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Development of an Improved Driver Eye Position Model

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ABSTRACT

SAE Recommended Practice J941 describes the eyellipse, a statistical representation of driver eye locations, that is used to facilitate design decisions regarding vehicle interiors, including the display locations, mirror placement, and headspace requirements. Eye-position data collected recently at University of Michigan Transportation Research Institute (UMTRI) suggest that the SAE J941 practice could be improved. SAE J941 currently uses the SgRP location, seat-track travel (L23), and design seatback angle (L40) as inputs to the eyellipse model. However, UMTRI data show that the characteristics of empirical eyellipses can be predicted more accurately using seat height, steering-wheel position, and seat-track rise. A series of UMTRI studies collected eye-location data from groups of 50 to 120 drivers with statures spanning over 97 percent of the U.S. population. Data were collected in thirty-three vehicles that represent a wide range of vehicle geometry. Significant and consistent differences were observed between eye-position data collected before and after driving, indicating that actual driving is important protocol feature for accurate measurement of driver eye position. In six vehicles, eyellipses obtained with two-way and six-way seat-track travel were only slightly different. Comparisons between mean preferred and design seatback angles show that design seatback angle does not accurately predict mean driver-selected seatback angle. On average, drivers select seatback angles that are about 1.6 degrees more upright than design. Stepwise regression techniques were used to identify the vehicle variables that have important effects on the distribution of driver eye locations.

INTRODUCTION

The expected range of locations of drivers' eyes is critical information used to design the interior of vehicles to accommodate vision requirements. Mean expected eye location is also used to anchor the headroom curves that define the headspace envelope required for typical driving conditions (SAE J1052). SAE J941 provides formulae to calculate the position and orientation of different percentile eyellipses given the vehicle seating reference point (SgRP), seat-track length (L23), and design seatback angle (L40). The resulting ellipsoids represent driver eye locations in the driver workspace(1).* Separate predictions are available for the right and left eyes and for the cyclopean eye, a reference point at the midpoint of the line segment connecting the right and left eyes.

SAE J941 is based on several studies of driver eye position and interpretation of the data for automotive design. The bulk of the data for the passenger-car condition were collected in a study described by Meldrum (2), in which 2300 drivers were tested in three convertibles (about 775 subjects per vehicle) with fixed seatback angles under static conditions to determine driver eye position and construct percentile eyellipses. Subsequent work (3, 4) expanded on the available data to include vehicles with seatback angle adjustment, driver head turn, definitions of the visual field, and methods to implement the eyellipse in automotive design practices.

Recent studies of automotive driver posture and driver-preferred seat position and seatback angle have raised several potential concerns about the use of design seatback angle (L40) as an input to the SAE J941 eyellipse. Typical automotive design practice leaves the selection of design seatback angle to the discretion of the designer. Most design seatback angles are between 20 to 27 degrees, as measured with the J826 manikin, and are typically selected to have an inverse relationship with seat height. Previous studies of driver-preferred seat position and seatback angle have shown that mean preferred seatback angles are generally two to four degrees more upright than design, and little relationship between preferred seatback angle and seat height has been found (5). Previous work at UMTRI has also shown only a weak relationship between manikin-measured seatback angle and driver torso orientation (6), and only small effects of vehicle geometry, including seat height, on driver torso posture (7). These findings suggest that

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* Numbers in parentheses designate references at the end of the paper.

design seatback angle is not a good predictor of driver eye position in vehicles with adjustable seatback recline.

In previous UMTRI studies of driver position and posture, statistically significant differences between the parameters of the observed eyellipses and those predicted by SAE J941 were observed (5). A typical result is shown in Figure 1, which compares the SAE-predicted eyellipse and the observed eyellipse for a 1987 Chevrolet Camaro. The empirical eyellipse has a centroid that is positioned more rearward and higher than the SAE-predicted centroid, a longer X-axis, and shorter Y and Z axes. These differences could be attributed to changes in vehicle features since the early 1970s, including increased range and type of seat adjustments, firmer and more contoured seats, and increased seat-track travel. The differences between J941-predicted and observed eyellipses could also originate in the differences in test conditions between the two investigations. Meldrum tested parked convertibles while the UMTRI studies collected data after on-road driving in vehicles with roofs.

