Effect of Alternate Population Mixes on Design Eye Locations in Vehicles

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Driver eye location distributions were studied as a function of the standing height growth for three decades of the U.S. adult population. Sample populations were used to determine the effects on the drivers' eyellipse and the possible impact on some of the automobile interior parameters. The eye locations were determined for three groups who were driving four types of cars. These groups represented the population during 1962 and 1972, and as estimated for 1990. Generally, the eyellipses were shifted rearward and upward compared to the previous decade, but differences were only statistically significant fore-aft in the side view and laterally in the front view. The technique of selecting subjects to create multiple populations permits development of tools for use in future automotive packaging. Otherwise, the current packaging tools use may not accommodate the younger, taller persons of the future population.

Changes in the size of future automobile drivers is of obvious interest to the automotive designer. The rate of change in the body size of the people in the driving population may be determined from the 1960–1962 National Health Survey *(1)* and the 1971–1974 National Health Survey *(2–4)*. One such report concerning the rate of change of body size is by Stoudt *(5)*. Stoudt anticipates world-wide stature growth of approximately 1.0 cm/decade. This rate will eventually decline, especially in certain places, such as the United States. Stoudt refers to the U.S. public health statistics just mentioned, which show an average increase of 1.7 cm/decade for males and 1.3 cm/decade for females. The growth rates in the U.S. survey are worrisome to L. Schneider *(6)*, who is concerned about the data when viewed by age groups. It would be expected that the age groups of the 1960–1962 survey would be similar to the age group plus 10 years in the 1971–1974 survey. Schneider shows that this is not the case. However, despite these potential problems, the HEW growth rates of 1962 to 1972 were used to project the future population of 1990.

The interest of this paper is in the effect of the body growth on driver's eye locations, as described by the SAE driver's eyellipse *(7)*, and in the eyellipse variability caused by changes in seat deflection or cushion firmness. An increased firmness, which results in reduction in the range of seat deflection, was expected to increase the vertical height of the driver's eyellipse. Also, because the future drivers would be larger, a significant movement of the eyellipse rearward and upward was expected. An eyellipse that would be elongated was also expected because back-angle adjustment was permitted in the study.

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METHOD

One each of four General Motors 1984 J cars [i.e., (a) Cadillac Cimarron, (b) Chevrolet Cavalier, (c) Oldsmobile Firenza, and (d) Buick Skyhawk] were used in the study. The vehicles had bucket seats with fore-aft adjustment and adjustable back angle. All had curved seat adjustment tracks except the Firenza, which had a straight-track power seat. The seat cushions had differences in deflection range or firmness. The production (Cimarron) seat provided the greatest deflection range (least firm), and the others had deflection ranges that were mutually similar but less similar to the production seat.

A total of 95 (50 females and 45 males) General Motors Technical Center employees were tested. Subjects were selected by standing height to represent three different U.S. driving populations *(8)*. The three test samples (1962, 1972, and 1990) overlapped to permit data from most subjects to be used more than once (Figure 1). Each subject drove each car only once; however, an individual subject's data were used in most cases in more than one mix. Data for 60 subjects per sample were placed in each of three samples (30 males and 30 females per sample). The standing height samples represented the 1962 population *(1)*, the 1972 population *(2–4)*, and a 1990s projection based on the recent growth patterns *(8)*.

In groups of four, the subjects were briefed, driven through a mock test run, given instruction sheets, and assigned cars. The instruction sheets had the same information given in the briefing. Seat belt use was optional for drivers in this test. The order of driving assignments was predetermined randomly to minimize order effects. Test cars were rotated among the subjects until each had driven all four cars. Each car was driven four times on a looping track and past a data station. At the data station, a passing car triggered a motor-driven camera that recorded side-view photographs. After the fourth loop (a total distance of 2 mi), drivers stopped at another station for a front-view photograph. After completion of the front-view photograph, each driver's seat location and seat frame angle were measured and recorded. The drivers drove at their own speed for the conditions, except when driving past the data station. There, speed was reduced to approximately 20 mph to minimize image blur in the photographs.

