Front-Seat Passenger Head Locations Based on Naturalistic and Laboratory Data

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I. INTRODUCTION

Although the distribution of driver head locations has been extensively studied and documented in vehicle design practices, front-seat passenger head locations in naturalistic conditions have not been studied extensively. This paper combines data from two sources to estimate the distribution of front-seat passenger head locations relative to the seat track. The results are compared to the nominal head location in the middle seat track position that is used in most occupant protection evaluations for that seating position.

II. METHODS

As part of a naturalistic study of front-seat passenger behaviour, posture and seat adjustments, video cameras were installed in the cabins of the personally owned vehicles of 75 drivers recruited in Ann Arbor, Michigan, USA [1]. The front passenger seats were measured and marked with reflective targets that could be tracked in the video frames. Figure 1 shows the distribution of fore-aft seat position in 13,638 video frames from 2,733 trips by 306 unique front-seat passengers. About 20% of the time, the seat was full-rear on the track, and 50% the time it was within the rear quarter of the seat track. The mean seat-back angle was 25.4 degrees (standard deviation 6.4 degrees). No relationships were observed between occupant characteristics and either seat position or seat-back angle. These results allow the assumption for the current analysis that the distribution of passenger sex and stature are the same at all seat positions and seat back angles.

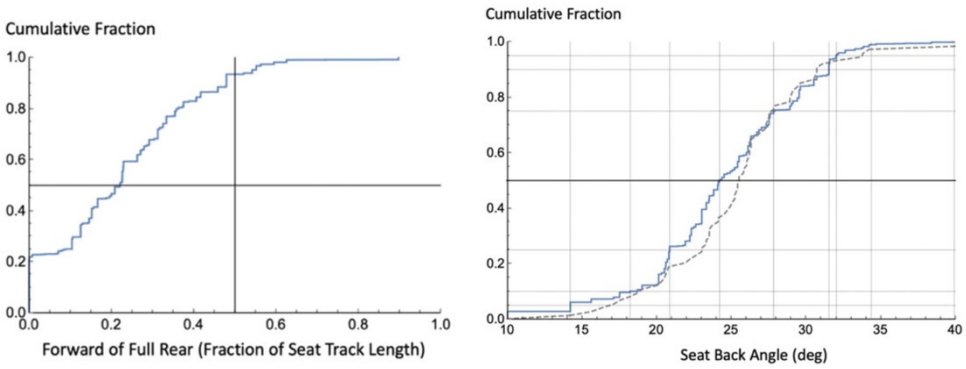

Fig. 1. Distribution of fore-aft seat position (left) and seat-back angles (right). Left plot shows the cumulative percentage of seat positions relative to full-rear. Seat-back angle (right) is referenced to the SAE J826 torso angle measured at 23 degrees. The dashed line shows the initial seat position at the start of the two-week data collection interval and the solid line shows data from the video analysis (13.6 k frames).

The single-camera video data from the naturalistic study were not sufficient to obtain accurate measurements of head location, so data from a laboratory study of passenger posture were used to estimate head CG location [2]. In the lab study, the postures of 61 men and women with a wide range of body sizes were measured in a mockup at seat-back angles (SAE A40) of 18, 23 and 27 degrees. Regression models were created to estimate head CG X (horizontal) and Z (vertical) location with respect to the seat H-point as a function of stature and seat-back angle. Sex was not a significant predictor after accounting for stature, and the head CG X and Z values were uncorrelated at each seat-back angle. Using methods described in [3], a single bivariate normal distribution was computed to approximate the head CG locations for a population that is 62% female, which matches the expected sex distribution in the front passenger seat [4]. The population distribution of head CG locations for a single seat-back angle was well represented on each axis by a normal distribution with a standard deviation of 46 mm.

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To obtain an estimate of the population distribution of head locations, the seat position and seat-back angle data were combined numerically with the statistical model head CG location. The seat track was assumed to be 250 mm long and angled at six degrees with respect to horizontal. A virtual population of 750 seat positions and seat-back angles was obtained by sampling from the distributions shown in Fig. 1. For each of these, the bivariate distribution of side-view head CG locations was estimated. These combined simulated distributions were then sampled on a uniform grid at 10 mm increments.

III. INITIAL FINDINGS

Figure 2 shows the resulting distribution along with the weighted mean. To compare with a typical ATD head location, the mean predicted head location for a midsize male in the middle seat track position with a seat-back angle of 25 degrees was added to the plot. Approximately 75% of the population head CGs lie rear of the nominal midsize-male, mid-track head location, and 64% are below. The plot also shows the predicted head location for a small-female ATD seated full-forward on the seat track. More than 95% of population head locations lie rearward of this point.

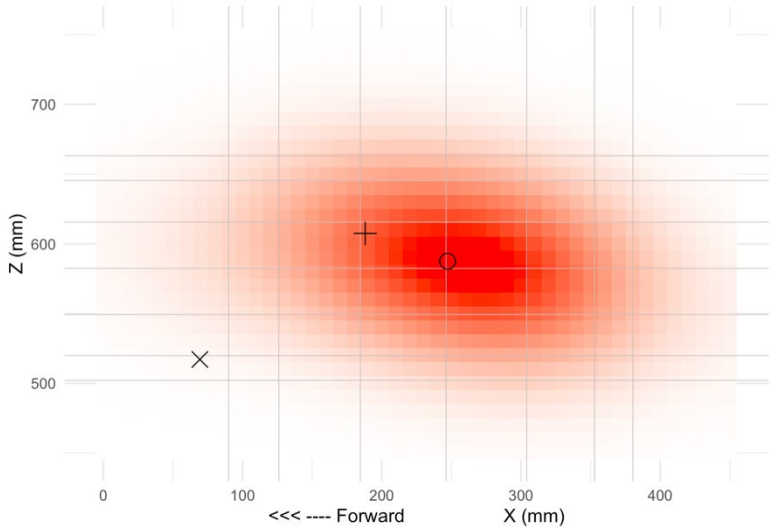

Fig. 2. Density plot of passenger head CG locations relative to the seat H-point location with the seat at the front of the seat track. o = population mean; + = midsize-male at mid-track at 25 degrees; x = small female at full-forward seat position (see text). Horizontal and vertical lines show 0.05, 0.1, 0.25, 0.5, 0.75, 0.9 and 0.95 quantiles on each axis.

IV. DISCUSSION

This method provides quantitative estimates of the distribution of passenger head locations based on naturalistic data on seat position and seat-back angle, as well as the effects of body size (stature) on posture. The central 90% of head CG locations extend from about 90 mm aft of the middle of the seat track to about 380 mm rearward, a span of 290 mm. Similarly, the central 90% of vertical positions extend over a 160 mm range.

This statistical analysis does not incorporate data from non-nominal postures, and the presence of child passengers is also not considered. Movements due to pre-crash manoeuvres can be expected to expand the range of pre-crash head locations. Although this analysis looked only at head CG location, other key body regions for occupant restraint, such as the knees, are also substantially rearward on average relative to the midsize-male ATD seated in the middle seat track position. The full-forward position used with the small-female ATD is shown to be extreme with respect to the population of head locations and is not representative of female head locations in general. Research is needed to determine the extent to which crash safety is affected by the range of head locations estimated in this study.

V. REFERENCES

[1] Reed, *et al*., *Traffic Inj Prev*, 2020.
[2] Park, *et al*., *Ergonomics*, 2015.
[3] Reed, *SAE International*, 2011.
[4] Klinich, *et al*., *Traffic Inj Prev*, 2021.