ROAD RESEARCH LABORATORY

Department of the Environment

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THE INFLUENCE OF VISUAL PATTERN ON PERCEIVED SPEED

by

G G Denton

Driver Aids & Abilities Section
Road Research Laboratory
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ABSTRACT

This report is concerned with the instability of the relationship between real speed and the sensation of speed experienced by the driver relative to the physical speed at which he is moving. The various contributing factors are outlined. Speed adaption is considered as a major factor responsible for errors in the driver's judgement of speed, and the hypothesis is made that by deliberately distorting the spatial geometry of the visual field it should be possible to counteract the effects of adaptation. The results of this experiment carried out on a simulator confirmed the possible value of such a technique. Proposals are made for future research into the control of behaviour by the use of illusion particularly in the driving situation.

I. INTRODUCTION

The use of designed objective distortion as a means of correcting or modifying subjective values have been exploited by artists, engineers and architects down through the ages. Examples of its use in architecture can be traced back to early Greece and today subtle use is made of structural proportions, colour and texture of materials to create the illusion of spaciousness, warmth, coolness etc. The illusion of movement by intermittent stimulation of the eye is an integral part of our daily lives, eg the cinema, television and animated advertisements which create the illusion of movement by the sequential switching of lights in the desired direction of movement. That one's sense of speed is considerably modified by illusion when driving a motor vehicle is perhaps not quite so well known, yet it is true none the less. Driving along a narrow country lane bounded by high hedges creates a sense of increased speed as opposed to a sense of reduced speed when driving over a flat featureless terrain. Yet another form of illusion particularly relevant to motorways or other high speed roads is that produced by sustained high speed. This is the so called negative adaptation effect predicted by Denton[1] from the results of a series of speed scaling experiments. Adaptation in this context refers to the change in sensory characteristics as a result of prior stimulation. For example, we only gradually adjust to our surroundings in a darkened room after previous exposure to bright light. Another example is the way we slowly adjust to the cold night air after leaving the warm fireside. The results of experiments not yet published, carried out on the 'Moving Road' simulator[2], and more recently the results of actual road experiments[3] have confirmed the influence of adaptation on the senses responsive to rate of movement. The influence of distorting factors on phenomenal speed is such as to force one to the conclusion that a stable relationship between the subjective and objective does not exist. This was the position taken by Brown[4], when, in a theoretical discussion of the influence of illusion on phenomenal velocity, he pointed out that all the early investigators of movement perception, with the possible exception of two, considered that there must be one correct phenomenal velocity to correspond with any given physical velocity. Any other phenomenal velocity observed for this stimulus velocity was illusory in nature. Brown, having varied several aspects of the geometrical structure of the visual field in which the given stimulus velocity occurred, was forced to the conclusion that it was futile to attempt to set up any phenomenal velocity as the exclusive phenomenal correlate of a given stimulus velocity. His opinion was that there was not a single criterion that can be used to determine that any one of phenomenal velocities is more correct than any other. Indeed, it is probable that this statement may be true of all psychophysical relations[5].

With this in mind, the question this paper attempts to answer is whether, by manipulation of the structure of the visual yield presented to the driver of a motor vehicle, it is possible to create a speed illusion which will counteract the influence of adaptation, and by so doing motivate the driver to adopt a slower and therefore safer speed when leaving high speed roads.

2. EXPERIMENTAL METHOD

The experiment described in this report was carried out on the 'Moving Road' simulator. This machine has been fully described elsewhere[2] and will therefore only be briefly outlined here. Experimental results of speed perception studies obtained on the machine compared with those obtained on the road show a high degree of correlation between the two situations.

The apparatus consists essentially of two parts, one being a special film projector and viewing screen simulating the road, the other a mock-up vehicle fitted with controls simulating the car. The system is shown diagrammatically in Fig 1. The optical scaling is such as to provide the subject with the equivalent of 67 m (220 ft) of forward vision at road speeds of up to 322 km/h (200 mile/h). Members of the general public formed the experimental group consisting of 6 males and 6 females all being fully licensed drivers aged between 27 and 50 years. The instructions were as follows. 'For the purpose of this experiment I want you to imagine that you are travelling in a real car on a real road. When you hear the 'go' signal (demonstrated a 400 HZ/S note) I want you to push the speed control hard forward. This will take your speed up to what we call the test speed and I want you to observe this carefully and remember it. During your journey over the next (0.8 km) ½ mile the speed at which you are travelling may or may not be changed but regardless of this when you hear this note (demonstrated a 100 HZ/S note) I want you to change your speed to what you think is half of that at which you were originally travelling, in other words, halve the test speed. I want you to do this as quickly as possible and having made the change, maintain it for the rest of the journey at the end of which the visual display will be cut off and you may then release the control and relax. After a two minute rest period the procedure will be repeated. You will notice some changes of pattern on the road surface during the experiment, pay no attention to this, your task remains the same regardless. The vehicle has a built in microphone and if you wish to talk to me you have only to speak because the microphone is permanently switched on. Are there any questions?'.

The pattern change referred to in the instructions was the independent experimental variable, TP. Three test patterns, TP_1, TP_2 and TP_3 were used, the latter serving as the control. A monochromatic speckled field was a common feature of all three patterns. This alone served as the control pattern TP_3. In the case of TP_1 and TP_2 an additional pattern of transverse white bands was superimposed on the basic specked pattern. Reference to Fig 2 will make this clear. Throughout the remainder of this report all dimensions quoted will be those that are being simulated rather than those of the actual display. This is perfectly valid, due regard having been paid to correct perspective of the visual scene and other relevant factors.

The width of the white transverse bands was 60 cm (24 in) and the successive separation between bands was an exponential decay function of distance along the line of travel. In the case of TP_1 the spacing between the first two bands was 6 m (20 ft) and that of the final two 3 m (10 ft). For TP_2 the spacing between the first two bands was also 6 m (20 ft) but that of the final two only reduced to 4.6 m (15 ft). Total number of bands for TP_1 was 80 and for TP_2 67. The first four and last twenty spacings were held constant at their respective values. The total length of the test run was approximtaely 1.2 km (¾ mile), the first 0.8 km (½ mile) being speckled and serving as a run up to the last 0.4 km (¼ mile) test pattern area. For TP_3 the whole test run was of the same pattern, ie speckled.

The signal to change speed was given at the instant when the vehicle entered the test pattern zone. Each subject carried out three trials on each TP at each of five test speeds TS (TS_1 to TS_5) these being 32, 48, 64, 81 and 97 km/h (20, 30, 40, 50 and 60 mile/h) making a grand total of 540 trials. Each subject's experimental session lasted approximately 4½ hours, 2½ hours in the forenoon and 2 in the afternoon. Each of these was divided into 4 periods with ¼ hour break between each. Data collection was fully automatic via punched tape.

3. EXPERIMENTAL RESULTS

A graph of the grand mean of the results showing the speed judged half of the test speed as a function of the test speed is given in Fig 3. Individual subject results are given in Figs 1 – 12 of the Appendix. The results in general show that patterns TP_1 and TP_2 caused the subjects to reduce speed to a fraction of the test speed lower than 0.5 (the perfect result) whereas the control pattern TP_3 produced a fraction of the test speed greater than 0.5 at all levels of the test speed. The pattern TP_2 yielded a fraction of approximately 0.5 at speeds up to 64 km/h (40 mile/h) beyond which it tended towards a value less than 0.5. The pattern TP_1 produced a fraction less than 0.5 and of a lower value than that of TP_2 at all levels of test speed. For the purpose of full analysis which is necessary to determine how real these effects are, the raw data which was in mile/h have been transformed to ratios simply by dividing each value by the particular test speed the subject was attempting to halve. The reason for this transformation is that there is an inherently large variation in the results that is a function of test speed ie half of 96 km/h (60 mile/h) is twice as large as half of 48 km/h (30 mile/h) and this variation must be eliminated from the analysis. The transformation referred to achieves this. A three factor analysis of variance[6] was then carried out on the transformed data; the factors being Subjects (S) test speed and TP. A summary of results is given in table 1 of the Appendix. This shows that accuracy of relative speed judgement in a decelerating situation is significantly affected by test speed. It also shows that the difference between subjects is not significant. Unfortunately it also appears that there are significant interactions between S and TP and test speed and TP meaning that some test patterns are more effective at some speeds than others and that some subjects are influenced by some test patterns more than others. This being the case there is no rigorous test for the effect of TP and it is therefore necessary to break the analysis down into five separate analyses having S and TP as factors. The results, summarized in Table 2 of the appendix show that TP has a highly significant effect on the subject's estimation of relative speed and we may therefore conclude that the graphs shown in Fig 3 are meaningful and that there is at least, a real difference in the results obtained for pattern TP_3 and those of the other two TP_1 and TP_2. What this does not show is whether there is a real difference between TP_1 and TP_2, ie is there any advantage to be gained by using the more rapidly decelerating pattern TP_1. As this pattern would be more expensive to apply to the road surface in the real situation it is necessary to establish how far it is superior in effect. To do this we compare the two sets of results for TP_1 and TP_2 at each of the five test speeds. Each of the five mean results of each graph of Fig 3 is the mean of the means of twelve subjects results, and if we take subject means for one pattern from the corresponding means for the other we obtain a set of twelve numbers for each of the five values of test speed. This is shown in Table 1. Assuming that performance for the two patterns were identical the difference $TP_2 - TP_1$ will be zero in which case no further test is necessary. There are however less clear cut cases where the difference is not zero and it becomes necessary to apply statistical tests to determine whether this difference is of any real importance. In the present case the Student t test was used to check this and the results obtained show that there is a very significant advantage (P' 0.001) in using the more rapidly decelerating pattern TP_1 at all levels of test speed except one, 32 km/h (20 mile/h).