Four small side-view roof-mounted antennas, one on each side and one each on the front and rear of the car, were used to determine parallax correction factors for off-axis eye location photographs. Front-view antennas were mounted above the windshield and back light, parallel to the design eyellipse centroid. A correction was made in the side view for car axis, driver's weight, induced car roll, and road crown.

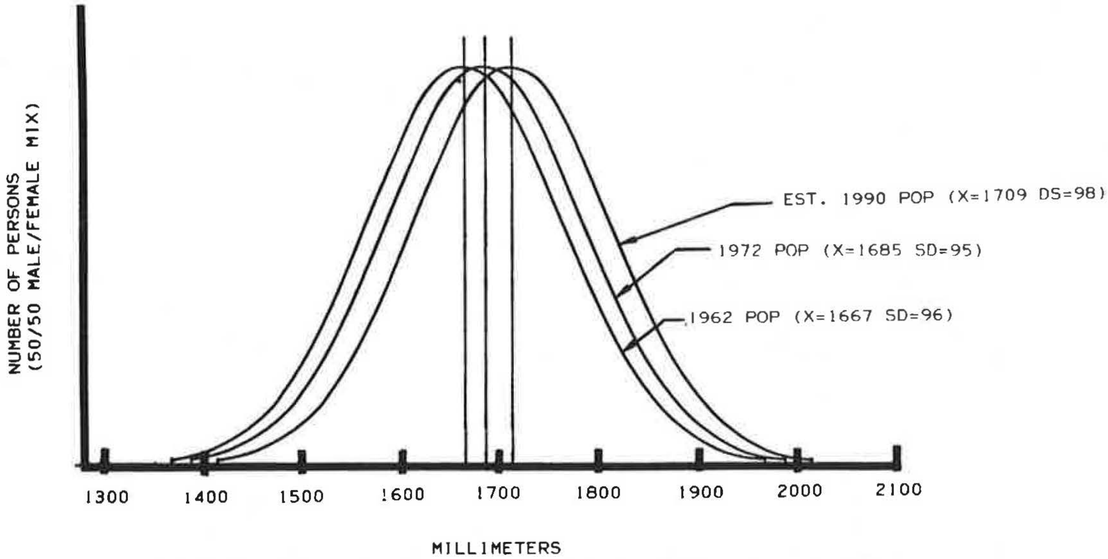

FIGURE 1 Standing height, U.S. populations for 1962, 1972, and estimated 1990.

Cameras were located at the car's design eyellipse centroid height above the road. The 35-mm camera lenses were set at a focal length of 175 mm. Shutter speeds were generally 1/1,000th or 1/500th sec. The four cars were measured and marked externally to correspond to interior grid line points. The chrome trim on the vehicles also provided measurement points. Driver front views were taken with a rail-mounted camera that shifted laterally to align with the fore-aft test car antenna markers. Reflections on the front windshield required the use of light reflectors and shade screens to get the front-view photographs. Reflections were avoided on the side-view photographs by having the driver's window down.

ANALYSIS

Drivers' eye positions were determined by measuring full-scale projections of the test photographs. Corrections were made for camera-to-car angle in the side views. The means of the three side-view eye locations for each driver and for each car were combined with the front-view eye position. This combination developed each individual driver's three-dimensional eye position for each car.

A computer program was used to convert the eye position data to eyellipse data. This program computed the *XYZ* axis means, standard deviations, and slope necessary to construct the eyellipse in three planes. This program and a description of the eyellipse are presented by Roe *(9)*. The statistical analysis was done by using existing ANOVA and TTEST programs in the Statistical Analysis System *(10)* and by using the Dartmouth Time Sharing System *(11)*.

RESULTS AND DISCUSSION

The different population test sample (1962, 1972, and projected 1990) eyellipses for the production (Cimarron) seat are shown in Figure 2. Figure 3 shows the projected 1990 population test sample eyellipses for the four seats.

