TRANSPORT and ROAD
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Department of the Environment
Department of Transport

TRRL LABORATORY REPORT 998

MASKING OF BRAKE LIGHTS BY HIGH-INTENSITY REAR LIGHTS IN FOG

by

R D Helliar-Symons BSc MInstP and A Irving MSc

Road User Characteristics Division
Safety Department
Transport and Road Research Laboratory
Crowthorne, Berkshire
1981
ISSN 0305–1293

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ABSTRACT

In fog the conspicuity of a vehicle may be increased by using high-intensity rear lights. However, these lights can be much brighter than the vehicle's brake lights and may mask them if they are installed too close to them. An experiment to investigate the effect of increasing the separation between these lights and the brake lights was conducted in artificial fog at TRRL. A rear light display of two brake lights and two high-intensity rear lights was situated in the peripheral visual field of the subject who had to react to the brake light onsets. At the same time subjects performed a second task, demanding similar concentration to driving, which also simulated a driver being distracted from looking straight ahead.

Subjects reacted more quickly and missed fewer presentations as the separation between the brake lights and high-intensity rear lights was increased. The greatest improvement in performance occurred when the angular separation, between the lights as measured from the subject's view-point, was changed from zero (the lamps touching) to 5.7 minutes of arc with smaller further benefits occurring with angular increases up to 17 minutes of arc. It is suggested that a minimum separation between the different types of lamp of 100 mm would be the most suitable since this would meet the 5.7 minute of arc criterion during following at high speed in thin fog and would exceed this at the shorter viewing distances likely in thicker fogs.

1. INTRODUCTION

It has been accepted for some time that the red rear position (side) lights fitted to vehicles are of limited value if used in daylight fogs. Indeed, in many cases the outline of a vehicle will become visible before these lights are seen at all. Also one possible causal factor in multi-vehicle motorway fog accidents that has been suggested is the tendency of drivers to try at all times to be able to see the rear lights of the vehicle they are following[1], regardless of whether this causes them to travel at a following distance inappropriate to their speed. In an attempt to mitigate these problems rear lights of much higher intensity have been developed, initially in the Federal German Republic, for use only in fog or other conditions of low visibility. The original stipulation in Germany was that they were to be used when the visibility was reduced to less than 50 metres. These lights were intended to give an early warning of vehicle presence and encourage following to take place at a greater, and therefore safer, distance. In a medium density daylight fog of 75m threshold visibility (a 600 mm x 600 mm black target would be just detectable if it had a 5 per cent contrast with its surroundings at this distance), calculations indicate that a high-intensity rear light of 200 candelas intensity will be visible at twice the distance of normal rear position lights.

The onset of braking is normally signalled by a change in the intensities of the rear lights. There is a substantial increase in the intensities of the rear lights (by five times at least) when the brake lights are switched on. If this criterion was adopted in the case of brake lights with respect to high-intensity rear lights, the intensity of the former would have to be as much as that of a low beam head light, which would not be acceptable as it would dazzle following drivers. An alternative is to use separate lamps which would allow braking to be detected using brake lights of the same intensity as existing brake lights. A number of workers have advocated the separation of all signalling functions into quite separate lights as an aid to their detection[2,3,4] and separations from 50 to 100 mm have been suggested between brake lights and rear position lights as an aid to the detection of the former. In contrast, however, Kinnear[5], examining the particular situation of the detection of brake lights in the presence of high-intensity rear lights, concluded that no separation was necessary. However he used a scaled-down experiment performed with the subjects concentrating completely on the lights with no additional workload to simulate driving in fog. It was therefore decided to examine this problem in order to establish the parameters of brake light to high-intensity rear light separation for acceptable detectability in low-visibility conditions.

In Germany the practice was to fit only one high-intensity rear light. However, although one light will help to establish the presence of a vehicle, the judgement of following distance is much easier when lights are used in pairs and each light is placed close to the edge of the vehicle. This was established during night-time distance-judging tasks performed in 1952 in this country[6]. In consequence a twin rear lamp configuration was made mandatory from 1954 in the United Kingdom. In fog, visibility changes may happen quite quickly due to variations in fog density which can occur in the space of a few metres. These can give rise to fluctuations in the apparent luminance of a light source viewed by an observer. In the case of a single source such variations might be interpreted as distance changes when in fact none has occurred. When two lights are used this is less likely to happen since it can be seen that the inter-light separation remains the same. In line with regulations for normal rear light configuration, the official recommendation for the fitting of high-intensity rear lights to vehicles in this country is that they should also be used in pairs[7]. The experiment was therefore conducted using pairs of lights.

The experiment described in this report was carried out in 1974 prior to introduction of regulations. European Economic Community Council Directive No. 756 dated 27 July 1976 called for manufacturers seeking Type Approval to this Directive to fit one or two high-intensity rear lights to most new motor vehicles other than motorcycles after October 1979. The Road Vehicles (Rear Fog Lamps) Regulations of 1978 (Statutory Instrument 1260) mandated the requirement in this country. Some European countries had tended to follow the original German practice of fitting only one high-intensity rear light. Therefore the Directive allowed for one light with the option of fitting two. In either case, the regulations stipulate separation of the high-intensity rear light from brake lights by at least 100 mm. The findings of the experiments reported here were used in discussions concerned with drafting the regulations.

2. EXPERIMENTAL DESIGN

The experimental conditions used were limited by the size of the building in which the tests were carried out. A viewing distance of 30m was used.