TABLE I

Speed ratios and differences between speed ratios for TP_2 and TP_1

Test Speed in mile/h	(km/h)	Test pattern	SUBJECTS 1	2	3	4	5	6	7	8	9	10	11	12
20	(32)	TP_2	0.53	0.51	0.43	0.45	0.46	0.47	0.49	0.49	0.46	0.54	0.49	0.39
		TP_1	0.50	0.51	0.42	0.44	0.44	0.49	0.49	0.47	0.44	0.51	0.46	0.41
		$TP_2 - TP_1$	0.03	0	0.01	0.01	0.02	-0.02	0	0.02	0.02	0.03	0.03	-0.02
30	(48)	TP_2	0.51	0.51	0.45	0.48	0.45	0.48	0.51	0.49	0.48	0.51	0.49	0.46
		TP_1	0.49	0.46	0.40	0.40	0.38	0.43	0.45	0.46	0.43	0.43	0.43	0.41
		$TP_2 - TP_1$	0.02	0.05	0.05	0.08	0.07	0.05	0.06	0.03	0.05	0.08	0.06	0.05
40	(64)	TP_2	0.55	0.54	0.47	0.50	0.51	0.51	0.50	0.50	0.48	0.47	0.47	0.44
		TP_1	0.49	0.43	0.41	0.41	0.42	0.43	0.41	0.41	0.40	0.41	0.42	0.39
		$TP_2 - TP_1$	0.06	0.11	0.06	0.09	0.09	0.08	0.09	0.09	0.08	0.06	0.05	0.05
50	(81)	TP_2	0.48	0.49	0.43	0.43	0.45	0.46	0.49	0.46	0.43	0.47	0.45	0.43
		TP_1	0.43	0.44	0.37	0.40	0.39	0.38	0.42	0.40	0.39	0.41	0.38	0.37
		$TP_2 - TP_1$	0.05	0.05	0.06	0.03	0.06	0.08	0.07	0.06	0.04	0.06	0.07	0.06
60	(97)	TP_2	0.48	0.48	0.43	0.44	0.47	0.46	0.46	0.46	0.44	0.52	0.45	0.41
		TP_1	0.40	0.40	0.34	0.41	0.37	0.39	0.39	0.39	0.37	0.41	0.38	0.34
		$TP_2 - TP_1$	0.08	0.08	0.09	0.03	0.10	0.07	0.07	0.07	0.07	0.11	0.07	0.07

4. DISCUSSION

These results show that relative speed judgements in a simulated driving situation are highly dependent on the nature of the patterns presented to the driver's eye and that the driver's sense of speed can be considerably modified by manipulating the pattern of the visual field. The basic concept is by no means new but is, rather, an extension and utilization of the much earlier work of Brown[4]. The phenomenon poses many interesting theoretical problems relating to the underlying mechanisms of movement perception. While such considerations would be out of place in this report the author believes that some understanding of the underlying principles leading to these results is necessary if only to form a tentative framework for future research. With this in mind the following theoretical explanation is offered.

Our ability to sense our movement in the environment is mainly mediated by vision. Moving elements in the visual field either track across the retina or are held stationary on the retina relative to a moving background. In either event, by a process of integration with respect to some metabolic time base [7, 8, 9, 10] or by movement sensitive detectors such as those reported by Hubel and Wiesel[11, 12, 13] we are able to compute relative rates of movement. The ability to discriminate between different rates of visual flicker is closely related to speed perception and there is evidence to suggest that the two processes probably utilise common neurological structures and that factors that influence one also influence the other[4, 14]. The particular visual field structure used in this experiment was highly persuasive to this form of discrimination and it is suggested that this is what the subjects were doing. Certainly if the visual field had been devoid of all other structures except the white bands ie no speckled background there would be little doubt that this were so and the results obtained would not have been unexpected. But they were obtained with a visual field which contained elements that were randomly distributed throughout the field and this raises questions about the relative strength of what might be considered to be the conflicting cues provided by the overall visual field, and about the point at which the speed illusion produced by the bar pattern breaks down.

The patterns used in this experiment are but two amongst many that might prove equally or even more effective as a counter-measure to the distortions of sensory speed experienced by drivers under certain conditions, particularly on high speed roads. Experiments of this type are by their very nature, time consuming and tedious to perform and for this reason the present study has been limited to investigating only two patterns and these somewhat superficially. A full scale investigation of the value of illusion created by spatial relationships of structures in the visual field as a means of negating speed illusion of sensory origin has as yet to be carried out. Such a study should include the effects of:-

1. Pattern geometry
2. Background to pattern contrast
3. Habituation
4. Contra-stimuli ie stimuli unavoidably present in the visual field which act in opposition to the structured pattern and therefore tend to destroy the illusion.

5. Auditory and kinesthetic cues, including road tests

6. Individual differences.

5. CONCLUSIONS

1. Under conditions simulating the essential features of a real driving situation, the driver's sense of speed can be manipulated by introducing structured patterns onto the road surface.

2. The degree of influence obtained in this experiment suggests that further experiments should be carried out in the real driving situation to determine to what extent extraneous cues may prove contra-indicative to that of the pattern, and so nullify its effect.

6. ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistence given by Mr C Gent of Statistics Section with the statistical analyses of the experimental data.

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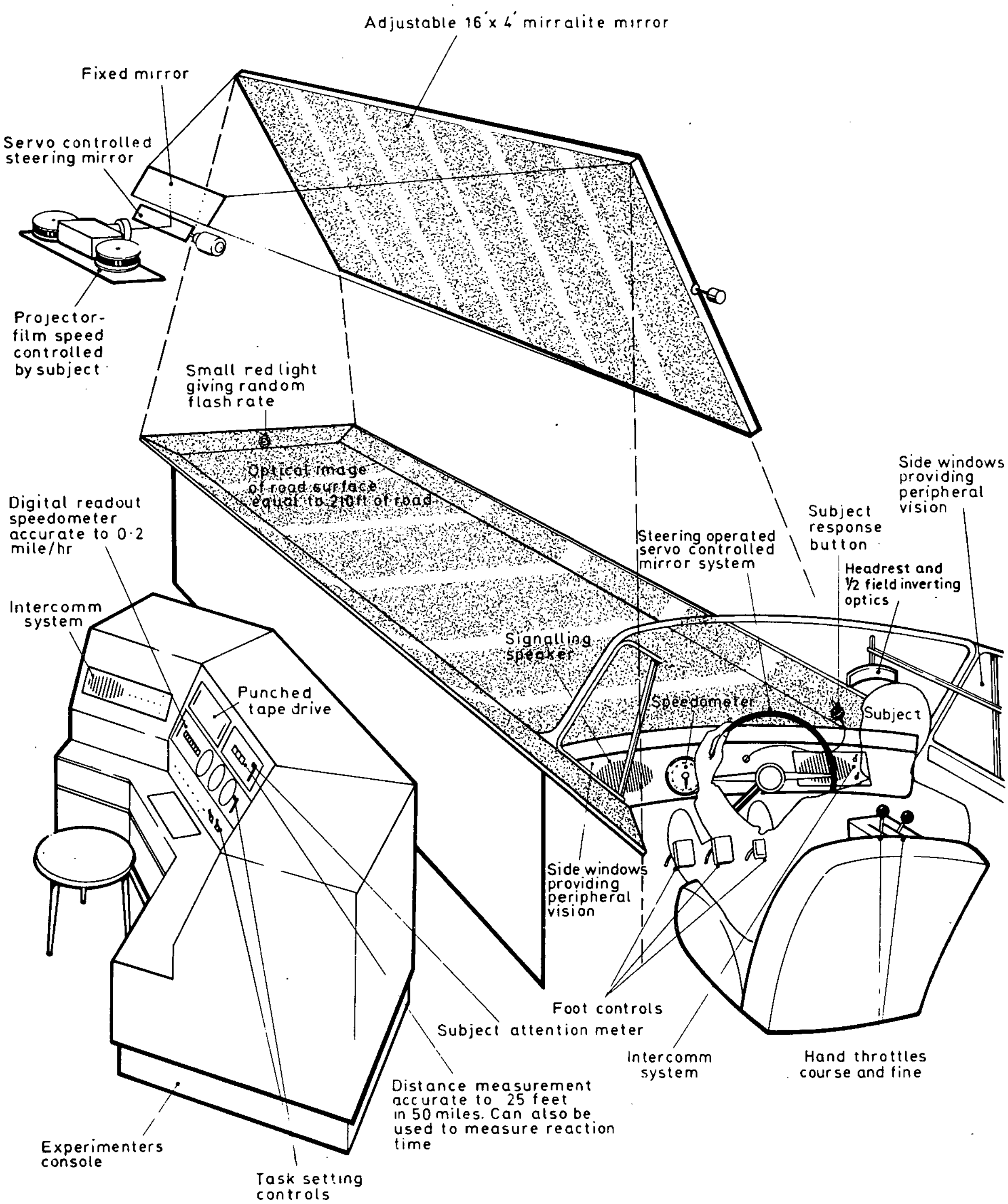

