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DRIVER PERFORMANCE AND WORKLOAD USING A NIGHT VISION SYSTEM

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16. Abstract

Infrared night vision systems have the potential to improve visibility of critical objects at night well beyond the levels that can be achieved with low-beam headlamps. This could be especially valuable for older drivers, who have difficulty seeing at night and who are especially sensitive to glare. It is unclear whether this benefit comes without ancillary costs, such as additional workload to monitor and interpret the forward view depicted by the night vision system. In this study, we asked young and old subjects to drive at night on a test track while we measured distance and accuracy of target detection, subjective workload, and longitudinal and lateral control of the vehicle. In some conditions, their direct view of the road was supplemented by a far infrared (FIR) night vision system. Two display configurations were used with the night vision system: a head-up display mounted above the dashboard and centered on the driver, and a head-down display mounted lower and near the vehicle midline.

Night vision systems increased target detection distance for both young and old drivers, with noticeably more benefit for younger drivers. Workload measures did not differ between the unassisted visual detection task and the detection tasks assisted by night vision systems, suggesting that the added workload imposed by the night vision system in this study is small.

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Contents

Introduction

There is little dispute that driver vision in darkness is seriously impaired. After controlling for the risk factors other than darkness that are often present at night—such as fatigue, alcohol use, and exposure—the risk of a fatal pedestrian crash is about 4 times higher in darkness (Sullivan & Flannagan, 1999) and the risk of a fatal rear-end collision is about twice as high (Sullivan & Flannagan, 2003). In the case of pedestrians, this elevated risk can be explained by drivers' poor visual detection abilities at the low levels of luminance and luminance contrast that are common at night for a typical pedestrian's clothing and the background environment. The pedestrian is often seen only at a very short distance. When coupled with a relatively high approach speed, the available time to detect and avoid a pedestrian is often too short. It is less clear how low light levels affect rear-end collisions, especially considering that marker lamps and reflectors are used to enhance a vehicle's conspicuity in darkness.

The effects of darkness can be mitigated somewhat by the use of roadway illumination and/or increased headlamp illumination. However, roadway illumination is both costly and often impractical, and increased headlamp illumination raises concern about additional glare to other road users. Night vision systems offer a solution that extends a driver's ability to see objects down the road without increasing glare to other road users. This is accomplished by rendering portions of the invisible infrared spectrum of the forward scene into a visible image on an in-vehicle display screen. Two forms of night vision enhancement technologies have begun to appear on vehicles: near infrared (NIR), or *active*, and far infrared (FIR), or *passive*, night vision systems. The active systems display reflected radiation emitted by near infrared sources on the vehicle, typically producing images that resemble monochromatic versions of the forward scene illuminated by high-beam headlamps. The passive, FIR, systems display infrared spectra radiated by warm objects in the forward scene. Displayed objects in passive FIR systems do not appear illuminated as they do in active systems; instead they appear to glow. Typically, warm objects are visually rendered as light images; cold images are visually rendered as dark. In this report, we investigated drivers' use of a passive, FIR-type night vision system.

Both active and passive systems use a display screen to render the forward scene. This requires drivers to switch their gaze periodically between the forward view (out the windshield) and the image presented on the night vision display screen, in order to detect a potentially *invisible* object. It is unclear what kinds of strategies drivers adopt for these systems, whether such strategies increase workload or affect driving performance, and whether they produce an overall safety benefit for drivers. For example, one strategy that drivers might adopt would be to consult the display whenever roadway conditions are sufficiently dark that forward seeing distance is reduced and there is some potential for pedestrians to appear on the roadway. However, drivers might not always know when their forward seeing distance is impaired (Leibowitz & Owens, 1977) and, based on the reported driver awareness of pedestrians prior to collisions (Allen, 1970), it seems clear that drivers often fail to anticipate pedestrian presence near the roadway. If drivers underestimate how often the night vision system could be of benefit, and therefore consult it infrequently, its potential safety benefit will be reduced. (It is conceivable that by using these systems drivers may eventually become better informed about their nighttime visual capabilities; however, this benefit is somewhat removed from the anticipated direct benefit of the system.) Alternatively, drivers may adopt a strategy in which they consult the display periodically, and unconditionally, to ensure detection of unanticipated objects in the roadway. This strategy is likely to involve more scans of the display screen than the former strategy, but would be more likely to take full advantage of the safety potential of the system.

Each scan of a night vision display involves some cost to the driver. For example, there is added effort to redirect the eyes to the night vision display, to identify objects in the display, and to locate these objects in the forward roadway scene. If the driver is relatively unburdened, this workload might easily be absorbed with little consequence to driving performance. However, if the driver is burdened with other tasks, the cost of consulting the night vision display could affect driving performance. In this study, effects on workload are examined indirectly using measures of speed and steering, and more directly using the NASA-Task Load Index (TLX), a subjective workload rating system (Hart & Staveland, 1988).

A driver's choice of speed has been linked to the level of workload experienced. Drivers reduce speed under conditions of increased workload (Lansdown, Brook-Carter, & Kersloot, 2004). Conversely, speed choice might also reflect a perceived change in risk such that lowered risk is offset by an increase in speed (Stanton & Pinto, 2000). With a night vision system, a device that may both increase workload and decrease risk, the net effect on speed choice is unclear.

Frequency analysis of a driver's steering wheel movement has been investigated in both a restrictive control-theoretic context to determine the likely input signal responsible for steering movements (McLean & Hoffman, 1971), as well as in a broader psychological context in which roadway preview time (McLean & Hoffman, 1973), lane-tracking error tolerance, driver experience, and driver workload have been suggested as factors affecting steering performance (Blaauw, 1984).

The spectral energy found in steering movements generally falls below 1 Hz, with the majority between 0.1 and 0.6 Hz. Some investigators (McLean & Hoffman, 1971) have noted that the frequency distribution of steering movements is often characterized by two peaks: one between 0.1 and 0.3 Hz and another between 0.3 and 0.6 Hz., suggesting that this pattern is indicative of two modes of steering control. In particular, power in the low-frequency (0.1 to 0.3 Hz) band has been associated with preview steering, and power in the high-frequency band (0.3 to 0.6 Hz) has been associated with immediate compensatory steering (McLean & Hoffman, 1973).

