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Eye Fixations of Drivers in Night Driving with Three Headlight Beams

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16. Abstract. This study was carried out to obtain information of the manner in which the beam pattern of headlamps which provide meeting beams affect the way in which drivers obtain visual information in night driving. By comparing the eye fixations of the drivers in night driving, with the various beams, with their eye fixations in daytime on the same road, inferences were made as to the extent to which different meeting beams allow drivers to obtain information from important aspects of the roadway scene. The results can be used to describe basic characteristics of suitable meeting beam patterns.

Two drivers drove an automobile in the daytime and at night using American and European low beam headlamps and an experimental mid beam. The eye fixations of the drivers were measured, using a silicon diode TV camera and light reflection from the cornea. Superimposition of the corneal light reflection upon the image of the roadway scene allowed recordings to be made of the eye fixations of drivers on the two-lane road course. Comparisons between the eye fixations used in daytime and at night showed that dwell time was longer when looking straight ahead at night than in the daytime, and that there was a reduction in the proportion of the viewing time devoted to the left lane at night than in the day, when there was no oncoming vehicle. Drivers looked at approaching vehicles in both day and night conditions with glance durations of intermediate lengths, which increased in frequency as the separation distance between the vehicles decreased. At night, preview distances were less than in the day.

The characteristic shift of the eye fixations in the direction taken by the road was found in this study, in both day and night driving. At night the eye fixations were influenced by the characteristics of the beam pattern being used. On left curves the American and European low beams provided the eye fixations which most closely resembled those used in daytime. On straight sections and particularly on right curves the mid beam provided the most compatible distribution of glances. It was suggested that an improved meeting beam should incorporate characteristics of the European low beam, to provide illumination to the left of the lane, and those of the mid beam to provide greater visibility along the lane and to the right of it.

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OBJECTIVES

The objectives of this study were:

1. To obtain initial information of the manner in which drivers use their eyes to acquire information for vehicle guidance and obstacle avoidance purposes in night driving on a two-lane road.

2. To determine the extent to which drivers view opposing vehicles.

3. To obtain data to show the manner in which eye fixations of drivers at night are influenced by characteristics of meeting beams.

4. To compare night driving and daytime driving eye fixation patterns, and to make inferences from the data concerning characteristics of meeting beam patterns which are most compatible with the driver's desired spatial distribution of eye fixations as assumed from the results of the eye movement studies.

SUMMARY OF FINDINGS

1. The mean dwell time of eye fixations in the driver's lane ahead of the driver is longer at night than in the day.

2. On straight sections of road, drivers looked less in the left lane at night than in the day.

3. At night and in daytime drivers looked at oncoming vehicles periodically, and slightly more frequently as the separation distance decreased.

4. Eye fixations are influenced by the road geometry, at night and day. Drivers looked in the direction of the road.

5. There were differences in the distribution of nighttime eye fixations with different beams.

6. Drivers tended to look more to the left with the H_4 (European) low beam than the 6014 (U.S.) low beam, and least to the left with the mid beam.

7. The compatibility of daytime eye fixations with those used at night was greatest for the H_4 and 6014 beams on left curves; similar for all beams, though slightly greater with the mid beam, on straight sections; and greatest for the mid beam on right curves.

8. The mid beam produced greater preview distances on left curves than the other beams.

9. Mean fixation distances up the road at night were less than in daytime on straight and curved sections of road.

10. Delineation of the right edge of the road was used by drivers at night, presumably providing a valuable cue for vehicle alignment in the lane.

11. It was concluded that an improved mid beam should incorporate characteristics of the European low beam, for improved visibility of the left side of the road, with those of the mid beam.

FOREWORD AND ACKNOWLEDGMENTS

This report describes one of a series of HSRI studies concerned with headlighting performance, sponsored by the Motor Vehicle Manufacturers Association of the U.S., Inc.

This report is issued under the general contract title: "Passenger Car and Truck Lighting Research: Headlighting Phase I, Beam Pattern Evaluation." Other reports describe the development of a mathematical model to predict visibility and glare effects provided by different beam patterns in opposed traffic conditions, multi-beam switching, factors affecting headlamp aim, and development of driving tests for the evaluation of headlamp beams.