Fig.1. MOVING ROAD SIMULATOR

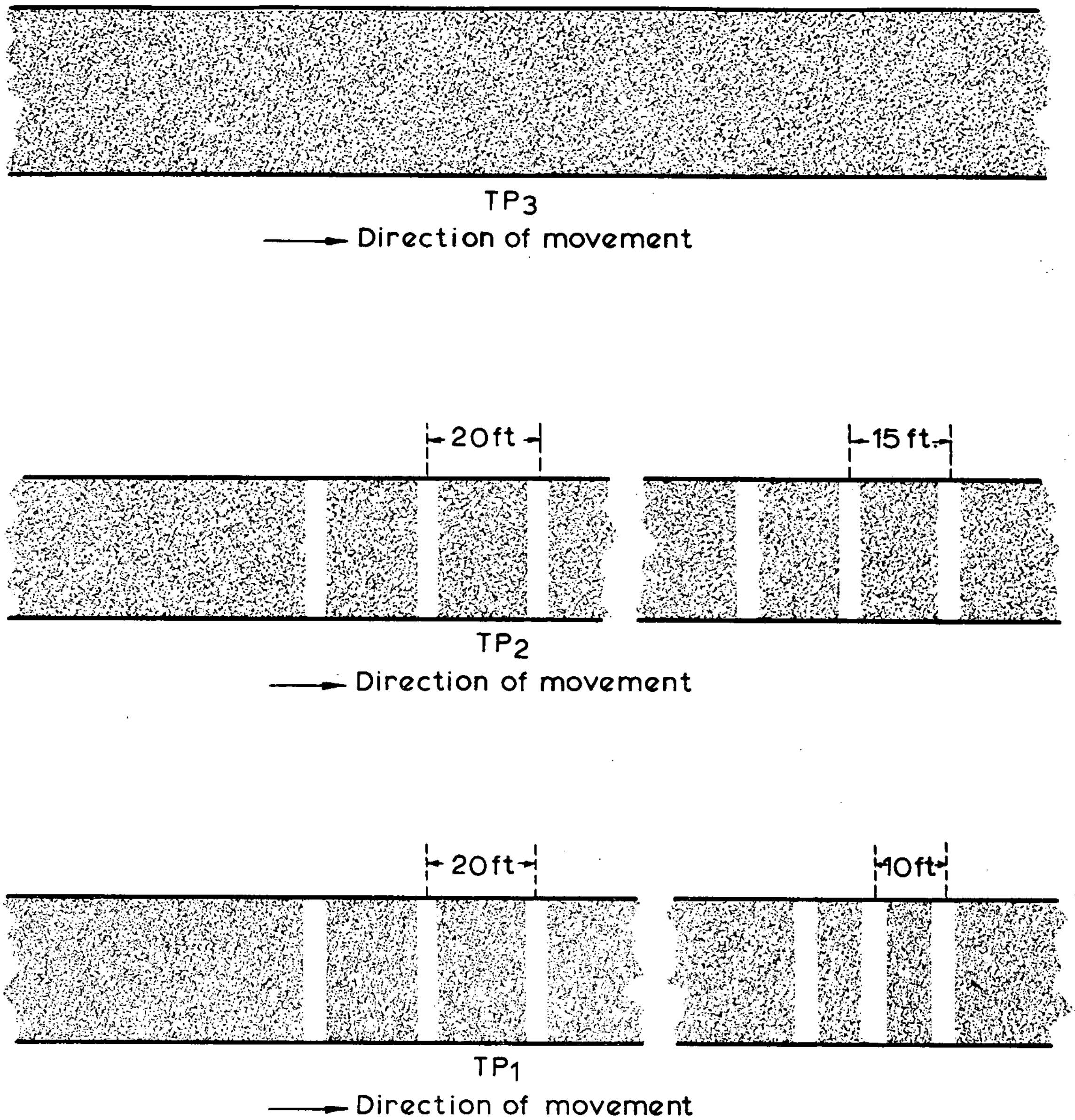

Fig.2. THE 3 TEST PATTERNS USED. SPACING BETWEEN BARS REDUCED EXPONENTALLY IN THE DIRECTION OF MOVEMENT BETWEEN THE LIMITS SHOWN

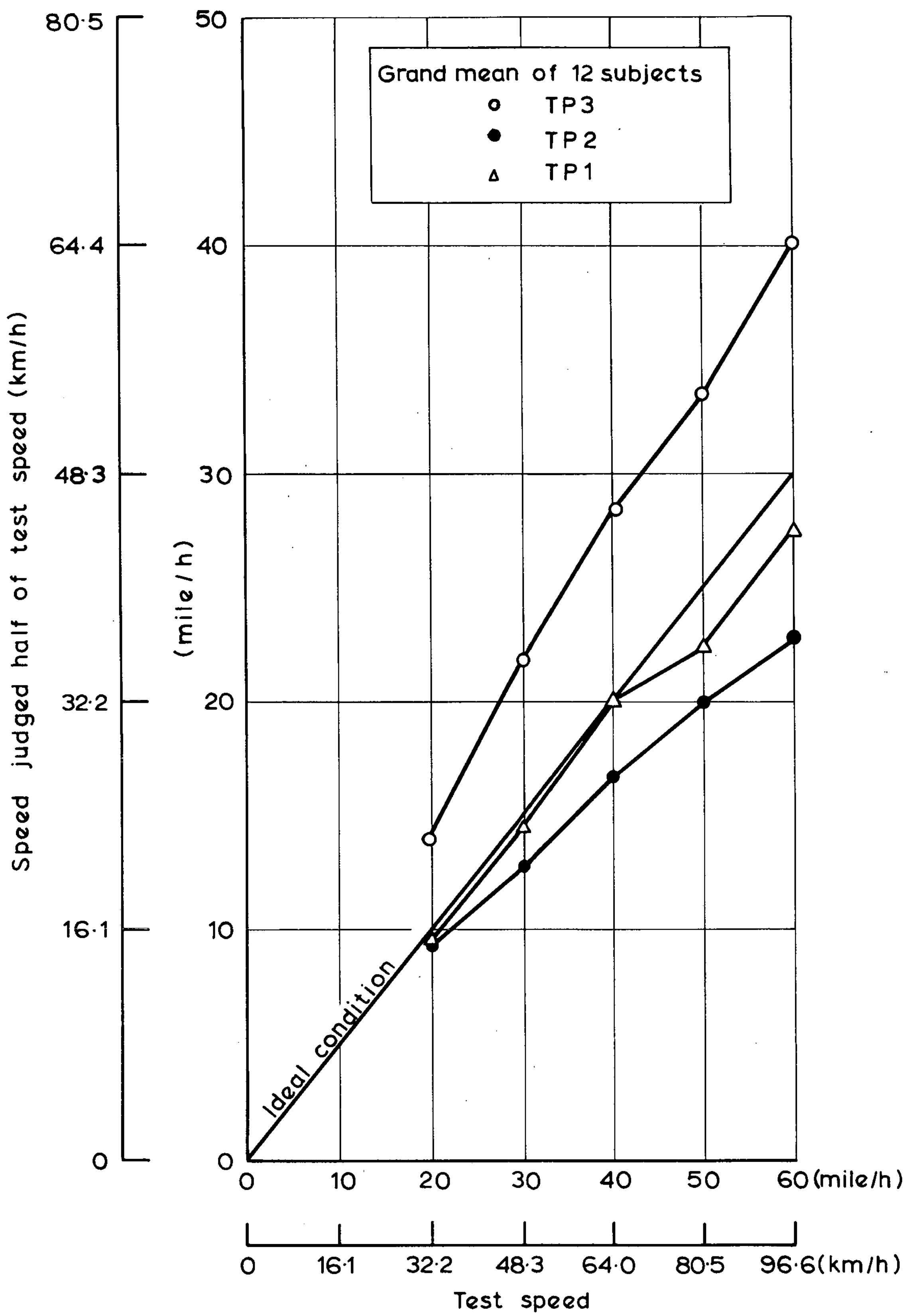

Fig. 3. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - GRAND MEAN

8. APPENDIX I

TABLE I

Summary of 3 factor Analysis of Variance

Source of variation	Sum of Squares	Degrees of Freedom	Mean Squares	F. ratios
Subjects (S)	0.2982	11	.0271	0.81
Test Speeds (TS)	0.2134	4	.0533	5.73
Test Pattern (TP)	7.9512	2	3.9756	–
Interaction (S) (TS)	0.1850	44	.0042	0.95
Interaction (S) (TP)	0.7350	22	.0334	7.59
Interaction (TS) (TP)	.0748	8	.0093	2.20
Interaction (S) (TS) (TP)	0.3871	88	.0044	3.66
Residual	0.4323	360	.0012	
Total	10.2770	539		

TABLE 2

Summary of 5 individual 2 factor Analysis of Variance

Source of variation	Degrees of freedom	Mean Squares					F. ratios				
		TS_1	TS_2	TS_3	TS_4	TS_5	TS_1	TS_2	TS_3	TS_4	TS_5
Subjects (S)	11	.0071	.0048	.0070	.0091	.0159	0.97	0.62	0.69	0.73	1.19
Test patterns (TP)	2	0.6490	0.9373	0.8337	0.7585	0.8346	88.90	120.17	81.73	61.17	62.28
Interaction (SXTP)	22	.0073	.0078	.0102	.0124	.0134	4.06	7.80	6.80	12.40	19.14
Residual error	72	.0018	.0010	.0015	.0010	.0007					