The general findings of this study were as follows:

1. The 1962 and 1990 population samples produced statistically significant differences in the side-view *X*-axis regardless of seat type at the .07 level. Tables 1 and 2 present the statistics and eyellipse descriptions, respectively.
2. Each population sample produced a similar eyellipse in the side-view plane regardless of the seat type. There were no statistically significant differences in the *X* and *Z* axes for any of the seats.
3. There were no population effects for the front view of the eyellipse for any of the seats.
4. Seat type produced significantly different eyellipses laterally (in the *Y* axis of the front view) and across population samples. Of 36 possibilities, 26 produced statistically significantly different eyellipses laterally from 2 eyes, 6 seat pairs, and 3 populations (Table 1).
5. The eyellipse moved rearward and upward as the driver populations increased in standing height (from 1962 through estimated 1990). All four seats produced 1990 sample eyellipses that were higher, but the differences from the 1962 population's eyellipses were not statistically significant.

The standing height of the 1962 population is statistically different from the estimated 1990 population (so is the test sample), but this difference shows up only in the *X*-axis of the test eyellipse.

In the side view, the difference in the 1962 to estimated 1990 sample means in the fore-aft *X*-axis was 16.4 mm. This difference was close to the expected value of 14 mm *(12)*.

Greater differences between the vertical positions of the eyellipse means for the 1962 and estimated 1990 samples were expected. The four seats showed only an average difference of 5 mm, whereas 20 mm or more was predicted. These differences were not statistically significant. The reason for the small differences may be buried in factors such as seat contours, seat cushion and back deflection, seat back adjustment, and driver slouch. Perhaps the seat cushion permits sufficient dampening to lessen any effect in the *Z*-axis.

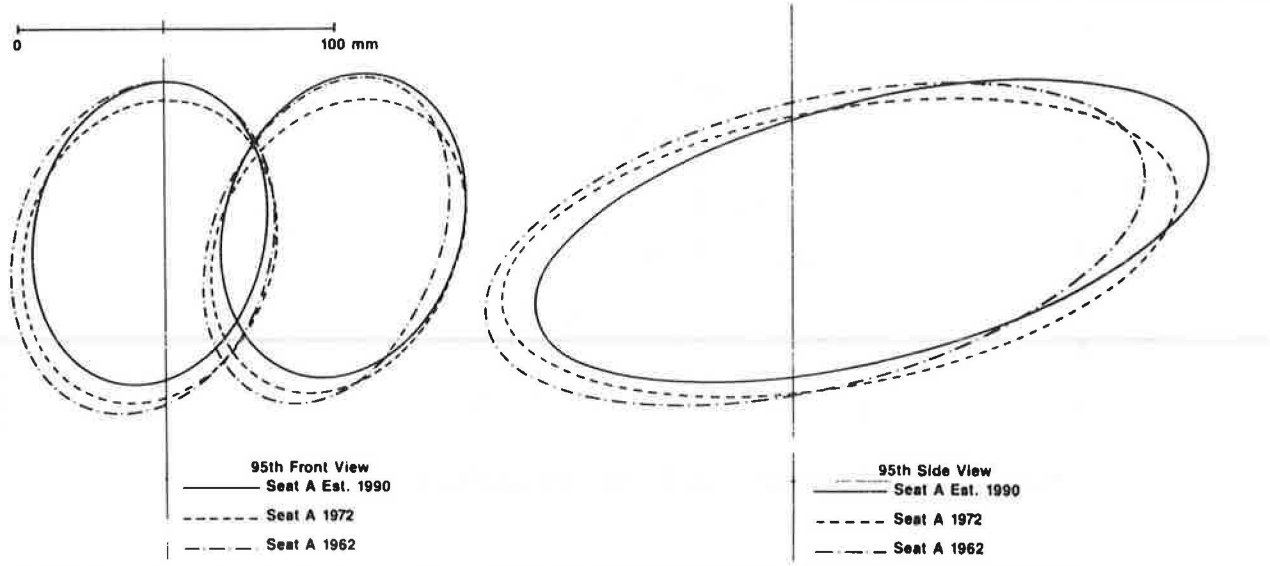

FIGURE 2 Front- and side-view eyellipses for three populations in the production (Cimarron) seat.