This measure has also been used to characterize a driver's workload in a fashion that is somewhat different from the explanations based on preview steering. Blaauw (1984) used the ratio of power in the high frequency band (0.3 to 0.6 Hz) to the power across the overall steering bandwidth (0.1 to 0.6 Hz) to investigate the effect of driving experience and task loading on steering performance. His results suggest that that ratio increases with steering task demand—when drivers were required to steer with very small tracking errors, numerous small steering corrections were produced, resulting in a relatively more power in the high-frequency band. When a speed-monitoring task was added to a novice driver's workload, a decrease in the steering ratio was observed. This was interpreted as a neglect of the steering control task, resulting in fewer corrective steering movements. When the same task was added to an experienced driver's workload, a higher steering ratio was observed. This was interpreted as a "self-chosen higher task-demand for lateral control."

More recently, the steering ratios of drivers were observed to decrease in the presence of post-mounted roadside delineators (Schumann, 2000), suggesting the influence of roadway preview. Decreases in steering ratios were also found when using HID headlamps (Sivak, Flannagan, Schoettle, & Mefford, 2002), suggesting that factors related to light distribution may also influence steering.

It thus appears that steering ratio may be influenced by a driver's lane guidance criteria (or tolerance for lane deviation), roadway preview (or the predictability of the path), or by secondary task demands. If use of a night vision system increases secondary task demands (e.g., monitoring the display screen) drivers may be encouraged to relax their tolerance for lane deviations, resulting in a lower steering ratio. In addition, roadway preview may have also been enhanced in this study by the residual heat retained in the asphalt roadway—with the FIR system, the relatively warm roadway (compared to other background objects) appeared lightly colored in the display image (see Figure 1).

A second topic of interest is whether older drivers obtain any benefit from vision enhancement systems. Because visual contrast sensitivity shows the greatest decline in this segment of the driver population, making nighttime driving difficult, older drivers might be expected to benefit most from vision enhancement systems. Ironically, some research suggests that older drivers might not reliably use these systems (Gish, Shoulson, & Perel, 2002). In this study, the performance of older and younger drivers is compared to determine if either detection performance or measures of workload reflect any age-related differences in the effectiveness of the night vision systems.

Finally, we also compare two display implementations that differ in mounting position and accommodative distance, to determine whether these aspects of information presentation affect either detection performance or workload.

Method

Experimental Overview

The primary research question addressed in this study was whether drivers experienced added workload while using a night vision system. Workload was assessed indirectly using two driving performance measures: average speed and the relative amount of high-frequency spectral energy in steering (Blaauw, 1984; McLean & Hoffman, 1971). Subjective workload was also assessed with the NASA-Task Load Index (TLX) questionnaire. Detection performance, including detection distances and errors, was also recorded. Secondary questions involved age- and gender-related performance differences, detectability of different target sizes, and use of different IR display technologies during driving.

Participants were asked to drive on an unlighted, closed test track at night, making two circuits in each of four conditions. In two of the conditions, drivers used a night vision system equipped with either a head up display (HUD condition) or a head down display (HDD condition). They were asked to report when they observed each of three targets along the roadside: a deer decoy, a small-animal decoy, and a pedestrian. Drivers were also requested to perform the same detection task unassisted by the night vision system (Visual Detection condition), and while unassisted by the night vision system and unburdened by the detection task (No Detection condition). Thus, the effect of the detection task on performance can be assessed apart from the introduction of the night vision system (by comparing the Visual Detection and No Detection conditions).

Subjects

Twelve paid subjects participated in the experiment. There were six younger subjects (ranging in age from 20 to 29 years old, with a mean of 24.9), and six older subjects (ranging in age from 63 to 73 years old, with a mean of 68.3). Each age group was composed of three females and three males. All subjects were licensed drivers with normal or corrected to normal vision.

Apparatus

Night Vision System. Participants drove a 2002 Pontiac Aztek sport utility vehicle fitted with a forward-looking far infrared (FIR) night vision camera mounted on the front of the vehicle in a weatherproof housing. The camera's horizontal field of view was nominally 25 degrees, centered on the forward roadway, and was measured as 3.86 m at a distance of 8.8 m (24.7 degrees) through the in-vehicle display. The vertical field of view was measured as 8 degrees in extent, offset one degree downward, providing a clear forward view of a pedestrian 1.8 m tall at a distance of approximately 20 m. Camera output was monochromatic with a resolution of 164 horizontal by 128 vertical pixels (see Figure 1 for an example). It was mapped into two higher-resolution (640 x 480) image displays: a head up display (HUD) and a head down display (HDD). The vertical extent of each display was clipped, producing an effective aspect ratio of 1:3.

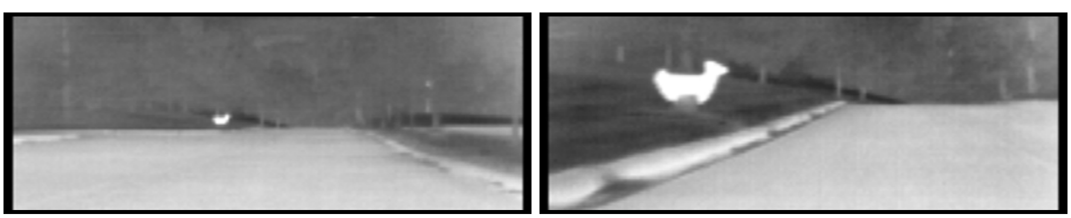

Figure 1. Example of night vision image of approach to a "deer" target from a distance (left image) and nearby (right image).

The HUD was mounted on the top of the dashboard on the driver's side, and was viewable over the steering wheel; the HDD was mounted to the driver's lower right, in the approximate area where a telematics display might typically be located (see Figure 2). From the driver's approximate head position, the HUD was centered at 0 degrees horizontal and 12 degrees down. The HDD was centered at 53 degrees right and 25 degrees down. The horizontal visual angle (screen width) subtended by the HUD was 10.4 degrees, and the HDD was 11.4 degrees. Images presented on the HUD were displayed at an optical distance of 2.5 m from the driver; images on the HDD display were directly viewed at a distance of 59 cm. Thus a shift in gaze between the forward view and the HUD required a smaller angular shift, and less accommodative adjustment, than a shift between the forward view and the HDD.

