THE EFFECT OF ROAD VISUALIZATION METHOD ON DRIVER'S ROAD VIEW PERCEPTION

Lidia ZAKOWSKA
Cracow University of Technology, A-9
Warszawska st. 24, 31-155 Cracow, Poland
e-mail: lzakowsk@usk.pk.edu.pl

Abstract:

The main objective of the research presented in this paper was to investigate the conditionings of the perception of road-view, related directly to road safety, and in particular, to elaborate experimental research method for road view evaluation.

The experimental laboratory method of perceptual properties evaluation for the two contrasting road visualisation techniques, static and dynamic, has been designed and tested

This experiment has shown that drivers are able, based both on still pictures and on motion road views, to discriminate different levels of curvature and angle of curves. The results revealed the complexity of the effects, expressed in significance of multi factorial interactions. The method applied have been tested for practical use in computer aided 3D road design evaluation.

The main conclusion is that the degree of simplification of the method is not directly proportional to the evaluation results accuracy. The perceptual properties of different visualisation techniques can be graded in terms of the target, time-saving and cost-effectiveness requirements.

1. INTRODUCTION

In order to achieve higher quality and efficiency of geometric road design, as well as to reduce the overall time and man-hours in the design process, new tools and techniques are being implemented.

In geometric road design process it is indispensable to test the perspective road picture of projected construction, as viewed from driver's eye position.

The very special nature of geometric road design comes from the spatial, three dimensional and dynamic character of the road. The road appears to its users, to drivers, as spatial and moving view. Road users, while driving, observe the road as continuously changing sequence of 3D spatial pictures. This moving, three dimensional road-view is the main and the most important information source that affects drivers perception and behaviour.

The critical point in rural road safety and geometric road design is the evaluation of perceptual properties of road curves. Accidents are more likely to occur on horizontal curves than on straight segments of roadway because of increased demands placed on the driver and the vehicle. Over 50 percent of the total number of accidents on rural two-lane roads involve single vehicle accidents on curves. The causes of the abnormally high frequency of such accidents are not yet fully understood, although investigators reporting on road safety claimed that perceptual factors play a significant role [1].

Previous research and literature review concerning the perception of rural road curves and its implementation into the designing practices lets the author draw several conclusions:

1/ there is no uniformity among researchers, in recommended method of testing and in the achieved research results concerning relationships between the road design parameters and their perception,
2/ theoretical research of the road view does not explain the effect of design road parameters on the proper perception of road curves, due to the limitations and simplifications of mathematical models applied, a large number of assumptions and the absence of allowance for psychological aspect of driver,
3/ the process of curve perception is a very complex one and derives research of interdisciplinary nature respecting the broad list of interrelated effects related to the road itself, road environment, exterior factors as light or weather conditions, driver's physiological and psychological responses, etc.,
4/ site experiments are of limited reliability of results because of difficulties in controlling external factors,
5/ the need of implementation the psychological aspect of perception process requires such a testing method that let us examine the subjective response of the objective measures and parameters,
6/ the results of road perception studies revealed from static road views are controversial: on the one hand, physiological restrictions of the length of stereoscopic vision permits static views to road perception research, on the other hand, psychological factors of the perception process contradict the above and claim that the results of research based on static representations are uncertain,
7/ to date, however, there has been little systematic empirical research comparing the effect of movement of the tested view on road curve perception process, and,
8/ modern technology gives advantage to use computerised methods for visualisation of designed segments of the road from any point of view, but, although several techniques of road visualisation are being developed, there are still no efficient methods of its evaluation.

2. OBJECTIVES

The main objective of the research presented in this paper was to investigate the conditionings of the perception of road curves, related directly to road safety, and in particular,
- to elaborate experimental research method for road view evaluation, and,
- to evaluate the effect of visual information from static and dynamic road views on driver's perception of road curves.

3. EXPERIMENTAL DESIGN

This study has been conducted on the basis of the subjective assessment method.
The laboratory experiment has been designed to test the perceptual properties of the method applied, and to test the effect of visualisation techniques and geometric road design characteristics on drivers perception of rural road curves.
Among many available methods of visual presentation, in this paper two methods, the most common and the most current ones, have been compared. The study aim was to classify the available visualisation techniques for its usefulness in testing and evaluating the spatial road-view.