During the conduct of this work periodic meetings were held with the MVMA Lighting Committee, Headlighting Research Task Force consisting of Mr. G. Gardner, Mr. R. Rossio and Mr. W. Rankin, chairmen; Mr. P. Lawrenz, Mr. P. Maurer, Mr. R. Donohue, and Mr. B. Preston. The members of this group were very helpful, and their comments and suggestions contributed materially to the progress of the work.

INTRODUCTION

It has only recently been possible to develop equipment which can reliably show where a driver is looking in a dynamic driving situation. These eye cameras or eye marker devices have been used in studies of the way in which drivers use rear-view mirrors (Kelley and Prosin, 1969), to evaluate the way in which changes in eye fixations occur as a function of driving experience (Zell et.al., 1969), to show some effects of alcohol in driving (Mortimer and Jorgeson, 1972), and in other aspects of driving in daytime.

The eye marker devices which have been reported to be used successfully in driving studies have utilized the corneal reflection technique which consists of the reflection of a source of light by the cornea of one eye of the driver. The image of the reflected light source is subsequently mixed with the image of the scene viewed by the driver, and by suitable super-imposition of the light spot upon the scene, registration of the driver's eye fixation within the scene is obtained. Initially, recording was made on film, but it soon became apparent that this has a number of drawbacks. Film recording required that the images be transmitted to the camera via fibre-optic bundles which suffer considerable light losses and image quality. Therefore, HSRI developed a TV eye marker system by substantial modifications of the NAC Eye Mark Recorder. The optical paths of the light source reflected from the cornea and that of the scene are combined at a beam splitter, with the images being fed directly to a half-inch vidicon. Various other modifications were made to be able to successfully make eye marker recordings with the type of accuracy that is required. This included the use of a bite-bar and an improved head and chin strap to prevent the eye camera system from moving with respect to the driver's head. A remote means of calibrating the eye spot was incorporated, so as to allow calibration checks and recalibrations to be made on the run, without stopping the vehicle or interfering with the driver.

Because of HSRI's long-standing interest in the problems of night driving, it became desirable to learn more about the way in which drivers use their eyes in conditions other than daytime. In addition, it became apparent that the eye marker would be a useful tool, not only to provide general information of the way in which drivers use their eyes in night driving, but also as a means of developing some basic data of the type of headlamp beam distribution which would allow drivers to obtain the visual information which they consider necessary. Further, the technique could also be used to evaluate the extent to which specific beam patterns affect the manner in which the driver uses his eyes to scan the roadway environment and, thereby, provide an indication of the extent to which such beams provide satisfactory visibility.

Such a study of drivers eye fixations in night driving and with different headlamp beams, will augment the results of other studies carried out in this research program, such as those concerned with headlamp aim (Olson and Mortimer, 1973) computer simulation evaluations of headlamp effectiveness (Mortimer and Becker, 1973) and field test evaluations (Mortimer and Olson, 1974).

A review of the literature on driver eye movements up to 1970 (Soliday, 1971) referenced no studies concerned with night driving visibility. Only quite recently, Rockwell (1974) described a study concerned with search and scan patterns of drivers in night driving. Such studies have become possible recently due to the development of silicon target vidicons which provide an optimum low light sensitivity and low weight. For the test to be described in this report, a Texas Instruments Tivicon was installed in the HSRI eye marker for the night driving studies and headlamp beam evaluations.

RATIONALE

Data were collected using the eye marker technique in both night and day driving conditions over the same road system by the same drivers. The underlying basis for this study was that the effectiveness of various headlamp beams can be gauged by comparing the eye fixation pattern when driving with various headlamps to those obtained in daytime. The assumption is made that the eye fixation pattern in daytime represents that which is desired by the drivers in order to allow them to obtain the necessary information required for safe driving performance, in a situation where visibility is unimpeded, other than by natural surroundings, including the geometry of the road. At night, on the other hand, it is assumed that visibility is limited due to the characteristics of the headlamp beams, and the effect of this limitation will be shown by differences between the night driving eye fixations and those considered as an "ideal" model obtained in the daytime. The extent to which a headlamp beam allows a driver to use the same eye fixation pattern at night as in the day was considered to be a rational measure of its performance.

