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THE PRESENTATION OF DIFFERENT VISUAL INFORMATION TO EACH EYE

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FOR THE COMMANDER

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

When completely independent images are presented to each eye, fusion normally cannot occur. Instead, either an involuntary alternation occurs between the two images (binocular rivalry) or one of the images is "suppressed," and visual performance is degraded. If the images are only partially independent (see-through display), the observer can control this alternation and presumably reduce degradation.

During the development of one version of the Honeywell Helmet Mounted (See reverse)

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20. Sight and Display (HMS/D) system, it was suggested that presenting a gun-sight reticle to one eye and target imagery to the other eye either sequentially, or with an inter-ocular delay interval (IOD), might minimize binocular rivalry.

To determine the relationship between binocular rivalry and visual performance, an experiment was performed in which target recognition performance was measured as a function of IOD interval. A factorial design with repeated measures on all factors was used to analyze the effects of six levels of IOD and two levels of presentation method. The dependent variable was target recognition time.

It was hypothesized that if binocular rivalry did exist, and if it occured even when only temporal summation linked the images to the two eyes, visual performance would be best when display imagery was presented to only one eye, and worst when presented to both simultaneously. Further, performance would fall off in a regular fashion between these two extremes as the IOD was decrease.

Statistical analysis of the data failed to confirm these hypotheses, and it was concluded that the influence of binocular rivalry on target recognition tasks was negligible with a see-through display.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of Mr. Carl Graf whose expert technical assistance made this study possible. The authors are indebted to Dr. Robert Woodson who suggested the need for the present experiment and to Mr. Robert Hughes who provided much of the equipment used to simulate a binocular HMS/D system. Credit should also go to Mrs. Helen Ginsberg who trained the subjects, and collected and collated the majority of the data.

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ILLUSTRATIONS

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SECTION I
INTRODUCTION

Helmet-mounted displays have traditionally been monocular. The occluded monocular display (Hall and Miller, 1960) presents imagery to one eye which is independent of the visual field of the contralateral eye. Shontz and Trumm (1969), Levelt (1966), and Treisman (1962) have pointed out that the occluded monocular display can produce "Fechner's Paradox." In this phenomenon, the overall perceived luminance is markedly reduced when only one eye has received a reduction in luminance. More serious, however, is the problem of binocular rivalry due to disparate visual information being presented simultaneously to each eye. This phenomenon, studied under controlled conditions over a century ago by Panum (1858) and elaborated on more recently by Ogle (1964), has been one of the most serious drawbacks to the occluded monocular display concept. A recently published report by Jacobs, Triggs, and Aldrich (1971) concluded that, based on both laboratory and flight evaluations, "[the occluded] display leads to problems of retinal rivalry which, in the daylight flight domain were found to be significant."

The see-through monocular display, however, encourages fusion because the two eyes see an essentially normal binocular view of the outside world. The contours of the display are imposed on only a portion of one monocular field. Ogle (1964) in referring to the similarity of visual inputs to each eye being conducive to fusion (and thus minimizing rivalry) said: "Similarity is of course the first prerequisite, ... but this similarity need not be complete as long as certain parts of the figures are the same .... " It would seem, therefore, that a see-through monocular display would not appreciably degrade visual performance with respect to either information viewed on the display or observed through the display in the outside world. This expectation was experimentally supported by Hall and Miller (1963). The next question that needs to be answered is whether or not a binocular see-through display, with different display imagery presented to each eye, would degrade visual performance. A partial answer to this question is presented in this report.

The present experiment was performed to answer a specific question relating to the design of one version of the Honeywell Integrated Helmet-Mounted Sight and Display System (IHMS/D). Designers suggested that presenting a gunsight reticle to one eye and target imagery to the other eye might be advantageous if it did not degrade visual performance. To minimize binocular rivalry, it was proposed that the reticle and target display should be presented sequentially rather than simultaneously. In addition, it was noted that an inter-ocular delay (IOD) might also be needed to minimize visual masking effects. Such masking effects might occur when the reticle and display interacted temporally and spatially, increasing the possibility of visual performance degradation. Visual masking has been shown by Crawford (1947) to be maximal when targets are presented simultaneously.

The present study tested the hypothesis that if binocular rivalry did exist using a see-through binocular display, it would be reflected in degraded target acquisition performance. If rivalry effects were significant, visual performance would be better where imagery is presented to only one eye and worse when presented to both eyes. It was further hypothesized that due to spatio-temporal masking effects, performance would decay as the IOD was decreased.

SECTION II
METHOD

SUBJECTS

Two female and eight male undergraduate subjects from the University of Minnesota participated in the experiment. All were paid for their participation and all had 20/20 corrected vision with no significant ocular pathology.

APPARATUS

A block diagram of the subject/apparatus interface in the present study is shown in Figure 1. Briefly, this system contained the following elements:

- A pilot's helmet modified by the addition of two brackets to hold and allow the easy interchange of the display and reticle optics.
- A Kodak "carousel" slide projector for projecting IR imagery on a back-illuminated screen.
- A 525 line video camera for televising the projected imagery and transmitting it by closed circuit to the display electronics.
- Helmet display electronics which provided the interface between the video camera and the helmet mounted display.
- A 1-inch CRT mounted in the helmet display optics assembly for projecting an image of the target display onto a combining glass in the subject's line of sight.

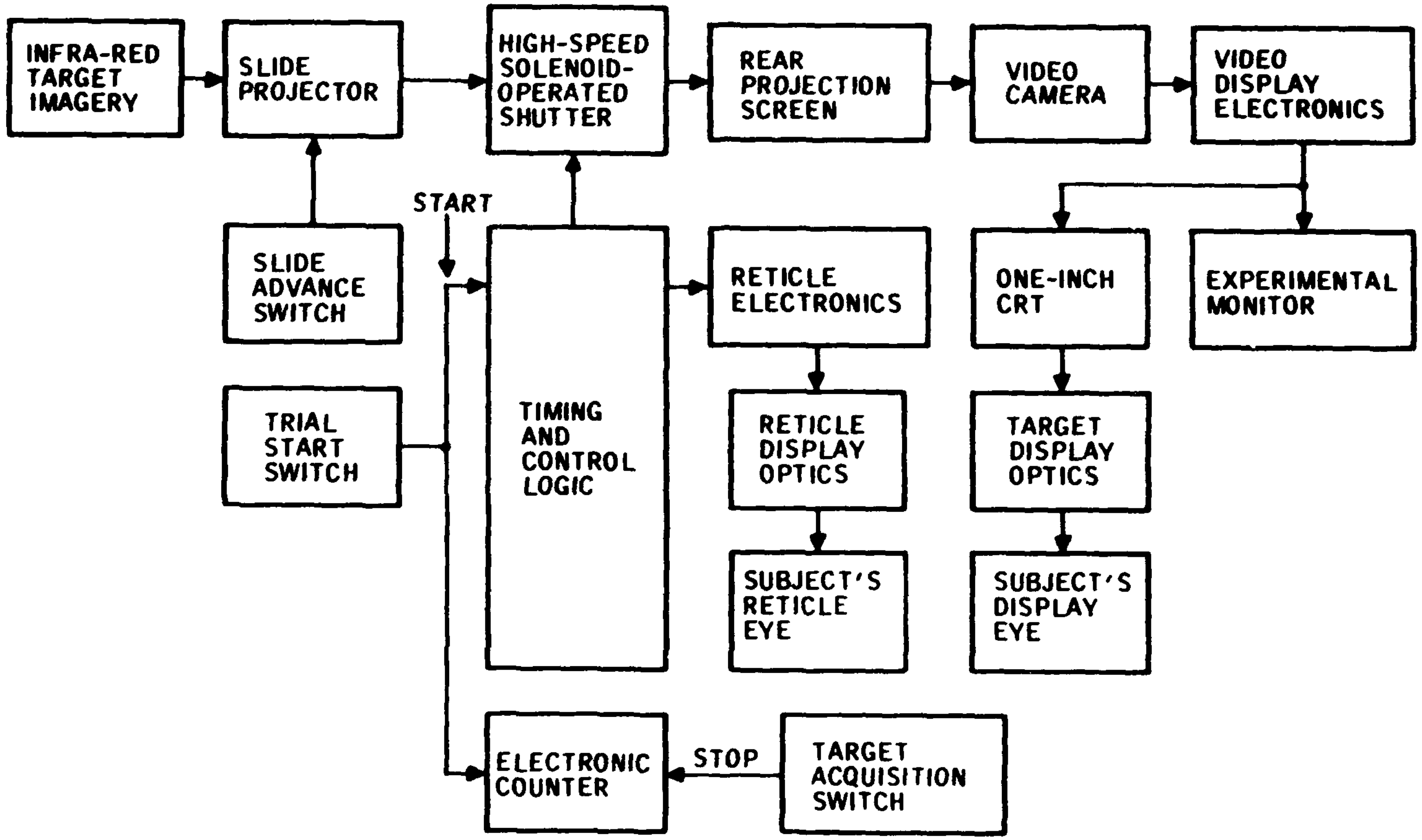

Figure 1. Block Diagram of Subject/Apparatus Interface

- A variable-intensity light source and reticle film mounted in the reticle display optics assembly for projecting an image of the reticle onto a combining glass in front of the subject's contralateral eye.

