Distribution of Driver Spare Glance Durations

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The statistical distributions of driver off-roadway spare glance durations for six in-vehicle and one out-of-vehicle viewing tasks are generated. An analytical model is fitted to experimental data from several sources to yield these distributions. Of the seven types of driver viewing tasks, two are required for navigation purposes, whereas five need only be viewed occasionally and usually under light traffic conditions. The two navigational tasks are viewing the rearview and left-side mirrors. The other five tasks include viewing the speedometer, temperature, and defroster gauges, glancing at the radio, and reading roadway name signs outside the moving vehicle. Mean, standard deviation, and median values are given for these viewing task durations, and probability distribution values are tabulated. A goodness-of-fit test comparing model values to experimental data is also conducted for the driver task of viewing the car radio.

The study of driver glance durations in scanning the roadway scene ahead of the moving vehicle has been a popular topic of human factors research, and much is known about this important topic. In contrast, comparatively little research has been conducted on driver spare glance durations for off-roadway viewing tasks, such as viewing dashboard displays and rearview mirrors. One of the earliest studies was published by Mourant and Rockwell (*1*). This study focused on the differences in the scanning behavior of novice and experienced drivers in viewing mirrors and the speedometer while driving under freeway and neighborhood conditions. Mourant and Rockwell noted that experienced drivers used the rearview mirror more than the novice drivers did but that the reverse was true for the use of the speedometer. They also concluded that the spare search and scan patterns of most novice drivers were generally inadequate for safe driving on public highways. Mourant and Donohue (*2*) later focused on the drivers' glance durations to the rearview and left-side mirrors while executing both left- and right-lane changing and merging maneuvers.

Within the past 5 years, several studies have been published that include statistical parameters of driver spare glance durations for several important viewing tasks. The availability of these statistical parameter estimates allows the distribution of these glance durations to be computed on the basis of an appropriate analytical model. Statistical distributions of driver spare glance durations to viewing two mirrors, four dashboard displays, and one out-of-vehicle target are presented. A goodness-of-fit test is applied between model estimates and experimental data for one of these viewing tasks.

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EXPERIMENTAL STUDIES OF SPARE VIEWING TIMES

Nagata and Kuriyama (*3*) published viewing times of automobile drivers using side mirrors. They found the mean glance durations of drivers to be 0.69 sec for the near-side mirror and 1.38 sec for the far-side mirror. The difference in viewing times was found because the near-side mirror was at a 41.5-degree angle from the longitudinal axis, whereas the far-side mirror was at a 70-degree angle from the longitudinal axis parallel to the roadway. Significant differences existed in the glance times of the three groups, which included driving instructors, male students under 20 years of age, and female students over 30 years of age. The driving instructors exhibited significantly shorter glance times than the other two groups did.

In 1987, two extensive experimental studies were presented at the Second International Conference on Vision in Vehicles held in Nottingham, England. Wierwille et al. (*4*) presented data on glance time durations of drivers viewing 26 different tasks. A total of 32 drivers drove a specially instrumented 1985 Cadillac Deville on public roadways in Virginia, under light and moderate traffic conditions. The drivers ranged in age from 18 to 73 and varied in driving experience from 2,000 to 40,000 mi of driving per year. The average glance times exhibited by this group ranged from 0.62 sec in viewing the speedometer to 1.63 sec in reading a roadway name sign as the vehicle approached and moved past the sign. Wierwille et al. concluded that drivers over 50 years of age required longer glance times and made greater errors in reading dashboard displays than did the younger subjects. Some conventional tasks, such as turning on and viewing the radio, required more time than viewing the speedometer. In general, viewing tasks requiring greater complexity in interpretation required longer glance times than those requiring only simple identification.

The second study, presented by Rockwell (*5*), contained data on driver glance durations in viewing the radio and the left-side mirror. A total of 106 drivers were tested over a 6-year period on highways and expressways under light to moderate traffic conditions. The subjects were equally divided according to gender and age to represent a composite of the general driving population. Average glance times were shortened by an average of about 20 percent under higher traffic density conditions than under lower, less crowded conditions.

It therefore appears that driver glance durations are a function of vehicular roadway density.

DISTRIBUTIONS OF SPARE GLANCE DURATIONS

The statistical parameters of radio viewing glance times were presented as 1.27, 1.44, and 0.5 sec, for the median, mean, and standard deviation values respectively, of 1,250 recorded glances. This finding yields a value of 0.376 for the dispersion parameter associated with the lognormal probability density model used here. The cumulative probability distribution estimates ranged from 0.68 sec for the 5th percentile to 2.35 sec at the 95th percentile.