METHOD

DATA RECORDING EQUIPMENT

The HSRI Eye Mark Recorder is shown in Figure 1, as used in the test vehicle. Data are recorded on videotape, with simultaneous monitoring in the car. The data reduction procedure involves reducing the data at less than real-time speed, usually one-fifth of real-time, by applying a mask to the monitor by which it is possible to simulataneously obtain information of the azimuth (lateral) distribution of the eye glances in three categories (0-5°R, 0-5°L, 5°L-10°L) and in three viewing distances ahead of the vehicle (100'-250', 250'-500', and >500'). There is an

Figure 1. The eye mark recorder as used in the test car.

added category for those eye fixations which are outside the field-of-view of the system or where the eye spot disappears during an eye blink. Secondly, the alternative mode of data reduction involves the assignment of the location of the eye spot to ten specified object categories, such as in the lane straight ahead, at an opposing vehicle, in the adjacent lane but not at an opposing vehicle, at the dash or interior of the vehicle, etc.

The operator continuously views the position of the eye spot, determining the eye location and holds down a switch on a keyboard containing ten push-button switches, for the time duration with which the eye spot is in a specific category (Figure 2). This results in the continuous accumulation of data in terms of time of an eye fixation within a specified category, and the frequency of eye fixations within each category. These data are subsequently analyzed for each of the dependent variables.

PROCEDURE

Two subjects, ages 25 and 40, used in this study had considerable prior experience in driving with the eye marker system. In order to obtain the data each subject drove a specified course of about 15 miles, on four different nights and four days. The route selected consisted of two lane roads with straight sections and right and left curves; some sections had edgeline delineation with a solid white line and some did not. Data were collected with and without opposing traffic on the straight road sections in order to discern the effect of this variable. Driving speed was between 40 and 50 mph, depending upon the road conditions. In all of the runs care was taken to avoid having another vehicle within a short distance ahead, so that the eye fixations were not constrained, as is the case in car-following.

Figure 2. Data reduction equipment.

The test car (Figure 3) was equipped with three headlamp systems, so that the effect of these beams could be evaluated in the night driving test. The beams consisted of the conventional U.S. low beam (type 6014), a European low beam (type H_4), and an experimental mid beam comprised of the U.S. low beams augmented by a third headlamp (type Q-4051) aimed in the lane and to the right. The patterns of the beams of these lamps, projected on an aiming screen at 25 feet, are shown in Figure 4.

DEPENDENT VARIABLES

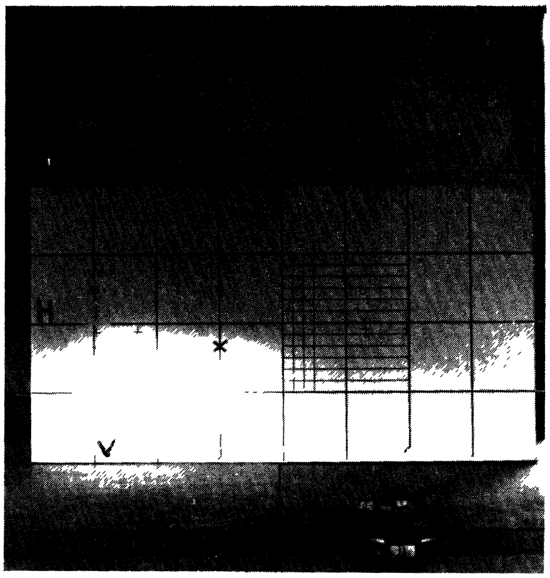
The dependent variables in this study were the duration and frequency of glances in viewing zones described by azimuth and distance ahead of the vehicle, and at ten objects.

