UMTRI-2007-2 MARCH 2007

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Report No. UMTRI-2007-2
March 2007

Technical Report Documentation Page

1. Report No. UMTRI-2007-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Improving pedestrian detection with a simple display for night vision systems		5. Report Date March 2007
		6. Performing Organization Code 302753
7. Author(s) Tsimhoni, O., Flannagan, M.J., Mefford, M.L. and Takenobu, N.		8. Performing Organization Report No. UMTRI-2007-2
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, Michigan 48109-2150 U.S.A.		10. Work Unit no. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address The University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety		13. Type of Report and Period Covered
		14. Sponsoring Agency Code

15. Supplementary Notes

The Affiliation Program currently includes Alps Automotive/Alpine Electronics, Autoliv, Avery Dennison, Bendix, BMW, Bosch, Com-Corp Industries, DaimlerChrysler, Decoma Autosystems, Denso, Federal-Mogul, Ford, GE, General Motors, Gentex, Grote Industries, Hella, Honda, Ichikoh Industries, Koito Manufacturing, Lang-Mekra North America, Magna Donnelly, Muth, Nissan, North American Lighting, Northrop Grumman, OSRAM Sylvania, Philips Lighting, Renault, Sisecam, SL Corporation, Stanley Electric, Toyota Technical Center USA, Truck-Lite, Valeo, Visteon/ACH, and 3M Personal Safety Products. Information about the Affiliation Program is available at: http://www.umich.edu/~industry/

16. Abstract

The objective of this work is to present a concept for a very simple driver interface to be used in a night vision system, and to partially test its effectiveness. The display consists of a pedestrian icon that indicates when there are pedestrians near the future path of the vehicle. The next generation of automotive night vision systems will likely continue to use in-vehicle displays that show enhanced images of the forward driving scene. In some displays there may also be highlighting of pedestrians and animals, which has been argued to be the primary safety goal of night vision systems. There are other design considerations for future night vision displays, such as improving mobility, addressing the driver's desire for better vision of the road, and providing the driver with a sense of support for subjective situation awareness. In this work, however, we focus on safety considerations.

Eight younger drivers (under age 30) and eight older drivers (over age 60) drove an instrumented vehicle during normal nighttime traffic on a 20-mile route. Seven pedestrians, simulated by inflatable mannequins dressed in dark clothes, were positioned on the shoulders of the road along the route. Subjects drove the route twice and indicated verbally as soon as they saw a pedestrian. On one pass, the pedestrians were all on the right side of the road, while on the other pass some were on the right and some were on the left side of the road. During half of each pass, the pedestrian icon was active, lighting up as soon as the pedestrian was within 150 m of the vehicle. During the other half, it was inactive.

The pedestrian icon improved mean detection distance from 34 to 44 m. The ratio of missed pedestrians decreased overall from 13% to 5%, correspondingly. The improvement may be attributable to the icon alerting the driver to the presence of a pedestrian. In this experimental context, the drivers were probably always more alert to the possible presence of pedestrians than most drivers in the real world, suggesting that the effect of the icon might be even larger in actual use.

17. Key Words Night vision, infrared, pedestrian detection		18. Distribution Statement Unlimited	
19. Security Classification (of this report) None	20. Security Classification (of this page) None	21. No. of Pages 28	22. Price

ACKNOWLEDGMENTS

Appreciation is extended to the members of the University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety for support of this research. The current members of the Program are:

- Alps Automotive/Alpine Electronics
- Autoliv
- Avery Dennison
- Bendix
- BMW
- Bosch
- Com-Corp Industries
- DaimlerChrysler
- Decoma Autosystems
- Denso
- Federal-Mogul
- Ford
- GE
- General Motors
- Gentex
- Grote Industries
- Hella
- Honda
- Ichikoh Industries
- Koito Manufacturing
- Lang-Mekra North America
- Magna Donnelly
- Muth
- Nissan
- North American Lighting
- Northrop Grumman
- OSRAM Sylvania
- Philips Lighting
- Renault
- Sisecam
- SL Corporation
- Stanley Electric
- Toyota Technical Center, USA
- Truck-Lite
- Valeo
- Visteon/ACH
- 3M Personal Safety Products

We would like to thank Brandon Schoettle, Joel Devonshire, Jason Schweitzer, Dan Huddleson, and Sean Walls for their help.

CONTENTS

INTRODUCTION

Background

One of the most critical features of a driver assistance or safety system is the driver-vehicle interface. The interface must be designed so that it can get the driver's attention and evoke an effective response under the time pressure of an emergency situation. The difficulty of achieving that is heightened by the fact that emergency situations are rare, so that there is little chance for the driver to learn the characteristics of the system. The rarity of real emergency situations also means that even a low rate of false alarms can undermine the driver's faith in the system, and possibly create distraction if the system's signaling is made strong enough to get the attention of a driver who is not paying attention. In this study, we describe and partially test the potential effectiveness of a very simple interface for a night vision system. The display involved is much simpler than the video displays that are currently used in most night vision systems, and the information that it provides to the driver is correspondingly limited. However, the proposed system is intended to address the main safety problem that has been attributed to darkness—specifically, pedestrian crashes. Furthermore, the display involved may represent a particularly desirable balance by being nonintrusive enough to reduce problems with distraction and false alarms, while still being salient enough to evoke an effective response from a driver under the nighttime conditions that it is designed for.

Crash data suggest that the main potential safety benefit of automotive night vision systems is in assisting drivers to detect and avoid hitting pedestrians, animals, and cyclists (Rumar, 2002). To achieve this potential safety benefit, a successful implementation of a night vision system need not help drivers see the entire night road scene better. Rather, it should focus on pedestrians, animals, and cyclists. Sullivan and Flannagan (2001) estimated that the nighttime deaths of about 2,300 pedestrians in the U.S. each year can be attributed to darkness. Night vision systems could be cost effective and valuable to society if they prevented some of those deaths.