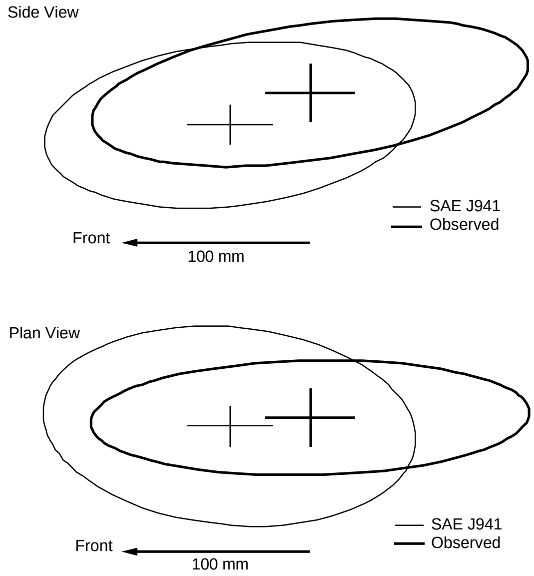

Figure 1. Side- and plan-view comparison of observed and J941 eyellipses for 1987 Chevrolet Camaro.

The consistent differences observed between J941 and experimental eyellipses generated interest in further study of driver eye position in late-model vehicles. The current investigation was initiated to:

1. compile previous data and collect additional data to create a comprehensive eye-position database that includes vehicles equipped with six-way seat-track travel (adjustable height, angle, and fore-aft position),
2. compare design and driver-selected seatback angles,
3. quantify the differences between eye-position data collected under static and dynamic driving conditions,
4. determine the effects of increased seat-track adjustability (six-way vs. two-way) on driver eye positions,
5. determine if the new eye-position database supports the need for changes to SAE J941,
6. identify the vehicle variables that significantly affect driver eye positions, and
7. suggest the form of a new eye position model.

To address these goals, driver eye-position data were collected for 60 to 120 subjects in sixteen vehicles, to increase the UMTRI database to include eye-position data collected in thirty-three vehicles. Experimental eyellipses were calculated for all vehicles and compared to those predicted by J941. Analysis of the empirical eyellipses provides an improved eye-position model that predicts the three-dimensional eyellipse centroid location, three eyellipse axis lengths, and two eyellipse offset angles, given the vehicle seat height, seat-track rise and steering wheel location relative to Ball of Foot (BOF), a pedal reference point defined in SAE J1516 (8).

METHODS

TEST CONDITIONS – Driver eye positions were measured in the thirty-three vehicles listed in Table 1, along with vehicle package dimensions of interest. In thirty of the vehicles, eye-position data were collected immediately after subjects had driven. For three vehicles, including the Econoline, Firebird and Taurus L, subjects had previously driven the vehicles but the eye-position data were collected in a laboratory buck study in which the subject-selected seat position and seatback recline angles from dynamic testing were established in a seating buck.

SUBJECT POPULATIONS* – Due to the duration of the eye-position test sessions and the importance of the data from the anthropometric extremes of the population, representative sampling was rejected in favor of a stratified sampling strategy was used whereby short and tall drivers are oversampled relative to their representation in the driving population. The resulting eye-position data can be weighted to represent many different population stature distributions (e.g., U.S., Asian, European) and/or different gender mixes of a defined target population, with assurance that an adequate number of subjects are available to define the extreme percentiles.

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* The rights, welfare, and informed consent of the volunteer subjects who participated in this study were observed under guidelines established by the U.S. Department of Health, Education, and Welfare (now Health and Human Services) on Protection of Human Subjects and accomplished under medical research design protocol standards approved by the Committee to Review Grants for Clinical Research and Investigation Involving Human Beings, Medical School, The University of Michigan.

Subjects were selected to fill twelve gender/stature groups described in Table 2. These groups include subjects who are shorter than the 5th-percentile U.S. female and taller than the 95th-percentile U.S. male based on the 1974 HANES survey data (9). An effort was made to select subjects so that weight, body proportion, and age spanned a wide range. Previous analyses have shown that this sampling strategy is effective in obtaining adequate ranges of these secondary anthropometric variables.