The condition represented was that of a narrow vehicle, a BL Mini, being followed in fairly dense fog; at a distance which represents a two second following interval at a speed of 50 km/h; by a driver able to see the lights but not the vehicle outline; whose attention was mainly focussed on happenings in the opposite lane, but who still had to monitor the braking of the vehicle in front of him. It was thought that this might represent one of the more difficult conditions for the detection of brake lights in the presence of high-intensity rear lights.

The array of lamps was fitted to a metal frame (Plate 1). The two brake lights were fixed at a separation of 1.04m and at 0.46m above the ground, as they would be on a BL Mini. Two moveable high-intensity rear lights were situated symmetrically between the Mini lights and these could be positioned at various distances inboard of the brake lights. The two high-intensity rear lights were always illuminated during the experiment. The intensities in the direction from which the lights were to be viewed were adjusted to 46 candelas for the brake lights (UK regulations allow intensities of between 40 and 100 candelas) and 220 candelas for the high-intensity rear lights. This is a ratio of 5:1 high-intensity rear light to brake light compared with 1:5 rear position light to brake light in the normal case.

The experiment was carried out in artificial 'fog' produced in a large building using commercially available equipment designed to produce simulated smoke or fog for theatrical or film productions.

The fog was an oil aerosol created by forcing an innocuous vegetable oil over heating elements and through an orifice using carbon dioxide gas under pressure. Particle sizes compared reasonably well with those of real fogs (0.1 to 5 μm in diameter compared with the water droplets in real fogs of about 0.2 to 40 μm in diameter). The fog produced by several of these generators was fed into the building via the forced-air ventilation system which had been temporarily reversed (Plate 2). The fog was lit by daylight passing through extensive roof-lights, supplemented by the internal lighting of the building. The background luminance of the fog was about 800 cd/m^2.

Once the building was fog-filled, the fog density was continuously monitored by an infra-red transmissometer and adjusted by re-starting the generators so that the visibility was always close to 24m (to a black target, 600 mm x 600 mm, detected at 5 per cent contrast). The fog was found to be very even and stable, usually requiring only one 'top-up' per subject.

In this particular fog both brake lights and high-intensity rear lights remained perfectly visible from 30m, their maximum visibilities have been calculated to be about 36 and 52m respectively. At 30m viewing distance both the outline and normal rear position lights of an actual vehicle would not have been visible.

The subjects, who viewed the light display whilst seated in a parked car, had their attention directed away from it to a second task located to the right of the display. The test layout is shown in Figure 1. The second task consisted of monitoring three white lights (0.3m apart) only one of which was lit at a time. At intervals chosen randomly from three time intervals (2, 3 or 4 seconds) the normally-lit centre lamp was switched off and one of the two side lamps switched on. The observer had to indicate which side lamp had come on. Since there was no frame of reference, because of the fog, the subject had to pay close attention to this task. If the change had not been responded to within two seconds the attention of the subject was drawn to this fact and the trial resumed. No record was made of reaction times or failure rates on this task but they were monitored to ensure that the task was being carried out without too many misses. Brake light presentations were not made unless the subject was reacting normally to the second task. The purpose of the task was to prevent complete concentration on the main array of lamps so that the amount of attention paid to it would not be too dissimilar from that which could be paid to a vehicle being followed during actual driving.

The reaction times of the subjects to the illumination of the brake lights were recorded. The brake lights were illuminated after an interval selected randomly from five possible timings of 20, 30, 40, 50 and 60 seconds. A millisecond electronic timer started when the brake lights were switched on and was stopped by the subject's response button. If no response was recorded after four seconds the brake lights were automatically extinguished, the next response sequence commenced and a 'missed response' recorded.

A total of 28 subjects of varying ages and both sexes took part in the experiment, each providing responses to 45 brake light onsets. Each subject attended for about 45 minutes and was given an instruction sheet (Appendix 1) to read at the beginning of the experimental session. Each was allowed a few minutes practice before the experiment commenced. Afterwards a number of subjects commented that the concentration required was similar to that needed in actual fog driving.

During the experiment nine separations between the brake lights and the high-intensity rear lights were tested: 0, 50, 100, 150, 200, 250, 300, 350 and 400 mm. Each was presented five times to every subject in a randomised order.

3. RESULTS

The distribution of reaction times found is shown in Figure 2 and can be seen to be markedly skewed. Median reaction times were calculated for each subject at each spacing and also the median was found for all subjects at a particular spacing (Appendix 2). The values obtained are plotted in Figure 3 against lamp separations.

The percentages of missed responses for each separation are shown in Figure 4 and also the percentage of reaction times which were longer than two seconds (the simulated following distance).

4. DISCUSSION

Considering either median reaction times, late responses or missed responses, the largest improvement may be seen from Figures 3 and 4 to have happened as soon as actual lamp separation occurred, that is, from actually touching (zero separation) to the smallest separation distance tested of 50 mm. Also, in all cases, further, but much smaller, improvements occurred up to 150 mm separation. Separations greater than 150 mm showed little further change.

A separation distance of 50 mm subtends an angle of 5.7 minutes of arc at a distance of 30m. In night time tests made in good visibility conditions, Mortimer[8] found that the minimum angular separation needed for lights of unequal intensities to be seen as separate was 4.3 minutes of arc. He used an intensity ratio of 15:1 signal to steady light viewed directly at a distance of 120m. The criterion of success used was the angle at which the lights were resolved on 90 per cent of the times on which they were presented. This result is comparable with the 10 per cent failure rate found for 5.7 minutes of arc separation in the present study.