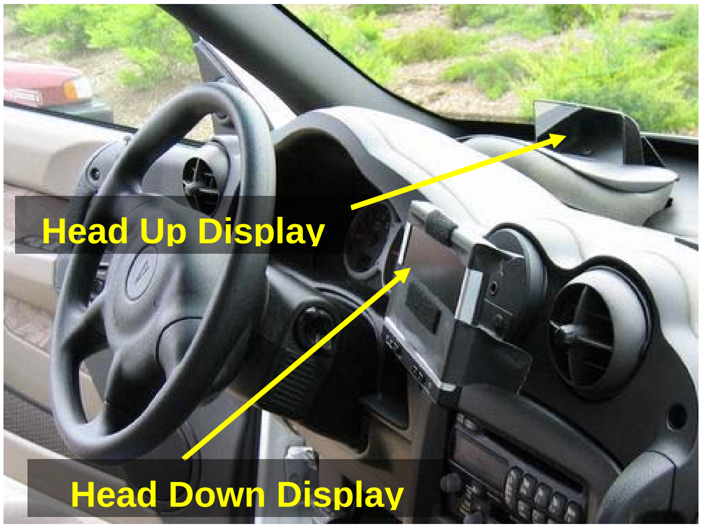

Figure 2. Locations of head-up and head-down night vision displays.

In order to make the two displays appear as similar to each other as possible, the sharpness, contrast, and luminance levels were calibrated between the displays. The calibration was done first with the aid of a gray-scale test pattern to adjust the sharpness, contrast levels, and initial luminance setting. Luminance levels were then adjusted prior to the start of each experimental session. Environmental conditions varied from day to day as a consequence of ambient temperature fluctuation and precipitation. This produced day-to-day variation in the luminance levels between the background environment and the target objects. The two displays were adjusted with the assistance of a spot photometer (Minolta LS-100 luminance meter) so that the brightness of target objects (which were relatively lightly colored) and the background environment (which was relatively dark) were similar in each display. This adjustment was only approximate, and the gray-scale transfer functions of each display were similar, but not equivalent.

Targets. Three kinds of detection targets were used in the study: a large deer-shaped target (80 cm wide and 100 cm tall; see Figure 3), a small low-lying target designed to resemble a small animal (30 cm square; see Figure 4), and standing pedestrians (180 cm height). The deer-shaped targets were heated to 30-50 degrees C so that they would easily stand out against the background using the FIR camera. The small-animal targets were actually 19-liter water-carriers (see Figure 4) filled with warm water (30-45 degree C). Targets were visually and thermally masked using either plywood blinds (Figure 3) or cardboard shrouds (Figure 4). Target reflectance was 10% for visible light from headlamps. Standing pedestrians were experimenters at the side of the road, facing the oncoming vehicle. Pedestrians were stationary, unreflectorized, and dressed in dark clothing (jeans and red t-shirts).

Target placement was restricted to the left and right sides of the roadway (never directly in the roadway) on straight sections of the track. Target position was changed after each trial to limit a driver's ability to anticipate target locations. The number of detection targets placed around the track on each circuit varied between three and four. Since the track was circled twice in each trial, drivers encountered either six or eight targets per trial.

Test Track and Driving Environment. All drives took place at night on an unlighted 4.4 km (2.75 mile) oval test track located in a rural area of southeastern Michigan. The outer perimeter of the track was marked for driver guidance with small reflectorized blocks spaced at 25 m on straight sections and 12 m on curved sections. The center area and outer perimeter of the track were partially wooded, sufficient to obscure experimenter activity around the track.

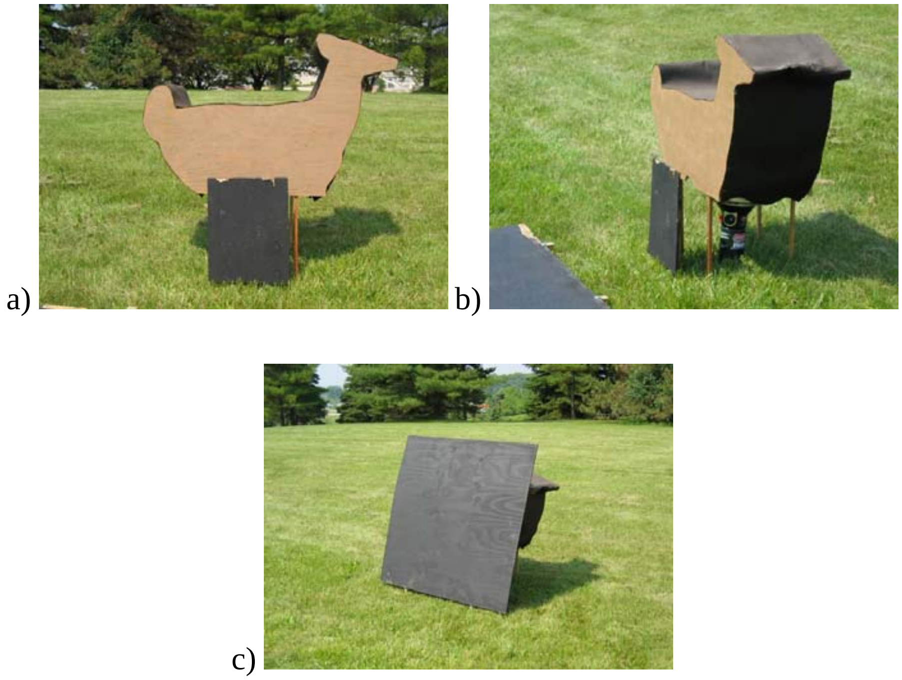

Figure 3. Deer-shaped detection target: front (a), side (b), and target with visual/thermal blind (c). Note that the target is heated by a propane-fueled tent heater.