In this study, women took shorter glances to the radio than men did. Older drivers also recorded longer times than those of their younger counterparts. Radio glance times were longer for viewing the radio than for viewing other dashboard displays, because radio operation required visual discrimination, whereas viewing other displays only required visual detection—a shorter process. Although station selection required an average of 1.50 sec, tuning the volume required only an average time of 0.97 sec. The degree of visual discrimination was, therefore, an important factor in determining the length of the driver glance duration required for a specific visual task.

The average time spent glancing at the left-side mirror was 1.10 sec, which is considerably shorter than the average radio glance duration. The median glance duration was 1.06 sec, with a standard deviation value of 0.3 sec. The corresponding dispersion parameter value was 0.268 sec. The 5th-percentile value of 0.68 sec was identical with the value for radio glances, but the 95th-percentile value of 1.65 sec was significantly shorter than the corresponding radio glance value. The older drivers, however, took shorter glances than their younger counterparts when viewing the left-side mirror. No significant differences in gender were noted for this viewing task.

The glance times presented for viewing the rearview mirror were significantly shorter than those required for viewing the left-side mirror. These values were 0.75 sec for the average, 0.68 sec for the median, and 0.36 sec for the standard deviation. The 5th- and 95th-percentile values were 0.32 and 1.43 sec, respectively.

The mean, median, and standard deviation parameters in viewing the speedometer were 0.62, 0.49, and 0.48 sec, respectively, with a dispersion estimate of 0.685.

The corresponding statistical parameter estimates for viewing the temperature gauge, the defroster gauge, and roadway name signs are presented in Table 1. The average values range from 1.10 sec for the temperature gauge to 1.63 sec for reading roadway name signs. The task of viewing roadway name signs was chosen to represent at least one task involving viewing a target outside the moving automobile. This task required visual discrimination as well as visual detection, thereby lengthening the time required to complete it.

LOGNORMAL PROBABILITY DENSITY MODEL

The probability density model of driver glance durations, $f(t)$, is lognormal distributed if the standard normal variable (z) defined by the equation

$$z = \frac{\ln(t) - \ln(t_m)}{d} \tag{1}$$

is normally distributed with a mean value of 0.0 and a standard deviation value of 1.00. In this equation t_m is the median, or 50th percentile, value of the driver glance time (t) in seconds. The dispersion parameter (d) satisfies the following relationship:

$$d^2 = \ln\left[1 + \left(\frac{s}{m}\right)^2\right] \tag{2}$$

where m is the mean and s is the standard deviation of t.

The mean, median, and dispersion parameters are related as follows:

$$\ln(m) - \ln(t_m) = (1/2)d^2 \tag{3}$$

The cumulative probability distribution function, $F(t)$, is the integral of the probability density function defined by the following:

$$F(t) = \int_0^t f(x)dx \tag{4}$$

TABLE 1 STATISTICAL PARAMETERS OF DIFFERENT VIEWING TASKS

Viewing Task	Mean Value m (Sec)	Standard Deviation s (Sec)	Median Value t_m (Sec)	Dispersion Parameter d (Sec)
Radio	1.44	0.50	1.27	0.376
Left-View Mirror	1.10	0.30	1.06	0.268
Rear-View Mirror	0.75	0.36	0.68	0.455
Speedometer	0.62	0.48	0.49	0.685
Temperature Gauge	1.10	0.52	0.99	0.449
Defroster	1.14	0.61	1.01	0.502
Roadway Name	1.63	0.80	1.46	0.465

TABLE 2 PERCENTILE VALUES OF DRIVER GLANCE DURATIONS IN SECONDS

Viewing Task Percentile	Radio	Left-View Mirror	Rear-View Mirror	Speedometer	Temperature Gauge	Defroster	Roadway Name
5th	0.68	0.68	0.32	0.16	0.48	0.44	0.68
10th	0.78	0.75	0.38	0.20	0.56	0.53	0.81
15th	0.86	0.80	0.42	0.24	0.62	0.60	0.90
20th	0.93	0.85	0.46	0.28	0.68	0.66	0.99
30th	1.04	0.92	0.53	0.34	0.79	0.77	1.14
40th	1.16	0.99	0.60	0.41	0.89	0.89	1.30
50th	1.27	1.06	0.68	0.49	0.99	1.01	1.46
60th	1.40	1.13	0.76	0.58	1.11	1.14	1.64
70th	1.55	1.22	0.86	0.70	1.26	1.31	1.87
80th	1.74	1.33	0.99	0.87	1.45	1.53	2.16
85th	1.88	1.40	1.08	1.00	1.58	1.69	2.37
90th	2.06	1.49	1.21	1.18	1.77	1.91	2.66
95th	2.35	1.65	1.43	1.51	2.08	2.30	3.14