3.1. Road View Perception in Laboratory Conditions

Laboratory methods of testing road-view perception varieties in a degree of real driving conditions simulation and the way of presentation the tested view. Although the closest to real driving conditions has been achieved in driving simulators, many researchers [2],[3],[4] claim, that for road-view studies relatively simple laboratory conditions are satisfactory if proper way of presentation of the perspective road-view is applied.

3.2. Static and Dynamic Presentation

The choice between static (2D) and dynamic (3D) method of presentation in laboratory experiments of road perception is dependant on the study scope and objective. Static stimuli has been applied in curve direction evaluation tests [5], [6], in curve deflection studies [7], [8] and in curvature evaluations [9], [10], [8]. Fildes claimed [8], that the perception of geometric road parameters is based on the static response of two-dimensionally perceived information from the road-view, which allows to apply 2D simulation in research.

Dynamic road-view presentation is more difficult method that require sophisticated equipment and organisation of research. Applied in laboratory experiments (as 8 or 16 mm cine/video films, or computer generated views of different level of simplification) were used mainly in speed assessment tests and driver's behaviour studies. Although it has been claimed [1] that movement of the observed road-view has to influence significantly the driver's perception, no systematic empirical research has been realised that would explain the effect of road movement on the perception of road parameters. This situation may have been caused by difficulties in collecting systematic, representative stimuli set.

4. THE EXPERIMENT

A multi factorial experiment has been designed to test the effect of the method of road-view presentation and road curve characteristics on the subjective assessment of curvature of rural two-lane roads curves.

4.1. Method

Forty licensed drivers of different driving experience were tested in laboratory conditions. They were shown two series of road pictures: dynamic (DYN) and static (STAT).

4.2. Stimulus Material

Former curve perception studies performed, [1], [5], [7], [8], were based on static stimuli in shape of computer generated edge lines of the road. Here, two-lane rural highways of southern Poland (fig.1) were chosen as an experimental polygon .

FIGURE 1   An example view of the road from the experimental polygon

FIGURE 2 The positioning of camera during recording sessions

Dynamic Representation (DYN)
The approaching zones to the selected horizontal curves (appr.300 meter long straight segments before curve) together with the curves were filmed on video, as moving perspective road view observed from driver's eye position (fig.2). The perspective viewpoint

was the front seat viewing point of a driver in a vehicle positioned in the right-hand lane, with 1 m eye height, as specified by the National Standards in Poland (similar specifications to those recommended by AASHTO [11]). Vehicle speed was the same as the designed speed for each site. To eliminate the influence of manipulated external factors, all sites were filmed at summer driving conditions, good light and weather, and none or limited traffic on the road.

Static Representation (STAT)
Still, computer-generated static (STAT) pictures, twodimentional, simplified representation of perspective road view as observed from the driving position of an automobile, drawn in black and white, as in Fig.3, were than constructed for each examined curve.
Assuming, that road plane curves are observed from the tangent straight section by approaching drivers from the distances not larger than the curve radius, the curve appears to driver in perspective as a hyperbola.

Approximating a circular curve by a parabolic curve section, which is viewed in perspective projection as a hyperbola, gives us preferences in very simple formulae for the perspective curve projected on a plane of projection, which was shown in [12]. On the basis of above approximation, with respect to traditional applied perspective projection model [12] and conic projective transformation principles (derived from Pascal theory) a static representations of curves were prepared.

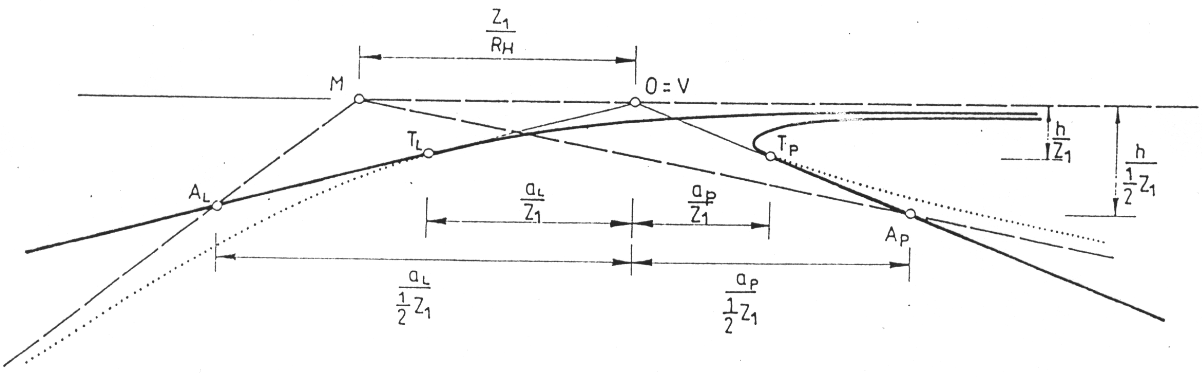

FIGURE 3 Sample STAT picture construction (Z1: distance to the curve, RH: curve radius, a: distance from driver eye to road edge).

