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BIOELECTRIC INDICANTS OF DIVER'S ABILITY TO PERFORM USEFUL WORK--ETC(U)
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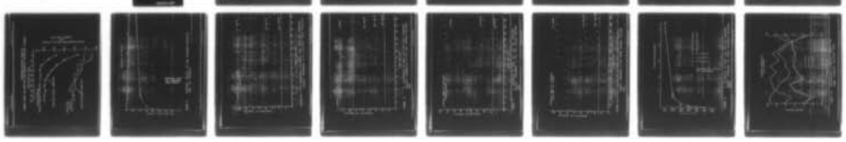

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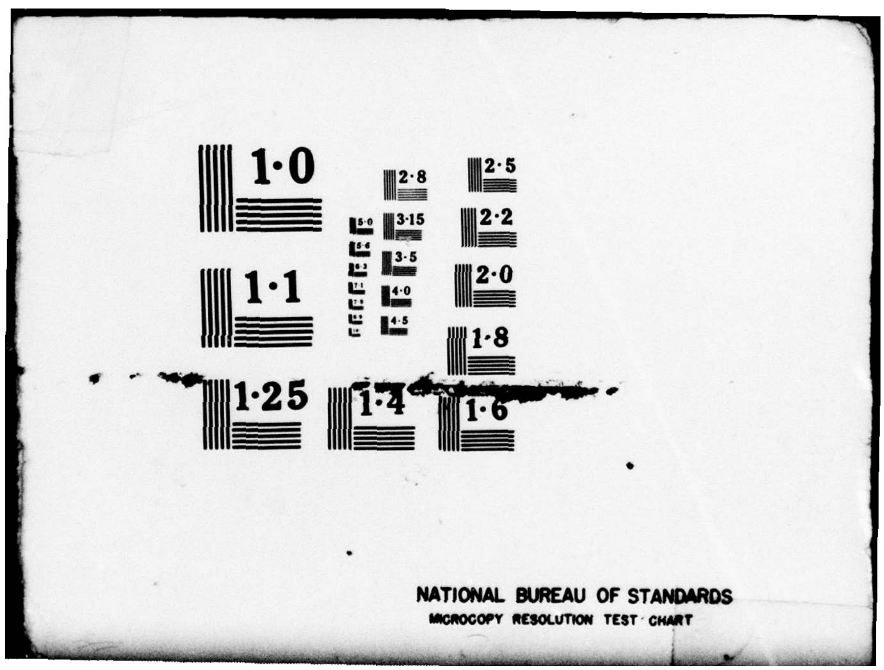
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MICROCOPY RESOLUTION TEST CHART

(6) Bioelectric Indicants of Diver's Ability to Perform Useful Work.

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The opinions are those of the author and do not necessarily reflect those of the Department of the Navy.

ABSTRACT

Presently, the majority of working dives are performed in shallow depths and the performances which are expected of the diver emphasize physical rather than mental work. Nevertheless, dives are continuing to be made to deeper depths and in the future increasing demands will be made of the diver for information processing and decision making. It was hypothesized that a neglected indicant of an operator's ability to perform useful work in air is eye movement activities. It was felt that aspects of eye movements could provide a useful index of the level of information processing or mental load of a diver and secondly, that research into eye movements might aid us in understanding better the effects of the physical environment experienced by a diver.

The present paper reports recent research in air between eye movements and performance. The findings are positive and offer promise that spectral analysis of eye movement velocities could provide valid early indication of behavioral dysfunction in compressed gas and under water.

INTRODUCTION

The present paper will discuss the relationship between certain characteristics of eye movement and overall central nervous system status, beginning with the study of vestibularly induced nystagmus.

The relationship of eye movement to vestibular stimulation is well known and has been described many times (Kennedy 1972). Specifically, as the head moves to a new position, the eyes lag behind the skull and effectively permit one to continue looking at the starting point. This is not a passive response due to inertia nor is it due to visual fixation, although both of those factors are present. Rather, the slow compensatory deviation of the eyes in the skull (which serves to keep the eyes fixed over the earth) - is caused directly by a vestibular signal and occurs also in the dark. This eye movement is the slow phase of nystagmus and has as its probable site of origin the vestibular nuclei (Gernandt 1959). The second phase - the fast phase - is considered to be compensatory to the slow.

