Global strategies in the negotiation of a triple bend at high speed: Analysis of gaze patterns

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INTRODUCTION

Cues or optic flow?
Local or global structures?

Traditionally, the visual control of driving has been explained in terms of the perception of local structures of the environment such as visual cues to road geometry (see Figure 1) and the driver's eye movement has been assumed to indicate the use of these cues (Shinar, 1978).

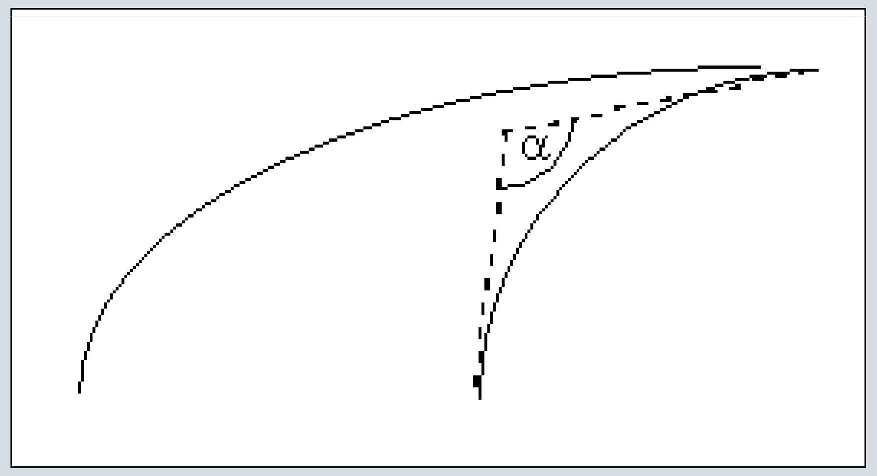


Figure 1. An example for a geometric cue (α) to road curvature

Gibson (1979) challenged this approach by proposing that the visual control of locomotion is based on invariant information detected from global transformation of the optic array (optic flow) (i.e., the centre and rate of optic expansion, see Figure 2). But he did not believe that eye movements play an important role in detecting optic flow properties.

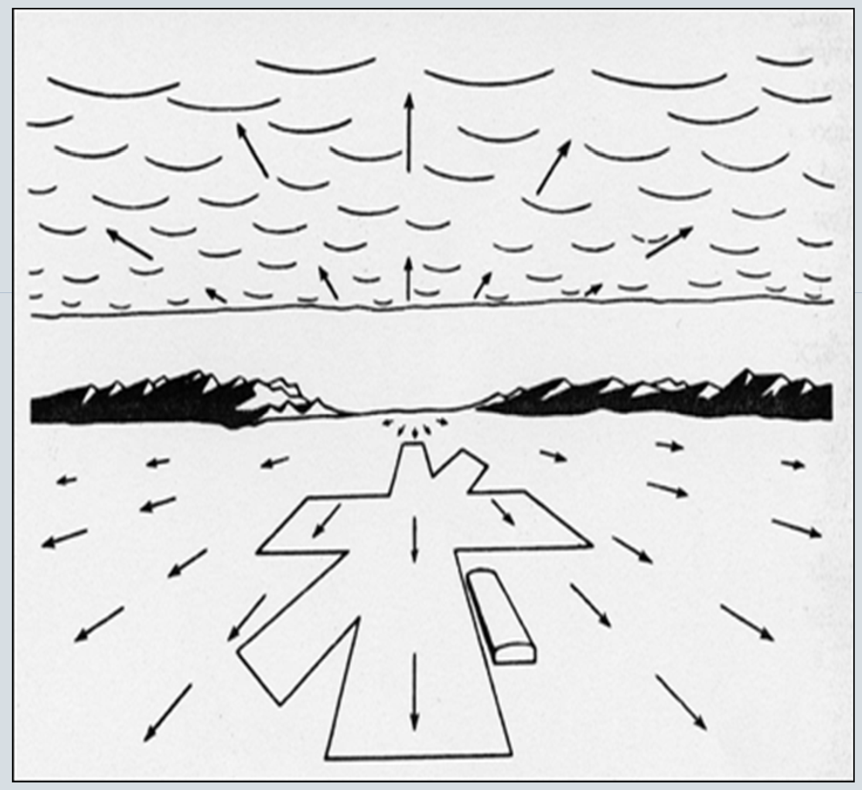


Figure 2. The outflow of the optic array in a landing glide.