- A rack-mounted logic system for controlling the target and reticle exposure durations and inter-ocular delay intervals (Figure 2).

- A 6 foot by 6 foot "Polacoat" rear-projection screen on which background imagery was projected by a 1600-watt Xenon-arc source.

Targets used for the present study consisted of 35 mm slides of IR photographs taken with a Barnes Model T-102 Indium Antimonide IR camera. Sixty targets, made up of six groups of 10 photographs of each of the following target classes, were used:

- Men
- Tank
- Semi-trailer
- Howitzer
- Jeep
- Delivery van

Targets were similar to the tank shown in Figure 3. Sample IR images of this target are shown in Figure 4. No attempt was made to control target contrast, but the vehicle photographs were approximately evenly divided among "hot", "cold", night, and day. The reticle consisted of two concentric clear film circles inscribed on an opaque film background. The diameter of the outer and inner circles were 50 and 10 milliradians, respectively, with a

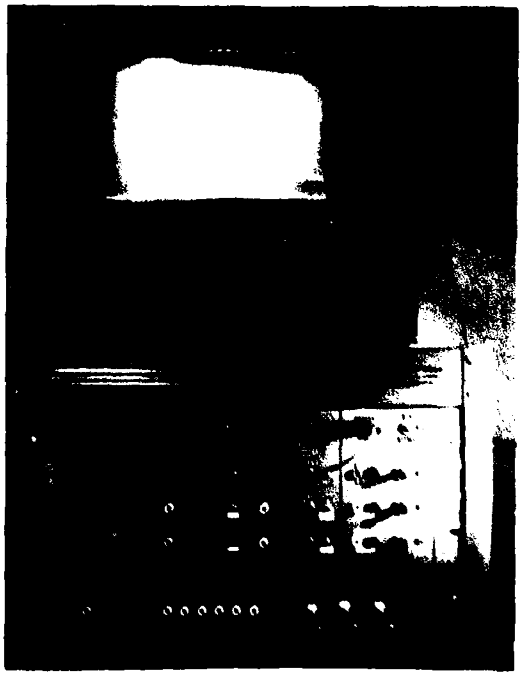

Figure 2. Upper Portion of Experimenter's Console. TV monitor showing IR image of tank (top); controls for adjusting exposure duration and inter-ocular delay (bottom).

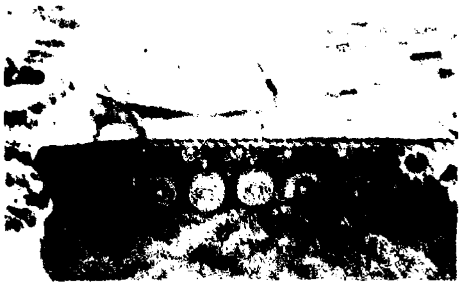

Figure 3. A "Normal" View of One of the Targets Used in the Present Study

Figure 4. Eight Different IR Photographs of the Target Shown in Figure 3

1-milliradian stroke width. The luminance of the display was approximately 50 foot-lamberts. The brightness of the reticle was adjusted until it was judged by an independent observer to be of the same brightness as the brightest portion of the display. This value, which was 22.6 volts input to the reticle light source, was monitored by a digital voltmeter.

PROCEDURE

The subject was initially shown a variety of IR targets on a 19-inch television monitor at the rate of one per second. This constituted his training session. When a criterion level of 15 correct recognitions in succession had been reached, the subject was seated in a dental chair which was located 2 meters from the rear projection screen. After the experimenter had read the instructions aloud (Appendix A), the subject was fitted with the helmet. The combining glasses of both displays were adjusted until the subject saw the reticle superimposed and centered over the display target.

A background scene of a continuous terrain was constantly viewed by the subject via the rear-projection screen. The interval between the reticle and target varied according to the values presented below. There was one condition where no reticle was presented. The reticle, when presented, lasted for a period of 10 seconds.

The subject's task was to press a hand-held button when he recognized the target. The time from target onset to button press was taken as the primary dependent variable. The subject was also asked to identify the target aloud so that the experimenter could determine if his response was correct. Only correct responses were used in data analysis.

When, in the experimenter's judgment, the subject both fully understood the task and was properly fitted and positioned, the formal data collection trials were begun. For half of the subjects the display was presented to the left eye and the reticle to the right eye for the first 60 trials and, following 24 hours rest, the presentations were reversed. This situation was counterbalanced for the other five subjects, where the display was presented to the right eye for the first 60 trials and to the left eye for the last 60 trials.

EXPERIMENTAL DESIGN

The experimental design was a two-way randomized block factorial design with 6 x 2 independent variable levels combined to provide 12 treatment combinations. The independent variables were IOD and method of information presentation. There were six levels of IOD:

1) 0 second (display onset immediately followed reticle termination)
2) 50 milliseconds
3) 100 milliseconds
4) 500 milliseconds
5) No reticle presentation
6) Simultaneous presentation of reticle and target

and two levels of method of presentation:

1) Reticle-right eye; target-left eye
2) Reticle-left eye; target-right eye

The 12 treatment combinations were presented in blocks of 10 trials, each trial consisting of a different target, with each subject viewing the same 60 targets for two successive days. All subjects received all 100 levels in a counterbalanced fashion. The experimental design is summarized in Figure 5.

IOD	NO RETICLE		500 ms		100 ms		50 ms		0 ms		SIMULT.	
TARGET EYE	L	R	L	R	L	R	L	R	L	R	L	R
TREATMENT *	1	2	3	4	5	6	7	8	9	10	11	12
SUBJECT												
1	(10 TRIALS/TREATMENT/SUBJECT)											
2												
.												
.												
.												
.												
10												

* SUBJECTS 1-5 = TREATMENTS 1-6 ON DAY 1 AND 7-12 ON DAY 2
SUBJECTS 6-10 = TREATMENTS 7-12 ON DAY 1 AND 1-6 ON DAY 2

Figure 5. Summary of Experimental Design

SECTION III
RESULTS

Table 1 summarizes the mean performance of each subject in terms of target recognition latency. The cells of this table contain the average latency over 10 trials. Table 2 contains these data collapsed across subjects as well as trials. Examination of the cell means, as well as the overall means, by inspection does not indicate any differences attributable to either the independent variables or the interaction between them. Figure 6 demonstrates this apparent lack of relationship graphically. A two-way analysis of variance of the data was performed and is summarized in Table 3. Again, neither the main effects nor the interaction term were statistically significant. The significant difference between subjects served only to demonstrate that, while there were differences in target acquisition time between subjects, these differences were not significantly influenced by the independent variables. Individual performance curves for each of the 10 subjects are presented in Appendix B.