The fog density used in the study represents a quite severe condition. Two studies in which measurements were taken over a period of time[9,10] indicated the rarity of this condition. In fact during these studies visibility seldom fell below 100m and it was only at this visibility that speeds began to be affected and even then they were only reduced to between 70 and 80 km/h. At a speed of 70 km/h a two second headway would represent about 40m, a visibility distance to both brake lights and high-intensity rear lights easily attainable in all but the thickest fogs. The problem is how to cater for the greater following distances which are needed at higher speeds in thinner fogs. Fortunately, a lamp separation which would be detected at a greater following distance would work as well, if not better, if viewed at a lesser one. Taking the

5.7 minute of arc angular separation as the minimum acceptable, and the case of a driver following two seconds behind another at the motorway maximum speed of 112 km/h (the distance between the vehicles would be about 62m), the required lamp separation would be 103 mm.

Thus a separation between brake lights and the high-intensity rear lights of 100 mm would allow acceptable detectability of the onset of braking in dense fog at a close following distance, as well as at the longer viewing distances necessary for safe following at the higher speeds possible in thin fogs.

Finally, it should be noted that the rates of missed responses found in the experiment should not be taken as representative of those which would occur in an actual driving situation. The effort required in this experiment was directed and sustained. In a real situation a much wider perspective would have been taken and many more brake light onsets would have been detected. There are also other cues to braking in a dynamic situation (eg the apparent change in the size of and distance between vehicle lights) which increase the likelihood of earlier detection. What was being measured was the relative efficiencies of the various separations in allowing brake light onsets to be seen.

5. CONCLUSIONS

Using a simulated daylight-fog driving situation, detection of brake lights in the presence of a pair of high-intensity rear lights was found to be greatly improved when the two types of lamp were physically separated.

The minimum separation necessary to bring about the best improvement in brake light detectability depends upon the viewing conditions to be catered for. Expressed as an angle the separation should not be less than about five and a half minutes of arc. Some slight improvements continue up to separations of about seventeen minutes of arc.

The best solution would be to cover the longer viewing distances necessary for safe following at the high speeds possible in thin fogs and this would automatically take care of the shorter viewing distances likely in much thicker fogs. A minimum separation distance of 100 mm would cover these points.

6. ACKNOWLEDGEMENTS

The work described in this report was carried out in the Road User Characteristics Division of the Safety Department of TRRL.

7. REFERENCES

1. WHITE, M E and D JEFFERY. Some aspects of motorway traffic behaviour in fog. *Department of the Environment Department of Transport, TRRL Report* LR 958. Crowthorne, 1980 (Transport and Road Research Laboratory).

2. UNIVERSITY OF CALIFORNIA AT BERKELEY.Motor vehicle rear lighting and signalling, Contract FH–11–6553, US Department of Transportation, National Highway Safety Bureau, May 1968.

3. PROJECTOR, T H, K G COOK and L O PETERSON. Analytic assessment of motor vehicle rear signal systems, US Department of Transportation, Contract No. F–11–6602, National Highway Safety Bureau, January 1969.

4. SCHREUDER, D A. Vehicle lighting within built-up areas, Stitchting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV), Voorburg, The Netherlands, 1974.

5. KINNEAR, R. Fog rearguard mounting proximity to stop lamp. 1974 (Polytechnic of Central London).

6. MOORE, R L. Rear lights of motor vehicles and pedal cycles. *Department of Scientific and Industrial Research, Road Research Technical Paper* No. 25. London, 1952 (H M Stationery Office).

7. DEPARTMENT OF THE ENVIRONMENT. Press Notice No. 99. February 1974.

8. MORTIMER, R G. Research in automotive rear lighting and signalling systems. *Engineering Publication No.* 3304. 1969 (General Motor Corporation).

9. SUMNER, R, C BAGULEY and J BURTON. Driving in fog on the M4. *Department of the Environment Department of Transport, TRRL Report* SR 281. Crowthorne, 1977 (Transport and Road Research Laboratory).

10. MOORE, R L and L COOPER. Fog and road traffic. *Department of the Environment, TRRL Report* LR 446. Crowthorne, 1972 (Transport and Road Research Laboratory).