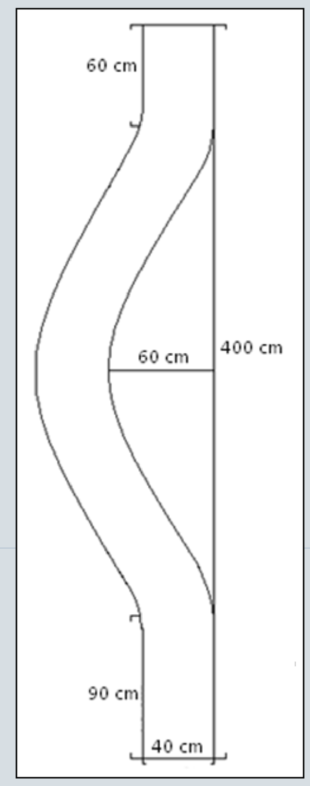
Recently, Rogers, Kadar, and Costall (2005a,b) have shown that driver's gaze is associated with the detection of optic flow properties. Specifically, in high-speed driving, the preferred gaze direction is coincident with the direction of heading (to detect global flow properties) and other gaze directions could be informative about the use of local flow properties (e.g., target setting for direction of steering and speed control to avoid collision with a specific surface area)

THE AIM OF THE STUDY

The present study investigated gaze control in a complex driving task: Learning to drive through a triple bend. Based on Rogers et al.'s (2005) study, it was predicted that the driver's gaze direction should show an increasing dependence upon global flow structures in the course of learning, along with a corresponding decrease in the use of local structures.

METHOD

Six participants (age range 21-26) were tested in driving a remote-controlled toy car through a triple bend. Each one drove through the track 30 times (Figure 3). Gaze patterns were measured and successful trials from trials 7-15 (Session 1) and 22-30 (Session 2) were selected for analyses. Visual control was based on a monitor displaying the driver's view (see Figure 4).



(a)

(b)

Figure 3. Schematic drawing of the driving track of the experiment (a) and the front view of the track with the car moving in the second bend (b).

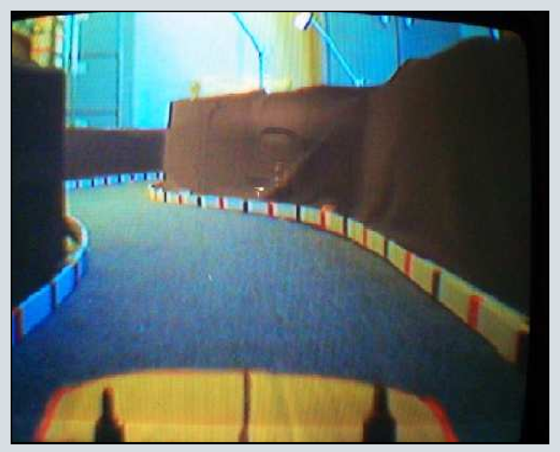


Figure 4 (a) Driving scene as viewed from the camera mounted on the car while driving in the track.

Figure 4 (b) The driver is sitting in front of a 20 inch monitor with the head mounted eye-tracking system.

RESULTS

Gaze data were analyzed using a car-centred coordinate system, and then measuring gaze duration on 3 areas of the barriers (3 tangent points and 3 barriers on the opposite side of the tangent points) and the road surface.

Figure 5 demonstrates changes in horizontal gaze directions in four sample trials.

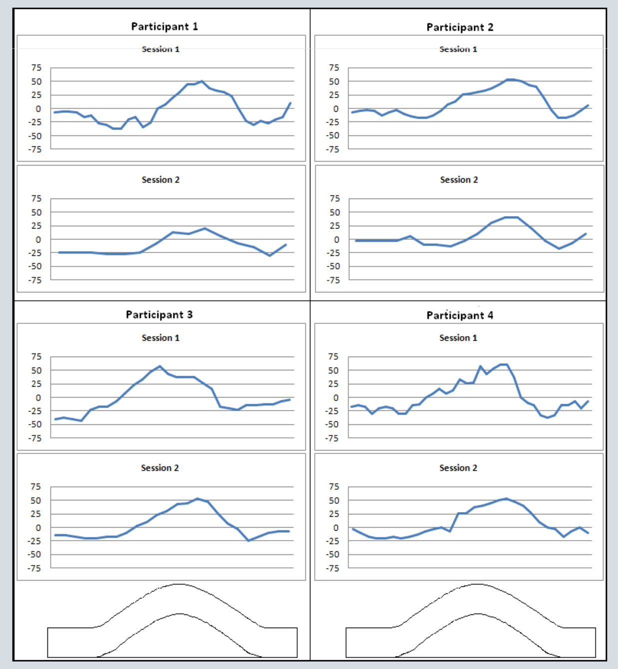


Figure 5. Sample trials with horizontal gaze directions as participants drove through the track (Participants 1-4). The vertical axis (y) displays the visual angle and the horizontal axis is scaled to the track as depicted in the bottom figures.

Average trial duration of the successful trials shows that performance was improved in Session 2. Trial duration was shorter (speed increased) in the second session as a result of learning (see Figure 6).

