Vision Mechanisms in Curve Negotiation

[1]Ardusso, E., [1]*Karimi, A., Portera, A. & [1]Bassani, M.
*lead presenter
[1]arastoo.karimi@polito.it, Politecnico di Torino, Italy

Introduction. Approximately 90% of the stimuli a driver processes to control, steer and navigate a vehicle derive from visual cues. When negotiating horizontal curves, reliance on vision is even more critical because of the need to determine how much and when to rotate the steering wheel so that the vehicle can proceed along a curved trajectory that follows that of the road as much as possible. The visual information gained from observing the elements that indicate the direction of the road then suggests what adjustments to the vehicle's trajectory and speed should be made.

Previous research has identified several strategies that drivers use to assess road curvature and adjust the steering angle accordingly. The best documented mechanisms include: (i) the *tangent point* (TP), where the driver's gaze aligns with the point of maximum curvature on the inner marking; (ii) the *future path* (FP), in which drivers focus on points along their intended driving path, whether in distant or nearby areas; (iii) the *occlusion point* (OP), in which drivers direct their gaze to the farthest visible point past side obstacles to anticipate hidden hazards; and (iv) the *fixed point* (FXP), where drivers may focus on static roadside objects like delineators or landmarks. They assess curvature by monitoring how the angle between their line of sight and the vehicle's instantaneous direction changes over time, before shifting their focus to subsequent features. This study aimed to determine (i) the vision mechanisms predominantly employed by drivers and (ii) the specific road space elements that activate these mechanisms during curve negotiation, while taking driver characteristics into account.

Methodology. Using a two-level factorial design, this study included four blocks and one centre point per block. The factors considered were: (i) *curve radius* (100 and 600 m); (ii) *sight obstruction*, specifically the lateral distance from the shoulder (0.6 and 15 m); (iii) *curve direction* (right and left); (iv) *presence of road markings* (yes, no); and (v) *presence of delineators* (yes, no). Each block consisted of 16 combinations of these factors, representing 16 different curves. Four two-lane roads were designed, each with 16 curves separated by 400 m long straights, with the order of the curves randomized. The two-lane road featured a lane width of 3.75 m and shoulder width of 1.50 m. Each participant drove on one road (i.e. one block); therefore, with eight replications of this experimental design, 32 participants (aged between 19 and 59 years, 16 of whom were female) were recruited. However, the results of two drivers had to be discarded. The experiment was conducted at the RSDS lab at the Politecnico di Torino, using a behaviourally validated fixed-base driving simulator from *AVSimulation* and a head-mounted eye-tracker from *Pupil Labs*.

Results. By evaluating the heatmaps of fixations, the primary mechanism that a driver used to negotiate each curve was determined. Figure 1 shows the four (i.e., TP, FP, OP, and FXP) vision mechanisms. To determine which variable(s) had the greatest influence over the driver's choice of vision mechanism, both multinomial logit regression and random-effects multinomial logit regression were estimated. However, the Likelihood-Ratio test suggests that both models are equivalent at the 95% confidence level. The results indicated that curve radius, curve direction, presence of road markings, presence of delineators, age, and gender significantly influenced the driver's choice of vision mechanism at the 95% confidence level. In contrast, lateral sight obstructions did not show a significant effect at the same confidence level.

Discussion and conclusions. Table 1 shows that the most common vision mechanism was FP, with a significantly higher probability than others. TP and FP were more likely to be used on right-hand curves, while FXP and OP were more likely on left-hand curves. The use of TP increased with the presence of road markings, whereas other mechanisms were more active in their absence. Without delineators, FXP was almost inactive due to the lack of objects on which drivers could focus their gaze, but delineators proved helpful in curve negotiation.

An increase in the radius resulted in a slight decrease in the probability of using FP and a corresponding increase in the reliance on OP. However, TP was used more actively on curves with a larger radius, while FXP experienced a significant decrease in use. This study found driver's choice of mechanism to be highly dependent on their characteristics, with the probability of using various mechanisms varying and showing different trends for males and females depending on their age. Understanding driver's vision mechanisms and the road features that activate them can enhance safety. Safety improvements can be achieved through specific engineering and maintenance practices, with particular emphasis on horizontal road marking and edge delineators.

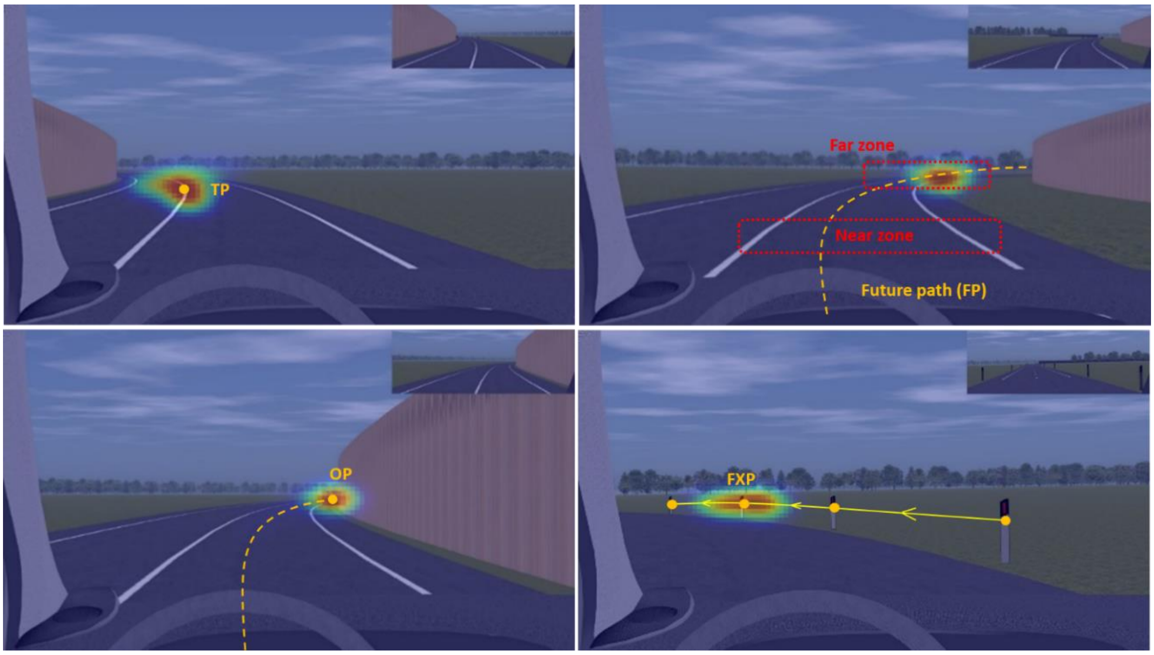

Figure 1: TP (left-top), FP (right-top), OP (left-bottom), FXP (right-bottom) and corresponding heatmap

Table 1: Average predicted probability (%) with respect to each variable

Vision mechanism	Curve direction		Presence of road markings		Presence of delineators	
	left	right	yes	no	yes	no
TP	10.85	20.26	22.79	8.31	13.96	17.17
FP	65.44	72.89	66.15	72.11	67.59	70.96
FXP	9.41	4.31	3.91	9.92	13.50	0.00
OP	14.31	2.54	7.14	9.66	4.95	11.87