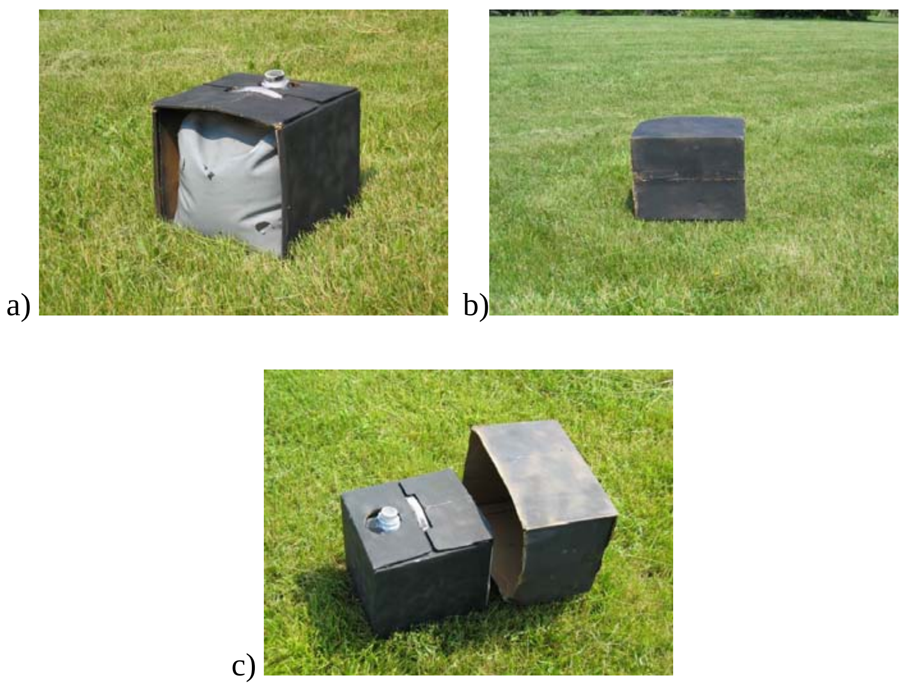

Figure 4. The small-animal target was a water-filled gray container. The three photos depict the revealed target (a), shrouded target (b), and target and shroud (c).

Procedure

Drivers were given a brief orientation describing the appearance of warm objects in FIR night-vision displays along with a few sample pictures. They were also shown photographs of the detection targets in daylight, and were instructed to report verbally to the experimenter (seated in the back seat of the vehicle) as soon as they spotted a target. Drivers were also cautioned that there could be more than one object to report, and that target locations were not fixed.

The experimental session began with a practice loop around the test track to familiarize drivers with the overall driving environment. Drivers were advised to maintain speed between 35 and 40 mph (56-64 km/h) and to use exclusively low-beam headlamps. Upon completion of practice, experimenters configured the vehicle for one of the four drive conditions (HUD, HDD, Visual Detection, or No Detection) and positioned targets around the track. After a brief instruction about the upcoming experimental condition, drivers made two circuits around the test track. During each circuit, drivers were asked to report verbally to the experimenter the moment they saw a target, whereupon the experimenter recorded a digital mark in the data record so that the vehicle's position at the time of detection could be determined. The experimenter also noted the object's identity, if reported, by the driver. Because drivers' target identification was haphazard, the detection data reported here are based on the verbal reports of both clearly identified objects and less precise identifications (e.g., "*I see something…*").

Immediately following completion of each driving condition, the NASA-TLX subjective workload questionnaire was administered. The order of drive conditions was counterbalanced across subjects. Target placement about the track was fixed with respect to trial order, and likewise counterbalanced across conditions.

The experimental design examined the effect of four driving conditions: HUD, HDD, Visual Detection, and No Detection); three target types (deer, small animal, and pedestrian); age (old and young); and gender (male and female) on five dependent measures. The dependent measures were as follows:

1) Detection percent—defined as the percentage of targets detected at or before passing the target. Targets not detected at all, or detected after they were passed, were considered undetected targets.
2) Detection distance—defined as the straight-line distance between the vehicle and the target object when detection was reported. Detection reports that occurred after a roadway target was passed were given a detection distance of zero. Targets that were not detected at all were treated as missing values in the analysis of detection distance. Note that only three drive conditions (HUD, HDD, and Visual Detection) are logically available for analysis of the detection data.
3) Average vehicle speed—computed as the average speed on the straight sections of the track. Driving speed data from the curved sections of the track were removed because targets were not positioned in the turns, and because the task of negotiating the curve introduced additional control demands on the driver (e.g., braking, steering, and accelerating) that are qualitatively different from straight driving.
4) Steering ratio—computed as the ratio of spectral power in the 0.3 to 0.6 Hz range to the power in the 0.1 to 0.6 Hz range. Like average speed, the steering ratio excluded data from the curved sections of the track.
5) Subjective workload index—was collected for each drive condition. All four drive conditions were available for analysis with the latter three measures.

Results

Detection Performance

Detection accuracy. A logistic regression was used to assess the probability of detection as a function of each category of independent variable. A significant effect of age was found. Using the coefficients shown in Table 1, an older male driver's odds (the ratio of detections to nondetections) of detecting a pedestrian while driving with the HDD display are about seven times that of not detecting a pedestrian (*exp*[$B_{Constant}$]). If the driver is a young male in the same conditions, the odds are 55 times that of not detecting a pedestrian (*exp*[$B_{Constant}+B_{Young}$]). (In terms of detection probability, this is equivalent to a change between a 0.88 probability of detection and a 0.98 probability.) An effect of target type was also found, suggesting that the small-animal targets were more difficult to detect than the pedestrian or deer targets. These effects can be seen in Figure 5. Drive conditions were not reliably different from each other—whether a target was detected or not did not appear to be affected by the presence or type of night vision system (see Figure 6).

Table 1

Results of logistic regression of detection on the odds of detecting a target under each condition. Starred items are statistically significant.

	Conditions	B	S.E.	Wald	df	Sig.	Exp(B)
	Young	2.076	.517	16.130	1	.000*	7.976
	Female	.325	.412	.622	1	.430	1.384
Drive Condition	**HDD**			.520	2	.771	
	Visual	.210	.491	.183	1	.669	1.234
	HUD	.361	.507	.506	1	.477	1.434
Target Types	**Pedestrian**			10.840	2	.004*	
	Small Animal	-1.682	.668	6.336	1	.012*	.186
	Deer	-.445	.702	.402	1	.526	.641
	Constant	1.937	.694	7.785	1	.005	6.935