4.3. Dependent Variables

Subjects were asked to give a rating of the presented road situation (the approaching zone of the curve and the curve itself of different geometric parameters) that reflects the subjectively perceived curvature and deflection angle of the road curve.

4.4. Independent Variables

Curve geometric features (curve radius and deflection angle), curve direction and distance to the curve were manipulated in the experiment. Ten levels of curve geometry (radii of 150 m, 300 m, 500 m, and 700m crossed with angles of 9, 18, 36 and 72 deg), 2 curve directions and 2 levels of viewing distance to curve (6sec and 3sec drive to curve) and two techniques of road visualisation (dynamic and static) produced 80 stimuli, that were presented in the preorganised order, in separate sessions of 20 road views each.

4.5. Rating Scales
Different rating scales with respect to the number of scale points and the definition of scale values were used by different experimenters: Ganton & Wilde (1971), Browning at al (1977), Moran (1983), Grant & Wilde (1985), Huddart (1978), which is well documented [13]. The relative, qualitative rating scale was used for both curvature and curve deflection angle as subjective measures. An important assumption underlying the use of this measure is that drivers are unable to verbalise the amount (in meters and degrees) of perceived curve design parameters in an adequate way. In former authors studies [14] five different ratings scales for the prior curve characteristics has been investigated: from the direct, quantitative i.e. radius in meters and curve angle in deg, to indirect and qualitative, i.e. the amount of curvature, the amount of deflection.
Taking together the psycho metric advantages and psychological disadvantages of many scale points, a rating scale of 5 scale points was selected as the most appropriate for curvature, and 3 scale points respectively for curve angle, in this experiment.

4.6. Subjects
40 licensed drivers took part in this experiment. They were selected and tested in four groups of 10 drivers of different driving experience, from very experienced professional drivers to inexperienced ones.

4.7. Procedure
The group presentations were used in this experiment. Subjects were seated in laboratory in front of a screen, having a good view of the screen, and they were discouraged from communicating during the experiment. A pre-recorded tape of experimental instructions and the practice film were presented as training at the start of the session. Then the sequences of 20 film-clips (DYN) and still pictures (STAT) were presented, with 30sec breaks between each picture, when subjects made their assessments on the response booklet provided beforehand. The whole experiment consisted of 16 sessions, each about 45 minutes long.

4.8. Statistical Analysis
The estimates were scored (from 1-for very small curvature, to 5-for very large), recorded and analysed using analysis of variance and the omega-squared statistics. The latter measure allows an estimate of the strength of the statistical relationship in terms of the percentage of variance accounted for by a particular manipulation, as proposed by Hays [15]. Statistical effect can be graded in terms of importance on the basis of the omega-square value (here, the value is shown as a percentage of an explained variance). Using this approach, the stronger effects can be selected for more detailed attention.

5. RESULTS

In these studies, only significant effects explaining more than 1.0 percent of the variance were considered. All significant effects and interactions are enlisted in Table 1.

Applying this criterion, the only main effect of curve geometry, and 5 interactions need to be examined. Curve geometry was the only significant main effect (10.63% explained variance, p<.0001). Also the highest range interactions included manipulations of curve geometry.

TABLE 1. ANOVA summary table of significant effects of curvature assessment
(* :manipulated parameters as listed above)

SOURCE OF VARIATION	*SS*	*MS*	*F-ratio*	*Explained variance [%]*	*Fprobability [%]*
GEOMETRY	.3342D+3	.3342D+2	.574D+2	10.63	.0000
GEOMETRY & DIRECTION	.1734D+3	.1734D+2	.354D+2	5.45	.0000
DISTANCE & GEOMETRY	.1538D+3	.1538D+2	.226D+2	4.76	.0000
METHOD & GEOMETRY	.3471D+2	.3471D+1	.678D+1	1.01	.0001
GEOM.& DIST.& DIRECT.	.4651D+2	.4651D+1	.913D+1	1.34	.0000
METHOD & GEOM. & DIR.	.3281D+2	.3281D+1	.830D+1	1.00	.0002

The effect of curve radius on the curvature subjective assessment in both methods of visualisation (STAT and DYN) is more significant in DYN method, than in a STAT one.