The characteristic features of the lognormal probability density function are described by Aitchison and Brown (*6*) and by Ang and Tang (*7*). This function has previously been applied to represent the probability distribution of brake reaction times of drivers (*8,9*). The skewness, or lack of symmetry, of this analytical model closely approximates the skewness exhibited by experimental data of driver glance durations published in the literature.

Because this function is a two-parameter model, one of the three statistical parameter estimates of mean, median, and standard deviation can be evaluated if two are known. The percentile estimates of driver spare glance durations for the seven visual tasks investigated are presented in Table 2.

CLOSENESS OF FIT TO EXPERIMENTAL DATA

The Kolmogorov-Smirnov test was used to test the goodness of fit between the lognormal analytical model and the experimental data of radio glance times reported by Rockwell (*5*). In this test the actual cumulative probability distribution function, $S_n(t)$, of the experimental data is computed for different values of successive driver glance durations. The corresponding theoretical cumulative distribution function, $F(t)$, is then computed for the same glance durations, and the absolute value of the difference between these values is denoted by $D(t)$, where $D(t) = F(t) = - S_n(t)$.

For the radio glance durations shown, the number of observations was 1,250. The critical value of D, denoted by D_{cr}, at the 5 percent level of significance, is given by the following:

$$D_{cr} = \frac{1.36}{(1{,}250)^{1/2}} = 0.0385 \qquad (5)$$

The successive values of $D(t)$ are presented in Table 3. It is clear that the maximum value of $D(t)$ is $D(0.70) = 0.0321$, which is less than the critical value of 0.0385. This test, therefore, confirms the hypothesis that the lognormal probability density model chosen accurately fits the radio glance data published by Rockwell (*5*) at the 5 percent level of significance.

The Kolmogorov-Smirnov test is considered more powerful than the chi-square test also used in analytical model fitting and is recommended by Ostle and Mensing (*10*). Its advantage is that it does not lump data into discrete categories but compares data in an unaltered form. It is an exact test for all sample sizes.

CONCLUSIONS

The statistical distributions of driver spare glance durations of six in-vehicle and one out-of-vehicle viewing tasks have been generated. The lognormal probability density function has been used to model driver glance durations and statistical parameter estimates computed for each task. A goodness-of-fit test was conducted for car radio glance times, and the fit was found to be satisfactory at the 5 percent level of significance.

The key parametric statistic presented in Table 2 is the 85th-percentile driver glance durations, because this statistic corresponds to the current design driver standard. This value ranges from 1.0 sec in glancing at the speedometer to 2.37 sec in reading roadway name signs. The 85th-percentile design driver completed all other glance times within a 2.00-sec time period.

Of the seven types of viewing tasks studied, two are required for navigation purposes, whereas the other five need only be glanced at occasionally, usually under light to moderate traffic conditions. The two tasks required for navigational purposes are viewing the rearview and side mirrors. The 85th-percentile driver requires 1.08 sec to glance at the rearview mirror and 1.40 sec for the left-side mirror. Both these tasks are, therefore, completed by the design driver within 1.50 sec, which appears to be the maximum recommended time interval that drivers should direct their visual attention away from the roadway scene directly ahead of the moving vehicle. Rockwell (*5*) noted that most drivers attempt