Table 1. Test Vehicle Summary

Vehicle	Seat Height: H30 (mm)	Seat Cushion Angle: L23 (degrees)	Horizontal Wheel-to-BOF (mm)	Design Seatback Angle: L40 (degrees)	Seat-track Adjuster Type	Seat-track Rise (degrees)	Seat-track Length (mm)
Firebird†	154	15.5	650	27	2-way	6.5	180
TransAm†*	165	14.0	623	24	2-way	8.7	256
Camaro*	177	13.0	616	26	2-way	11.5	293
Avenger 2	189	16.6	577	24	2-way	5.5	230
Avenger 6	189	adjustable	577	24	6-way	5.5	230
Laser 2*	197	11.3	550	25	2-way	5.0	180
Laser 6*	197	adjustable	550	25	6-way	5.0	180
Neon†	212	22.5	565	24	2-way	8.6	210
Probe	216	adjustable	576	24	6-way	4.7	232
Acclaim 2 *	220	17.7	559	24	2-way	9.0	188
Acclaim 6*	220	adjustable	559	24	6-way	9.0	188
Monte Carlo*	231	11.0	597	27	2-way	8.0	262
Mazda 626†	234	18.0	561	25	2-way	5.1	232
Cadillac DeVille*	240	8.0	590	26	2-way	9.0	262
Grand Prix	250	12.0	623	24	2-way	8.0	282
LHS 2	250	17.7	597	24	2-way	8.2	221
LHS 6	250	adjustable	597	24	6-way	8.2	221
Grand Prix*	254	adjustable	610	24	6-way	7.9	279
Taurus SHO†	257	12.0	557	24	2-way	7.0	184
Pontiac 6000*	266	16.0	583	26	2-way	7.5	196
Acclaim 0*	278	9.0	555	24	2-way	0.0	188
Blazer*	288	7.5	591	23	2-way	11.1	231
Grand Cherokee 2	298	11.3	607	24	2-way	9.4	192
Dakota Pickup†	298	12.0	600	22	2-way	2.9	135
Grand Cherokee 6	298	adjustable	607	24	6-way	9.4	192
CK Pickup Truck*	303	12.5	570	21	2-way	5.7	310
Voyager 2	326	14.0	504	22	2-way	7.6	190
Voyager 6	326	adjustable	504	22	6-way	7.6	190
Cherokee Sport	333	adjustable	589	24	6-way	9.9	189
RAM†	346	13.0	512	20	2-way	5.8	189
Windstar	349	adjustable	504	26	6-way	3.3	181
APV*	381	12.0	518	24	2-way	0.0	300
Econoline†	420	9.5	447	21	2-way	4.5	130

* indicates vehicles that were modified from design to meet specific criteria of the studies.
All package dimensions were measured directly from the vehicle to assure accuracy.
† denotes manual-transmission vehicles

TEST PROTOCOL – The same general procedure was used for all testing, although the eye-position data were collected in six separate studies. Each subject completed a consent form, health questionnaire, and survey asking about their current vehicle and driving habits and a set of twenty standard anthropometric measures were taken. In each test session subjects were tested in 2 to 6 vehicles and the vehicles were tested in random sequence. The initial positions of the seat, seatback, and steering wheel prior to testing in each vehicle were the same for every subject. The subject was instructed on the operation of the seat, seatback, and steering wheel adjustments and was asked to experiment extensively with the adjustments while driving over a 10- to 20-minute road route. During the drive the subject was asked to find the most comfortable driving position and to note the posture of his/her head in straight-ahead driving. Immediately after returning from the drive, driver eye position was measured while the subject maintained a relaxed, normal driving position. While remaining in the vehicle, s/he rated the position of the primary controls and selected seat parameters using a standardized questionnaire.