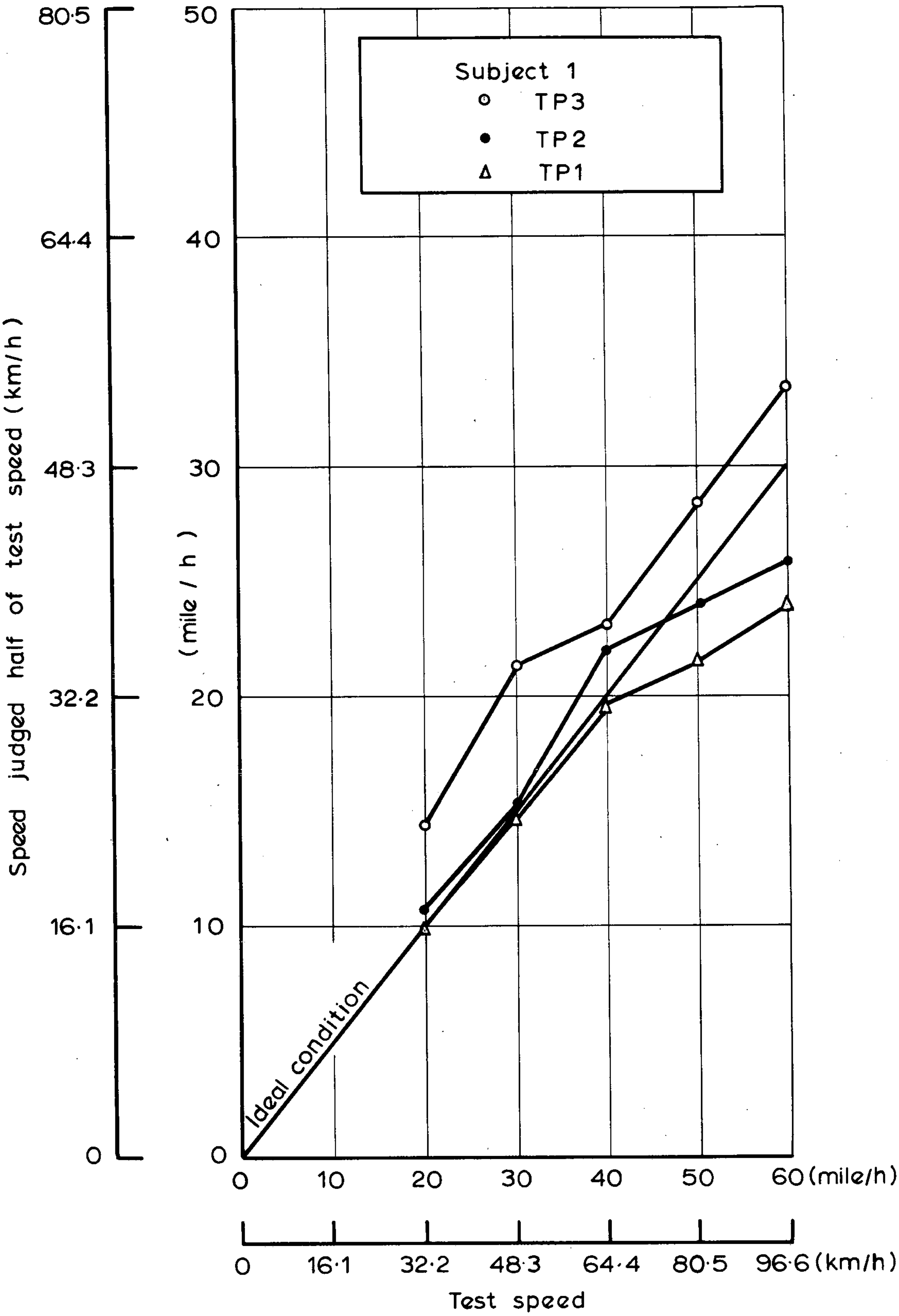

Fig.1, THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 1 RESULTS

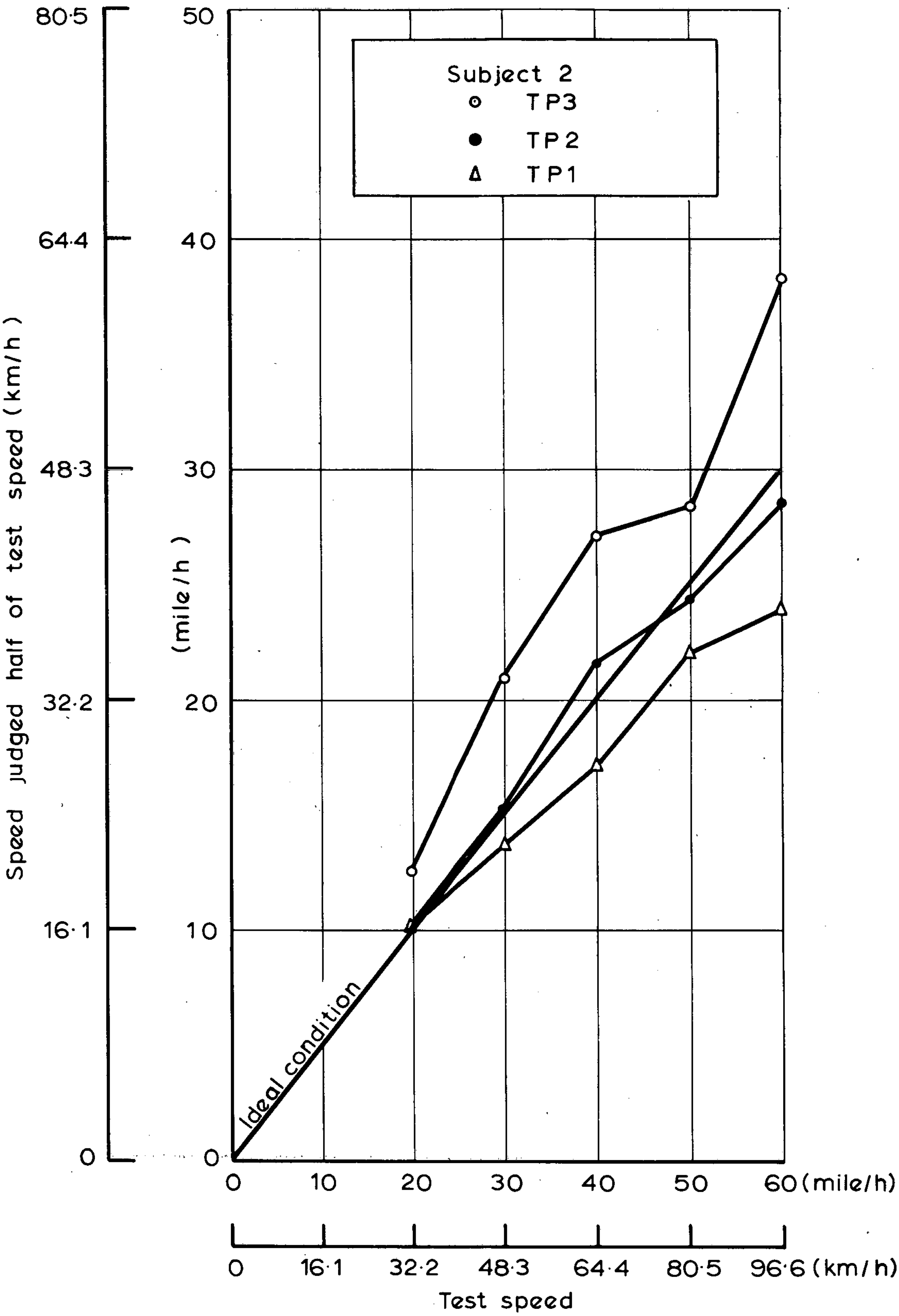

Fig.2. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 2 RESULTS

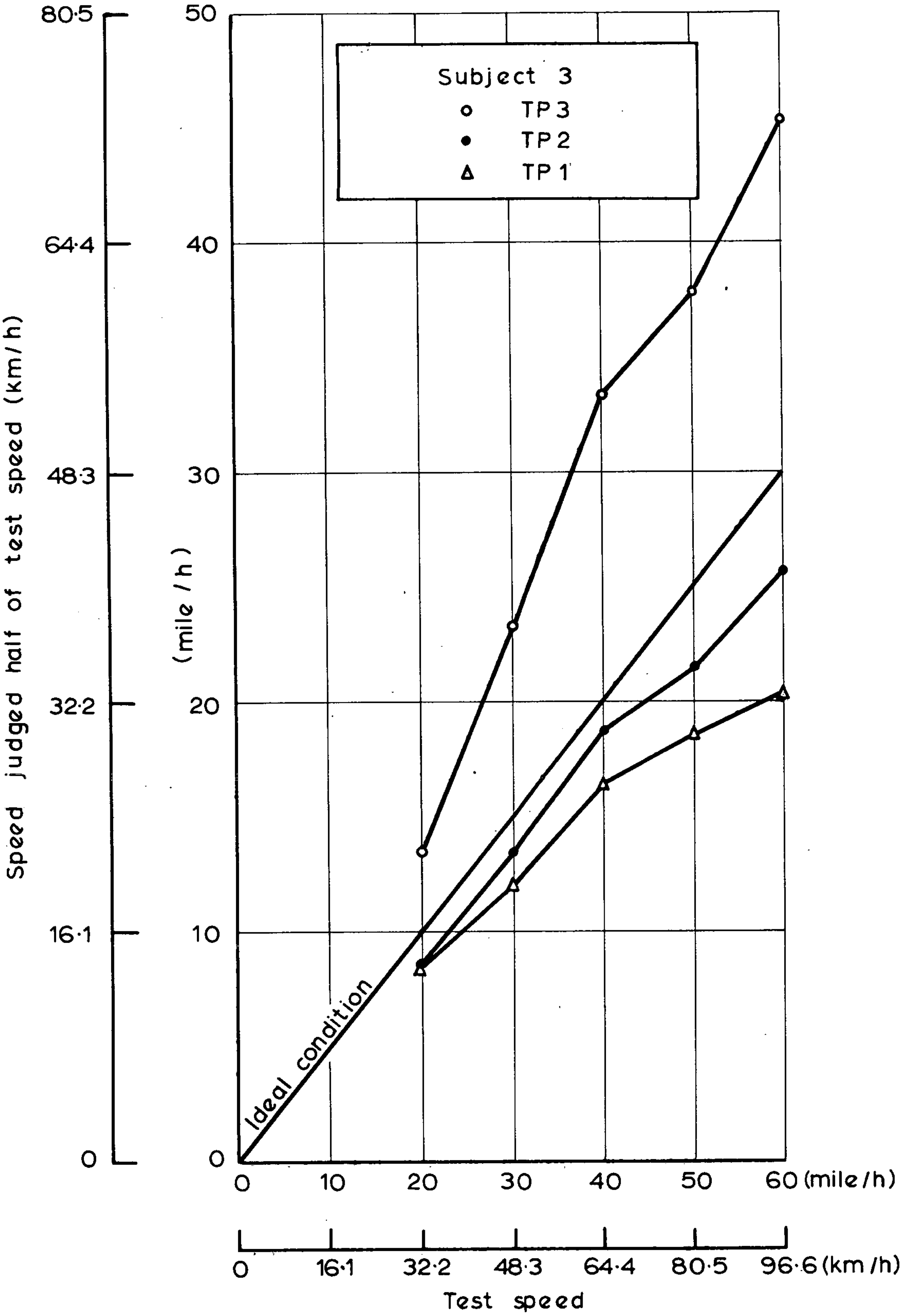