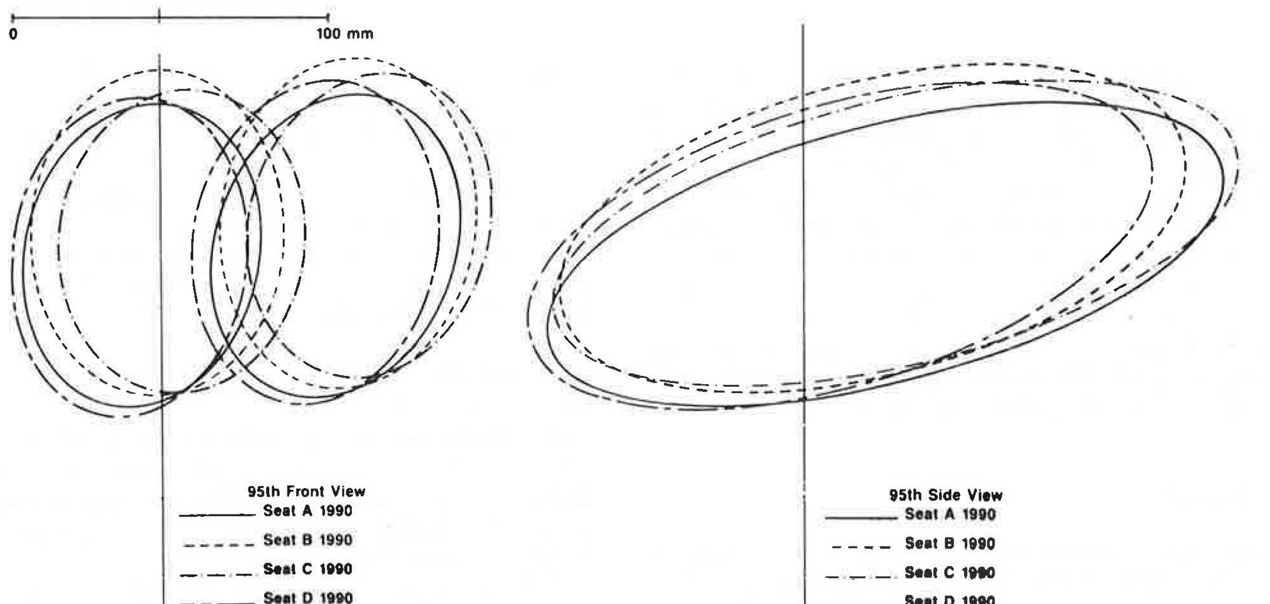

FIGURE 3 Front- and side-view eyellipses for estimated 1990 populations for all four seats.

The back angles selected by the test populations averaged 22.7 degrees compared to the 25.0 degree design back angle. The selected back angle ranged from 13.5 to 33.5 degrees (see Table 3). The test seats had lumbar support, which can cause seats to be adjusted by the driver to be 3 degrees more erect and also position the head higher and further rearward than in non-lumbar-supported seats *(13)*. The mean selected back angle of the 1990 sample population was 0.9 degrees greater than that of the 1962 sample population, which was not statistically significant.

The 0.9 degree back angle increase implies that an average eye drop would be only 2.5 or 3 mm (on the basis of current SAE mean eye location), even at the top of the 99th eyellipse. The 3-mm vertical decrease is not significant statistically or practically.

A test analysis of variance of the possible effects of the order in which the drivers drove the cars showed no statistically significant difference at the $\alpha = .05$ level.