Further studies have been performed to analyse the effect of method and curve geometry in depth. This involved manipulation of curve radius alone, with the constant level of angle, and curve angle manipulation when the radius level is not changed (fig. 5, fig. 6).

Curve angle occurred to be an important factor deciding of the level of subjectively perceived curvature of small radii curves. This effect is strongly influenced by the viewing distance, as well as by the curve direction.
Curve radius and angle were also significant for subjective assessment of curve angle. This effect is again stronger for DYN, than for STAT method (fig. 6).

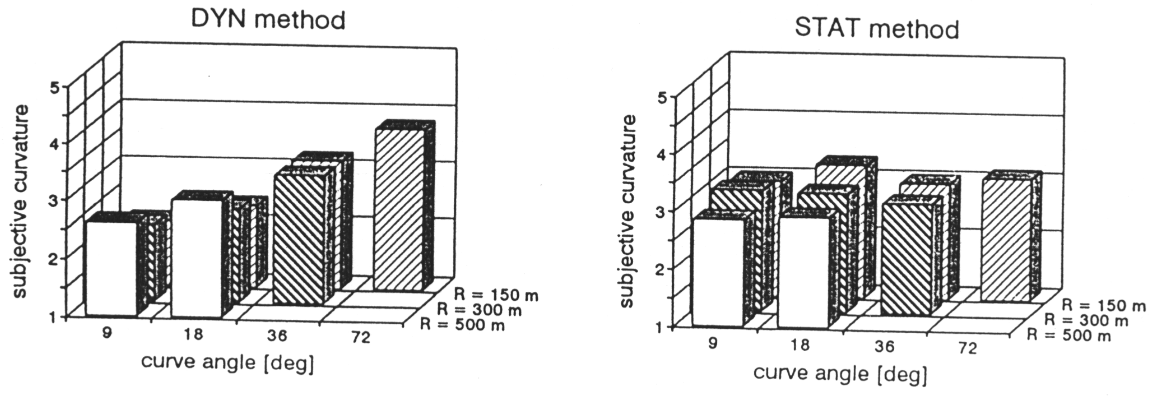

FIGURE 5 The effect of curve radius and curve deflection angle on the subjective curvature in both DYN and STAT methods

Surprisingly strong effect of visualisation method on the level of angle assessment, regardless the level of curve radius, may suggest, that visual properties are higher for the dynamic environment, which is an important factor in subjectively perceived curves parameters.

This effect is illustrated in fig.6. It should be noticed, however, that in both methods curve geometry is well discriminated by drivers.

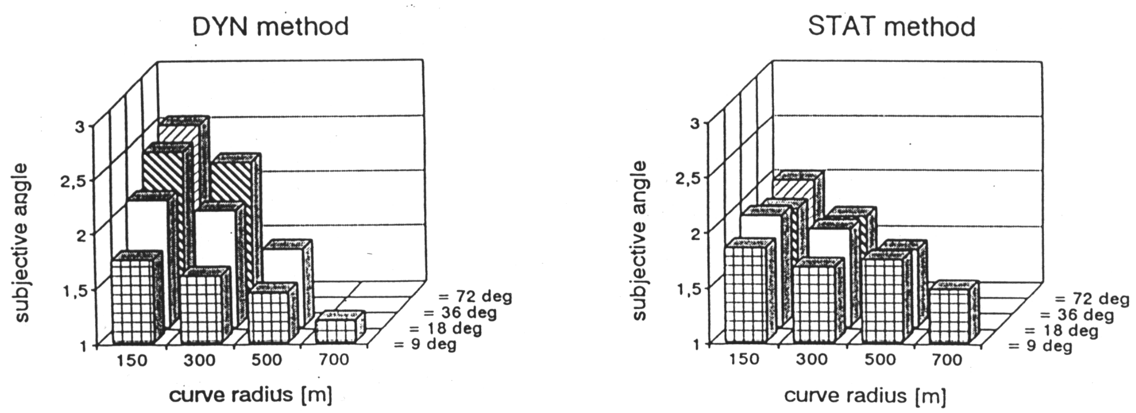

FIGURE 6 The effect of curve radius and curve deflection angle on subjective assessment of angle in DYN (left) and in STAT (right) methods

Two major findings should be stressed to show the revealed relations between the objective, designed curve parameters, and subjectively perceived by drivers approaching the curve:
- the effect of visualisation method on the subjective angle assessment accuracy decreases with the increase of the objective curve angle, and,
- also radius affects the subjective angle assessment strong enough, not to be neglected if compared with the angle effect.