Table 2. Subject Groups

Group	Gender	Percentile Stature Range by Gender (9)	Stature Range (mm)
0	Female	< 5th	under 1511
1	Female	5-15	1511 - 1549
2	Female	15-40	1549 - 1595
3	Female	40-60	1595 - 1638
4	Female	60-85	1638 - 1681
5	Female	85-95	1681 - 1722
6	Male	5-15	1636 - 1679
7	Male	15-40	1679 - 1727
8	Male	40-60	1727 - 1775
9	Male	60-85	1775 - 1826
10	Male	85-95	1826 - 1869
11	Male	> 95th	over 1869

METHODS FOR MEASURING EYE POSITION

Stereophotogrammetry – Three-dimensional eye locations in fourteen of the vehicles were collected immediately after the subject's return from the drive using two-camera stereophotogrammetry. Direct Linear Transformation (DLT) techniques (10) were used to calibrate eye space inside the vehicle using a set of high-contrast targets, whose locations were precisely known. The targets were attached to the exterior of each vehicle surrounding the driver seating space. A pseudo-eye target of known location was established inside the vehicle and used to confirm the accuracy of the stereophotogrammetric measurements.

To collect eye position data, two cameras were positioned about 70 degrees apart in the parking lot so that all the calibration targets on each vehicle and the left eye of each test subject were visible from both cameras. The cameras were triggered simultaneously to collect a front and side-view image of the driver. The resulting slide film was processed, cut, and mounted between two glass plates. Each pair of images was projected on a tablet digitizer and the position of the calibration targets and the left eye of each subject were manually recorded using a PC equipped with software for processing the 2-D image coordinates into vehicle X, Y, Z coordinates. Location data from the pseudo-eye targets were processed for each subject in each vehicle as a check on the accuracy and consistency of the data-acquisition and processing protocol. This method locates the driver eye within 4 mm of its actual position.

Sonic Digitizer – A Science Accessories Corporation, Inc. sonic digitizer was used to measure eye position in three vehicles whose package geometry was simulated in a laboratory seating buck. The sonic digitizing system uses a fixed array of four microphones to detect the three-dimensional locations of sonic emitters within 2 mm. A sonic probe, with two emitters is placed on a palpated body landmark and the emitters are fired in rapid sequence. The three-dimensional coordinates of the probe tip are calculated from the measured locations of the probe emitters. For each trial, the subject's corner of eye, infraorbitale landmark and glabella were digitized and the location of the pupil was calculated using measured inter-eye anthropometric data.

FARO Arm – A portable, articulated arm for coordinate measurement, manufactured by FARO Technologies, Inc., was used to measure eye position in sixteen vehicles. The FARO arm is a three-link mechanical pointing device instrumented at each of six joints with rotary transducers. The joint angles and the lengths of the three articulated links are used to calculate the position of the probe tip.

To measure subjects' eye positions, the FARO arm, attached to a rolling platform, was positioned next to the vehicle immediately after the subjects returned from the drive and braced rigidly against the vehicle body. Subjects were asked to maintain their driving posture while the FARO arm apparatus was aligned to the data-collection coordinate system by digitizing three reference points on the vehicle body. The FARO arm was then used to record the driver's corner of eye, infraorbitale and glabella locations, followed by seventeen other subject and vehicle landmarks. The digitization was completed in approximately thirty seconds. The FARO arm accuracy under the data collection conditions was determined to be ± 2 mm.

RESULTS

PRE-DRIVE VERSUS POST-DRIVE EYE POSITION – In six of the vehicles, eye position was measured both before and after the subjects drove to determine the effects of driving on eye position. Table 3 lists the p-values resulting from paired t-tests of pre- and post-drive eye position in six test conditions. In every vehicle there is a significant difference between pre- and post-drive eye positions, particularly for eye height. Subjects' eyes are an average of 9 mm lower after the drive. The average differences in the X and Y directions are smaller and not always significant, but the eyes tend to be further rearward and further inboard after the drive.