Table 1. Target Recognition Latency (milliseconds) for Each Subject Averaged Over 10 Trials per Treatment Combination

	IOD	No Reticle		500 ms		100 ms		50 ms		0 ms		Simultaneous		
	Display Eye	L	R	L	R	L	R	L	R	L	R	L	R	Mean ($\bar{X}$)
Subjects *	1	797	565	761	657	970	524	626	663	799	547	767	692	697
	2	842	1030	1034	1045	825	1025	836	982	1142	1126	960	966	984
	3	824	508	740	479	663	567	474	483	568	614	1089	650	638
	4	777	1153	653	774	652	990	646	745	768	732	882	925	808
	5	1480	767	1135	1125	1314	1170	1251	1205	1324	1143	1460	1782	1258
	6	939	972	769	1012	1089	1085	962	1228	984	1187	1140	1264	1052
	7	1598	1512	1204	1565	1263	1383	1589	1573	1526	1344	1242	1386	1432
	9	1055	1028	1239	933	1164	1015	910	831	1127	937	1184	1083	1042
	10	1031	774	1122	1099	820	994	1015	977	1033	844	974	1156	986
	11	1094	1471	924	1217	1180	1280	957	1421	1122	1349	1180	1399	1216
Mean ($\bar{X}$)		1044	978	958	981	994	1003	927	1011	1039	982	1082	1130	

*Subjects 8, 12, 13, 14, 15, 16 not included due to equipment malfunctions during testing.

Table 2. Summary of Results Collapsed Across Subjects. Average Target Recognition Latencies (milliseconds).

IOD		No Reticle	500 ms	100 ms	50 ms	0 ms	Simult.	$\bar{X}$
Target Eye	Left	1043	958	994	927	1039	1082	1007
	Right	978	991	1003	1011	982	1130	1016
	Mean ($\bar{\bar{X}}$)	1011	974	999	969	1011	1106	

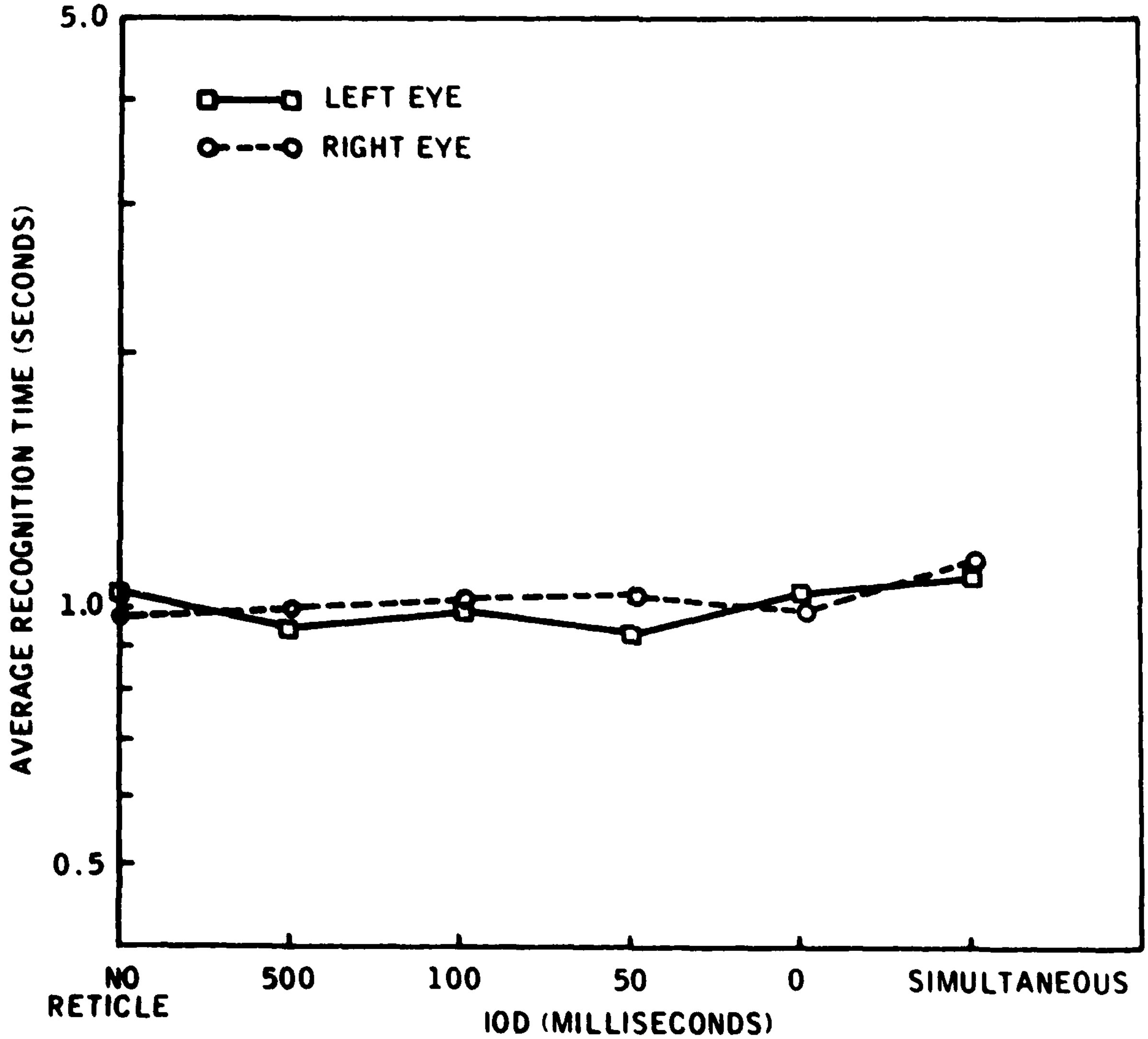

Figure 6. Graphical Summary of Experimental Results

Table 3. Summary of Analysis of Variance of Target Recognition Latency

Source	Degrees of Freedom	Mean Square	F-Ratio
Target Eye (E)	1	2,184.54	---
IOD (I)	5	49,497.75	2.08
ExI	5	17,655.37	---
Subjects (S)	9	750,886.50	31.63**
Treatments X S	99	23,736.54	
Total	119		

**$p < 0.01$

SECTION IV
CONCLUSIONS

The major finding of this study was that target acquisition performance was not significantly affected by either simultaneously or sequentially presenting target imagery to one eye and a gunsight reticle to the other eye. There were some subjects whose overall performance may have appeared to contradict this finding but variations within subjects were neither high nor consistent (Appendix B), accounting for only three percent of the total variation of the data. The variance attributable to treatment effects (IOD, target eye, and any interaction between them) accounted for only another four percent of the total variance. By far the largest single source of variance in this experiment was that which was attributable to differences between subjects -- approximately 93 percent of the total variance. This significant inter-subject difference, which is typical of repeated measures experimental designs, only serves to point out that one must anticipate and make allowances for variations among observers.

The above findings differ from the findings of many previous studies in which occluded displays have been used. These studies, as exemplified by the classical experiments of Panum (1858), demonstrated a marked degradation in visual performance due to disparate information being presented to the two eyes simultaneously, producing binocular rivalry. The present study used a see-through rather than an occluded display so that the two eyes were receiving two kinds of visual information -- monocularly unique, and binocularly common. In other words, one eye saw a reticle, the other saw a target image, and both saw the common background beyond the combining glass. This aspect of the present study makes it unique. Other studies of see-through displays, such as Hall and Miller (1963) have presented display imagery to only one eye, not to both. Therefore, it is premature to attempt to generalize the results obtained here to all see-through HMS/D systems. Rather, the most reasonable conclusion that can be drawn is that for the types of equipment used, and for the classes of visual tasks studied, the Honeywell HMS/D system allows the presentation of partially independent information to the two eyes without significantly degrading simple visual target recognition performance.

The next question to be asked is: What happens if we increase the difficulty of the visual task? For example, the subjects in the present study only viewed the reticle for 10 seconds, which was simultaneous with or followed by a target. In an operational environment, a pilot might be looking through the reticle for long periods of time against constantly changing backgrounds. Also, he might have to detect a target that was not easily discernible from the background. Or, once having found the target, he might have to track it. In other words, the present experiment has only sampled a small number of possible visual tasks. Failure to demonstrate any statistically significant performance decrement in the present experiment does not mean that such a decrement will not exist in a more complex visual environment.

It is suggested that future research investigate the binocular presentation of information using more complex and difficult visual tasks.

SECTION V
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APPENDIX A

INSTRUCTIONS READ TO THE SUBJECTS BY THE EXPERIMENTER

APPENDIX A

INSTRUCTIONS TO SUBJECTS: HMS/D BINOCULAR RIVALRY STUDY

1) "You are participating in an evaluation of the Honeywell Helmet Sight and display system. Your task will be to identify each of a variety of televised targets that will appear on your display (pick up helmet and show CRT). In addition to the display, the helmet also produces a circular reticle which can, for example, be used to aim a remote TV sensor at an object so that you can examine it more closely."