The potential safety benefit of night vision systems has to be weighed against the cost of continuously displaying information to drivers that may not improve, and may even hinder, their safety and the safety of others. This cost may include driver distraction if drivers need to either look away from or draw their attention away from the road intermittently. Furthermore, it is possible that some drivers will use night vision systems only when they think they can't see well enough, and ignore the system when they feel confident that they can see well. It has been shown that drivers do not always correctly estimate the limitations of their vision at night. For example, data from the U.S. show a substantial underuse of high beams in situations without opposing traffic (Hare and Hemion, 1968; Mefford, Flannagan, and Bogard, 2006). This phenomenon might be explained by the selective degradation theory (Leibowitz and Owens, 1977). Leibowitz and Owens proposed that at low levels of illumination, typical in night driving, certain "focal" visual capabilities (such as detecting pedestrians) are significantly impaired, whereas certain "ambient" visual capabilities (such as the visual guidance needed to steer the vehicle) are relatively well preserved. Furthermore, they suggested that drivers are not fully aware of this selective degradation.

The probability of any particular driver being involved in a pedestrian crash is very low. For most drivers, it is less than once in their lifetime. The total vehicle miles traveled in the U.S. in 2004 was 2,965 billion (NHTSA, 2005). Of that, about 25% are estimated to have been at nighttime (741 billion vehicle miles per year). Considering the estimation of 2,300 pedestrian deaths per year due to darkness, there are about 322 million motor vehicle miles per pedestrian death due to darkness. A similar calculation for pedestrian injuries results in 26.5 million miles per incident. Assuming 3,750 nighttime miles per driver annually, it is expected that a pedestrian death due to darkness would occur every 85,000 driver years. Similarly, a pedestrian injury would occur about every 7,000 driver years.

The probability of hitting an animal is higher than that of hitting a pedestrian, but those crashes tend to be less fatal. In 2004, there were 195 fatalities in the U.S. due to animal-vehicle crashes (NHTSA, 2005). For six upper Midwestern states in the U.S., there were 41 fatalities, 5,575 injuries, and vehicle damage estimated at $236 million (Knapp et al., 2005). Knapp and colleagues estimated deer-vehicle crash rates in the upper Midwest at 1 per 2.5 million vehicle miles (about one crash every 166 driver years). Although a breakdown into daytime and nighttime was not reported, most animal crashes (about two thirds) occur in the dark (GES, 2005). It should be noted that these estimates are high compared to the entire U.S. (one crash every 660 driver years where the first harmful event is associated with an animal [NHTSA, 2005]).

These estimates of the volume of vehicle-pedestrian crashes and vehicle-animal crashes, and a driver's probability of experiencing them, are summarized in Table 1.

Table 1
Vehicle-pedestrian and vehicle-animal crash estimates.

Description	Estimate		Source
Number of pedestrians killed in the U.S. annually due to darkness	2,300 deaths		Sullivan and Flannagan, 2001
Frequency of a driver experiencing a fatal pedestrian crash that is attributed to darkness	1 per 300 million vehicle miles traveled	1 in 85,000 driver years	Estimated based on NHTSA, 2005
Frequency of a driver experiencing an injury pedestrian crash that is attributed to darkness	1 per 26.5 million vehicle miles traveled	1 in 7,500 driver years	Estimated based on NHTSA, 2005
Frequency of a driver in the upper Midwest U.S. being involved in a deer crash (including no-injury crashes)	1 per 2.5 million vehicle miles traveled	1 in 166 driver years	Knapp et al., 2005

There are several implications of these estimates for the design of effective night vision systems. First, there is clearly a potential safety benefit from night vision systems that focus on the detection and avoidance of pedestrians, animals, and cyclists. Second, the rarity of events that an individual driver is likely to experience requires special consideration. Many of the considerations for the design of crash avoidance systems (e.g., COMSIS, 1996) apply well in this context. For example, if warnings are not heard frequently, drivers may respond to them slowly, or not respond at all. To address this issue, it may be helpful to provide the driver with nonintrusive alerts to noncritical cases, which would facilitate learning of appropriate responses. The alerts would have to be nonintrusive so as not to distract the driver, but sufficiently noticeable to draw the driver's attention in rare situations. Some considerations for the design of an effective night vision system are summarized in Table 2.

Table 2
Design considerations for an effective night vision system.

<table>
<tr><th></th><th>Description</th><th>Design consideration</th></tr>
<tr><td>System goal</td><td>Improve safety</td><td>Focus on pedestrian and animal detection</td></tr>
<tr><td rowspan="2">Critical events</td><td rowspan="2">Crashes are extremely rare (less than once in a lifetime).</td><td>System should be effective and easily noticeable despite the rarity of critical events.</td></tr>
<tr><td>When providing a warning, the system should require minimal processing to allow the driver to respond quickly and without interruption.</td></tr>
<tr><td rowspan="2">Noncritical events</td><td rowspan="2">There are many encounters with pedestrians and animals that do not result in a crash.</td><td>System can facilitate the driver's learning of appropriate responses during noncritical events.</td></tr>
<tr><td>System should not distract the driver during noncritical events.</td></tr>
</table>

Several night vision systems are currently offered in the automotive market. Their displays are installed in the central console, the instrument cluster, or on a head-up display. They provide a good view of the road scene ahead and are capable of detecting pedestrians and animals as far as 300 m ahead of the vehicle. Automatic pedestrian detection at shorter distances is already available, and is expected to be implemented in some of the next-generation night vision systems.