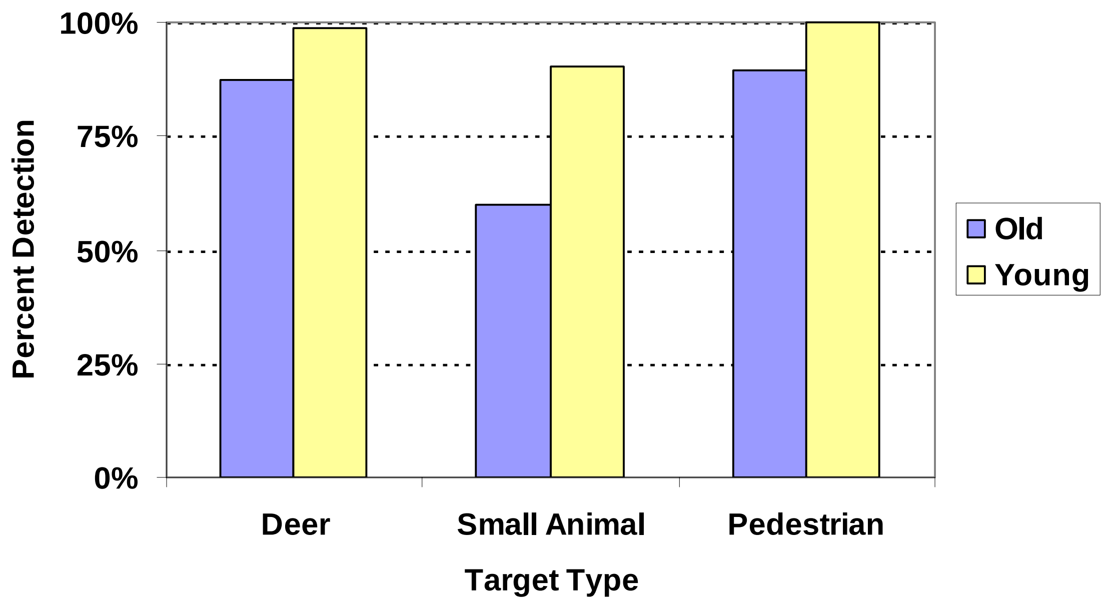

Figure 5. Average detection percentage pooled across subjects and conditions. Younger drivers detected more roadside objects than older drivers; both groups were poorer at detecting the small-animal objects.

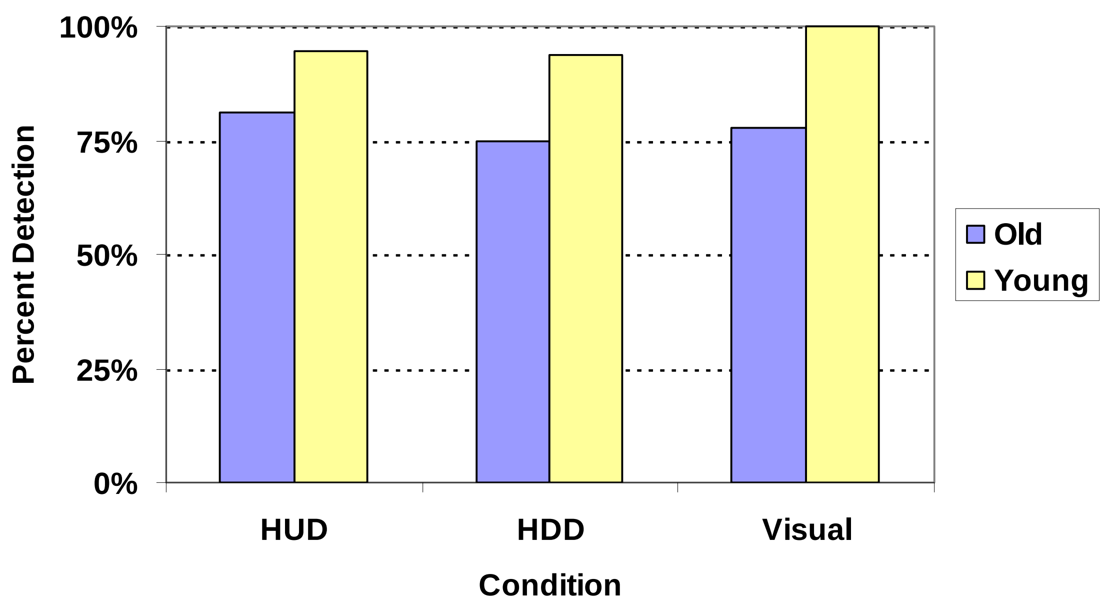

Figure 6. Average percent detection was not affected by the presence of the night vision system for either the older or younger drivers.

Detection Distance. Analysis of variance on detection distances revealed significant main effects of age ($F_{(1,8.2)}$ = 5.4, p < .05), target type ($F_{(2,186.9)}$ = 14.6, p < .01) and drive condition ($F_{(2,186.8)}$ = 6.7, p < .01). In general, younger drivers detected objects at longer distances than older drivers (shown in Figure 7), all drivers detected the large targets (pedestrian and deer) at longer distances than the small targets (Figure 8), and all drivers had longer detection distances using the night-vision systems than without them (Figure 9). An interaction was also found between driver age and drive condition ($F_{(2,186.8)}$ = 3.4, p < 0.05) such that the older drivers' detection distance did not increase as much as that of younger drivers when using the night vision systems (Figure 10). Notably, a significant interaction was *not* found between target type and drive condition, although it seems plausible that the larger size targets would show the greatest improvement in detection distance. The detection distance between each condition by target type is shown in Figure 11. The average benefit appears greatest for the HDD condition, particularly with pedestrian targets, although pairwise comparisons between the HUD and HDD conditions did not indicate a significant advantage of one over the other (p > .50).

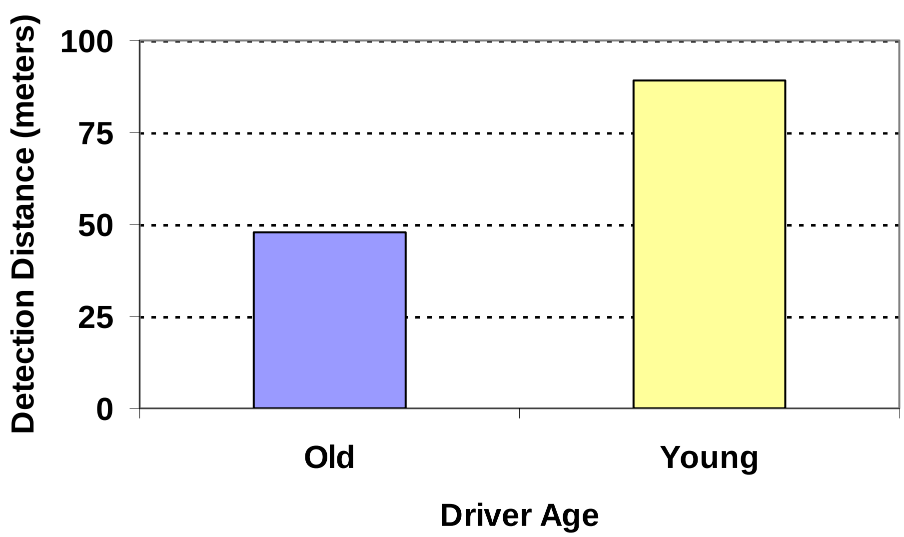

Figure 7. Average detection distance of the targets among older drivers is about 48 meters; among the younger drivers it is 90 meters.