2) "You will be looking at the following types of targets (show black and white photographs): TRUCK, MEN, GUN, VAN, TANK, and JEEP."

3) "The pictures you will see with the helmet display are somewhat different however - They are IR photographs, and the resulting imagery looks like this." (example)

4) "If you will now look at this large TV monitor, I will show you a series of IR targets for identification practice only. Try to be both fast and accurate, because during the experiment, we will be measuring both how <u>accurately</u> you respond, and how <u>quickly</u> you respond." (Show entire practice tray or until S can identify 15 targets in a row.)

5) "Now that you are familiar with the kinds of targets we will be using, let's adjust the helmet to fit you."

6) (Seat Subject in dental chair, put on helmet and bring both left and right beam splitters into S's fields of view.) "The green TV display in your left (or right) visual field will contain the targets. Is the circular reticle in the center of the TV display?" (If not, adjust it until it is.)

7) (Turn on rear projector so that background scene is presented.) "The background scene you see projected on this large screen represents the kind of terrain in which targets might be found. For this experiment, a different scene will be projected with each IR target. Please ignore targets that may appear in the background scene - they are not related to the IR targets you will be seeing. I'll repeat that; pay attention to the IR targets only - ignore any targets that you may see in the background. We are using this scene merely to provide background contrast."

8) "Now let's go over your tasks:

1. Sit erect but comfortably.
2. If the green TV image appears to slant or if the reticle image is not centered in the green TV image, please tell the experimenter and adjustments will be made."

4) The experimenter will say "READY"

5) "Fixate your eyes on the screen in front of you and as soon as you are ready, say "GO"."

6) "At this time, the reticle will appear. Fixate on the reticle."

7) "Soon afterward, a target will appear for a short time on your TV screen. As soon as you know what it is, press your response button and identify it aloud to the experimenter."

8) "A target will appear each time, but in some cases there may be no reticle. When this happens continue to fixate your eyes on the screen."

9) "Remember, you are being scored in terms of both speed and accuracy of identification. If you don't know what the target is, guess!"

10) "If you feel tired, tell the experimenter, and a break will be arranged at the next convenient point."

11) "Once again, let's go over the test:

relax - "READY" - fixate on screen -

- "GO" - fixate on reticle - identify target to yourself - press button - Identify target aloud"

12) "If you have any questions, please ask them at this time."

APPENDIX B

INDIVIDUAL PERFORMANCE CURVES FOR EACH OF THE 10 SUBJECTS

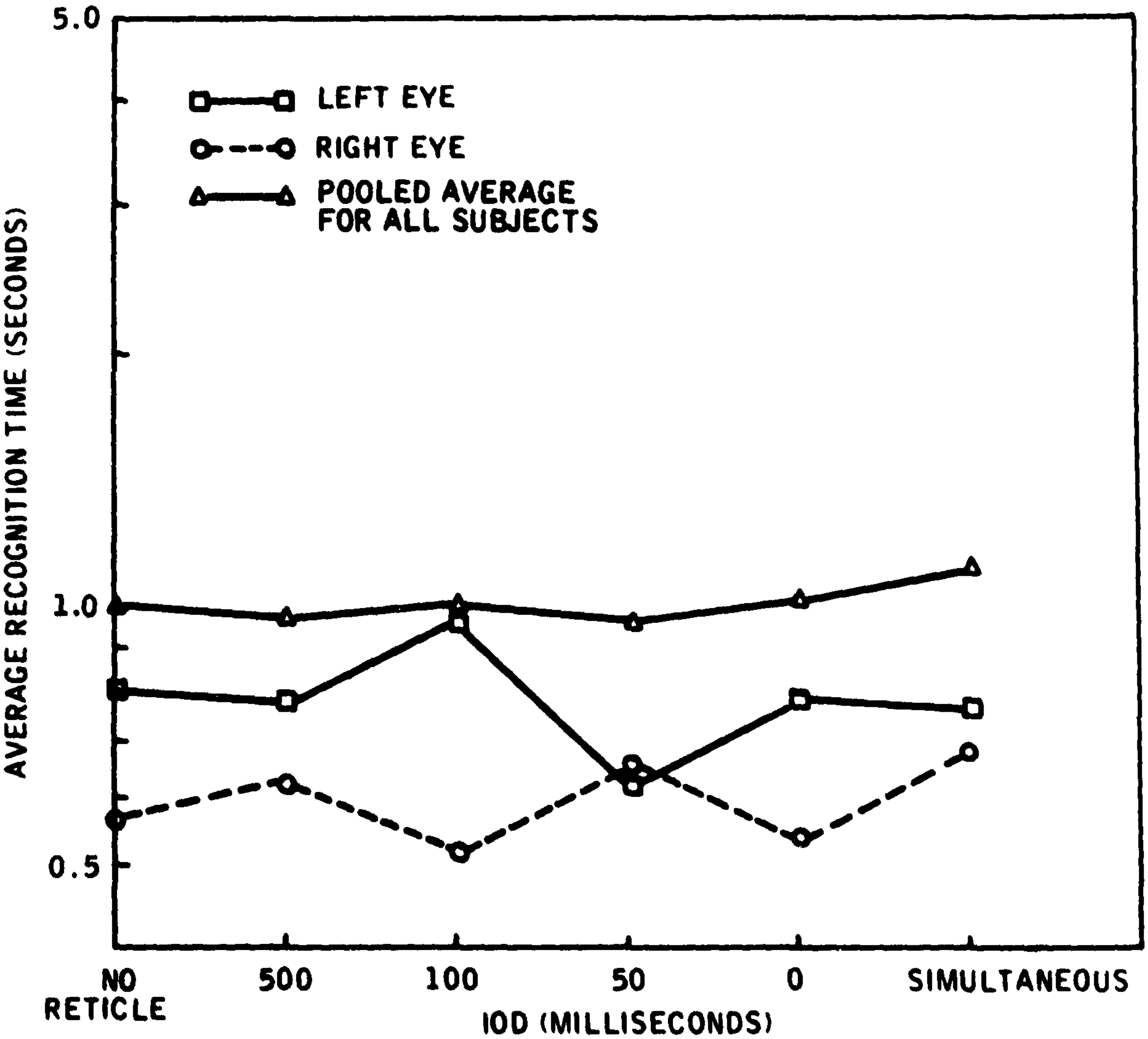

Figure B1. Subject B. P.