Table 3 shows an analysis of the performance of existing systems based on the criteria in Table 2. Systems without automatic pedestrian detection do not explicitly focus on pedestrians. Some provide better detection distances than others (Tsimhoni et al., 2004), but there is no indication to the driver about the importance of detecting pedestrians relative to other tasks. Because these systems provide information that is continuously available without special alerting, a driver might miss a rare event, especially if the expectation or level of vigilance is low. During an event, the driver might need to continuously scan the display to confirm the presence of a pedestrian instead of looking outside the vehicle and focusing on an avoidance maneuver. There is some facilitation of learning in that the night vision system enhances visibility and the driver might learn of the presence of objects otherwise not seen. A possible downside of these systems is that they have the potential to distract the driver because they require attending, and sometimes looking, away from the driving task. Nevertheless, it is possible that drivers may use such systems for reasons beyond safety, such as increasing their mobility in bad weather.

Systems with automatic pedestrian detection can highlight pedestrians, thus conveying their importance to the driver. They are expected to be effective for rare events because they draw the driver's attention whenever there is a pedestrian ahead. After a pedestrian has been detected, there is almost no need for the driver to look again at the display because the pedestrian is already highlighted. Interruption during the event itself is therefore expected to be minimal. There is still a potential for negative impact because the display is regularly on and drivers may tend to look at it more often than necessary to avoid pedestrians, animals, and cyclists. Possible problems with automation may arise if the driver becomes overreliant on the system's ability to detect pedestrians.

We propose that pedestrian detection can be improved with a simplified display that has the potential to comply with all the discussed safety criteria. The proposed system focuses on pedestrians and is designed to be effective for low-probability pedestrian events. During an event, there is no major interruption by the system. It is based on automatic pedestrian detection and is subject to some level of overreliance and complacency, but because it is not very intrusive, it can be designed with a greater bias towards false positives than false negatives (misses), thus reducing the effects of the overreliance problem.

Table 3
Analysis of night vision systems based on criteria for effectiveness.

Criteria for effective night vision system	Existing systems	Systems with pedestrian detection	Proposed system
Focus on pedestrians	Not explicitly	Highlights pedestrians	Primary focus
Effective for a rare event	Driver might not be looking	Draws attention to the display	Yes
Interruption during event	Requires glances to display	Nearly none	None
Facilitates learning	Somewhat	Yes	Yes
Minimal distraction	Driver has to attend away from the road	Looking at the display may distract	Minimal distraction
Problems with automation	No automation	Possibly	Possibly

The proposed simplified night vision system consists of a pedestrian icon (Figure 1) that indicates the presence of a pedestrian near the future path of the vehicle. The icon is visible, but nonintrusive. It is designed so that it is easy to detect, especially at night, without directly looking at it. It alerts a driver to the presence of a pedestrian ahead, and is expected to increase the distance at which the pedestrian will be detected. A likely driver response to the pedestrian icon is attending carefully and preparing to slow down. In unopposed situations, the driver may turn on the high-beam headlights. In some cases, such as when driving in heavily populated areas, the vehicle will already be slow, and the driver may already be fully aware of the presence of pedestrians. The system is primarily intended, however, for higher speed driving and roads on which pedestrians are less expected. It is primarily in those conditions that pedestrian crashes are likely to occur because of darkness (Sullivan and Flannagan, 2001).

Another potential benefit of the proposed system is that it may facilitate learning. If the blue icon turns on during the day and night every time there is a pedestrian, drivers will be able to learn about the performance of the system by confirming the alerts with what they see during daytime. Additionally, they are likely to receive implicit feedback about the visibility problem of pedestrian detection at night.

Although the display concept is simple, the system would require an underlying set of sensors and computing algorithms that are not available on most current systems. It is expected, however, that in the next few years the hardware and software for such systems will be available as research is currently underway in this direction (Bertozzi et al., 2004; Fang et al., 2003; Nanda and Davis, 2002; Shashua, Gdalyaho, and Hayun, 2004; Xu, Liu, and Fujimura, 2005; Zhao and Thorpe, 2000).

Figure 1. Proposed pedestrian warning ("pedestrian icon").

METHOD

Subjects

Sixteen licensed drivers participated in this experiment: eight young drivers (ages 23 to 30, mean 26) and eight older drivers (ages 62 to 76, mean 66). All subjects' corrected vision was 20/40 or better (mean of younger drivers was 20/19, mean of older 20/28), as tested using an Optec 2000 Stereo Optical Vision Tester.

Apparatus

Vehicle Setup

Two Nissan Altimas, equipped with data acquisition systems (DAS), were used for this experiment. The DAS recorded the exact position of the vehicle using a differential global positioning system (DGPS) and also recorded the timing and position at which two digital inputs were activated. One input was a button that was used by the experimenter to mark when the subject reported they first identified a pedestrian. A second input was connected to the experimenter's laptop computer and recorded the point at which a pedestrian warning was turned on. A schematic diagram of the experiment setup is shown in Appendix A.

Pedestrian Warning

A pedestrian warning icon (Figure 1) appeared on a 5.6" LCD. When the experimenter determined, using DGPS, that the vehicle was 150 m from the pedestrian, the pedestrian warning icon appeared on the display. (A post-test analysis of all warning distances showed that the actual distance at which the warning was initiated was 150 m with a standard deviation of 12 m.) The warning disappeared after the car passed the pedestrian (Figure 2). In order to avoid cases in which the driver might miss the pedestrian warning, the warning was designed to be very conspicuous at about 50x50 mm. The luminance of the icon was approximately 11.3 cd/m^2 (measured in the blue area).