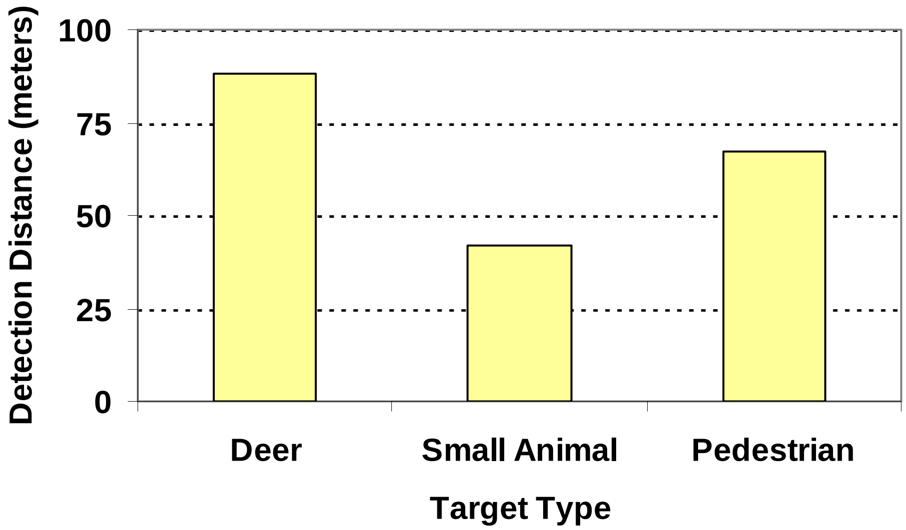

Figure 8. Average detection distance of targets by target type.

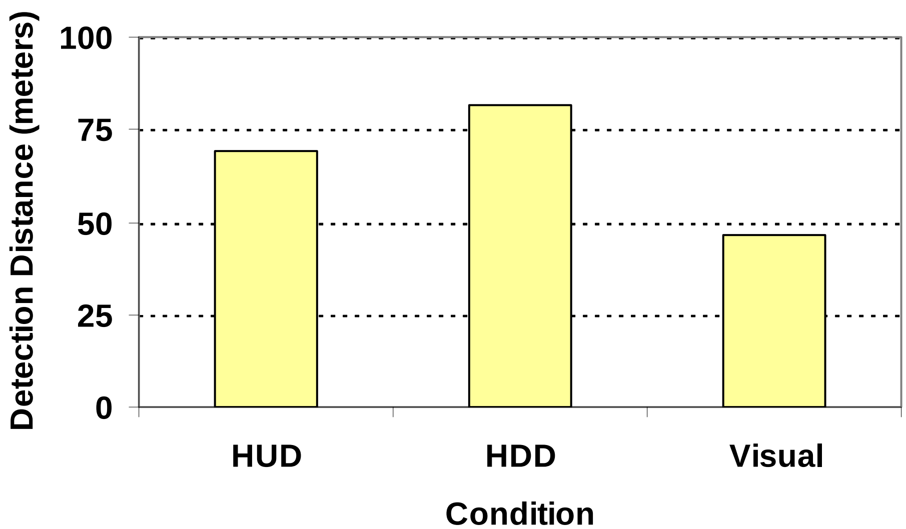

Figure 9. Average detection distances of targets by drivers accompanied by the night vision systems (HUD and HDD) and without (Visual).

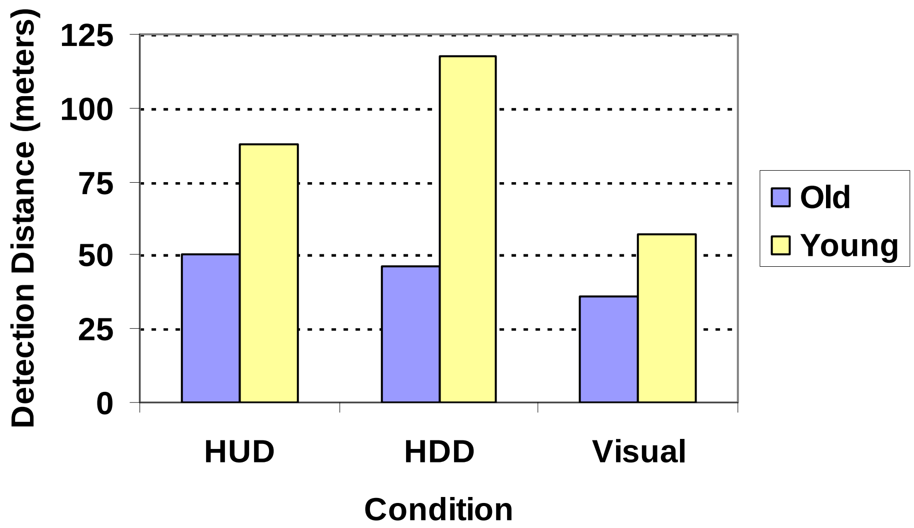

Figure 10. An interaction was observed between driver age and detection distance such that older drivers' detection distance did not appear to increase as much when assisted by the night vision system, as did that of younger drivers.