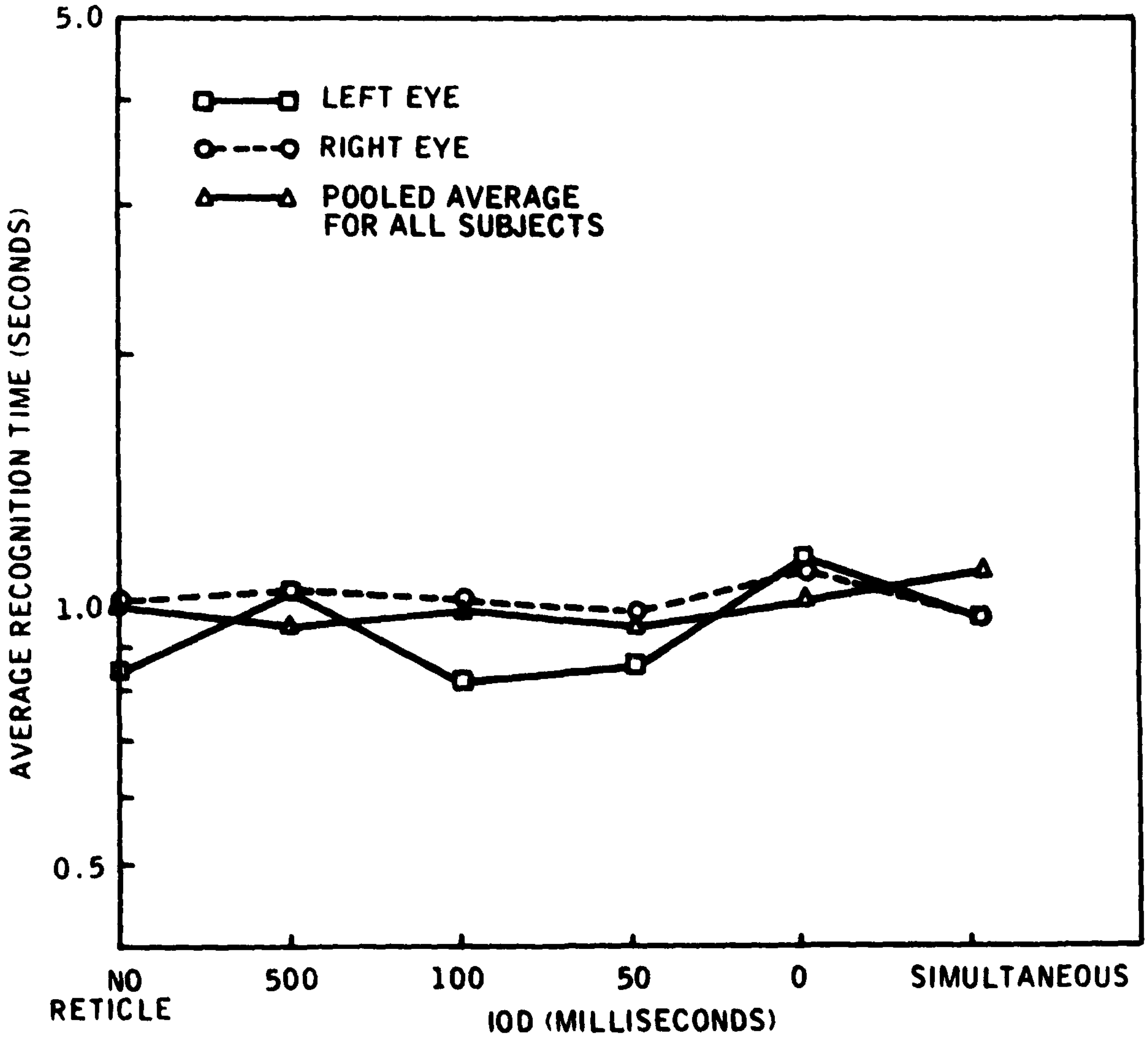

Figure B2. Subject B. H.

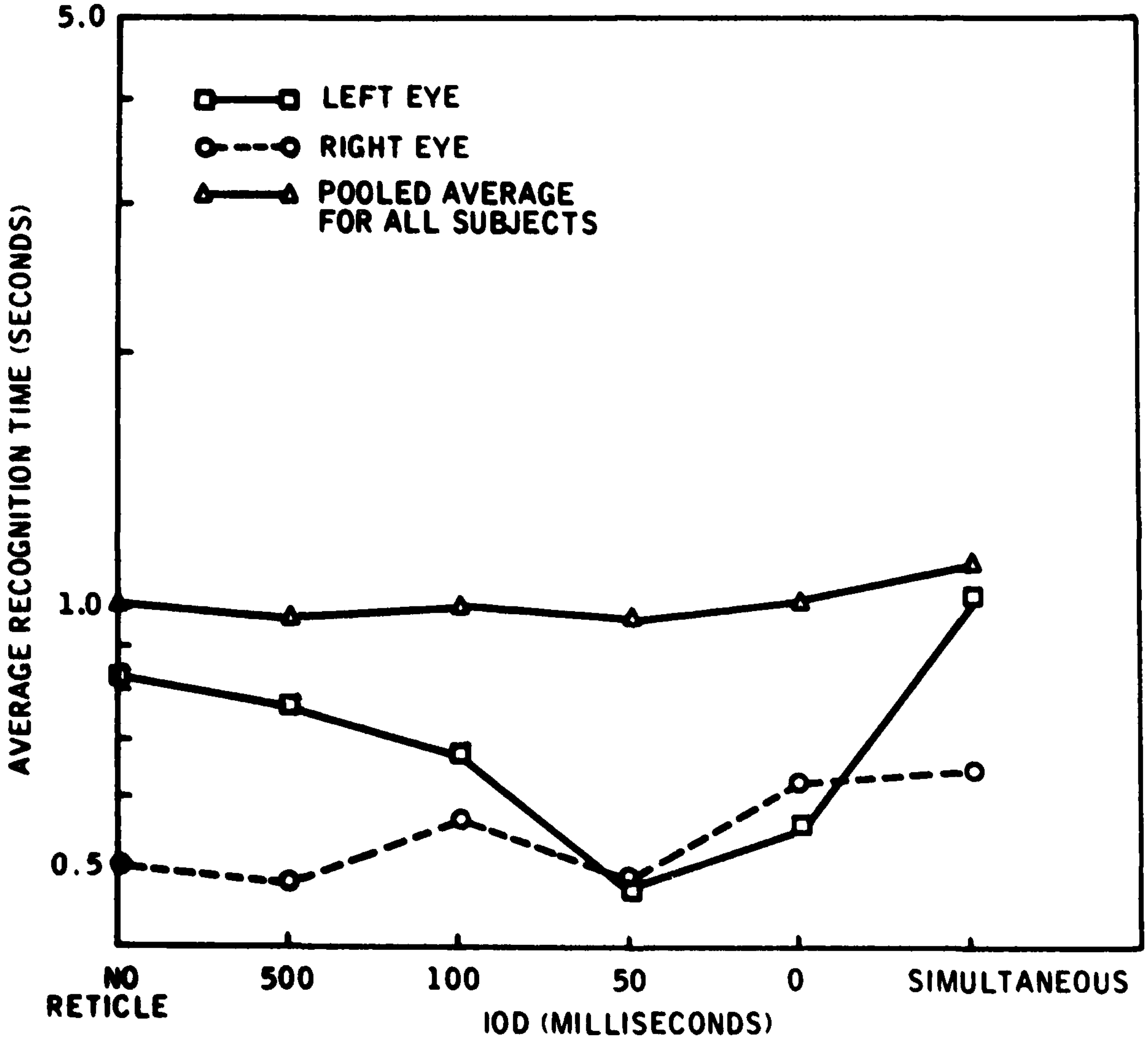

Figure B3. Subject J. M.