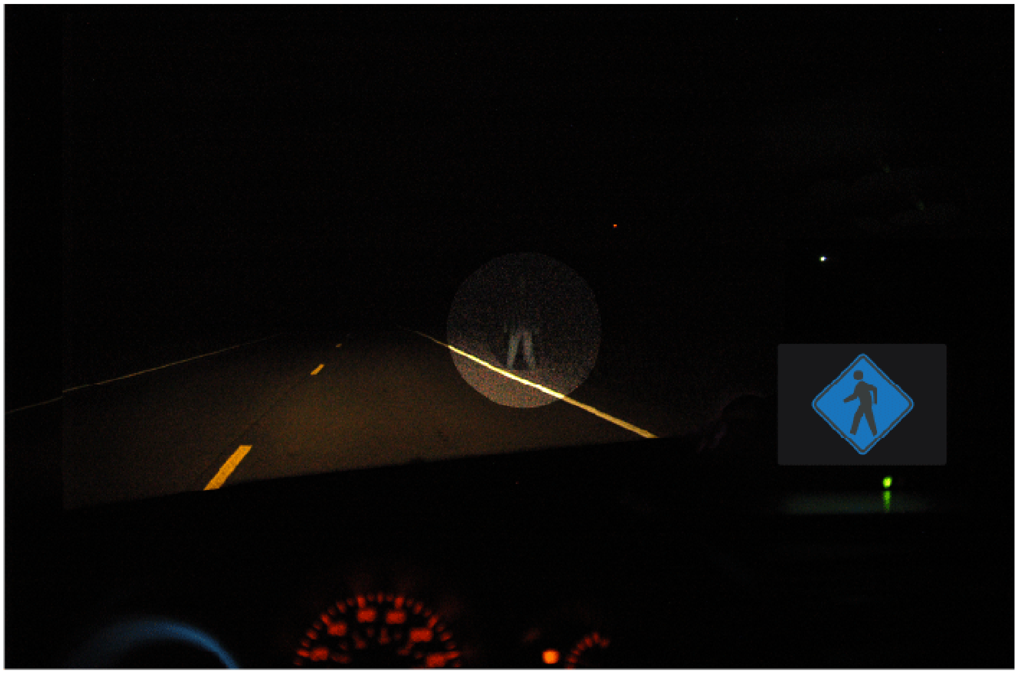

Figure 2. An illustration of the view from the driver seat. A pedestrian mannequin is shown at a distance of about 30 m, and the pedestrian warning is on.
(The image has been modified to enhance the pedestrian and adjust the lighting of the pedestrian icon.)

Route and Pedestrians

Subjects drove the instrumented vehicles on a 20-mile route that consisted of rural roads. Most sections had no streetlights. Speed limits varied from 45 mph to 55 mph. Figure 3 shows the route and the positions of pedestrians. Pedestrians were simulated by 6 ft (180 cm) inflatable mannequins that were dressed in dark denim clothes and were facing traffic about 3 m from the edge of the lane (shown in Figure 4). The reflectance ratio of the clothes was 6.6% for halogen headlamps. The median reflectance of pedestrian clothing has been reported to be about 5% (Bhise et al., 1977, Figure 6-9). Subjects drove the route twice, encountering each of seven pedestrians on each pass.

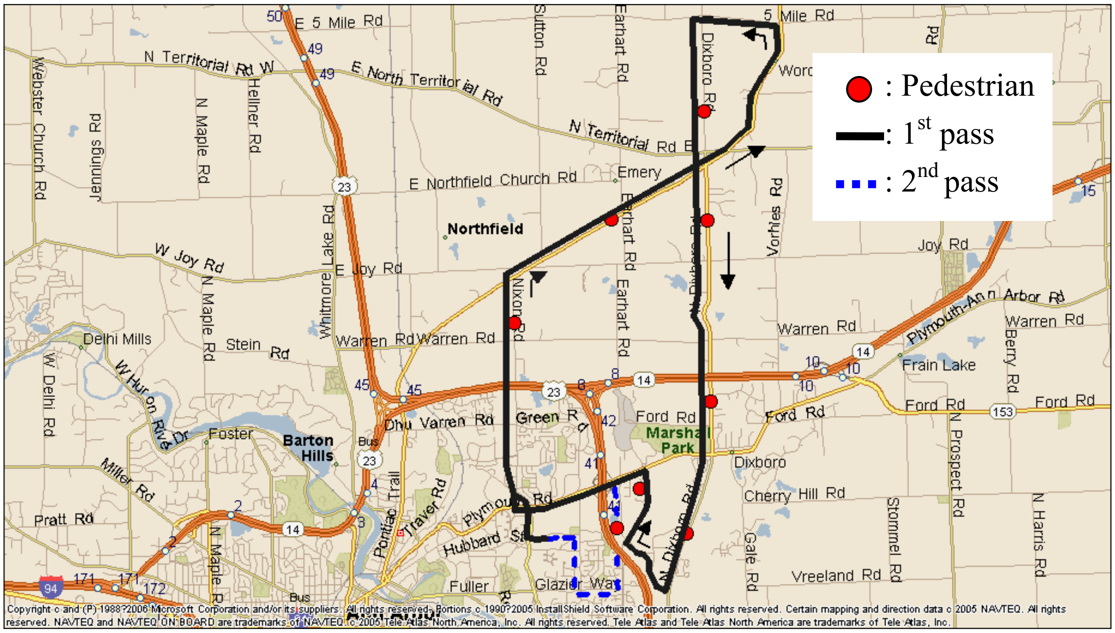

Figure 3. Route map.

Figure 4. Image of mannequin pedestrian standing.

Video Clip (Face Camera)

A low-light face camera was directed at the subject's face to collect glance data. Digital video clips were captured by a DVCAM digital video cassette recorder (Sony DSR-20). Figure 5 shows an example of the face video.

Figure 5. Example of the face video.