RESULTS

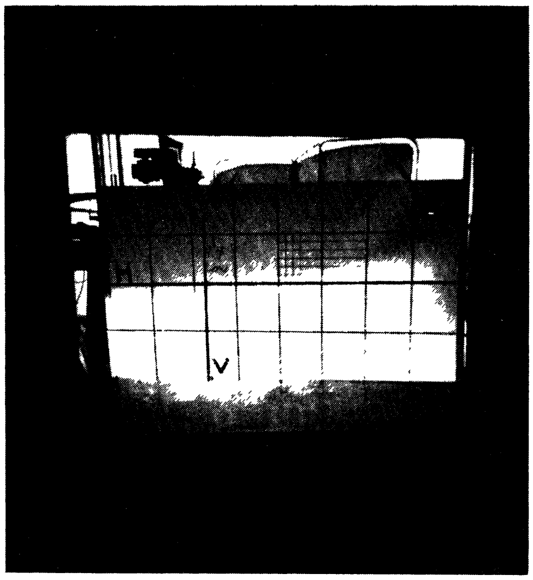
MEAN DURATION OF EYE FIXATIONS

Table 1 lists the mean durations of eye fixations in the lane being traveled for straight and curved road sections and day and night conditions. In the daytime, on left and right curves the duration of glances is about half that on straight sections of road; whereas, at night the mean glance durations differ proportionally less, but are greater than those used in daytime. The duration of glances in other parts of the field-of-view, other than straight ahead, are generally lower and much more similar in both day and night tests.

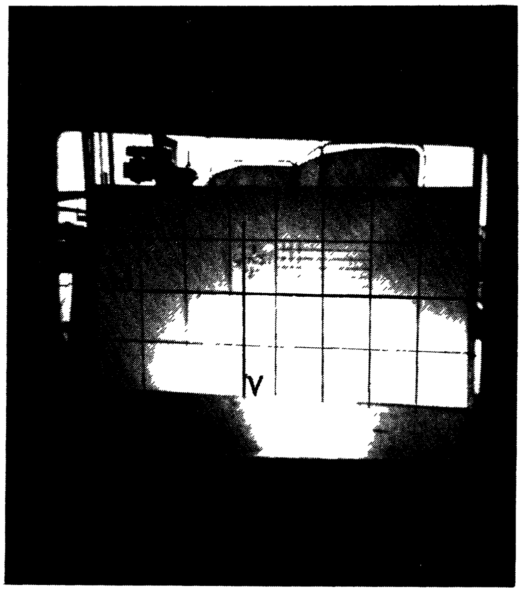
Figure 3. The headlamps mounted on the test car.
(Not all these lamps were used in this study.)



(a) 6014 low beam



(b) H_4 low beam



(c) Q4051 in nominal aim

Figure 4. Beam patterns of the type 6014 (U.S.) low beam lamp, H_4 (European) low beam lamp, and Q-4051 lamp.

TABLE 1. Mean Durations of Eye Fixations Straight Ahead in Driver's Lane in Day and Night Tests, in Seconds.

Road Geometry	Day	Night
Left Curve	0.43	1.05
Straight	0.93	1.18
Right Curve	0.47	1.35

DISTRIBUTION OF THE PERCENT OF TOTAL VIEWING TIME ON STRAIGHT ROAD SECTIONS

The mean percent duration of glances made by drivers in the day and night tests, on straight sections of road only, with and without an opposing vehicle, are shown in Tables 2 and 3. These demonstrate, as already mentioned, that the bulk of the driver's eye fixation time is spent in the lane he is using.

TABLE 2. Percent Duration of Eye Fixations in Various Locations on Straight Sections of Road, by Opposed and Unopposed Traffic Conditions, in Daytime.

Location	With Opposing Vehicle	Without Opposing Vehicle
Off road to left	0.2	0.5
In left lane at opposing vehicle	13.7	N/A
In left lane not at opposing vehicle	1.7	7.5
Center line	6.4	12.6
Straight ahead in lane	63.8	61.5
Right edge	2.8	2.5
Off road to right	4.6	5.4
Mirrors	0.1	0.2
Dash/Interior	1.2	2.9
Blinks, out-of-vew	5.5	6.9

TABLE 3. Percent Duration of Eye Fixations in Various Locations on Straight Sections of Road, by Opposed and Unopposed Traffic Conditions, at Night.