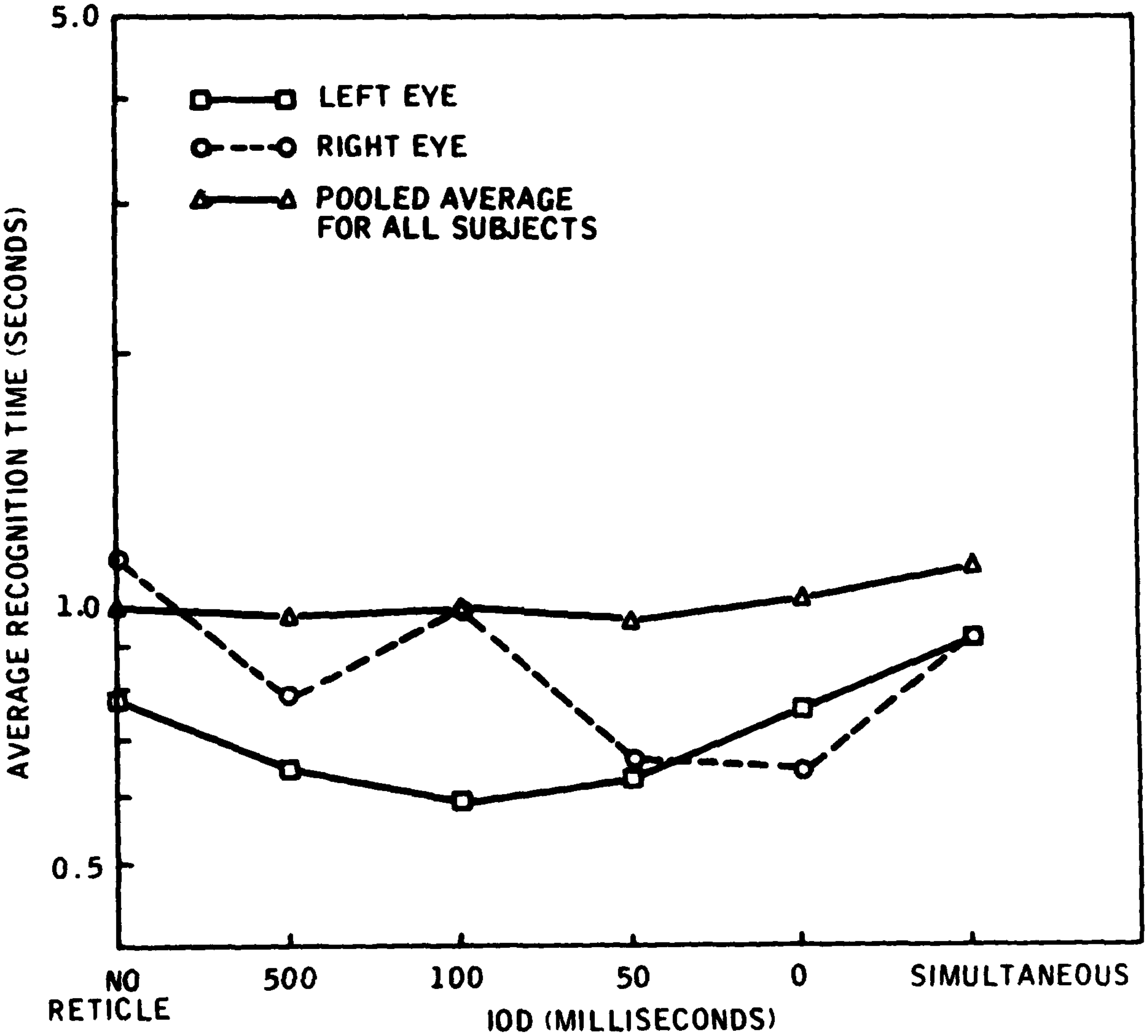

Figure B4. Subject D. J.

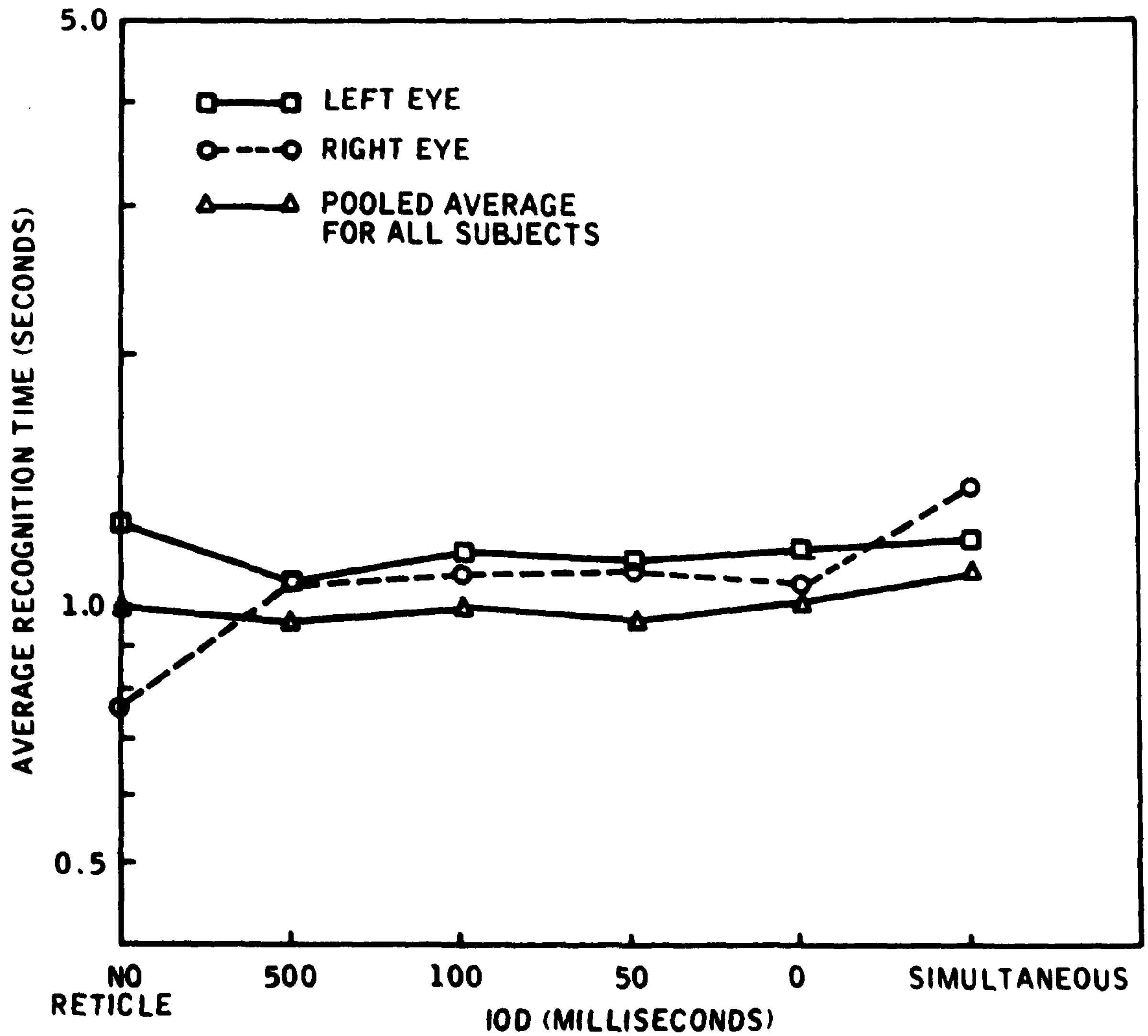

Figure B5. Subject B. C.

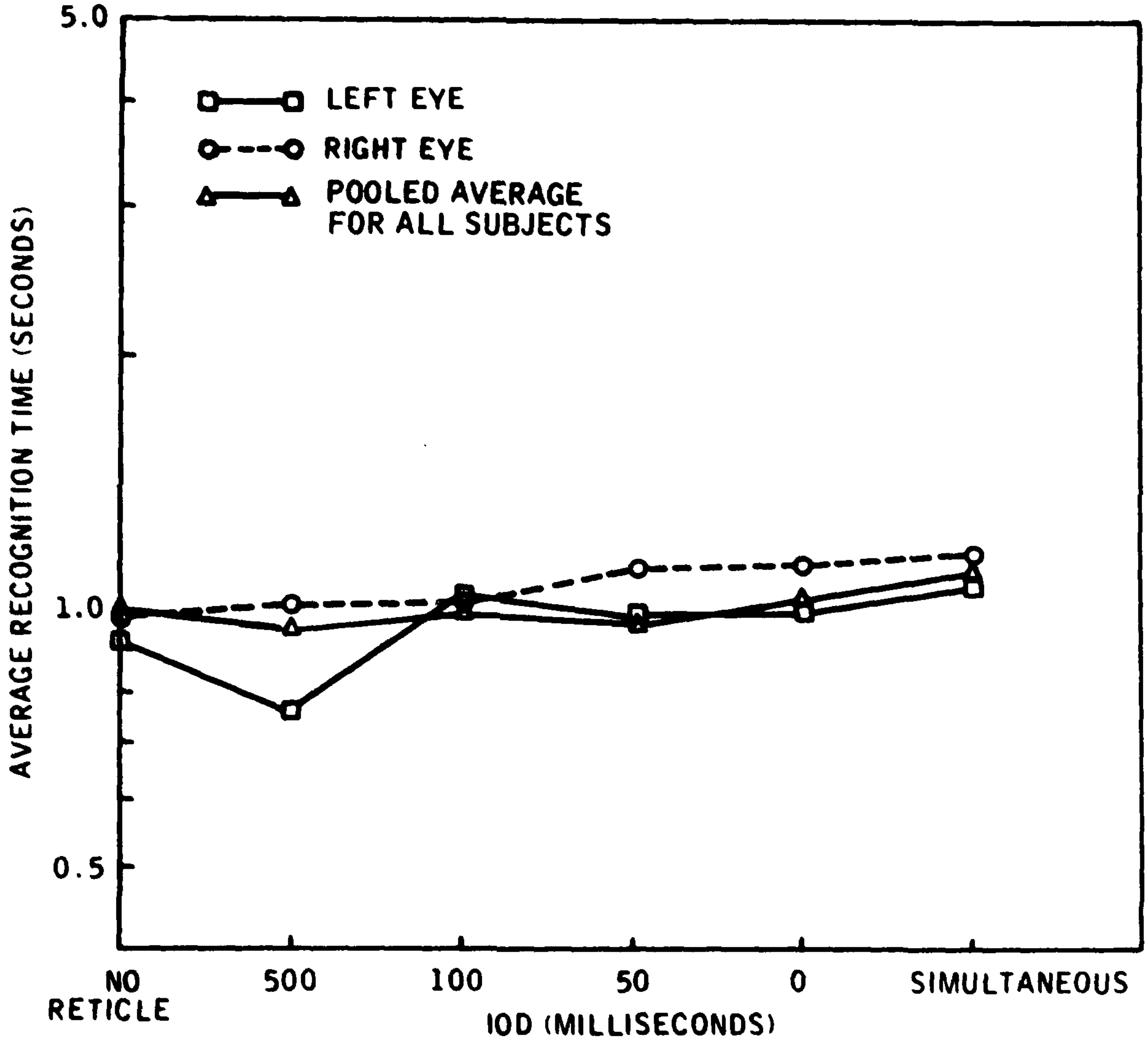

Figure B6. Subject T. H.