Procedure

The experiment was performed from nautical twilight until about four hours after nautical twilight during the summer and fall of 2006. Subjects were instructed to drive normally while using only low-beam headlights except in an emergency. An experimenter in the back seat provided driving directions. The experimenter told them in advance whether the pedestrian would be on the right side only or could be on either side of the road, and whether the pedestrian warning would be active. The subjects said "pedestrian" as soon as they saw a pedestrian (mannequin) on the side of the road. The experimenter pressed a button as soon as the subject said "pedestrian." The exact position at which the button was pressed would then be marked by the data acquisition system. When the vehicle just passed the pedestrian, the experimenter released the button to mark the position of the pedestrian. (A post-test analysis of all button releases revealed a mean precision of 2.1 m (range: 0.1 to 4.9 m) in the recorded position of the button release.)

During the first pass of the route, drivers did not have any prior knowledge of the number of pedestrians or their positions. During the second pass, some of the pedestrians were on the opposite side of where they had been before, but some were in the same position as in the first pass.

Experimental Design and Data Analysis

Experimental Design

Pedestrian detection was the primary dependent variable of this experiment. Two independent within-subject variables were manipulated: warning (with or without pedestrian warning) and pedestrian side (whether the pedestrian was on the right side only or on either side of the road). The experimental design was fractional factorial such that each subject drove by each of seven pedestrians only twice—with and without a warning. Table 4 shows an example of the order in which one subject encountered pedestrians. The order was counterbalanced across subjects. For each age/gender group of four subjects, the four possible orders of warning presence (yes/no) and of side of pedestrian (right/both) were assigned to each subject.

In the last trial of the experiment, a pedestrian warning was not provided for any subject. For the subjects that were in the experimental condition of pedestrian warning present, the absence of a warning was a surprise. For the subjects that were in the "no warning" condition, this trial was in agreement with the description of the condition.

Table 4
Pedestrian position and warning.

Location	First pass		Second pass	
	Pedestrian position	Warning	Pedestrian position	Warning
1	Right	No	Either (Right)	Warning
2	Right	No	Either (Left)	Warning
3	Right	No	Either (Right)	Warning
4	Right	No	Either (Right)	Warning
5	Right	Warning	Either (Right)	No
6	Right	Warning	Either (Left)	No
7	Right	Warning	Either (Right)	No
8			Either (Right)	No

Data Analysis

The detection distances were analyzed using a mixed-model design while taking into consideration the confounding of run with the presence of warnings and the positioning of the pedestrian. A detection distance of zero was assigned to cases in which there was no detection of the pedestrian. A total of 222 data points out of 240 possible data points (16 subjects x 15 pedestrians) were collected. The lost 18 data points were the results of a missing pedestrian, a vehicle parked next to the pedestrian, etc.

RESULTS

Detection Distance

Detection distance was marked by the experimenter from the point at which the subject said "pedestrian" to the point at which the vehicle passed the pedestrian. Detection distance without a warning (34 m) was significantly shorter than with a warning (44 m) $F(5,84) = 2.92$, $p < 0.05$. As expected, older subjects had shorter detection distances (31 m) than did younger subjects (46 m) $F(1,10.7) = 6.22$, $p < 0.05$. The interaction between age and warning was not statistically significant (Figure 6).

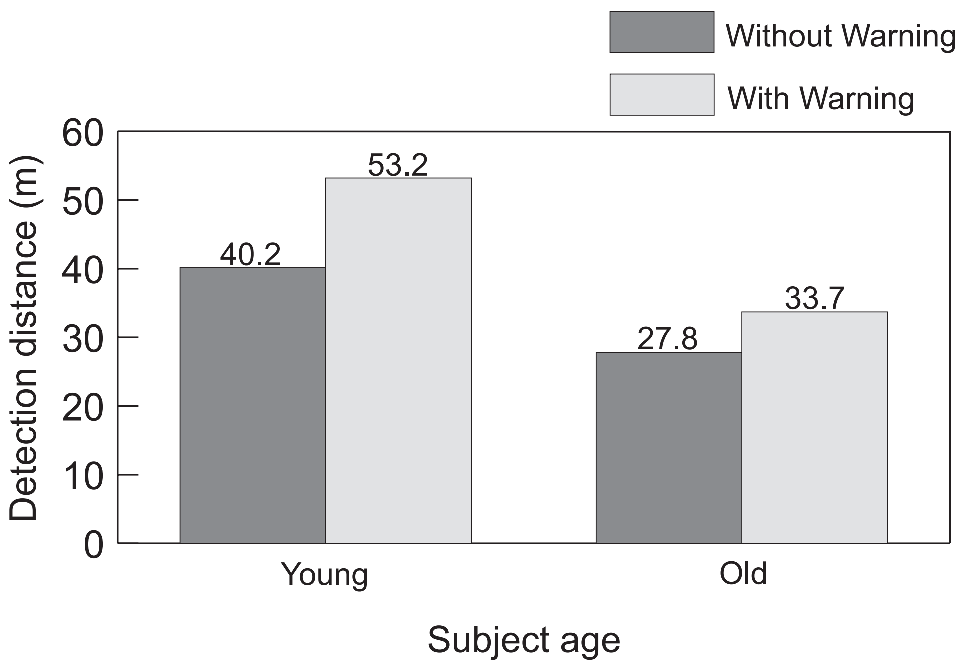

Figure 6. Pedestrian detection distance by age and warning.

Overall, detection distances were longest when pedestrians were expected to be on the right side of the road only and shorter when pedestrian were on either side of the road $F(2,36.8) = 7.18$, $p < 0.01$. Within the latter condition, detection distances were shortest when pedestrians were on the left side of the road (Figure 7).

Detection distance improved the most by the presence of the warning when pedestrians were on the left side of the road, from 16 m without a warning to 34 m with a warning. When pedestrians could be on either side of the road and were on the right side, detection distance improved only slightly from 36 m to 39 m. When pedestrians were expected to be only on the right side, the improvement was from 38 m to 49 m.