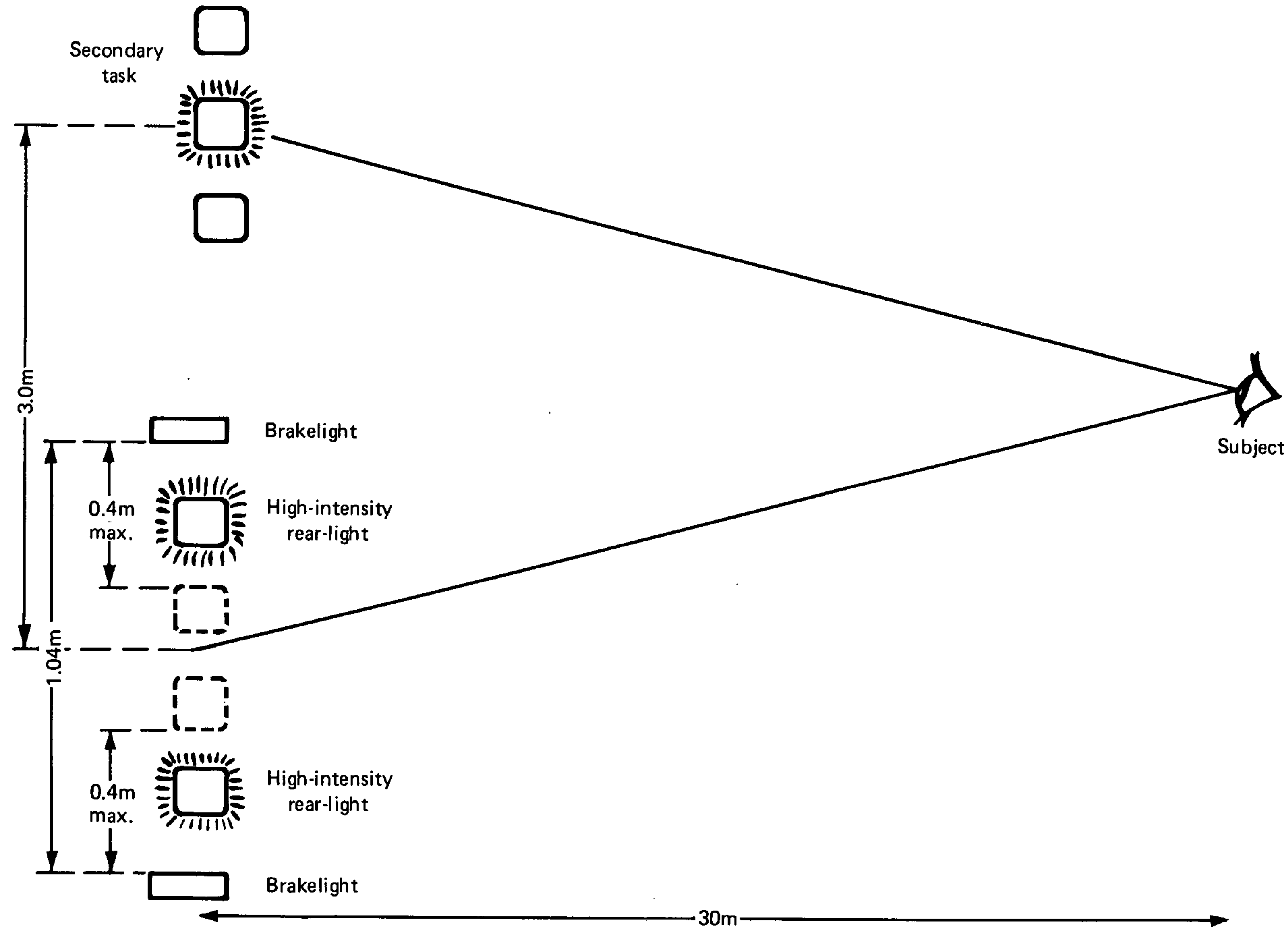

Fig. 1 Position of lamps used in the experiment

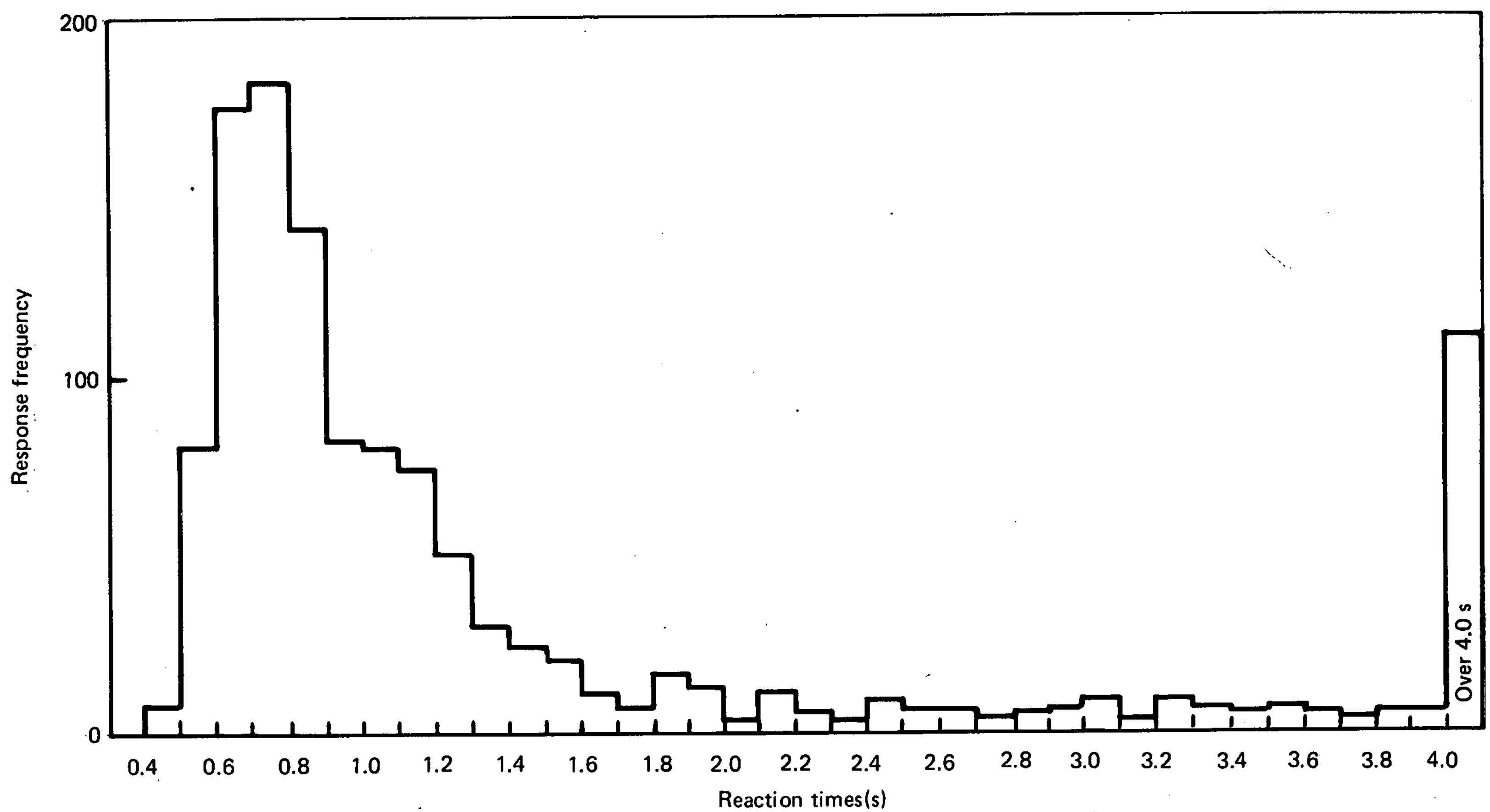

Fig. 2 Distribution of reaction times