Location	With Opposing Vehicle	Without Opposing Vehicle
Off road to left	0.1	0.1
In left lane at opposing vehicle	20.6	N/A
In left lane not at opposing vehicle	0.1	2.2
Center line	1.5	3.4
Straight ahead in lane	65.7	78.0
Right edge	2.5	6.0
Off road to right	0.3	0.6
Mirrors	0	0
Dash/Interior	1.7	3.6
Blinks, out-of-view	7.5	6.1

When there was no opposing traffic 78% of the viewing time at night and 61.5% in the day was straight ahead in the lane, indicating a greater concentration of the glances in this area at night than in daytime. With oncoming traffic 65.7% of the viewing time at night and 63.8% in the day was in the same area, indicating a change in the viewing pattern at night with opposing vehicles. It will be noted that, in the latter situation, 20.6% of the viewing time was devoted to opposing vehicles when these were present, at night, compared with 13.7% in the daytime. Thus, in both day and night driving conditions, drivers looked at opposing traffic. Without opposing traffic the drivers at night devoted 2.2% of their viewing time in the left lane whereas in the daytime they looked there for 7.5% of the time. This again illustrates that drivers tended to restrict their lateral eye fixations in night driving when there was no other traffic in front of them. This is also shown by the negligible proportion of the viewing time at night devoted off the road to the right or left compared to the daytime.

Also, less time was spent fixating the road centerline at night than in daytime, potentially indicating that it was less visible with the meeting headlamp beams being used on the test vehicle in the night driving conditions, whereas in the daytime, obviously, there was ample illumination on the centerline. Conversely, since the meeting beams generally place the emphasis of their illumination toward the right side of the road, it will be noticed that in the unopposed case at night the drivers devoted 6% of their viewing at the right edge whereas in daytime only 2.5%.

DISTRIBUTION OF EYE FIXATIONS AT OPPOSING TRAFFIC

Tables 2 and 3 showed that subjects looked at opposing vehicles, in both day and nighttime. Further analysis was made, in a limited set of the night driving conditions with one of the headlamp beams, to determine the frequency distribution of glances at opposing traffic and the duration of these glances, as a function of the distance to the opposing vehicle. Table 4 shows that there was some increase in the mean frequency of glances as the separation distance decreased.

TABLE 4. Mean Frequencies* and Durations of Glances at Opposing Vehicles at Night as a Function of the Separation Distance.

Separation Distance (Feet)	Mean Frequency	Mean Duration (Sec.)
1500 - 2000	0.88	1.07
1000 - 1500	0.85	0.79
500 - 1000	1.16	0.71
0 - 500	1.40	0.70

*Per run in which a glance at the opposing vehicle occurred in the separation distance interval.

On the other hand, the mean duration of glances at the opposing vehicles was greatest at the largest distance interval and then dropped to a fairly constant value at inter-vehicle separation distances of less than 1500 feet.

These data suggest that drivers may look less often at the oncoming traffic at longer distances than when the distance becomes smaller, but the dwell time of an eye fixation decreases only slightly with the separation distance.

EFFECTS OF ROAD GEOMETRY AND HEADLAMP BEAMS ON LATERAL DISTRIBUTION OF EYE FIXATIONS

The frequency distribution of eye fixations in azimuth, in the intervals 10°L-5°L, 5°L-0°, and 0°-5°R, are shown in Table 5. The table also indicates the effects attributable to left curves, straight road sections and right curves in daytime, and when negotiating the same curves at night using each of the three meeting beams.

The effect of road geometry can be discerned most readily by observing the shift in the distribution of the eye fixations in the daytime test, which shows that on left curves the eye fixations moved to the left, on straight sections are centered in the field-of-view ahead of the driver, and on right curves shift over to the right. This effect has been established in previous studies (e.g., Mortimer and Jorgeson, 1972). The same trend is also observable in the data obtained in night driving conditions with each of the three beams, but with some variations between the beams.

TABLE 5. Percent* Frequency Distribution of Eye Fixations by Azimuth in Daytime and at Night, With Three Beams, on Curves and Straight Sections of Road, Without Opposing Traffic.

	Azimuth		
	10°L-5°L	5°L-0°	0°-5°R
Left Curve			
Day	67.0	29.7	3.3
6014 Low	51.0	39.6	9.5
H_4 Low	56.2	31.8	12.2
Mid	29.3	48.7	22.1
Straight			
Day	9.0	71.0	20.1
6014 Low	14.7	56.5	29.0
H_4 Low	19.3	64.8	15.9
Mid	4.3	63.4	32.6
Right Curve			
Day	5.3	25.5	69.2
6014 Low	28.0	29.9	42.1
H_4 Low	29.4	38.0	32.6
Mid	5.7	26.9	67.4

*With fixations outside these zones removed (e.g., car interior, mirrors, outside field-of-view of system).