Figure 7. Pedestrian detection distance by pedestrian location and the presence of a pedestrian warning.

Detection Accuracy

The proportion of missed pedestrians was defined as the number of pedestrians, of all the trials in that condition, to which the subject did not say "pedestrian". The proportion of missed pedestrians without a warning (13%) was significantly higher than with the warning (5%) (Figure 8). The proportion of misses was improved the most by the presence of the warning when pedestrians were on the left side of the road. It improved from 31% without a warning to 15% with a warning. When pedestrians could be on either side of the road and were on the right side, the ratio of missed pedestrians decreased from 11% without a warning to 6% with a warning. When pedestrians were expected to be only on the right side, the ratio of missed pedestrian decreased from 9% to 2%. It should be noted that all but one of the misses occurred with older subjects. As shown in Figure 9, reduction in the proportion of misses was related to an increase in the mean detection distance.

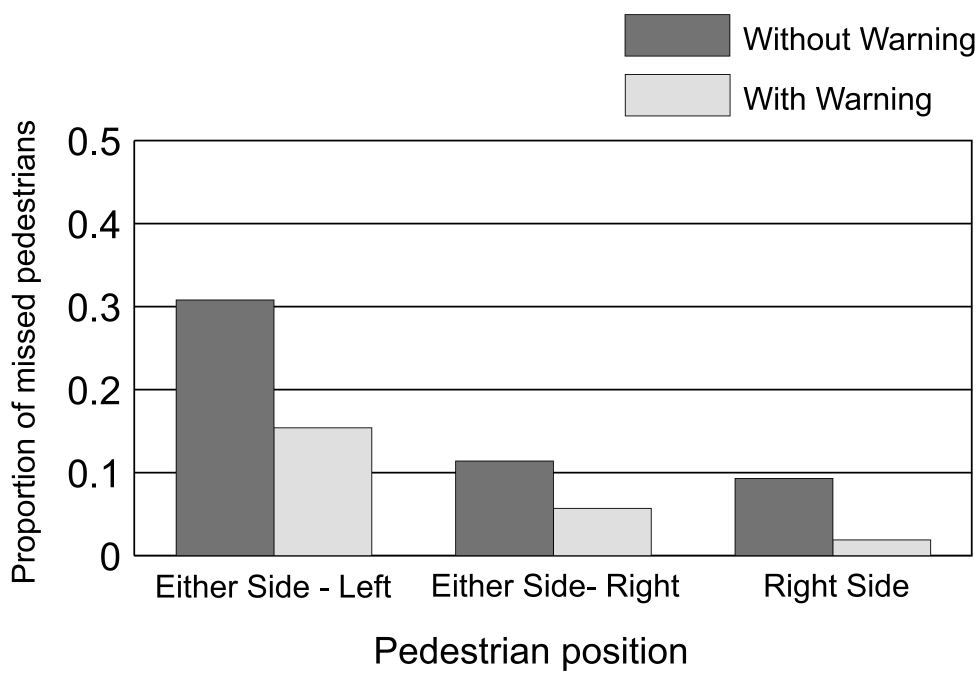

Figure 8. The proportion of missed pedestrians by pedestrian location and presence of a pedestrian warning.

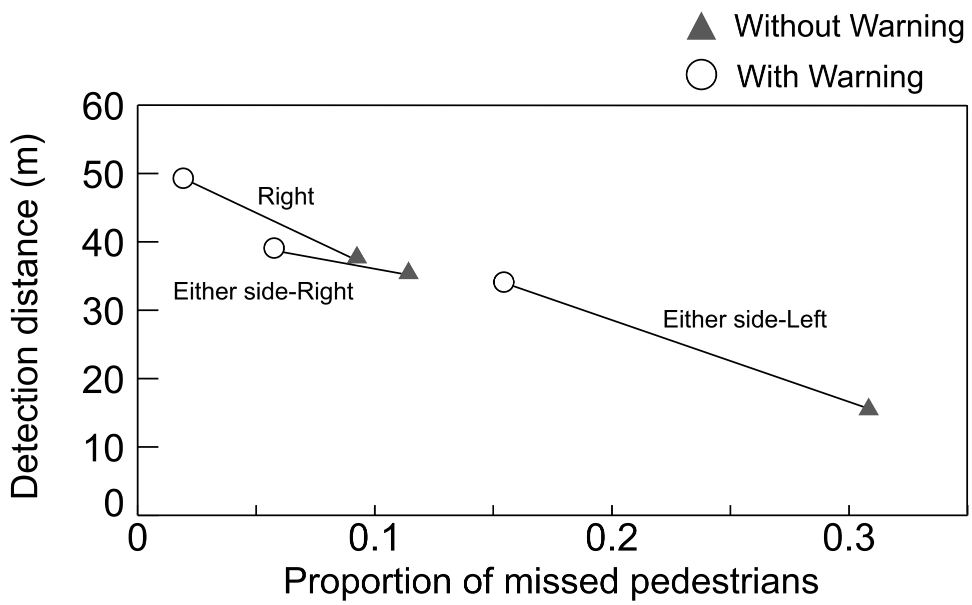

Figure 9. Detection distance and the proportion of missed pedestrians.

Exploratory Glance Analysis

The number of gaze shifts was defined as the number of noticeable changes in the eye gaze direction in the interval from 30 s until 5 s before the pedestrian. In the warning condition, this interval never included a time during which the subject had already received the warning (because the warning was delivered less than 5 s before the pedestrian). The analysis was exploratory and consisted of only three younger subjects, for which good video data were available.

The number of gaze shifts without a warning where the pedestrian could be on either side of the road (5 glances per 25s) was higher than all the other conditions (2.5 glances per 25s) (Figure 10).