Fig.3. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 3 RESULTS

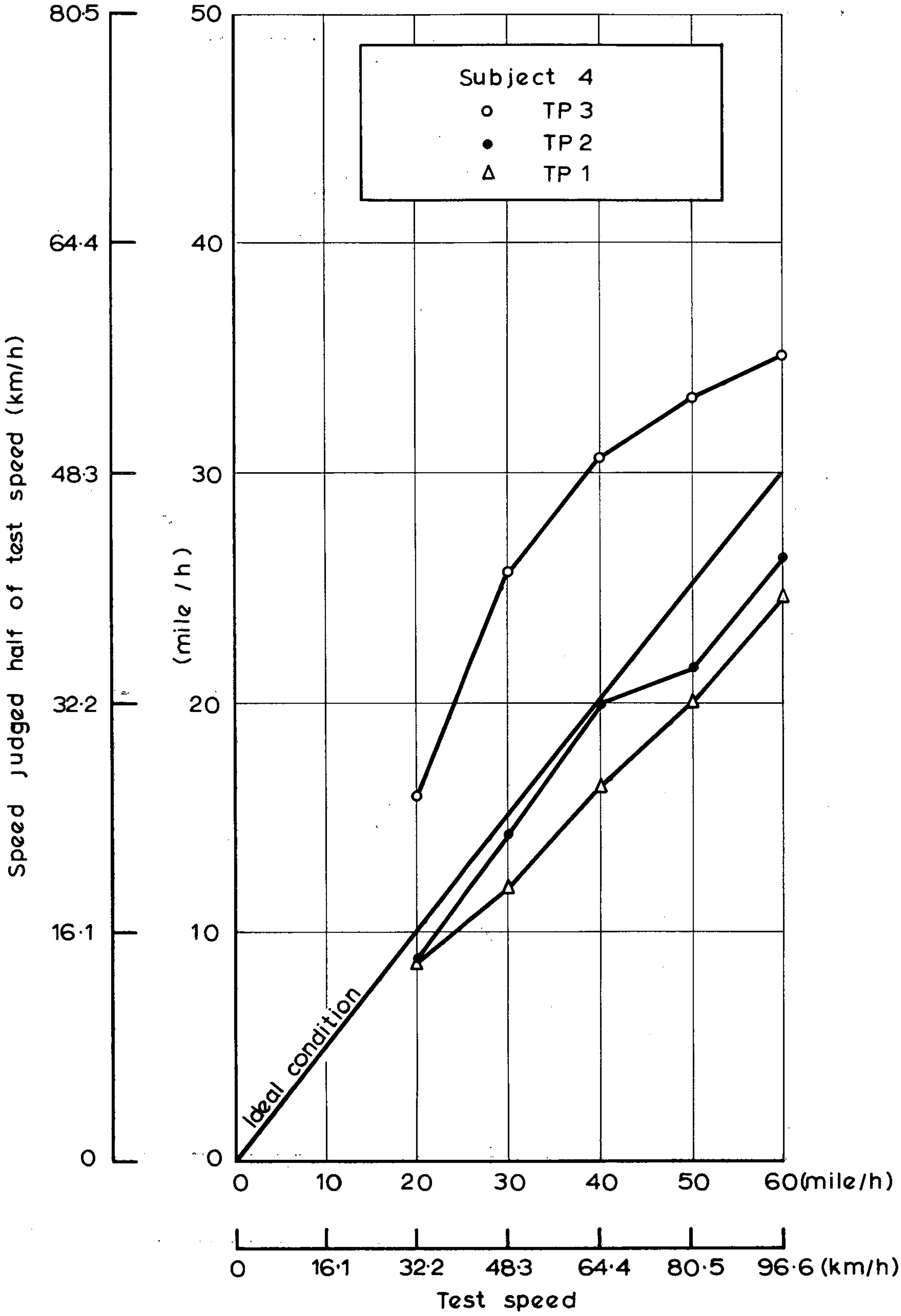

Fig.4 THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 4 RESULTS

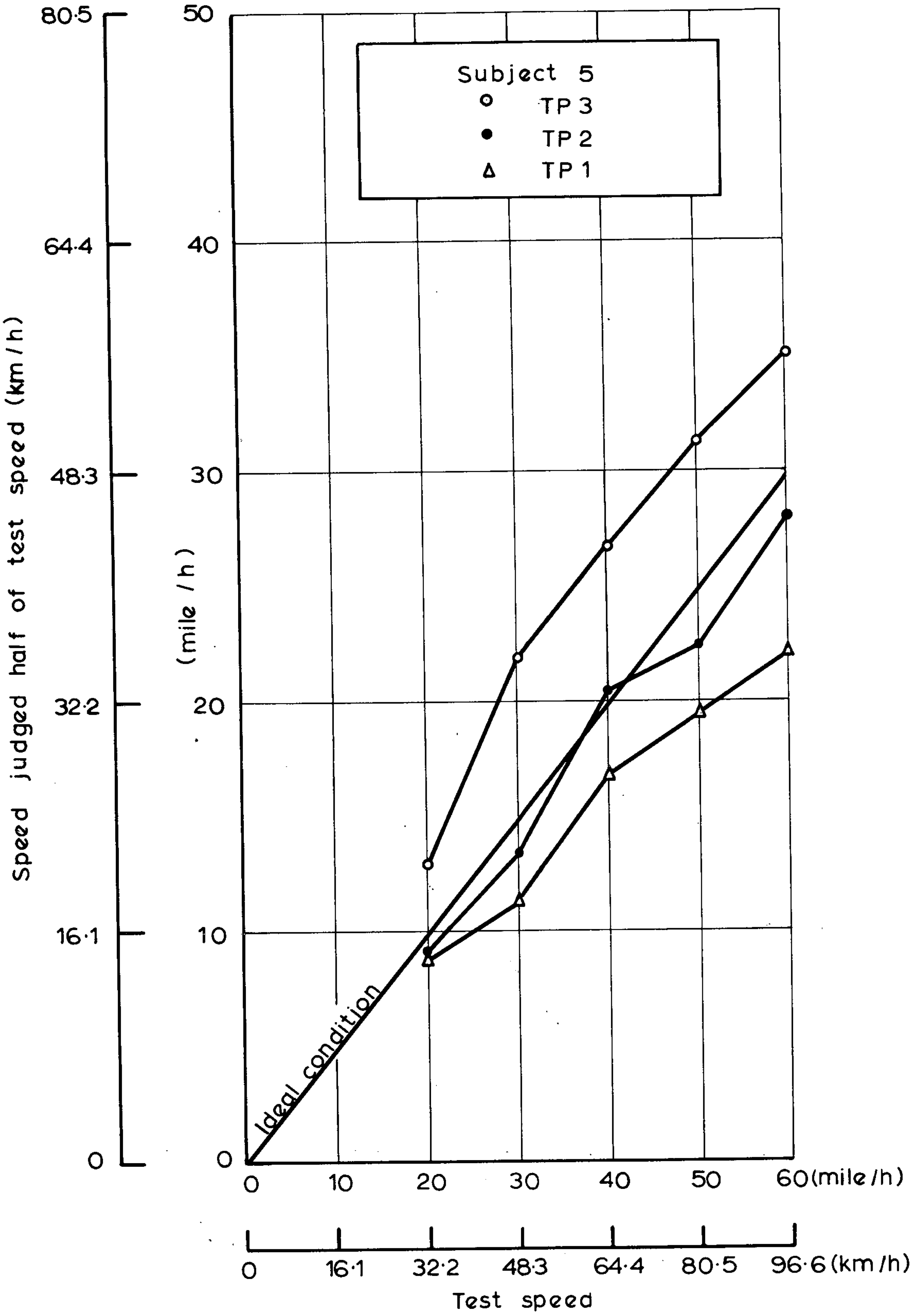