On left curves the lateral distribution of eye fixations with the U.S. (type 6014) and European (type H_4) low beams is shifted to the left, with 51.0% and 56.2%, respectively, of the eye fixations in the 10°L-5°L zone. By comparison only 29.3% of eye fixations were in this zone when driving with the mid beam.

On straight sections of road the drivers primarily looked straight ahead with all the beams, though there were more glances to the left with the conventional U.S. and European low beams than the mid beam, which produced relatively more glances in the central portion of the driver's field-of-view.

On right curves the differences among the beams in the lateral frequency distribution of eye fixations is more pronounced. The U.S. low beam produced a shift to the right, but still maintained a substantial proportion of glances in the left of the straight ahead, which is even more noticeable with the European low beam. By comparison, the mid beam produced a preponderance of glances to the right of the straight ahead location.

Comparing the daytime distribution of eye fixations with those obtained at night with the various beams, suggests that on left curves the U.S. low and European low beams produced the most desirable viewing pattern; on straight roads the differences among the beams are not marked, but the European beam produced a greater tendency for eye fixations to the left whereas the U.S. low beam and the mid beam produced eye fixation distributions which were more centered ahead of the driver; and this trend is more noticeable on right curves in which there was a stronger tendency for the European beam to produce an eye fixation distribution which favored the left over the right side of the road, which is less noticeable with the U.S. low beam. The mid beam produced a distinct shift in the frequency of eye fixations to the right of the straight ahead field-of-view. By comparison with the daytime distribution of eye fixations, it would appear that the U.S. and European beams produced the most desirable effects on left curves; the mid beam provided the most desirable characteristic on straight road sections, although the differences between beams were small; and the mid beam provided the most desirable pattern on right curves and the European low beam the least desirable pattern.

EFFECTS OF ROAD GEOMETRY AND HEADLAMP BEAMS ON PREVIEW DISTANCE

The frequency distribution of eye fixations by distance ahead of the vehicle in the three intervals 100'-250', 250'-500', and >500', is shown in Table 6.

TABLE 6. Percent* Frequency Distribution of Eye Fixations by Distance Ahead of the Vehicle in Daytime and at Night, With Three Beams, on Curves and Straight Sections of Road, Without Opposing Traffic.

	Preview Distance (Feet)			
	100-250	250-500	>500	Median
Left Curve				
Day	11.3	34.4	54.3	>500
Night				
6014 Low	40.5	42.7	16.9	306
H_4 Low	33.3	49.9	17.0	334
Mid	29.1	34.2	36.8	403
Straight				
Day	6.8	39.8	53.5	>500
Night				
6014 Low	14.2	49.4	36.6	431
H_4 Low	20.3	42.5	37.2	425
Mid	21.0	47.1	32.2	404
Right Curve				
Day	3.6	25.8	70.6	>500
Night				
6014 Low	10.7	45.4	43.9	466
H_4 Low	15.3	51.1	33.6	420
Mid	12.0	45.8	42.2	457

*With fixations outside these zones removed.

It is immediately apparent that in the daytime more than half of the eye fixations are in the largest distance category, whereas this is not the case for any of the beams used at night. Thus, eye fixations are closer to the vehicle at night than in the day. The preview distances selected on left curves and straight sections of road during the day are quite similar, whereas on right curves the driver appeared to look further ahead.

Comparisons among the beams indicate that on left curves, the driver's eye fixations were further ahead of the vehicle when driving with the mid beam than the U.S. or European low beams; on straight sections of road differences between the beams are quite small; and this is also true on right curves, except that the eye fixations are slightly closer to the vehicle with the European low beam than the other two beams. Table 6 also shows the median visibility distances for each beam in each of the road geometries. The major difference is found on left curves where the mid beam appeared to provide considerably greater preview distances than the conventional low beams.

ROAD DELINEATION

The eye fixations were influenced by the presence or absence of delineation of the edge of the road with a white line. At night on right curves and averaged over all beams, there was a mean of 21.7% of all glances directly at the white line at the right edge of the road, compared to a mean of 2.5% without delineation. In daytime the corresponding values were 18.1% and 18.9%, with and without delineation, showing that the right edge of the road was an important reference for vehicle guidance. That the day values are independent of the presence or absence of delineation is to be expected, because the edge of the road can be seen more effectively in daytime in either case.