The driver test groups were compared with the U.S. population data. No statistically significant differences were found for standing height or weight between population data and the driver samples for the three groups (1962, 1972, or estimated 1990). A difference did occur for the age of test females in 1962 and 1972 groups. The test females were younger in average age than both populations (for 1962, 38.6 versus 43.7 years, and for 1972, 36.9 versus 43.5 years) *(14)*.

The test side-view eyellipse had a slope of 10 to 17 degrees. This case resembles the eyellipse slope found for truck drivers of 11.6 degrees *(15, 16)*. The slope of 11.6 degrees is a change from the previously used SAE eyellipse slope of 6.4 degrees *(7)*.

A measurement of the movement of the 1962 population eyellipse mean to the estimated 1990 population eyellipse mean on the production seat was made. The mean moved 6.3 mm/decade along a 17.5-mm line with a 15 degree slope. These

TABLE 1 EYELLIPSE STATISTICAL COMPARISON OF *t*-VALUES

CAR/ SEAT	1960 - 1970 View: side X	Plan/Front Y Left	 Right	Side/Front Z	1960 - 1990 X	Y Left	 Right	Z	1970 - 1990 X	Y Left	 Right	Z
A Prod.	t= 0.641 df= 117	t= .568 df= 117	t= .573 df= 117	t= 0.150 df= 117	t= -1.468¶ df= 117	-1.151 df= 117	-0.600 df= 117	t= -0.890 df= 117	t= -0.825	-.575	.0	t= -1.088
B Vert. Adjust.	t=0.751	t=-.855	t= -1.040	t= 0.179	t= -1.590¶	-0.570	-0.663	t= -0.794	t= -0.800	0.272	0.364	t= 0.988
C Proto.	t= -0.871	t= -0.488	t= -0.475	t= -0.075	t= -1.480¶	-0.217	-0.165	t= -0.992	t= -0.596	0.265	0.308	t= -0.596
D Reg. Adjust.	t= -0.569	t= -0.662	t= -0.604	t= -0.374	t= -1.565¶ df= 117	-.098 df= 117	-.075 df= 117	t= -0.947 df= 117	t= -1.004 df= 117	0.530 df= 117	0.659 df= 117	t= -0.595 df= 117

MINIMUM DEFLECTION (B–D)

If not noted, the degrees of freedom is =118

Reject at = 1.654 with df= 120 at .05 level, one tailed test. Reject at =1.46 at .07 level Reject at = 1.56 at .06level

* = significant difference at .05 level. Refer to rejection statement value above to determine the level.

¶ = Significant difference at .07 or .06 level

CAR/ SEAT	1960 X	Y Left	 Right	Z	1970 X	Y Left	 Right	Z	1990 X	Y Left	 Right	Z
A-B Prod. Vert.	t= 0.356 df= 117	* -1.673 df= 117	-1.192 df= 117	t= -1.365	t= 0.318	-1.940*	-1.629¶	t= -1.416	t= 0.355	-1.095	-1.254	t= -1.356
A-C Prod. Prot.	t= -0.240 df= 117	* -3.267 df= 117	* -3.197 df= 117	t= -1.076	t= 0.318	* -3.155	* -3.111	t= -1.421	t= -0.281	* -2.086	* -2.924	t= -1.207
A-D Prod. Reg.	t= 1.060	0.557	0.283	t= -0.229	t=1.168	0.523	.327	t= 0.796	t= 1.045 df= 117	1.605¶ df= 117	0.948 df= 117	t= -0.351 df= 117
B-C Vert. Proto.	t= 0.601	-1.571¶	* -2.060	t= 0.302	t= -0.829	-1.159	-1.478¶	t= 0.057	t= -0.644	-1.153	-1.515¶	t= 0.202
B-D Vert. Reg.	t= 0.748	* 2.355	1.584¶	t= 1.116	t= 0.906	* 2.557	* 2.047	t= 0.602	t= 0.718 df= 117	* 2.663 df= 117	* 2.259 df= 117	t= 0.975 df= 117
C-D Prot. Reg.	t= 1.287	* 3.384	* 3.763	t= 0.829	t= 1.651*	* 3.857	* 3.619	t= 0.571	t= 1.330 df= 117	* 3.926 df= 117	* 3.872 df= 117	t= 0.809 df= 117