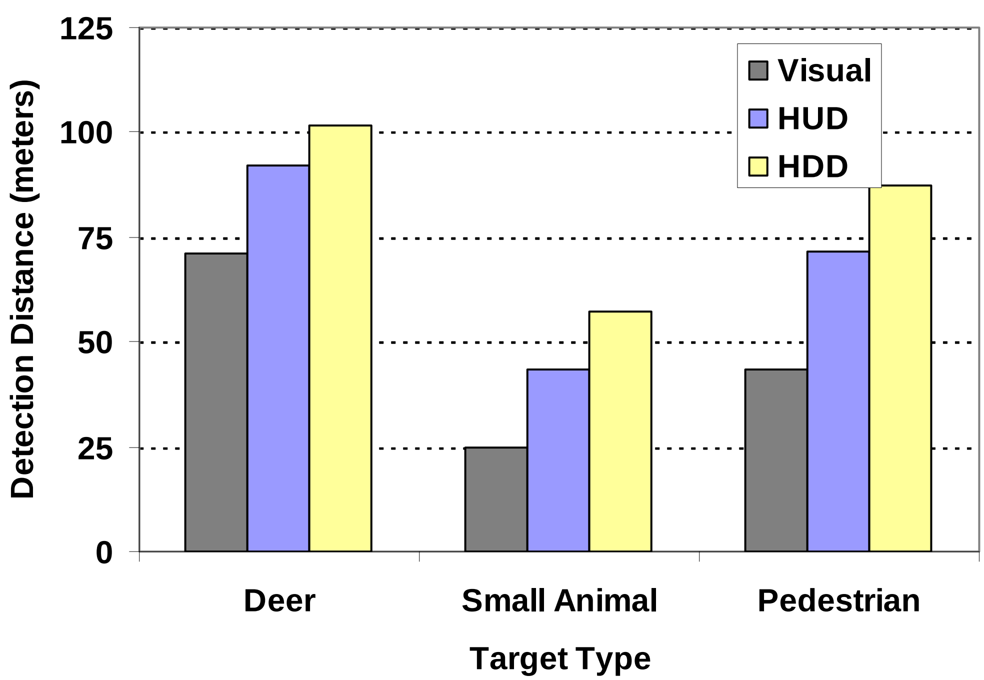

Figure 11. Detection distance for each target type by drive condition appears to show that the HDD display offered the most improvement, however a pairwise comparison between the HDD and HUD detection distances did no show a significant difference.

Subjective Workload and Driving Performance

NASA Task Load Index (TLX). A repeated measures analysis of the task load index that examined the factors of gender, age, and drive condition (including the free driving condition) found a main effect of drive condition ($F_{(1.3,\ 10.2)} = 11.8$, $p < .01$). No other factors appeared to influence subjective workload. In examining the pairwise effects of the drive conditions, it was clear that the workload measure reflected the added workload associated with the task of detecting and reporting the target objects, but did not distinguish between searching using visual, HUD, or HDD. This can be seen in Figure 12, which provides a further breakdown by driver age. Notably, older drivers appeared no different from younger drivers in their subjective experience of workload.

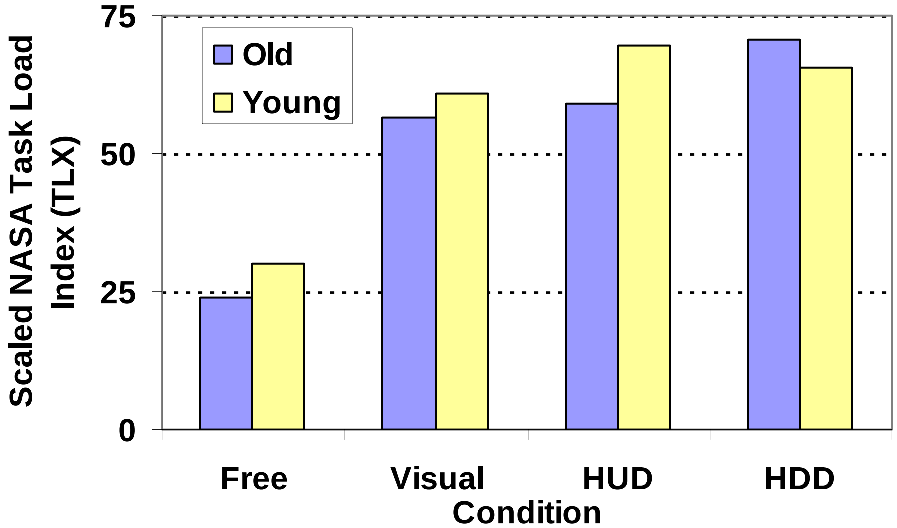

Figure 12. The subjective workload of old and young drivers appeared to be most affected by the addition of a detection task (free versus the other three conditions). A pairwise analysis of the driving conditions found statistically significant differences only between the free driving condition and the other three conditions.

Average Speed. A repeated measures analysis of average speed on straight sections of road echoed the results of the NASA task load index, finding a main effect of condition on driving speed ($F_{(3,24)}$= 7.1, p < .01). Average speed in the free driving condition was 1 to 2 mph faster than in the visual, HUD, and HDD conditions. Pairwise comparisons of the average speed of the visual, HUD, and HDD conditions found no differences among the other conditions. A two-way interaction between gender and drive condition was also found ($F_{(3,24)}$ = 4.1, p < .05). Average speed among male drivers was slower than female drivers in the free and visual driving conditions, and faster when using the two night vision systems (see Figure 13).

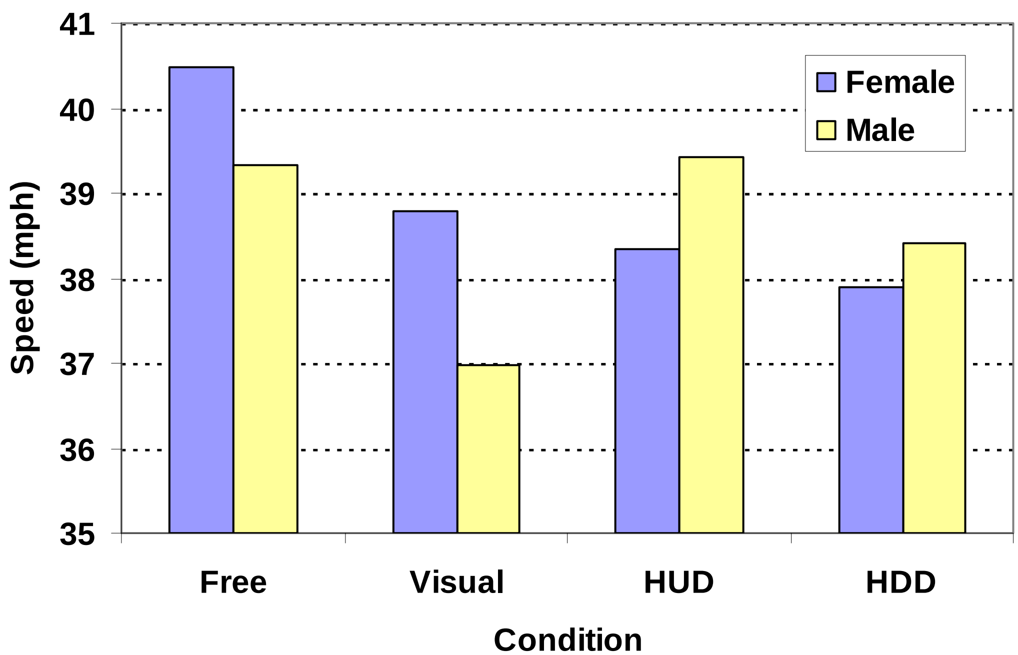

Figure 13. The average speed of male drivers was slower than female drivers when driving in the free and visual conditions, and faster when using the night vision HUD and HDD systems.