CONCLUSIONS

The mean dwell time of eye fixations, in the most frequently fixated aspect of the driver's field-of-view, consisting of the lane in which he is traveling, was longer than in daytime. This seems to be reasonable behavior, because on dark, unlighted roads where the driver relies upon the illumination provided by the headlamps, visibility is expected to be restricted because headlamp meeting beams emphasize illumination of the driving lane.

Thus, at night, there is also a restriction in the lateral distribution of eye fixation durations to the left of the lane being traveled, whereas there is a relative increase in time viewing the right edge of the road, compared to daytime. These conclusions apply to the case where the driver is on straight sections of road when there is no opposing traffic.

Of particular interest to this study was the evaluation of the viewing patterns of drivers as a function of the headlamp beam being used at night, and the comparison of these patterns with those used in daytime. These data showed quite clearly, what has been observed in previous studies, that eye fixation lateral distributions are influenced by the road geometry. In essence, drivers tend to look in the direction of the road, thus shifting their gaze to the left on left curves, straight down the road on straight sections and to the right on right curves. Thus, behavior was somewhat modified according to the headlamp beam being used at night, although the general trend was still apparent.

On right curves part of the shift of the frequency of eye fixations to the right can be attributed to the presence of a white line at the edge of the road. It was fixated frequently and, therefore, used as a useful cue for guiding the vehicle at night when the edge of the road is otherwise not as discernible due to the normally low contrast between the pavement and the shoulder.

The distributions of eye fixations in azimuth and by preview distance, in Tables 5 and 6, indicated that on left curves, at night, the U.S. and European low beams produced the viewing pattern that was most compatible with that used in daytime, compared to that which resulted when driving with the mid beam. The mid beam pattern produced eye fixations which remained further to the right relative to the other beams. Therefore, it is likely that drivers mostly utilized the road certerline or left edge of the road for guidance cues at night with the conventional low beams, whereas they emphasized the centerline and right edge of the road with the mid beam. Since the mid beam utilizes the U.S. low beam, augmented by a third lamp which provides additional illumination along the lane being traveled and the right edge, those zones are illuminated at a greater intensity than with the low beam alone. Thus, it seems that the mid beam encourages drivers to look in those places where the greatest illumination is provided.

This effect of the mid beam was clearly beneficial on right curves, in which it provided a lateral distribution of eye fixations very closely matching that obtained in daytime, and more compatible to the daytime situation than the other two beams.

On straight roads the lateral distributions of eye fixations is largely in the zone ±5° of the straight ahead position of the driver, with all beams, and particularly the mid beam.

These results must be considered with the distribution of preview distances used by the drivers, shown in Table 6. Thus, the greatest preview distance on left curves was obtained with the mid beam. This suggests, that while the beam influenced the drivers in fixating more on the road centerline and right edge, than the conventional low beams, it also provided greater preview distances which are valuable for retention of stability in vehicle control. On straight road sections and right curves the differences in the distributions of preview distances are small, although they are slightly less with the European low beam in right curves than the other two beams.

Each of these beams has certain attributes that are beneficial for acquisition of visual information in night driving on rural roads. The European low beam produced a greater distribution of eye fixations in the driver's visual field left of the highway center line than the U.S. low beam, and particularly the mid beam. Since information in this region is useful on left curves, as well as for the detection of obstacles, such as pedestrians that may be crossing the street from left to right, such a beam has certain desirable characteristics. On left curves, the mid beam provided the greatest preview distances although these would be provided by eye fixations which are in the lane or to the right of it. Clearly, the mid beam provided the most compatible eye fixation behavior on right curves and somewhat more compatible eye fixations on straight road sections, than the other beams.

These data suggest that an improved meeting beam should utilize a combination of headlamps which produce a low beam similar to that of the European (ECE) low beam augmented by a third headlamp which produces illumination along the lane being traveled and to the right of it, as was used in this study. Such a configuration may allow drivers to utilize eye fixations on left and right curves, and straight road sections, that are more compatible with those they use in daytime.

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