Table 3. Comparison of Pre- and Post-Drive Eye Positions (Post- minus Pre-Drive) (mm)

		X		Y		Z	
Vehicle	**Seat-track Condition**	***p*-value**	**mean diff.**	***p*-value**	**mean diff.**	***p*-value**	**mean diff.**
Acclaim	2-way	0.0589	3.6	0.0003	4.2	0.0000	-8.8
Acclaim	6-way	0.0402	4.4	0.0000	6.0	0.0000	-8.4
LHS	2-way	0.0006	6.9	0.0000	5.3	0.0000	-9.7
LHS	6-way	0.0060	5.2	0.0000	5.6	0.0000	-8.4
Voyager	2-way	0.0426	4.2	0.0430	2.2	0.0000	-9.2
Voyager	6-way	0.0927	3.4	0.5819	0.7	0.0000	-10.2

DESIGN SEATBACK ANGLE VERSUS MEAN PREFERRED SEATBACK ANGLE – Subject-selected seatback angle was recorded after the drive and compared to the design seatback angle for each vehicle. In Figure 2, symbols below the diagonal line indicate vehicles in which the mean selected seatback angles are more upright than design. In twenty-eight of thirty-three vehicles, the mean preferred seatback angle is more upright than the design seatback angle. The average observed difference is 1.6 degrees and the average absolute error is 2.0 degrees.

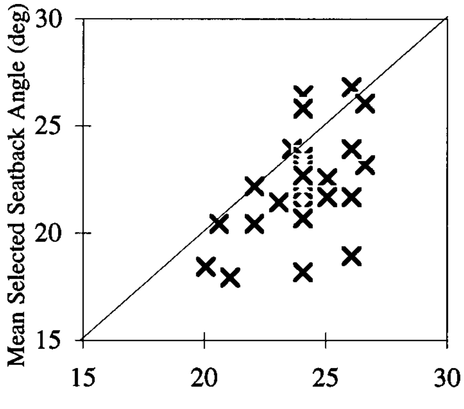

Figure 2. Design seatback angle versus mean selected seatback angle.

SAE J941 VERSUS EXPERIMENTAL EYELLIPSES – The eye-position data collected for one eye were converted to cyclopean eye using anthropometric data from each subject. The data were weighted according to the fraction of the U.S. population represented by each subject group. The weighted data were used to compute cyclopean side- and plan-view eyellipses following the procedures given by Hammond and Roe (3). The X-,Y-, and Z-coordinates of the centroid of the eyellipses are expressed relative to BOF, seat centerline, and Accelerator Heel Point (AHP).

Table 4 summarizes the observed differences. Every parameter of the empirical eyellipse is significantly different from the corresponding SAE J941 parameter (paired *t*-tests, $p<0.01$). In general, observed eyellipse centroids are rearward and above J941 predictions. Also, the observed X and Z axes are longer and the Y-axis is shorter than J941. In addition, the side-view angle is steeper and the plan-view angle is shallower. The mean differences are illustrated in Figure 3.

Table 4. Average Parameter Values for Empirical and SAE J941 95th %ile Eyellipses

		Eyellipse		
Parameter	**Coordinate** or view	**SAE**	**Empirical**	**Difference**
Centroid	X	914	934	20
(mm from	Y	0	7	7
BOF/SCL/AHP)	Z	892	902	10
Axis length	X	199	212	13
(mm)	Y	105	59	-46
	Z	86	100	14
Angle of offset	Side	6.4	9.3	2.9
(deg)	Plan	-5.4	0.3	5.7

EFFECT OF SIX-WAY VS. TWO-WAY SEAT ADJUSTMENT ON DRIVER EYE POSITION – Six of the vehicles were tested both as two-way and six-way seat-track vehicles and the resulting data afford a direct comparison while minimizing the possible effects of other variables. Table 5 shows the differences in the eyellipse parameters between the six-way and two-way seat-track conditions. In general, the differences are quite small and only one difference, less vertical variability of eye position with six-way seats, is common to all vehicles. Paired t-test analysis shows that both the Z-axis difference and the decrease in side-view angle inclination are significant with $p<0.01$.