In Guedry's (1965) psychophysiological review he referenced about 20 papers where the subject's mental state modified recorded vestibular nystagmus. Gernandt (1959) has suggested that the fast phase is influenced by the reticular activating system (RAS) and Wolfe (1966) has retrieved habituated nystagmus by RAS stimulation. Further, it was shown that the fast phase was absent in patients who lacked a *pontine reticular formation*, (Daroff & Hoyt 1971). Therefore, it was decided to expose a large group of people to vestibular stimulation while recording nystagmus and measuring their performance on a vigilance task. The hypothesis had been that vigilance performance would bear some relationship to the quality of the fast phase. In other words, knowledge of the fast phase could be predictive of the vigilance performance.

<u>Vigilance test</u> - three tones which were clearly audible and distinguishable were presented randomly for an hour. The subject's task was to monitor the low (8 pulses/minute) and middle (6 pulses/minute) and ignore the high (5 pulses/minute). Each occurrence of a tone was mentally counted and a key was pressed when a given tone had been sounded four times. The subject then began again for that tone. The subject's score was percent correct for each 5/minute period. Figure I shows the temporal distribution of tones and Figure 2 shows the expected values for six versions of this test. The one labelled "two channel complex" is described above and was employed in the eye movement experiment.

<u>Nystagmus</u> - the subject was dark adapted for 20 minutes to partially control for fluctuations in the cornea-retinal potential (Kennedy 1972), and was then exposed to sinusoidal oscillation about the spinal axis for 50 minutes. Stimulus parameters were

a 75° displacement every five seconds. (.2 Hz; 46.8/sec peak velocity and 53.5°/sec^2 peak angular acceleration.)

Lateral eye movements were obtained by standard electro oculographic techniques with electrodes at the outer canthi. Pre and post calibrations were not significantly different. One hundred fifty healthy student pilots comprised the experimental population, 50 were tested for vigilance only, 50 for nystagmus only and 50 for both.

Scoring - the procedure used is best described as an examination of the fast phase. In general, 100% of a cycle with good nystagmus received a 10, and almost no nystagmus was scored 1.0. Two lower categories were used, .5 and .1 for finer determinations. The reliability of the method was good. (r = .95). It should be noted that while using mainly fast phase (presence/absence) in scoring, Wendt (1965) felt that other eye movements qualify as habituation, particularly with shorter arcs of oscillation.

RESULTS

The next slide (Figure 3) shows the performance of these three groups. The vigilance performance of both groups was not significantly different but the quality of nystagmus in the group without the vigilance task decayed more rapidly than for those who did mental work. This is what one would expect from the literature as reported by Guedry (1965). Vigilance and nystagmus follow the same time course (r = .93).

In order to determine whether the vigilance performance of a particular subject could be predicted from his nystagmus at any point in time, each subject's scores were correlated within a session. The average of these correlations was r = .30 and significant ($P < .0001$). Another correlation was obtained for the 500 matched scores (50 subjects and 10 five minute time frames). This operation is statistically indefensible but has a practical utility for vestibular investigators. For instance, you may wish to predict a person's vigilance score regardless of who he is or what time in the session it is. This correlation is r = .49 ($P < .001$).

In conclusion, this researcher feels that under the experimental conditions used, a general correspondence exists between the quality of the fast phase and the alertness as measured by a vigilance task. This correspondence supports what would be expected from the neurophysiological literature regarding the pathways of the fast phase and has both applied and scientific implications. It suggested that (1) perhaps the fast phase of vestibular nystagmus could be used as a quantitative and independent index of arousal, so that a person's performance in a job could be monitored without interfering with his work; (2) perhaps other quick flicks of the eyes (optokinetic fast phase, involuntary movements and microsaccades) reflect similar mechanisms. If true, they also could provide indicants of the level of arousal. If the latter could be shown to be so, it might be possible for a computer to analyze the eye movements of a pilot or diver and when they meet a criterion level of drowsiness, inform him of this condition and remove him from the situation. Because of these results, the second phase of this experiment was begun, wherein no vestibular stimulation at all was used, but merely the subjects sitting in the dark, performing the same two channel monitoring task and again recording movements but with some variation. Two recording techniques were employed: first, surface electrode as before with EEG type electrodes at the outer canthi and secondly on infrared scleral reflection device. The comparisons of these two methods will be reported elsewhere and need not be discussed further, except to indicate that each has different characteristics which would make it more or less feasible, depending on the working conditions, diving conditions, etc. Secondly, an analysis of eye movement data which differed from before was undertaken. It was felt that the reason for the previously obtained relationship between eye movement and performance occurred because something happened relative to the fast phase - whereas the slower eye movements remained essentially the same; albeit with a slight change in phase and in gain.

