites where no delineation was compared with treatments that included the nose and back panel combination, the crash cushion was detected only 35 percent of the time with no delineation versus 54 percent with a striped back panel and 49 percent with a diamond back panel. Thus it is apparent that adding delineation to the device improves its detection.

Comparisons among different delineation elements (nose, back, side), or different alternatives for a given element, were less clear. Whether as a nose panel or a back panel, the detection rate was generally higher for the bidirectional striping than for the yellow diamond. At six sites, the striped nose panel was detected 55 percent of the time versus 48 percent for the diamond panel. At 6 sites, the striped back panel was detected 62 percent of the time versus 56 percent for the diamond panel. However, these differences were generally not statistically discriminable for a given site, and, in four cases, the diamond panel performed just as well. Where the striped nose panel treatment was compared with the nose-plus-back panel combination, the back panel treatment was detected at a nonsignificantly higher rate at all three sites; however, this advantage was quite small, averaging only 4 percent. Thus in terms of the advantage of the bidirectional striping over the diamond panel, and in terms of the advantage of the back panel over the nose panel, the results of this experiment are consistent with those of the previous one, but the findings are less robust.

Among the other comparisons of treatments, only one set yielded a clear result. Among the nose-plus-side treatment conditions, the horizontal reflective band was less effective than the two alternative side markings. Crash cushions marked with the band were detected 60 percent of the time versus 70 percent for the diagonal striping and 76 percent for the chevron alignment arrows.

DISCUSSION OF RESULTS

These laboratory studies support the value of delineation in making crash cushions more conspicuous to approaching drivers. The findings indicate improved conspicuity for both night and day and that some delineation treatments are more effective than others. Benefits of delineation were observed in detection time, apparent distance, and probability of seeing. Some of these differences were substantial. However, the absolute magnitude of the response measures, and the difference among treatments, should not be taken literally; it is relative performance with different delineation conditions that is meaningful.

The findings suggest that of the two common nose panel treatments, the bidirectional striped panel may be preferable to the Type 1 object marker (yellow diamond panel, simulated without buttons). In particular, it took longer to detect crash cushions when the diamond panel was used. These nose treatments differed in pattern, shape, and size, and the experiments were not designed to isolate one aspect as more critical than another.

Comments from the research participants indicated further drawbacks to the diamond panel. Despite its frequent use as a gore marker in the Washington, D. C., area, many subjects thought it an unusual and unfamiliar marking. It did not convey much meaning (except a most general "caution"); some people expressed the opinion that the marker was a warning sign in which the "message" had been left off.

The findings also indicated potential benefits from the use of back panels. However, there are a number of additional site-specific factors that must be considered in determining whether.

a back panel is appropriate. It should be emphasized that back panels must be viewed as an optional marking treatment.

Although treatments that included back panels were detected more rapidly than those with only nose panels, the most extreme differences between treatments were in perceived distances. For both day and night viewing, crash cushions with back panels appeared closer than in identical scenes with nose panels. The magnitude of this difference was as high as 39 percent. If a crash cushion appears farther away, it is assumed that it is more likely that a driver will attempt a last-second change of course in front of the device. Thus, by causing the crash cushion to appear perceptually nearer, the back panel may be expected to reduce the number of erratic maneuvers through the gore area. Back panels have a number of other potential advantages in addition to those specifically identified in the laboratory evaluation. First, they can be larger than other markings because there is more area at the rear of the cushion array. In complex environments this may improve the detectability of the crash cushion; Cole and Jenkins (*12*) have found target size to be the most critical determinant of conspicuity of traffic control devices, and Mace et al. (*13*) have found that conspicuity effects interact with the visual complexity of the surrounding scene. Second, back panels are more elevated than nose (or side) markings. This will improve sight distance, particularly through vertical curves. It may also improve detectability through surrounding traffic. Third, the marking will survive accidents, particularly nuisance hits, better than nose markings. Finally, the marker should maintain its visibility better; it is raised beyond the splash zone and may also be less obscured by snow. Thus there are a number of reasons for considering the use of back panels as a means of marking crash cushions under certain conditions.

Nonetheless, back panels must be deployed with restraint. At sites with adequate sight distance and good geometrics, less extensive treatments are probably adequate. At narrow crash cushions, back panels may also be of limited use. Perhaps the major concern is with interference with other gore area signs and markings. Back panels must not obscure exit signs or other devices and must not contribute to a cluttered or distracting array of traffic control devices at the gore. Thus the laboratory findings and other considerations suggest that back panels may be effective in reducing crash cushion collisions, but only under appropriate conditions that must include full consideration of site factors.

Another interesting aspect of the results was the substantial age effect revealed in the attention conspicuity experiment. It is not unusual to find that older subjects have more difficulty in studies of roadway perception (*14*). Many factors may contribute to such age-related deficits, including visual abilities, information processing rate, search behavior, cognitive strategies, and decision processes (*15*). (The limited accident data available suggest that males under 35 are most frequently involved in crash cushion collisions; however, little is known about involvement rates. Other factors, in addition to visual detection, may be influencing the accident rates.) What is particularly interesting in the present findings is the suggestion that a fairly sharp change in performance may occur by age 40. More extensive data are required to substantiate this. The general procedure may prove interesting for evaluation of age effects and individual differences in driving. Some elderly subjects performed very well, and a method that uses a limited viewing time and demands search may prove useful in investigating what factors contribute to this ability. The difficulty in detecting roadside objects experienced by some middle-aged and older viewers further underscores the importance of adequate delineation, particularly as the driving population ages.

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