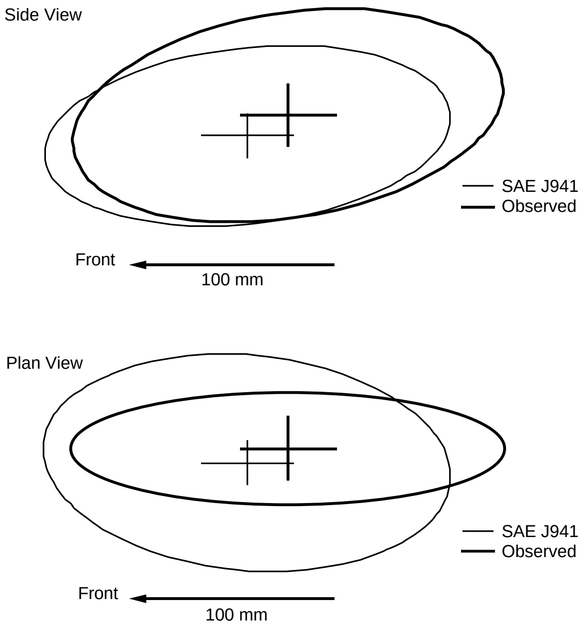

Figure 3. Side and plan-view comparison of mean observed and J941 eyellipses.

Table 5. Differences in Eyellipse Parameters due to Seat-track Adjustability (two-way seat-track minus six-way seat-track)

Vehicle	Eyellipse Centroid (mm)			Eyellipse Axes (mm)			Offset Angle (degrees)	
	X	Y	Z	X	Y	Z	Side	Plan
Avenger	-4	0	-8	9	6	4	3	0
Laser	-4	3	-11	-10	3	9	6	-2
Acclaim	-8	0	-6	-15	-5	3	5	0
LHS	1	2	-2	-1	-5	2	3	-2
Gd. Cherokee	-3	-1	6	-5	3	5	3	1
Voyager	0	-1	2	0	-4	6	0	-2
Mean	-3	0	-3	-4	0	5	3	-1

PREDICTING EYELLIPSE PARAMETERS – The consistent differences between the SAE J941 and empirical eyellipses indicate that further analysis with regard to the relationship between vehicle dimensions and eyellipse parameters is warranted. Eight stepwise regressions were performed, one for each of the eyellipse parameters (three centroid coordinates, three axis lengths, and two angles of inclination). The centroid coordinates were expressed relative to package reference points (BOF in the X direction, AHP in the Z direction, and seat centerline in the Y direction). Each eyellipse parameter was regressed on seat height (H30), steering-wheel-to-BOF distance, seat-cushion angle, seat-track rise, seat-track length, SgRP-to-BOF distance, and design seatback angle. Two different seat position predictions were included to determine if eye location could be best predicted with respect to seat position. The 50th-percentile seat position predicted by the new Seating Accommodation Model (11) and J1517 50th-percentile predicted seat position were included for each vehicle. Since J941 includes design seatback angle as an input variable, the mean subject-selected seatback angle was also used to determine if an accurate predictor of seatback angle would be useful in predicting eye location. Finally, two dummy variables were included, one for seat-track type (two- vs. six-way) and one for transmission type (auto vs. manual). Due to the preliminary nature of this model, only its general form is provided.

For each regression, the results of each step were inspected for improvement in prediction and mechanistic plausibility. For present purposes, there was a bias toward simpler equations and predictors with strong effects. As the model is honed in the future, it is possible that new components will be added.

The results of this analysis indicated that steering wheel position is the best predictor of X centroid location, accounting for over 90% of the variance. The Y-coordinate of the eyellipse centroid is best described by a constant, as in SAE J941. Also like J941, the Z-coordinate is a function of seat height (H30). The form of the three prediction equations are given below.

$$c_x = C_1 + C_2 w$$
$$c_y = C_3$$
$$c_z = C_4 + h$$

where, h = seat height (H30) in mm, and
w = fore/aft distance from steering wheel center to BOF in mm.

The regression analysis indicated that the X-and Y-axis lengths are not substantially related to any of the potential predictors and so are best described by constants. The Z-axis length, however, was related to seat-track rise, with steeper track rises associated with decreased vertical variability. The prediction equations for the axis lengths take the form:

$$l_x = C_5$$
$$l_y = C_6$$
$$l_z = C_7 - C_8 r$$

where, r = seat-track rise in degrees.