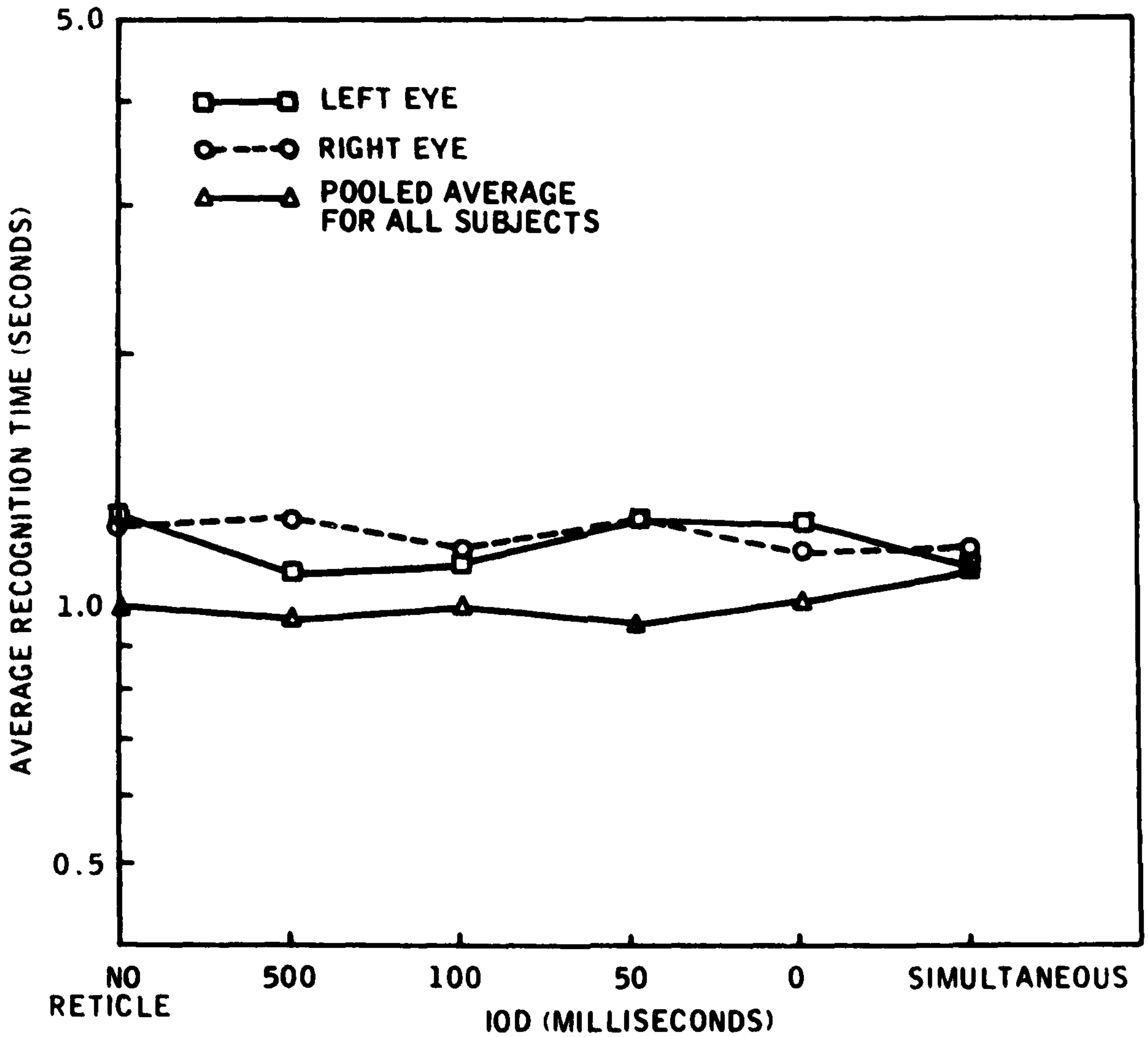

Figure B7. Subject K. M.

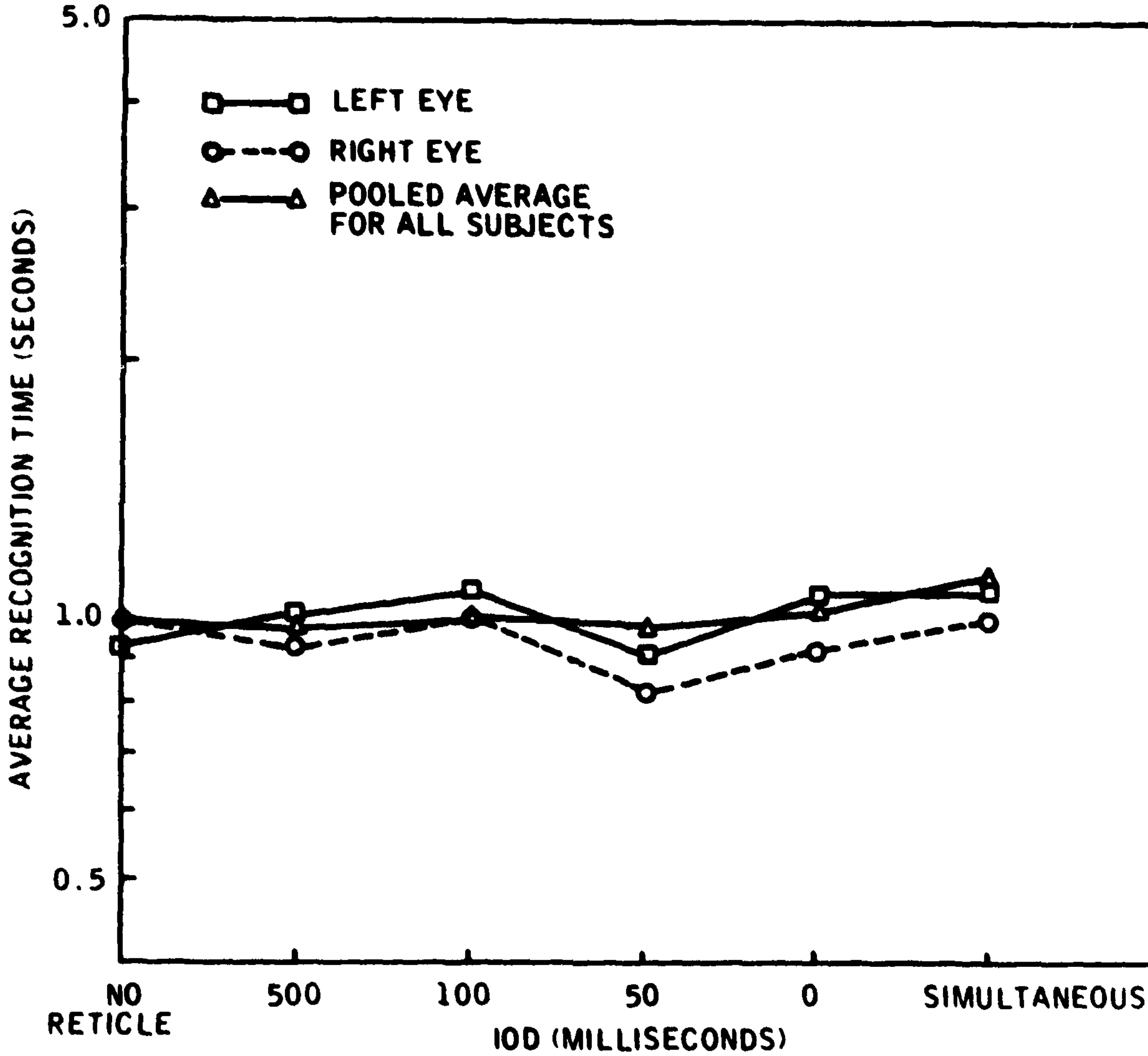

Figure B8. Subject M. C.