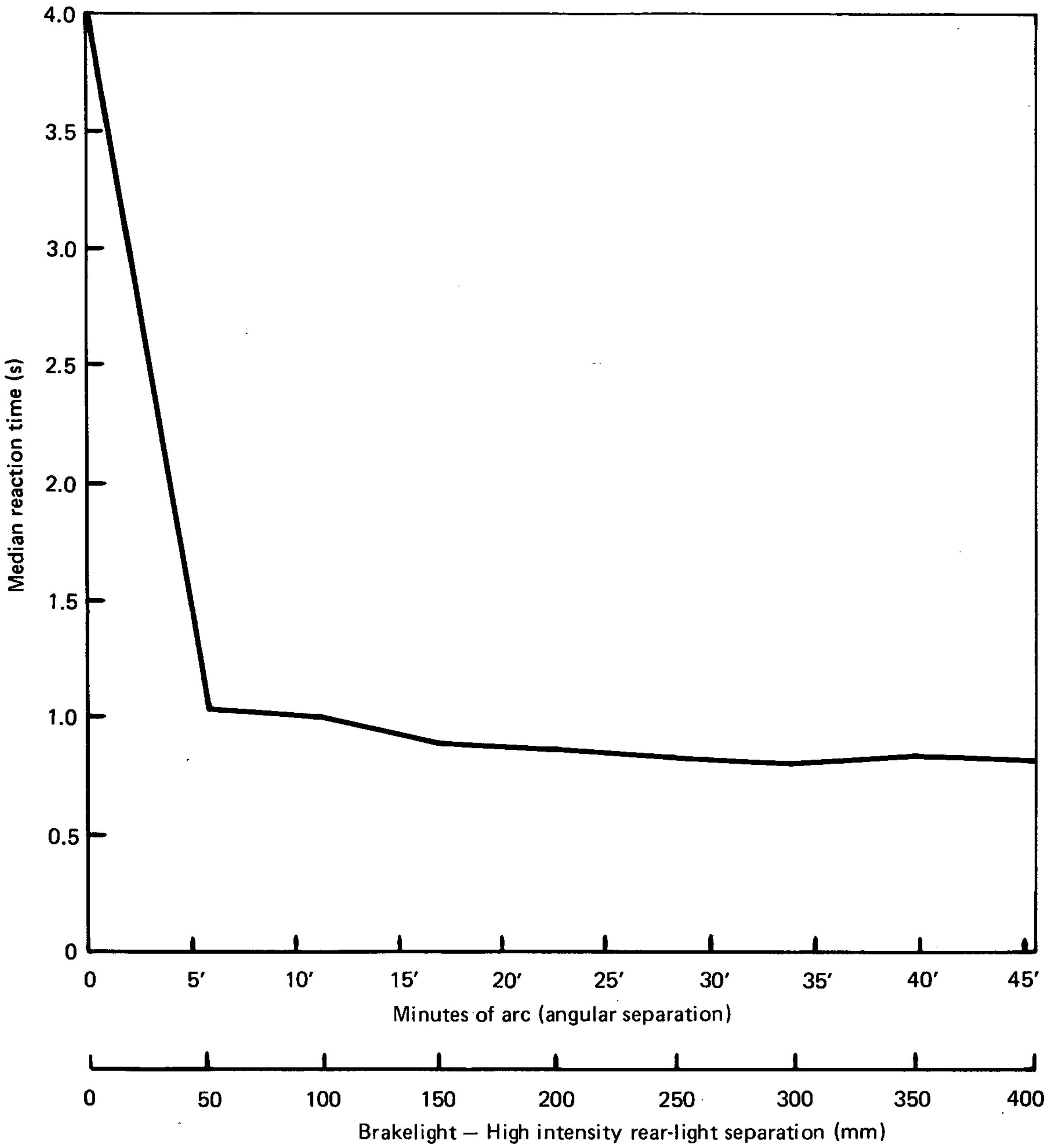

Fig. 3 Relationship between separation distance and median reaction time