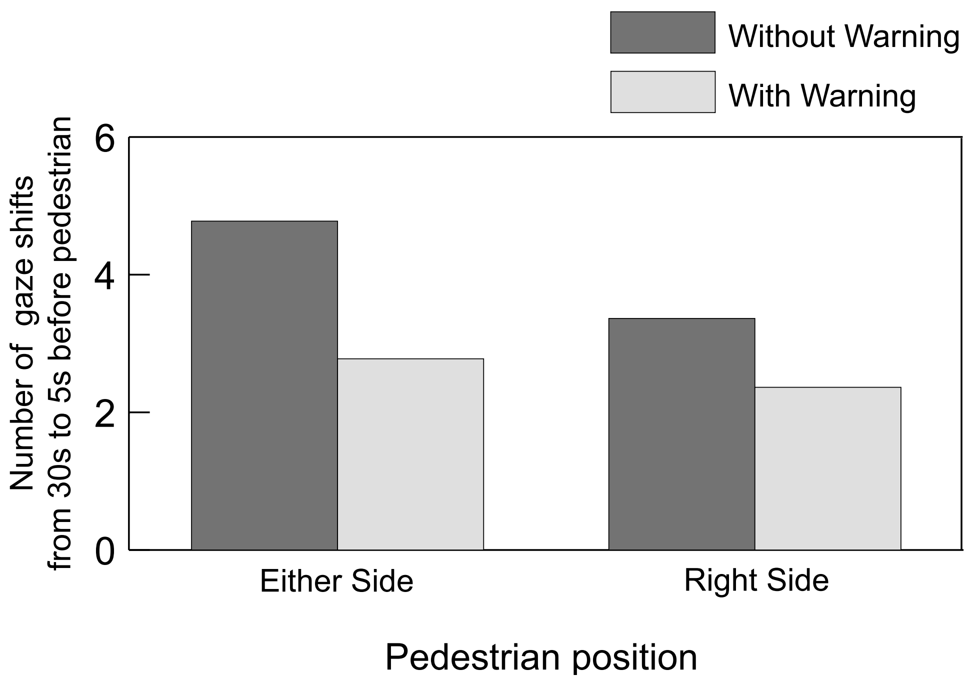

Figure 10. Driver's eye gaze shifts from 30s to 5s before the pedestrian detection.

Subjective Workload

Subjective workload was rated by the subjects at the end of the experiment on a scale of 1 to 10 where 1 represents extremely low workload and 10 represents extremely high workload. The rating of driving with a pedestrian warning system (3.8) was lower than without it (6.0), $F(1,14.5) = 26.6$, $p < 0.0001$. The rating of detecting pedestrians only on the right (4.0) was lower than detecting them on either side of the road (6.0) $F(1,14.5) = 20.1$, $p < 0.001$. The interaction between warning and pedestrian side was not significant.

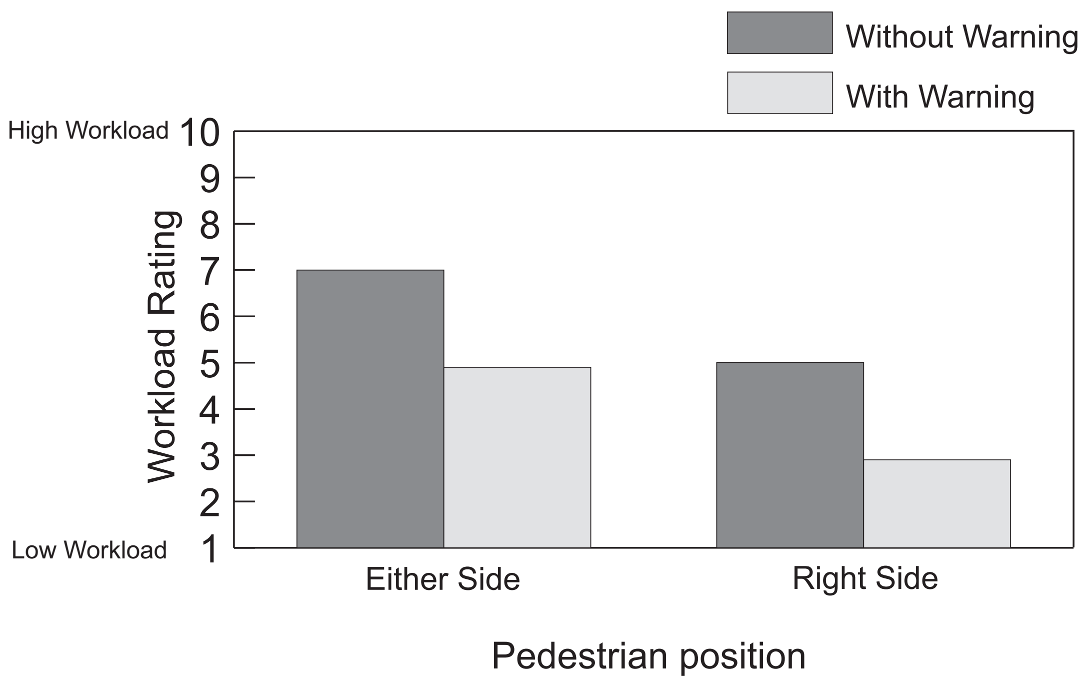

Figure 11. Subjective workload by pedestrian location and presence of a pedestrian warning.

CONCLUSIONS

The pedestrian warning improved pedestrian detection in several ways. It improved overall detection distance from 34 to 44 m. The proportion of missed pedestrians decreased overall from 13% to 5%. Subjective workload (on a 10-point scale) decreased from 6.0 to 3.8. We attribute the improvement to directing the driver's attention to the presence of a pedestrian mannequin just before it could be seen. It should be noted that in the unalerted condition drivers were in fact looking around more than in the alerted condition, as demonstrated in the exploratory glance analysis. Nevertheless, detection was not better because of the increased looking.