TABLE 2 EYELLIPSE DESCRIPTIONS

Car/Population	Eye Location	Mean X	Mean Y	Mean Z	Std. Dev. X	Std. Dev. Y	Std. Dev. Z	95th Percentile X	95th Percentile Y	95th Percentile Z	Slope FV/SV/FV	Corr. FV/SV/FV	Number of Subjects
	Right		290.9	1071.0		24.9	30.8		82.3	101.8	72.4°	0.151	
A 1960											sv=14.4°	0.433	59
	Left	3106.9	349.4	1072.7	62.4	23.9	30.3	206.0	78.9	100.1	66.1	0.267	
	Right		293.5	1069.8		24.6	28.7		81.1	94.6	69.7°	0.132	
1970											sv=10.9°	0.369	60
	Left	3114.3	351.9	1071.9	63.5	24.1	27.9	209.5	79.6	92.1	58.8°	0.279	
	Right		293.5	1075.3		22.3	28.5		73.7	94.0	75.2°	0.140	
1990											sv=14.2°	0.486	60
	Left	3123.9	354.4	1077.5	63.9	23.5	28.5	210.7	77.6	94.0	69.0	0.174	
	Right		299.1	1081.9		24.3	30.3		80.1	99.9	25.3°	0.018	
B 1990											sv=13.8°	0.367	60
	Left	3119.9	359.2	1084.9	59.4	24.5	30.9	196.0	80.8	101.8	81.5°	0.071	
	Right		305.7	1079.3		23.4	28.5		77.4	94.1	81.2°	0.063	
C 1990											sv=13.4°	0.456	60
	Left	3127.2	364.2	1083.8	64.6	23.0	28.7	213.2	76.1	94.6	74.6°	0.131	
	Right		289.4	1075.0		22.5	30.0		74.3	98.9	80.9°	0.096	
D 1990											sv=16.3°	0.450	59
	Left	3112.1	347.5	1079.4	59.1	23.4	30.6	195.0	77.3	101.0	78.6°	0.115	

key: sv = side view, viewing of the driver's left side

TABLE 3 SELECTED BACK ANGLES

Seat	Population Year	Mean	Standard Deviation	Min.	Max.	Range
A. Production Manual Adjust	1990	21.8*	3.6	15.5*	30.5°	15°
	1972	21.4*	3.4	15.5*	28.5°	13°
	1962	21.1*	3.9	14.5*	28.5°	14°
B. MD Modified Vertical Adjust	1990	23.0°	4.2	12.5°	30.5°	18°
	1972	22.7°	4.0	12.5°	30.5°	18°
	1960	22.3°	4.1	12.5°	30.5°	18°
C. Prototype MD Manual Adjust	1990	24.0°	3.4	16.5°	31.5°	15°
	1972	23.7°	3.7	16.5°	31.5°	15°
	1962	23.3°	3.4	16.5°	30.5°	14°
D. MD Modified Manual Adjust	1990*	23.5°	3.9	13.5°	33.5°	20°
	1972*	22.3°	3.7	13.5°	31.5°	18°
	1962*	22.3°	3.4	13.5°	33.5°	20°

MD = Minimum Deflection
*Significant difference statistically at .05 level 1990 vs. 1962 & 1990 vs. 1972

rates of change for eye and body size provide a way of estimating the location of future driver eyellipses and even head position contours.

CONCLUSIONS

If body size changes continue to occur at the rate indicated from 1962 to 1972, the eyellipse of 1990 is expected to be farther rearward but not much higher than the eyellipses for 1962 and 1972 population-sized drivers. This result assumes that seat cushion construction does not change.

Body size changes for given population years have less of an effect on the front-view *Y*-axis of the eyellipse than seat construction differences.

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