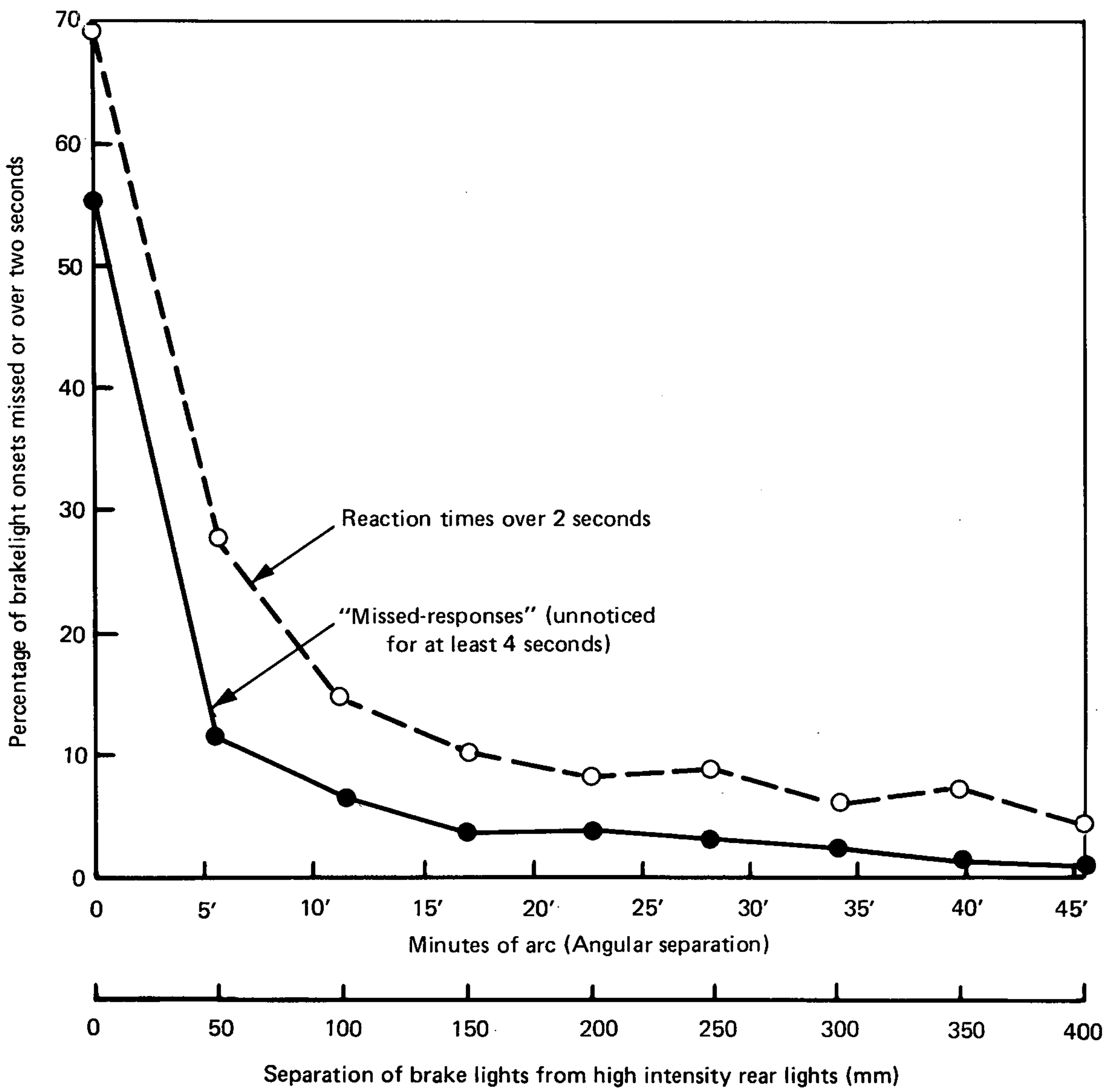

Fig. 4 Relationship between separation distance and brake light onsets which were unnoticed or exceeded two seconds reaction time