TABLE 3 KOLMOGOROV-SMIRNOV TEST APPLIED TO RADIO GLANCE DATA (*5*): CUMULATIVE PROBABILITY DISTRIBUTION VALUES

Glance Time t (SEC)	Model Estimate F(t)	Data Value $S_n(t)$	Difference $D(t) = \|F(t) - S_n(t)\|$
0.5	0.0184	0.0028	0.0156
0.6	0.0230	0.0064	0.0166
0.7	0.0565	0.0244	0.0321
0.8	0.1095	0.8080	0.0287
0.9	0.1799	0.1608	0.0191
1.0	0.2625	0.2584	0.0041
1.1	0.3512	0.3616	0.0104
1.2	0.4401	0.4576	0.0175
1.3	0.5247	0.5316	0.0069
1.4	0.6023	0.6008	0.0015
1.5	0.6709	0.6480	0.0229
1.6	0.7305	0.7264	0.0041
1.7	0.7810	0.7688	0.0122
1.8	0.8232	0.8108	0.0124
1.9	0.8580	0.8428	0.0152
2.0	0.8865	0.8708	0.0157
2.1	0.9094	0.8968	0.0126
2.2	0.9281	0.9220	0.0061
2.3	0.9429	0.9396	0.0033
2.4	0.9547	0.9536	0.0011
2.5	0.9642	0.9652	0.0010
2.6	0.9717	0.9740	0.0023
2.7	0.9776	0.9830	0.0054
2.8	0.9823	0.9920	0.0097
2.9	0.9859	0.9976	0.0117
3.0	0.9889	1.000	0.0111

to keep their spare off-roadway glance durations below 1.5 sec despite poor in-vehicle display designs and poor roadway designs. These drivers apparently prefer to take several short glances to a target rather than one or two longer glances, which enables them to drive more safely. Drivers also appear to adjust to denser traffic conditions by shortening their spare glance duration times as intervehicular spacings become shorter. Driver glance times appear to decrease with headway spacing. Three in-vehicle display viewing tasks required correspondingly longer glance times by the 85th-percentile design driver. The viewing times were 1.58 sec for the temperature gauge, 1.69 sec for the defroster, and 1.88 sec for the radio. All of these tasks were therefore completed in 1.90 sec by the design driver. These tasks required visual discrimination as well as visual detection, resulting in correspondingly longer glance durations. Because these tasks are usually performed under light traffic conditions, a 1.9-sec value for these glance durations may be acceptable for most drivers.

The design driver needs 2.37 sec to view roadway name signs outside of the moving automobile. This task requires greater visual discrimination than any of the other viewing tasks studied. The glance duration depends on the number and lengths of the names on the roadway sign. The roadway sign is also the only target that is moving in the driver's visual field. Although experimental data on this viewing task are sparse, it appears that a 2.4-sec viewing time for this task is probably too long and may indicate an unsafe driving situation, because 2.00 sec appears to be an upper bound for the time interval that a driver can safely divert vision away from the roadway scene ahead.

The applicability of using the lognormal probability density function to model driver glance durations has been demonstrated. Although current design standards are based on the 85th-percentile driver, it is possible that this standard may be raised at some future date to the 90th- or 95th-percentile driver. Should this change occur, this analytical model can be used to compute these higher driver percentile estimates of driver spare glance durations.

The time spent in viewing the right-side, or far-side, mirror was not studied, because statistical parameter estimates were not available for this viewing task. A rough estimate given by Rockwell (*5*) is that this task takes about 10 percent longer than glancing at the left-side mirror. This estimate would correspond to a value of approximately 1.54 sec for the 85th-percentile driver. However, standard deviation estimates for this viewing task were not available.

It appears that drivers use the right-side mirror much less than the left-side mirror or the rearview mirror. Most driving manuals, such as one issued by the American Automobile Association (AAA) (*11*), recommend the use of both side mirrors and the rearview mirror, as well as direct vision by drivers turning around, before any lane change is made. The AAA manual first advises drivers to check the appropriate mirror to see if there is adequate time and space to perform a lane change safely. It then recommends that drivers turn and look over their shoulder momentarily to view traffic conditions directly before initiating the lane change maneuver. This procedure will eliminate the possibility of not seeing an approaching vehicle because of the presence of a blind spot in the mirror's viewing field. However, Mourant and Donohoe (*2*) found that novice drivers tended to rely primarily on direct over-the-shoulder viewing rather than mirror viewing when changing lanes on a highway.

Nagata and Kuriyama (*3*) found that glance durations to the far-side mirror were longer than near-side mirror glance times. Robinson et al. (*12*) reported that driver mirror glance times ranged from 0.8 to 1.6 sec, with an average value of 1.1 sec. However, they did not break these viewing times down by the types of mirror being used. They tested eight drivers over a 1.5-mi course. The drivers ranged in age from 20 to 25 years, with an average driving experience of 5 years. The average speed on the course was 30 mph, with each driver circling the course about six times. These glance duration estimates agree well with the results derived here and tend to confirm the hypothesis that the lognormal probability model closely fits the experimental data.

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