Steering Ratio. A repeated measures analysis of variance found no effects or interactions among the factors examined in the experiment. Averaged steering ratios are shown in Figure 14 along with 95% confidence intervals on the marginal means.

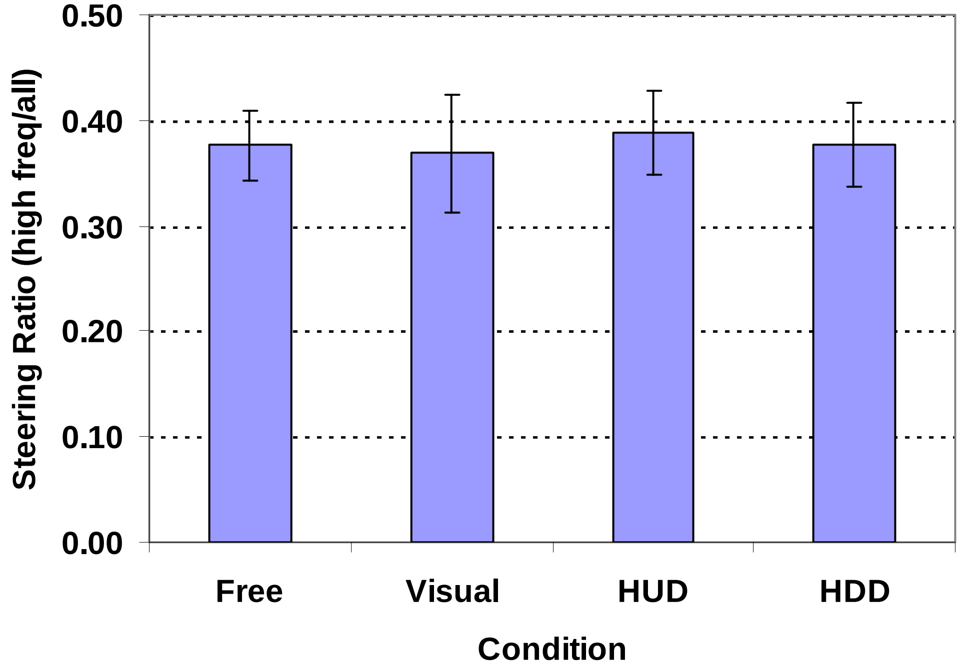

Figure 14. No reliable differences were found in the steering ratios observed across all driving conditions.

Discussion and Conclusion

Night vision systems increased detection distances for both young and old drivers, as indicated by the main effect of drive condition (Visual, HUD, or HDD) on detection distance (see Figure 10). This result differs from the findings of Gish et al. (2002) in which the observed benefits seemed to be restricted to younger drivers, under conditions of glare, and for pedestrian targets. However, the interaction in our results between drive condition and age suggests that older drivers experience less benefit. There also appears to be a trend in our results toward greater improvement in detection distance for pedestrians. This, in part, stems from the relatively poor detection distance observed in the unassisted visual detection condition (see Figure 11). We suspect that this is due to the comparatively small amount of a pedestrian's body (lower legs and feet) that is below the upper limit of light from a low-beam headlamp. In comparison, the deer targets were wide and short (about 80 cm wide and 100 cm tall) and therefore may have been more effectively illuminated in low-beam lighting conditions. For viewing with night vision systems, where the greater height of the pedestrians does not matter, both pedestrians and deer are highly visible, thereby perhaps resulting in a greater improvement in pedestrians.

Overall, the current detection results are also consistent with prior research indicating an age-related decline in contrast sensitivity and acuity in darkness (Ball et al., 1998; Sturr, Kline, & Taub, 1990). This diminished visual capability among older drivers is probably responsible for the missed target detections and the shorter detection distances (Figure 7) observed here. The results also suggest that, while the night vision systems improved detection distance, they did not substantially improve the likelihood of target detection. Among younger drivers, the overall percent detection of targets was high (96%) whereas among the older drivers, overall percent detection was lower than for younger drivers (78%). For both younger and older drivers, there appeared to be little, if any, effect of the night vision system on detection errors (see Figure 6). In evaluating the detection results, we should remember that detection failures do not necessarily mean that drivers were oblivious to the presence of the targets. In addition to cases in which the drivers may have missed the target completely, detection failures included reports made at zero distance from the targets and reports made after targets were passed.

Although it was not statistically significant, one trend worthy of further investigation is that, contrary to expectation, the HDD display appeared to produce greater detection distances among the drivers than did the HUD. It would be useful to determine whether there were differences in the glance durations of drivers for each display type. Perhaps the proximity of the HUD to the forward view encourages many short glances between the display and the forward screen, while the large HDD offset leads to less frequent, but longer, glances. If target detection is better with longer glances to the display screen, then the HDD display is perhaps more effective in improving detection distance. If so, this would come at the cost of longer eyes-off-road time and such a tradeoff should be examined.

The results of the subjective workload measure, the NASA Task Load Index, indicate that, although drivers judged the task of looking for and reporting objects at the side of the roadway to result in increased workload, they did not find much difference in workload between monitoring the roadway with or without the assistance of night vision support. This interpretation is further supported by the average speed data; higher speeds, indicative of lighter workload, were observed for the free driving condition, but little difference was found among the visual, HUD, or HDD driving conditions (Figure 13). In this study, a specific regime for using the night vision system was not prescribed to drivers—drivers were free to use it (or not use it) any way they chose. Indeed, some drivers could have elected not to use the system at all. The detection data suggest that most of the drivers obtained some detection distance benefit, confirming that drivers did use the system. At the same time, the workload data imply that, if workload differences exist, they are smaller than the added workload incurred by actively searching for a roadside target.

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