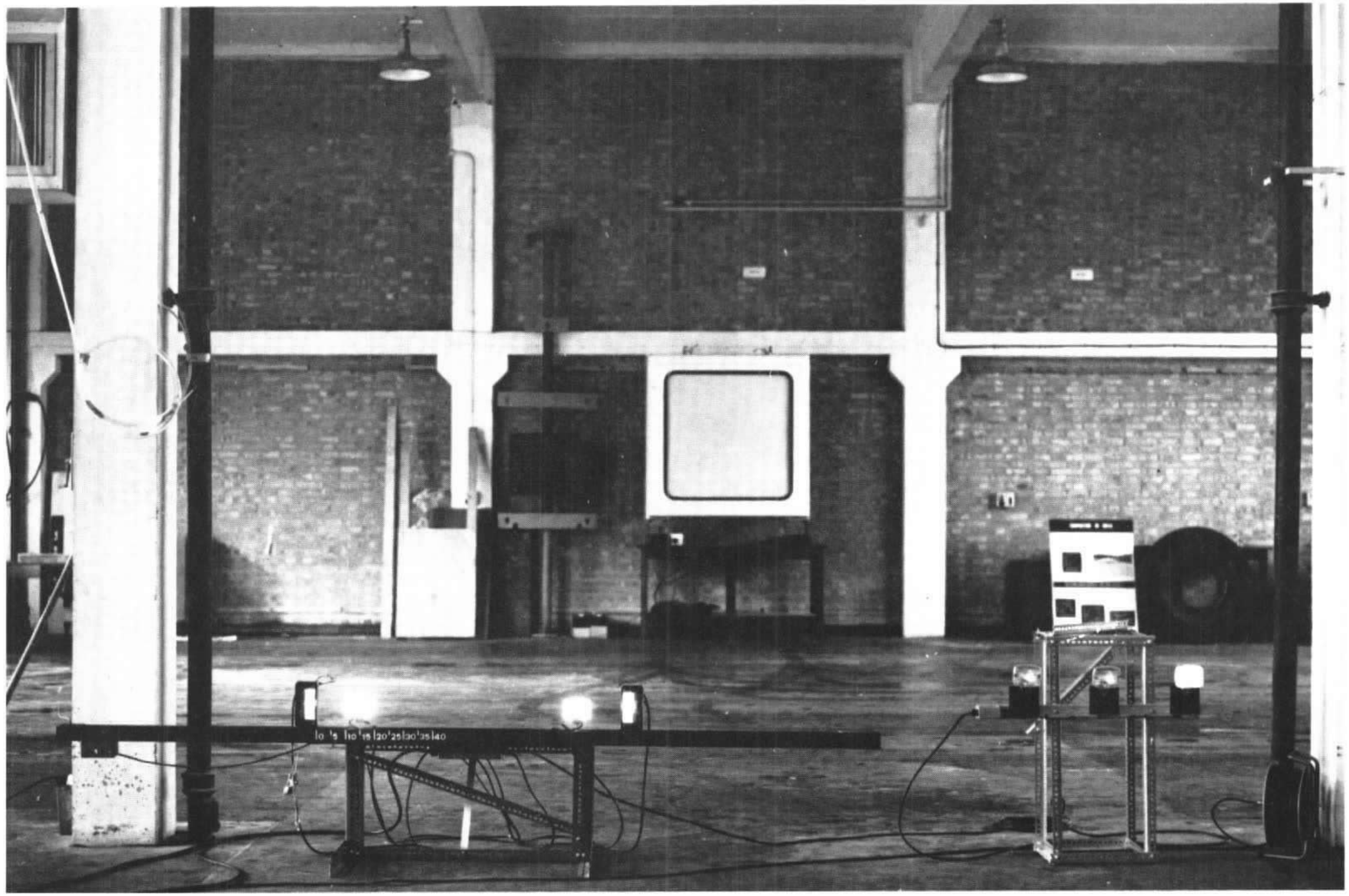

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Plate 1 The simulated vehicle rear light display with both high intensity rear lights and brake lights illuminated. The secondary task is to the right

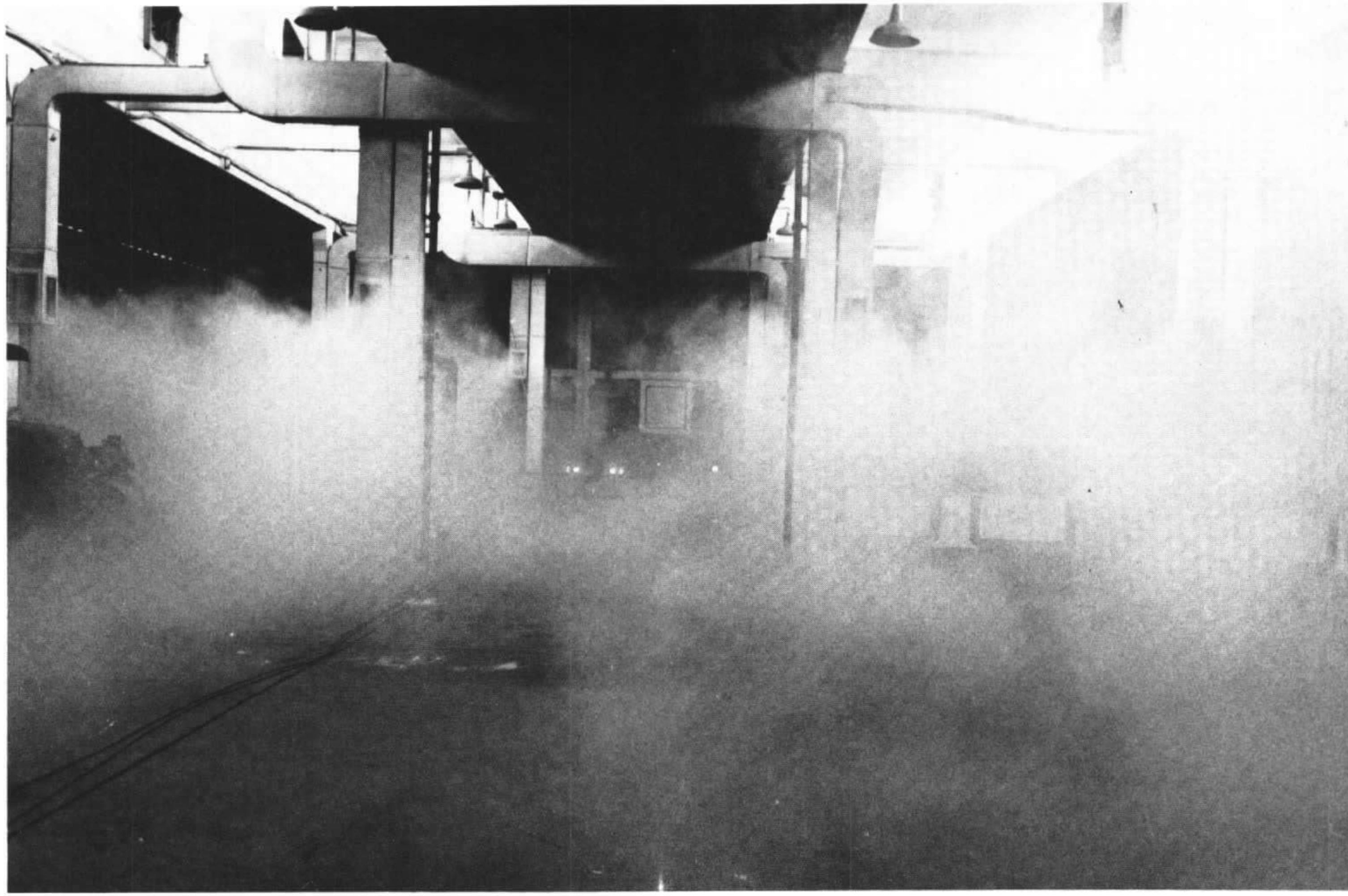

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Plate 2 Fog beginning to enter the experimental area showing the rear lights and secondary task from the subject position

8. APPENDIX 1

INSTRUCTIONS TO SUBJECTS

This experiment is concerned with how well you can see car lights in fog. It is designed to measure how quickly you can respond to:

a) the movement of a single light
b) the onset of brake lights of various configurations.