The ranges of angles of inclination in side and plan views are small and the angles are not strongly related to any vehicle variables. Thus side- and plan-view angles of inclination are best predicted by constants, based on these data.

$$a_{xz} = C_9$$
$$a_{xy} = C_{10}$$

DISCUSSION

For six vehicles, driver eye height was measured before and after the drive and a significant difference in eye height, ranging from 8-10 mm, was observed in all vehicles. These consistent differences between pre- and post-drive eye height show that the driving experience is important to the study of eye position. At the same time, very few differences were observed between pre- and post-drive seat fore/aft position and seatback angle. This suggests that the difference in eye height originates in a change in driver posture during the drive or a change in the amount of seat deflection due to increased load time for the seat cushion.

Data from six vehicles tested with both two-way and six-way seat-track travel provide for direct comparison of the effects of the additional seat adjustability on eye position. The differences in the eyellipse centroid parameters are small and suggest that the same eyellipse model is appropriate for vehicles equipped with two-way or six-way seat-track travel. However, six-way adjustability significantly decreased the vertical range of eye position and decreased side-view offset angle. These differences suggest that the added vertical adjustability allows drivers to deviate from the path of the nominal seat-track travel so that eye height is more consistent across statures.

Comparisons between the empirical and J941 eyellipses show large and consistent differences and suggest that J941 can be improved. Stepwise regressions demonstrate that the distribution of driver eye positions is influenced by seat height, steering-wheel-to-BOF distance and seat-track rise. Although it makes intuitive sense that the X-coordinate of the eyellipse centroid might be most strongly related to measures of driver-selected seat position, steering wheel position emerged as the best predictor. However, research at UMTRI has shown that wheel position is influential to both selected seat position (11) and driver-preferred torso posture (7) which are in turn hypothesized to be closely related to driver eye location.

As expected, the Z component of the centroid is related to seat height, with the centroid a fixed distance above SgRP. The Z-axis length, a measure of the vertical variability in eye locations, is lower in vehicles with higher seat track angles. One potential interpretation of this finding is that the steeper rise raises the eye position of shorter drivers who sit toward the front of the seat track, reducing the eye height difference between short and tall drivers. However, seat-track rise is not well-defined for six-way travel seats and may be undesirable as an eye position predictor.

Design seatback angle and seat-track length are inputs to the J941 eyellipse location procedure, but did not significantly influence eye position in the current study. Mean subject-selected seatback angles were, on average, 1.6 degrees more upright than design seatback angles. Subject-selected seatback angle was explored as a potential input to the eye location model, under the assumption that a mechanistic relationship might exist between seatback angle and eye location. However, no significant relationship was found, suggesting that seatback angle should not be used as a predictor of driver eye location when the driver is provided with an adjustable seatback angle.

SAE J941 provides for two ranges of seat-track length, 100 to 133 mm and over 133 mm. The range of seat-track lengths in the sample was 130 to 411 mm, with all but two vehicles over 180 mm. A seat track length of 170-230 mm is typical in most late-model passenger cars. If more vehicles with restricted track length were included in the study, censoring of seat and eye position would likely result in decreased X-axis length and increased Z-axis length, but testing for these conditions would only be warranted if reduced track lengths were likely to become more prevalent.

The work described in this paper will be expanded and used to suggest improvements to SAE J941. In the future, topics such as Class B vehicles and reference points for the J1052 headroom curves will be addressed. Methods for generating eyellipses for populations with different gender mixes and different anthropometry will be considered.

SUMMARY AND CONCLUSIONS

Previous studies of driver position conducted at UMTRI have found substantial differences between SAE J941-predicted and empirical eyellipses in late-model vehicles. The current investigation combined existing data for seventeen vehicles with newly-collected data for sixteen vehicles to provide an extensive database to study driver eye position. Analysis of these data support the following conclusions:

1. Manufacturer-designated design seatback angles are, on average, 1.6 degrees more reclined than mean subject-selected seatback angles.
2. Eye position collected after subjects drove over a road route was consistently lower than that measured before the drive.
3. Increased seat-track adjustability (i.e., six-way power seats) have little effect on the eyellipse location, size or orientation. A small, though significant, trend for decreased vertical variability and side-view offset angle was associated with the presence of six-way power seats.
4. Large and consistent differences were found between SAE J941-predicted and empirical eyellipses.

5. Stepwise regression techniques show that the distribution of driver eye positions is significantly influenced by seat height, wheel position, and seat-track rise.

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