It may be that the effect of the warning would be even greater in actual use, given that the drivers in this experiment were probably always substantially more alert to the possible presence of pedestrians than most drivers are in the real world, thus diminishing the contrast between the nominally alerted and unalerted conditions of the experiment. The best estimate that we have of the difference between pedestrian detection by drivers in an explicitly alerted state versus detection in a state that is a reasonable approximation to normal, unalerted driving is probably the data of Roper and Howard (1938). They conducted an experiment in which 46 subjects drove an instrumented car at night. They used a surprise test in which a pedestrian mannequin unexpectedly appeared directly in the lane of travel of their subjects at the end of a headlight evaluation experiment. The distance at which drivers first released pressure from the accelerator was measured and compared to their detection distance for the same object in repeat runs under the same physical conditions. The results indicate that the average driver perceived the unexpected obstacle only half as far away as when it was expected. Figure 12 shows the cumulative distribution of the ratio between the detection distance of the obstacle when unexpected and when expected.

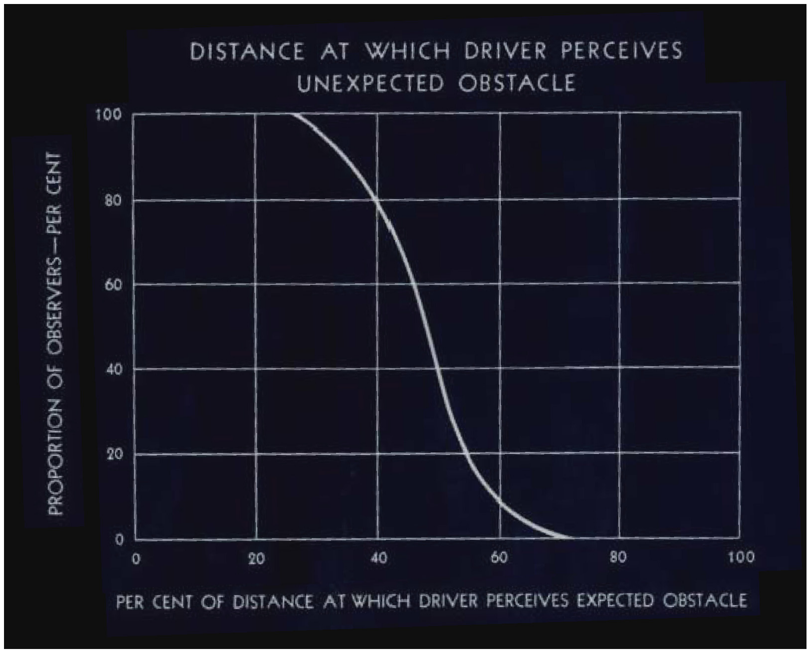

Figure 12. Distance at which a driver perceives an unexpected obstacle (Roper and Howard, 1938).

In light of Roper and Howard's findings, it may be that the positive effect of a pedestrian warning would be greater than was found in the present experiment. Subjects in the present experiment were instructed to respond to pedestrians and were therefore expecting them. The addition of a pedestrian warning served as a temporal cue to "look even harder" and indeed improved detection distance. It is possible that in many real-world situations detection distance with the warning would be even higher than in the present experiment because drivers could switch to high-beam headlights. In contrast, in most real-world situations, without the warning, detection distance and miss rates would be less than in the present experiment because drivers would not be as prepared to detect a pedestrian as they were in the experiment.

Another way in which the current experiment may underestimate the real-world benefits of the warning provided by the icon is in terms of how the warning might affect general preparation to respond to and avoid a pedestrian. The present experiment measured only the effects of the warning on seeing distance. In addition to improving seeing distance, the warning provided by the icon would allow drivers in the real world to begin some avoidance responses to pedestrians before they are visible—e.g., slowing down, being prepared to steer, or brake.

The subjective ratings of workload and the exploratory analysis of glances indeed suggest that subjects were vigilant when the warning was not present. They looked around more and experienced heavier workload than when the warning was available. This is probably a result of the experimental instructions to find pedestrians and of the subjects' attempt to "do well" in the experiment. It is likely that in real-world situations drivers would not be as vigilant and would not keep their workload at high levels continuously unless prompted by an automated system.

The results of the present study are not sufficient in themselves to evaluate the overall effectiveness of the sort of night vision system that is described here, but they do demonstrate the potential effectiveness of the minimal driver interface for increasing pedestrian detection. It is likely that keeping the driver interface as simple as possible would also have favorable effects on the driver workload imposed by the system, although that aspect of the system was not directly tested here. Although we have proposed what is virtually the simplest possible driver interface, there are clearly other solutions between our proposed display and existing displays (e.g., Graf et al., 2005). For example, the display might include information about the distance to the detected pedestrian, the relative location of the pedestrian and the number of new pedestrians. More research is needed to understand what design would provide the most benefit. The decision on whether to add additional elements to the display should include an assessment of the added workload or distraction they would add during normal operation, when the display is not actively helping the driver avoid pedestrian crashes (which occur only once per 300 million vehicle miles traveled for fatal crashes, and once per 26.5 million vehicle miles traveled for nonfatal crashes). Additionally, there should be an assessment of whether including additional information in the display might provide benefits in terms of driver acceptance or understanding of the system.

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APPENDIX A – EXPERIMENTAL VEHICLE SETUP

1: LCD for warning
2: Face camera
3: Laptop
4: GPS on vehicle roof used for detecting the warning point
5: Video converter
6: DV recorder
7: Video camera display
8: Button for position marking
9: Data acquisition system