Ahead of you can be seen three lights. The one on the extreme right will periodically go out to be replaced by a similar one to its right or left. The two lights on the left are supposed to represent the rear lights of a car you might be following. You will be required to perform two tasks:

1. At frequent but varied intervals the rightmost light will go out and a similar one will appear just to the left or right of it. You should respond to this 'movement', as quickly as you can, by pressing the joystick (attached to the car door) to the right when the light 'moves' to the right, or to the left when the light 'moves' to the left. This will cause the central light to reappear by itself. If you should make a mistake, by pressing the wrong way, *or* by 'missing' a 'movement', BOTH the right and left lights will come on together. You must then cancel this by pressing the joystick left AND right which causes the central light to reappear by itself. This task will be fairly demanding and you should try to speed up your responses as much as possible by concentrating on this task.

2. The pair of lights on the left represent a car's rear lights. At frequent intervals this 'car' will put on its brake lights (of various configurations). When this happens you should press the push-button response key (which you hold in your left hand) as quickly as possible.

The experiment is so arranged that you will have to make more responses to the 'moving' light than you will to the brake lights coming on, so in order to respond as quickly as possible at all times you should concentrate on the right hand light as much as you can.

<u>REMEMBER</u> – respond as quickly as you can
– move joystick 'right' if light 'moves' right and 'left' if it 'moves' left
– cancel errors by left-right movement
– respond to onset of 'brake lights' by response key in left hand.

The experiment will last approximately half an hour, if you have any problems during this time you can contact the experimenter via the intercom which will be pointed out to you.

9. APPENDIX 2

TABLE OF MEDIAN REACTION TIMES

Lamp separation (millimetres)

Subject No.	0	50	100	150	200	250	300	350	400
1	4.00	4.00	0.73	0.95	0.81	0.70	0.75	0.84	0.75
2	2.35	0.75	0.92	0.72	0.78	0.70	0.66	0.79	0.71
3	4.00	2.42	4.00	1.29	0.72	0.70	0.77	0.88	0.71
4	4.00	1.05	0.79	0.73	0.70	0.61	0.79	0.73	0.79
5	2.25	1.71	0.98	0.83	0.78	0.88	0.73	0.76	0.82
6	4.00	4.00	3.23	0.93	1.00	1.99	0.99	0.82	0.97
7	1.14	0.60	0.68	0.65	0.60	0.80	0.73	0.71	0.67
8	4.00	0.87	1.18	0.73	0.86	0.76	0.75	0.74	0.84
9	4.00	0.82	0.74	0.75	0.75	0.67	0.79	0.68	0.64
10	4.00	0.62	0.69	0.80	1.01	0.86	0.72	0.85	0.70
11	4.00	3.41	1.19	0.81	0.99	0.90	0.89	0.87	0.87
12	4.00	1.29	0.80	1.04	0.69	0.65	0.70	0.88	0.82
13	4.00	0.92	1.49	0.94	1.00	0.73	0.98	1.09	0.86
14	4.00	1.12	1.22	1.30	1.50	1.42	0.89	1.90	1.14
15	0.80	0.64	0.66	0.59	0.60	0.60	0.56	0.60	0.78
16	3.29	1.36	1.12	1.91	1.15	1.26	3.04	1.13	0.92
17	4.00	2.25	1.05	1.22	1.37	1.35	1.05	1.15	0.90
18	4.00	4.00	1.69	1.09	1.10	1.29	1.08	1.14	1.16
19	1.61	1.52	1.45	1.12	1.10	1.16	1.37	1.33	1.52
20	4.00	1.30	1.14	1.21	0.97	1.00	1.11	1.21	1.08
21	4.00	3.25	0.79	1.03	1.40	0.93	0.88	1.15	1.40
22	1.32	1.92	1.07	0.81	0.89	1.64	0.86	1.08	0.95
23	1.19	0.82	1.30	1.57	0.69	0.63	1.17	0.89	0.83
24	0.73	0.80	0.73	0.61	0.66	0.68	0.70	0.70	0.72
25	4.00	0.80	0.55	0.88	0.84	0.73	0.60	0.57	0.64
26	4.00	0.97	1.07	0.94	0.79	1.01	0.77	0.74	0.96
27	1.69	1.02	1.66	0.65	0.73	0.68	0.82	0.81	0.79
28	3.41	0.94	0.90	0.79	0.71	0.65	0.74	0.66	0.70
Overall median	3.996	1.050	1.015	0.892	0.875	0.841	0.813	0.848	0.824
Total number of presentations	131	133	136	135	134	135	134	134	135
Percentage of 'missed responses'	55.7	11.3	6.6	3.7	3.7	3.0	2.2	1.5	0.7
Percentage of reaction times over 2 seconds	69.5	27.8	14.7	10.3	8.2	8.9	6.0	7.5	4.4

(1527) Dd8041301 1,400 9/81 HPLtd So'ton G1915
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