6. CONCLUSIONS

The main result concerning curve angle and radius effect on subjective curvature supports the findings from previous studies performed in a driving simulator [16].

The advantage of the dynamic method used in this experiment (employing filmed road views) in relation to driving simulator is, that it allows to study the effect of real world driving environment on road perception in more complex way. Difficulties in selecting and controlling the stimuli set, however, may result sometimes in lowering the accuracy of results.

The main disadvantage of composed methods employed static drafting and real road environment with the dynamic of road view movement is the high cost.
This experiment has shown that drivers are able, based both on still pictures and on motion road views, to discriminate different levels of curvature and angle of curves. The results revealed the complexity of the effects, expressed in the significance of multi factorial interactions.

The general interpretation of the test results is that the choice of the visualisation technique and the method of the road-view evaluation should be related to, and depend on the cost-effectiveness for particular designing problem, with tendency on the most advanced techniques, easily applicable with CAD.

7. REFERENCES

1. RIEMERSMA, J.B.J., "Visual Aspects of the Road and Road Context". Institute for Perception TNO, Oog Werk 141, Denmark, 1989.

2. DENTON, G.G. The Influence of Visual Pattern on Perceived Speed. TRRL LR 409, Crowthorne, 1971.

3. WATTS, G.R. & QUIMBY, A.R. Aspects of Road layout that Affect Drivers' Perception and Risk Taking. TRRL LR 920, Crowthorne, 1980.

4. MICHON, J.A. A Critical View of Driver Behaviour Models: What Do We Know, What Should We Do? Human Behaviour and Traffic Safety, Plenum Press, New York, 1985.

5. TRIGGS, T.J. & HARRIS, W.G. & FILDES, B.N., "Delineation Cues on Rural Roads at Night; A Laboratory-based Study of Curve Direction Estimation". Australian Road Research Board Internal Report AIR 266-2, 1979.

6. TRIGGS, T.J. & MEEHAN, D.E. & HARRIS, W.G. Rural Road Delineation at Night: The Influence of Road-Side Post Location and Frequency on Curve Direction Estimates. Proceedings of Human Factors Society 26th Annual Meeting, Seattle, Washington, pp.233-236, 1982.

7. RIEMERSMA, J.B.J., "Perceptual Factors in Driving Perception of Characteristics of Horizontal Curves". Proceedings of the 14th ARRB Conference, Part 4, pp.121-125, 1989.

8. FILDES, B.N. & TRIGGS, T.J., "The Effects of Road Curve Geometry and Approach Distance on Judgements of Curve Exit Angle". A.R.R.B. 11th Conference, 11(4), pp.135-144, 1982.

9. TOLANSKI, S. Optical Illusions. Oxford, Pergamon, 1964.

10. SHINAR, D. & McDOWELL, E.D. & ROCKWELL, T.H. Improving Driver Performance on Curves in Rural Highways Through Perceptual Changes. Interim Report, Project EES 428, System Research Group, The Ohio State University, Columbus, 1974.

11. AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS: A Policy on Geometric Design of Highways and Streets. Washington DC, AASHTO, 1990.

12. ZAKOWSKA, L., "Geometria Perspektywicznego Obrazu Drogi". Wybrane Zagadnienia Geometrii Wykreslnej, PK, Monografia 115, 1991.

13. HEINO, A. & MOLEN, van der, H.H. & WILDE, G.J., "Risk - Homeostatic Process in Car Following Behaviour; Electrodermal Responses and Verbal Risk Estimates as Indicators

of the Perceived Level of Risk During a Car-driving Task". Report VK 90-22, VSC Traffic Research Centre, R.U. Groningen, 1990.

14. ZAKOWSKA, L., "Sprawozdanie z Projektu Badawczego U2/69/GRANT/91, Badania Percepcji Obrazu Drogi oraz jej Wplywu na Czytelnosc i Bezpieczenstwo Drog". Raport IM PK, 1991.

15. HAYS, W.L., "Statistics". The University of Austin at Texas, Holt, Rinehart and Winston, New York, 1986.

16. TENKINK, E. & Van der Horst, A.R.A., "Effecten van Wegbreedte en Boogkenmerken op de Rijsnelheid". TNO Rapport, IZF C-26, Soesterberg, 1991.