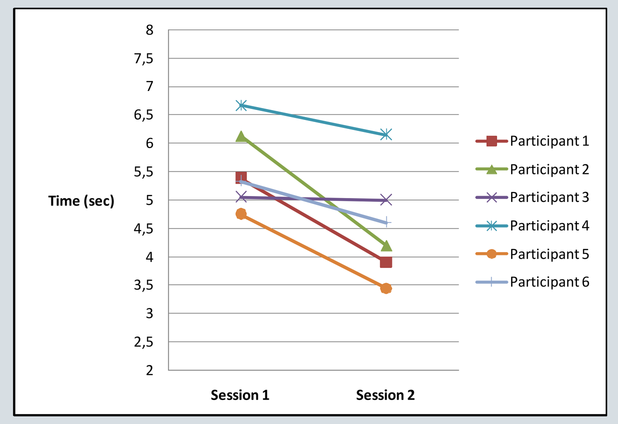


Figure 6. Average trial duration of the successful trials for each participant in the two sessions of learning.

Average values of the absolute horizontal gaze co-ordinates (|x|) show that drivers' gaze became more constrained as evidenced by reduced horizontal eye-movements (see Figure 7).

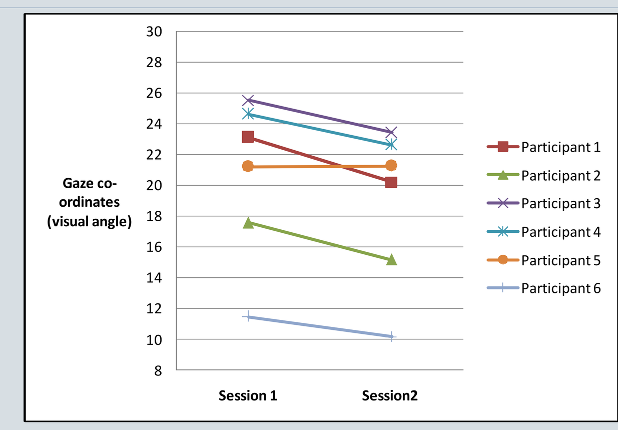


Figure 7. Average gaze |x| co-ordinates for each participant in the two sessions.

Average values of the vertical gaze co-ordinates (y) indicate that drivers tended to look further ahead of the car as a result of learning (see Figure 8).

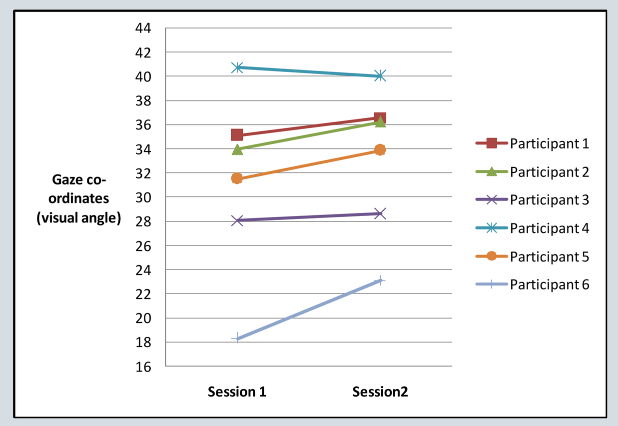


Figure 8. Average gaze y co-ordinates for each participant in the two sessions.

Due to the individual differences, normalization was used on the pool data in order to assess learning. For all three variables, *t*-tests show significant differences between the two sessions:

Trial durations: t (78)=5.210, $p < .01$
Horizontal gaze distribution: t (78)=4.001, $p < .01$
Vertical gaze distribution: t (78)=3.497, $p < .01$

Table 1 shows that drivers predominantly looked at the road surface in both sessions suggesting the use of global optic flow (global structure).

Table 1. Gaze distribution of average % gaze durations and their relative hange between the two sessions.

	Tangent	Barrier	Road
Session 1	20,92	28,60	50,20
Session 2	21,15	33,23	46,95
Change	1%	16%	-6%

The second most frequently used surface area was the outside barrier especially in the middle part of the track probably due to the higher speed in the middle zone. This surface area was useful to detect the rate of optic expansion (both local and global) for speed control. Tangent points of the three bends were the least frequently used areas contradicting Land and Lee's (1994) proposal that the tangent point is crucial in the visual control of driving in a bend.

CONCLUSIONS

The increase in looking in the direction of heading and the overall dominance of gaze data on the road surface indicates a strong reliance upon the global optic structures in the visual control of driving. These findings confirm the robustness of Rogers, Kadar, and Costall's findings (2005a,b). Further in-depth analysis would be needed to assess the distribution of gaze data in order to differentiate between the use of global and local flow when drivers were looking at the barriers and tangent points.

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