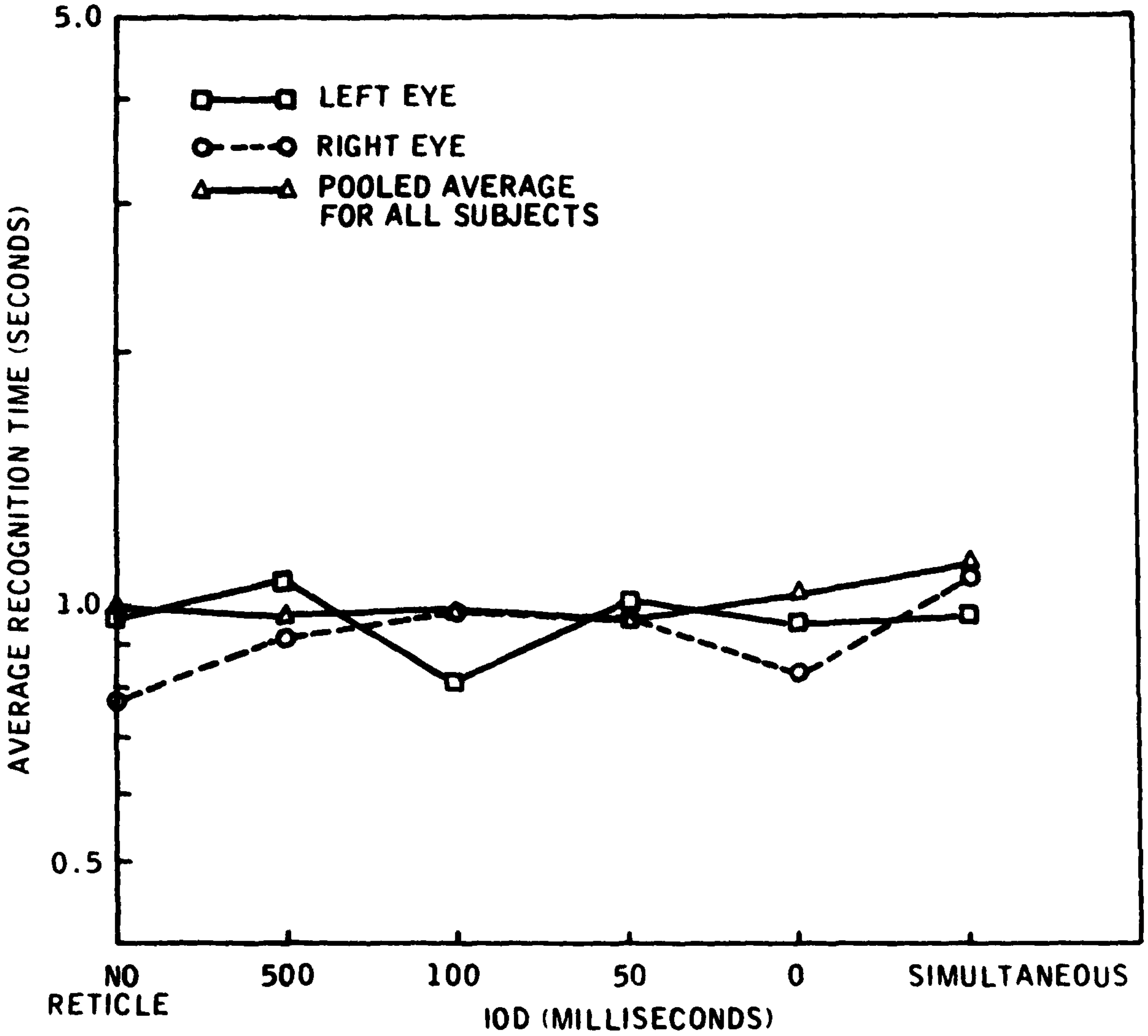

Figure B9. Subject T. C.

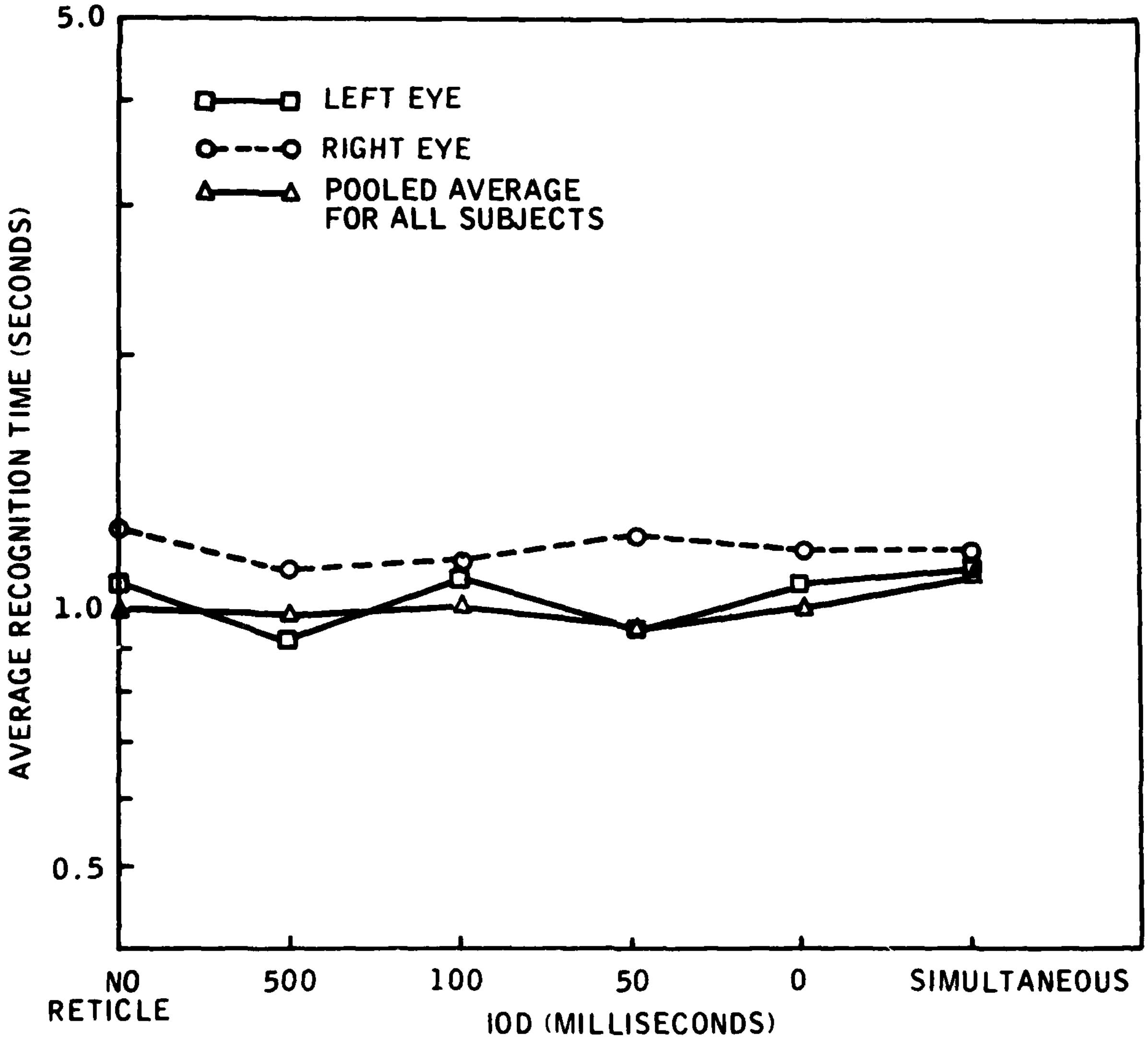

Figure B10. Subject D. W.