Fig.5. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 5 RESULTS

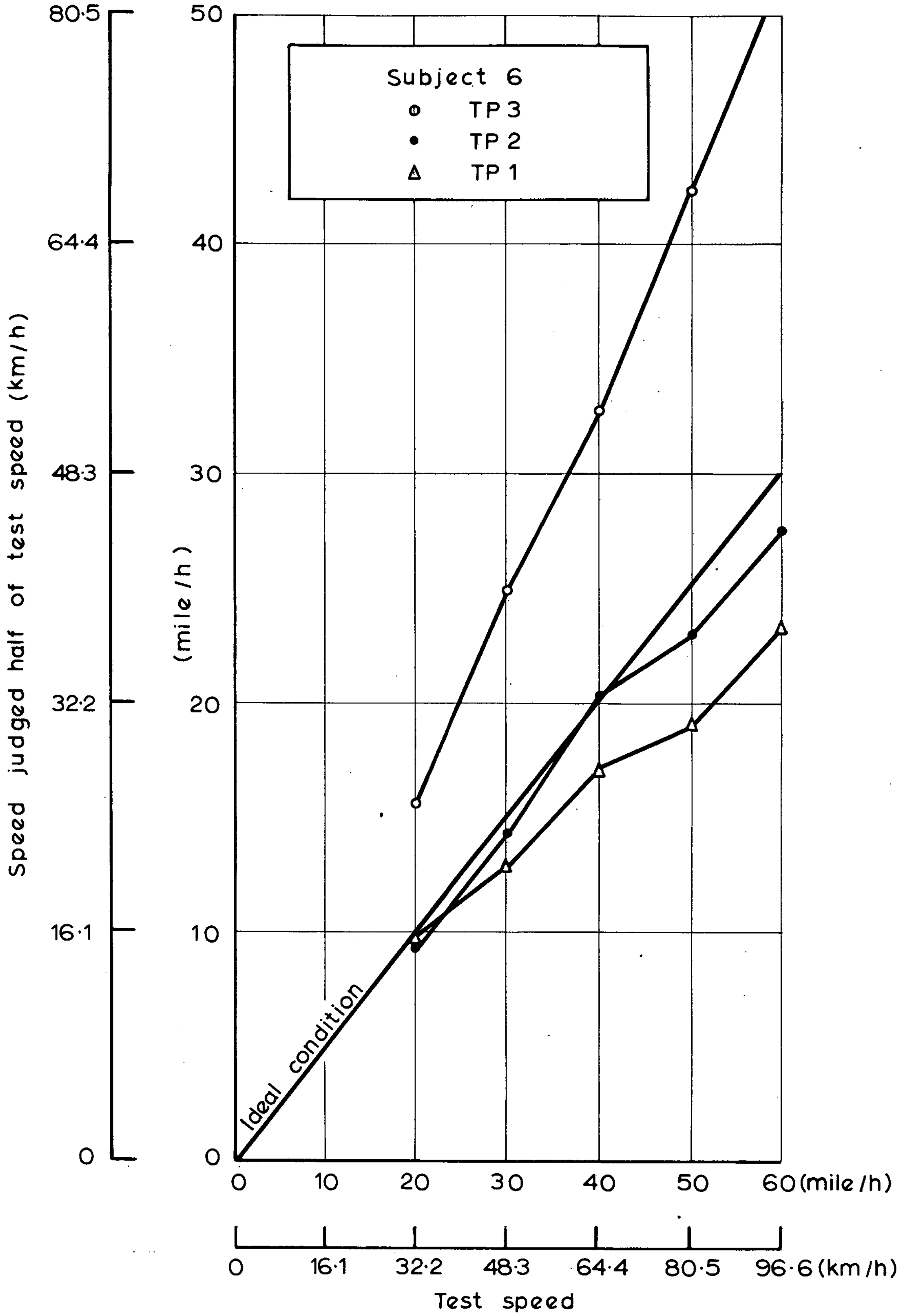

Fig. 6. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 6 RESULTS

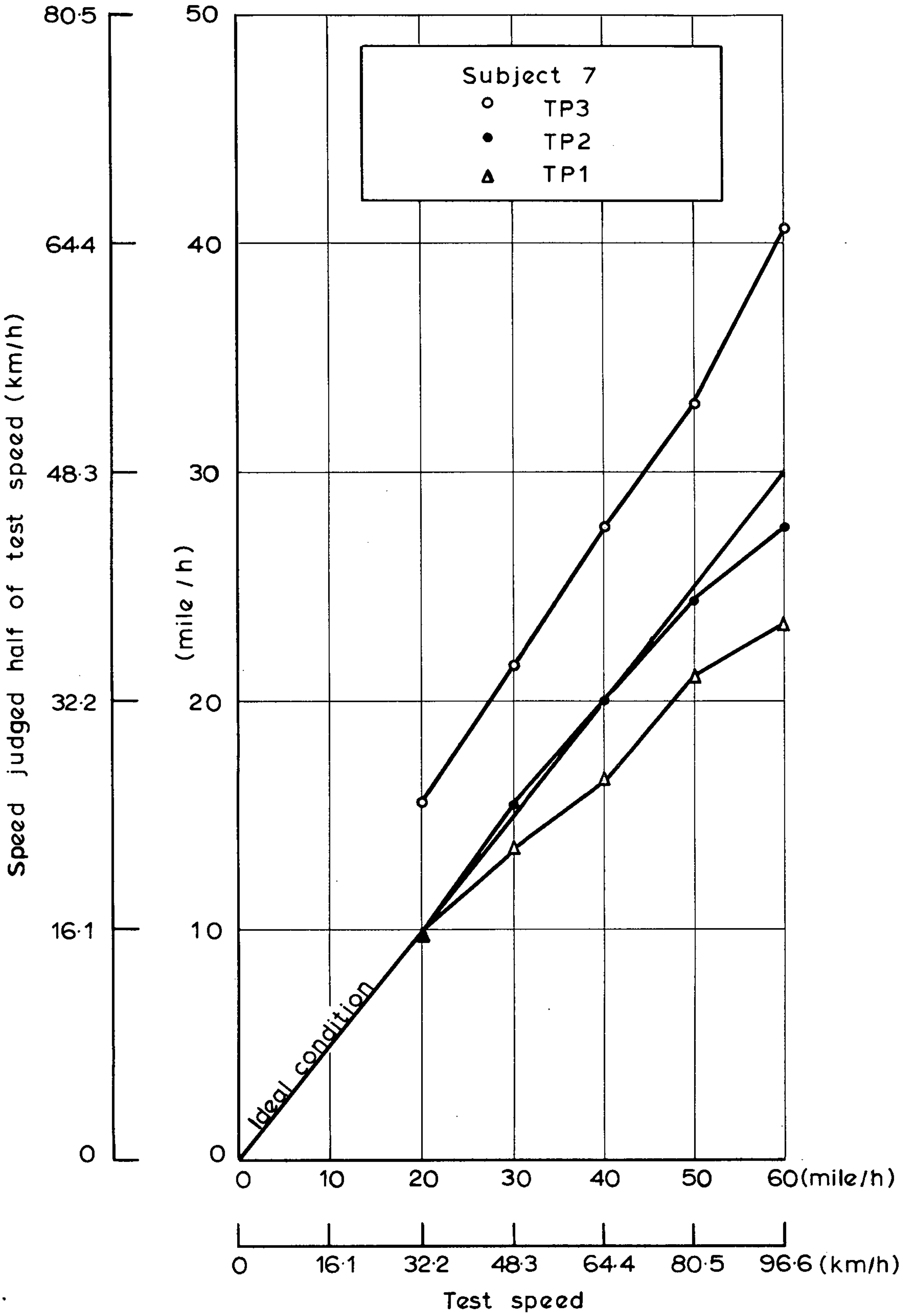

Fig.7. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT – SUBJECT 7 RESULTS

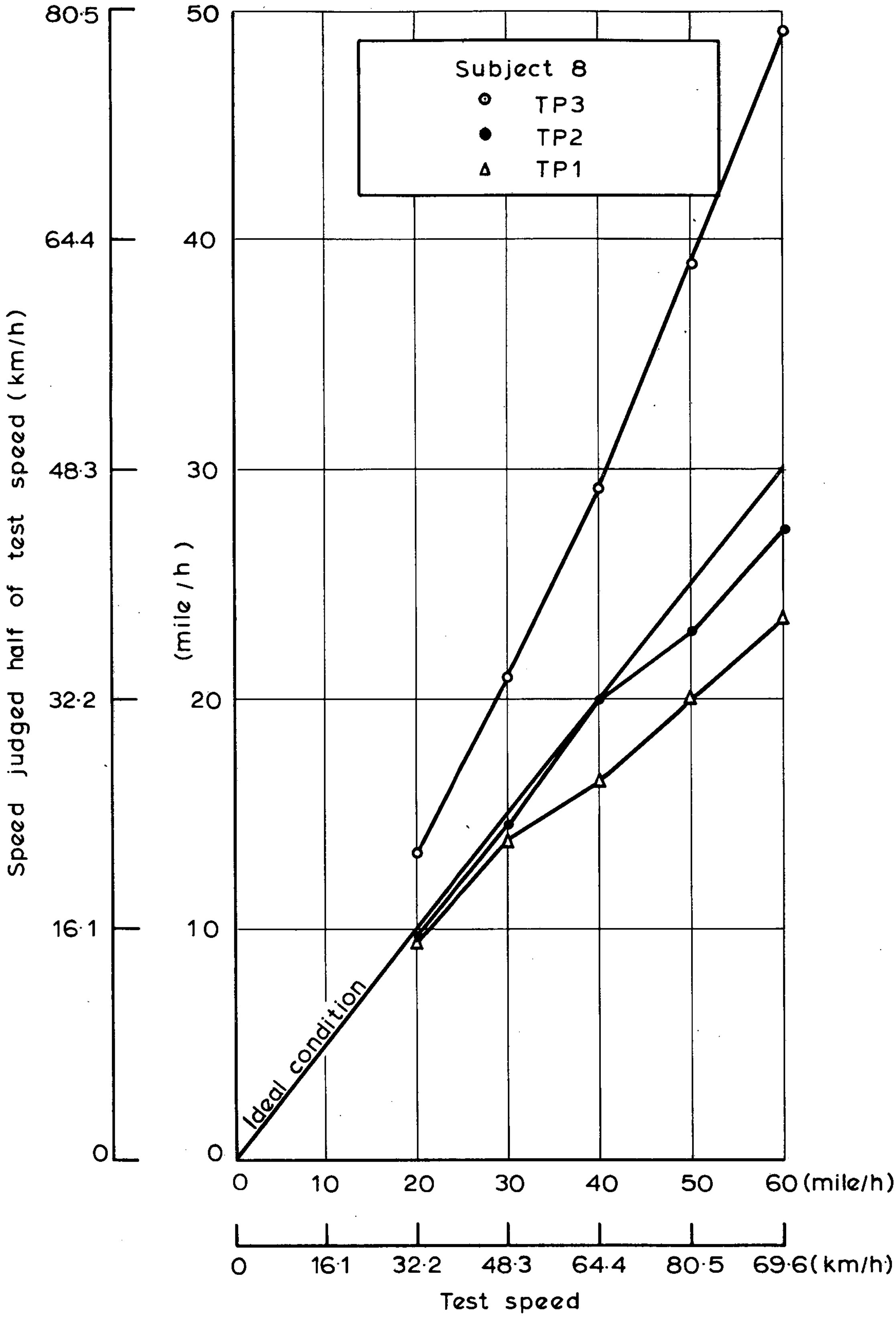

Fig.8. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT – SUBJECT 8 RESULTS

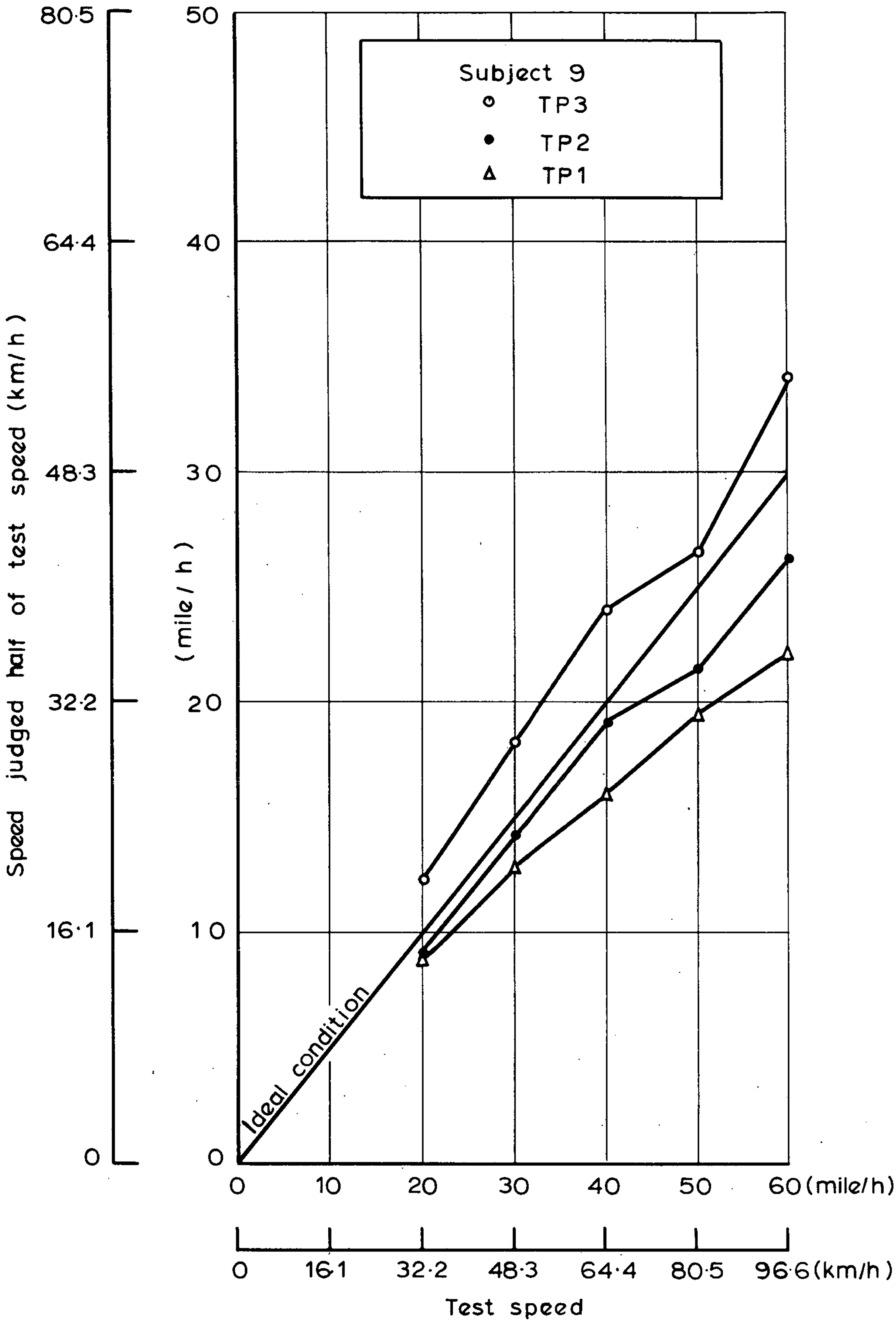

Fig. 9. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT – SUBJECT 9 RESULTS

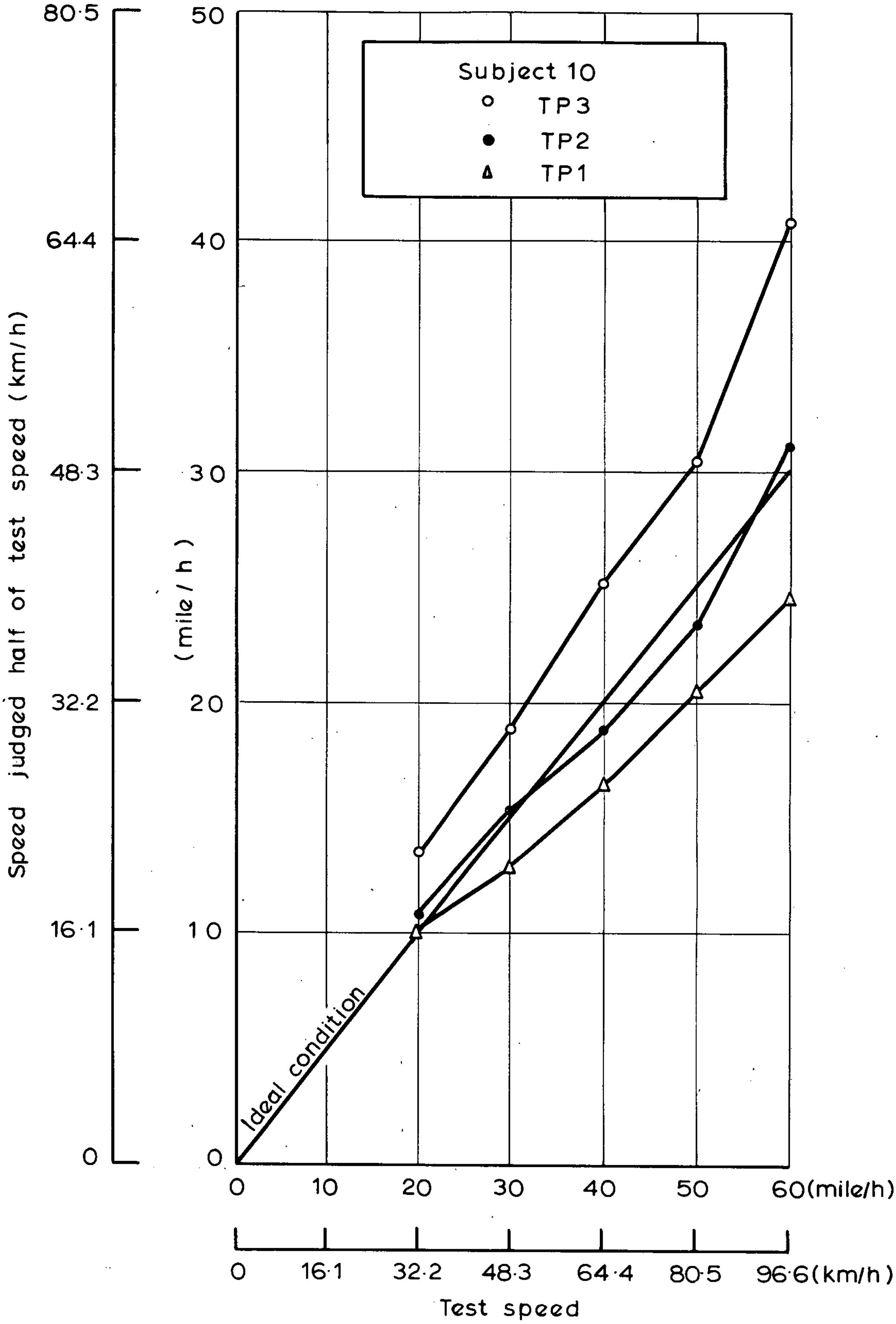

Fig.10. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 10 RESULTS

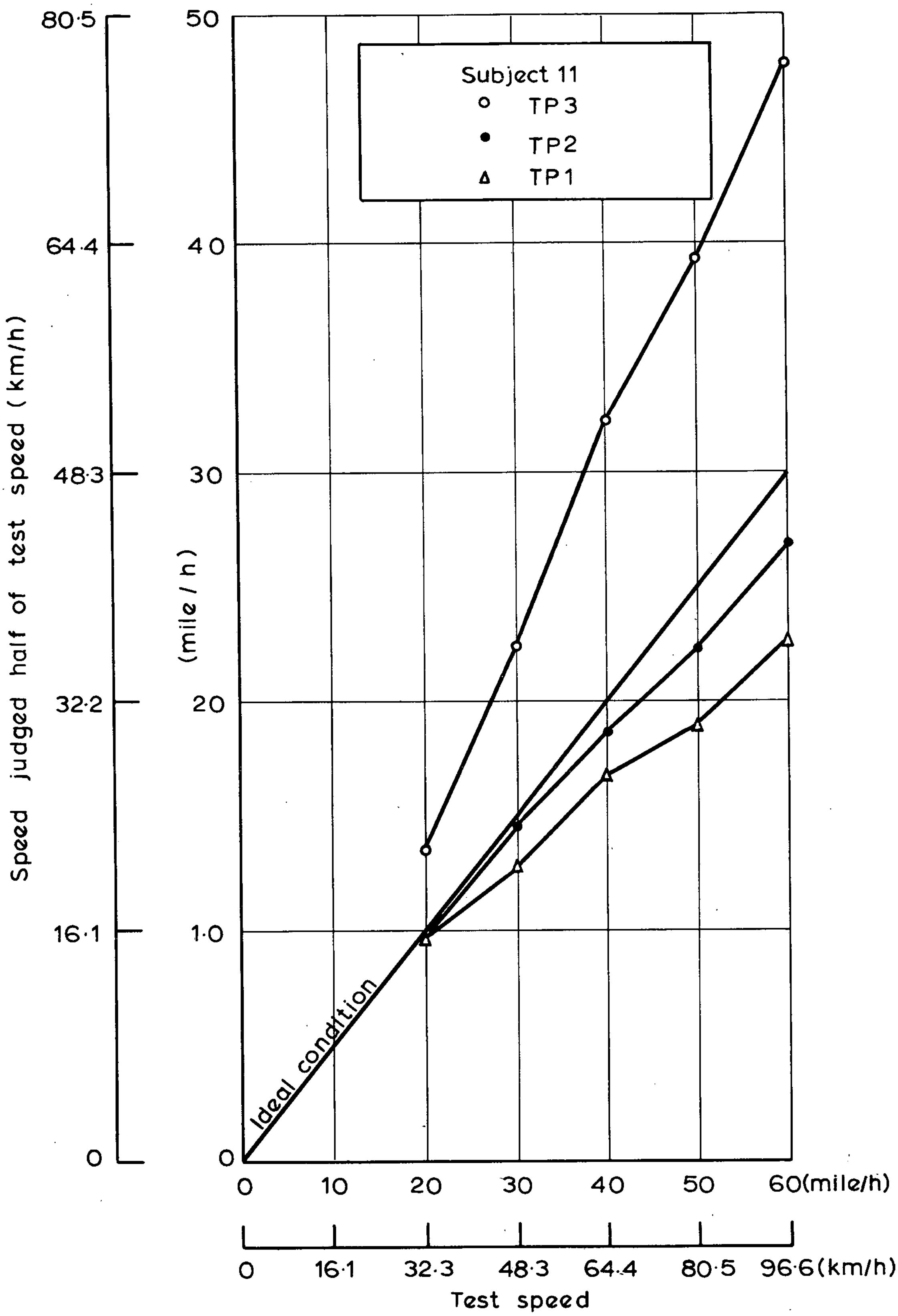

Fig.11, THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT – SUBJECT 11 RESULTS

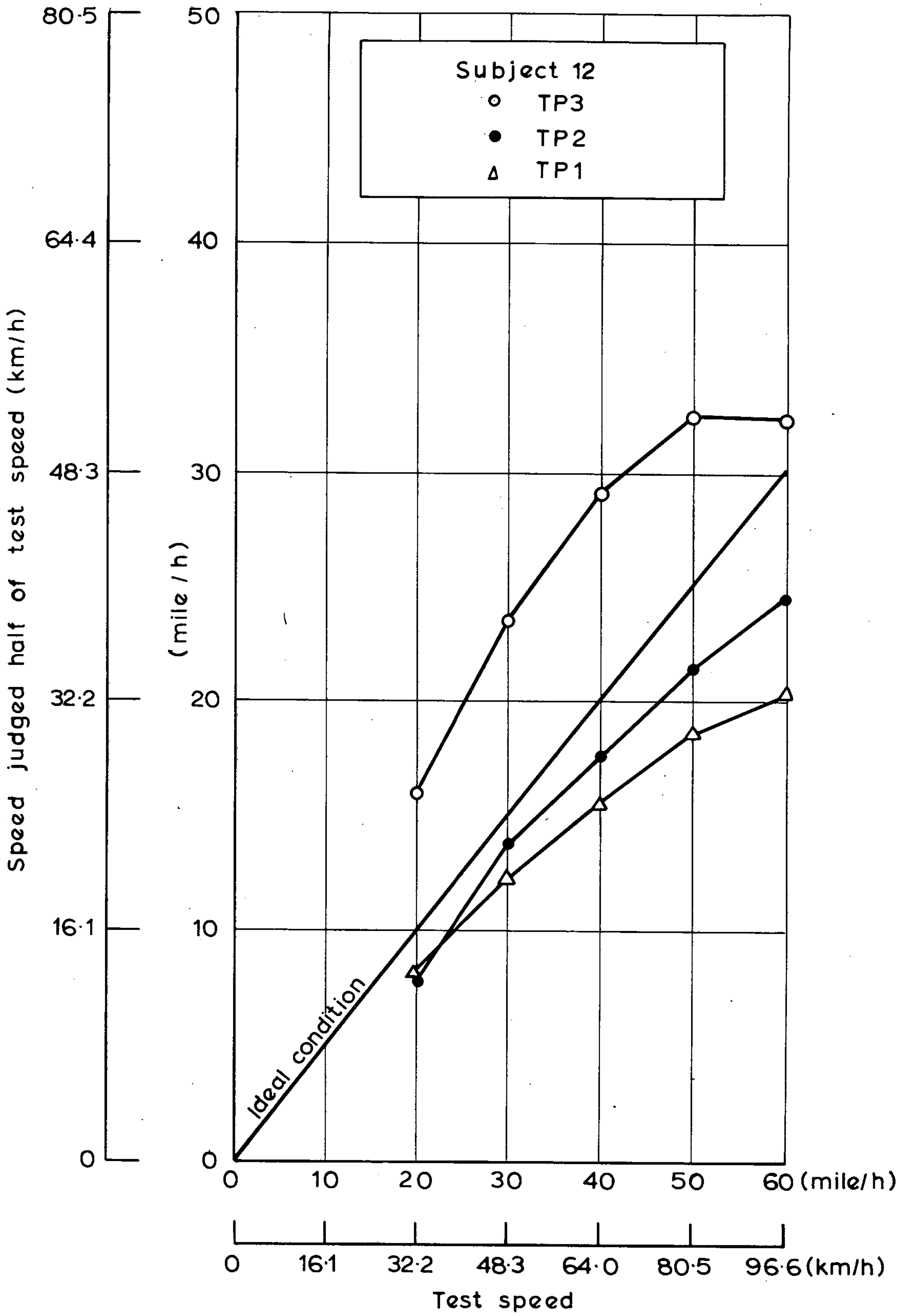

Fig.12. THE INFLUENCE OF VISUAL FIELD ON SPEED JUDGEMENT - SUBJECT 12 RESULTS

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ABSTRACT

The influence of visual pattern on perceived speed: G. G. DENTON: Department of the Environment, RRL Report LR 409: Crowthorne, 1971 (Road Research Laboratory). This report is concerned with the instability of the relationship between real speed and the sensation of speed experienced by the driver relative to the physical speed at which he is moving. The various contributing factors are outlined. Speed adaptation is considered as a major factor responsible for errors in the driver's judgement of speed, and the hypothesis is made that by deliberately distorting the spatial geometry of the visual field it should be possible to counteract the effects of adaptation. The results of this experiment carried out on a simulator confirmed the possible value of such a technique. Proposals are made for future research into the control of behaviour by the use of illusion, particularly in the driving situation.

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