In a previous study the data were all scored by hand and an inspection of the data revealed that the presence of a brisk, strong, fast phase contributed to alert scores and what appeared like slower fast phases occured when vigilance was poor. It was hypothesized that the briskness or velocity of the fast phase of eye movements may be generally indicative of alertness or of overall potential for work. Therefore, a new method for scoring eye movements was employed: specifically, a spectral analysis of eye movement velocities which were sampled 100x/sec, directly from the infra-red eye movement recording device was performed. These were totalized by computer and printed out as scores each minute. The next Figure (4) shows the data for the entire experiment. Note that nearly all the eye movement power is found in the range 0 - 100°/sec. Figure 5 shows the same type of information but in this case early and late eye movement are separated for the various ranges of velocities. It may be seen that the 100° - 200°/sec category is changed so that there are fewer "later" than "earlier" and the converse occurs with 0 - 100°/sec eye movements. It should be emphasized that while these differences are small, they are also highly reliable, therefore likely to be real. It should also be noted that these differences, and other data to be presented, are consistent within subjects as well. The next figure (6) shows the eye movement data for a single channel performance - the simplest test comparing early and late. It may be seen that later eye movements show less activity in the 100^{o} - 200^{o}/sec category. Additionally, vigilance performance also degraded on this test. Figure 7 shows two things; (1) the same effect, but note that the average scores (approximately .89 versus .75) correspond to overall differences in the task loading (see also Table I). Figure 8 completes the picture where a similar effect is present viz., more overall eye movement between 100^{o} - 200^{o}/sec, with a greater task load, and also a drop in performance with time on task. All these data are compiled in the next slide, Fig. 9. What has occured, is that different task loads produce different distributions of eye movement velocities whereby higher loads appear to coincide with more rapid movements. Secondly, as performance degrades with time on task, there appears to be a corresponding drop in eye movement activity but this relationship is less clear cut because the least amount of reduction occured in the two channel test; concurrently there was also very little drop in performance. The overall speculation is twofold: when larger numbers of fast eye movements are available, the operator may have greater potential for information load; secondly, operator workload is characterized by the lower number of eye movements in the 0 - 100^{o}/sec range, whereby relatively more of them indicate a light load. In general, these two factors would be correlated most of the time, but not necessarily. The eye movement data of the present study would tend to support this notion, particularly when considered in connection with the percent correct scores on the various forms of the counting tests. In summary, in all cases with time on task there is a change toward relatively more "slow" (0 = 100^{o}/sec) later and relatively more "fast" (100^{o} - 200^{o}/sec) early. Secondly, the eye movement level early in a test in consonant with this finding, whereby the overall amount of fast activity (see Table I) is proportional to the level of workload.

In addition to the above it is felt that the technology necessary for eye movement measurement might also bring with it assessment monitoring techniques that would have the following additional spinoff for the working diver:

First, untoward vestibular effects which result in nystagmus can be recorded.

Second, information about where a diver is looking can be recorded for purposes of display, design and other training of diver work operations.

Third, eye movements may be considered to be a cortical evoked response indicator, and changes thereto could be monitored.

Fourth, the recording technology would promote development of visually coupled systems like those used in aircraft, viz., a) the visual target acquisition system (VTAS) for remote handling of mass and b) the energy management display which enables the pilot to better utilize his resources.

In conclusion, the analysis of velocity of eye movements can be a useful, sensitive and reliable parameter which may be predictive of changes in the state of an individual. This research could progress from a hyperbaric chamber to open sea conditions in two to three years.

TABLE I

FREQUENCY OF EYE MOVEMENT VELOCITIES DURING AUDITORY MONITORING

FOR 6 SUBJECTS (BEATS/SEC)

	ALL TESTS	EARLY IN SESSION	LATE IN SESSION
	0-100 DPS	5.12	5.25
	100-200 "	.85	.78
	200-300 "	.20	.19
I CHANNEL	0-100 DPS	5.25	5.45
	100-200 "	.75	.65
	200-300 "	.19	.17
II CHANNEL	0-100 DPS	4.90	5.00
	100-200 "	.89	.85
	200-300 "	.26	.27
III CHANNEL	0-100 DPS	5.20	5.40
	100-200 "	.94	.80
	200-300	.15	.14

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LIST OF FIGURES

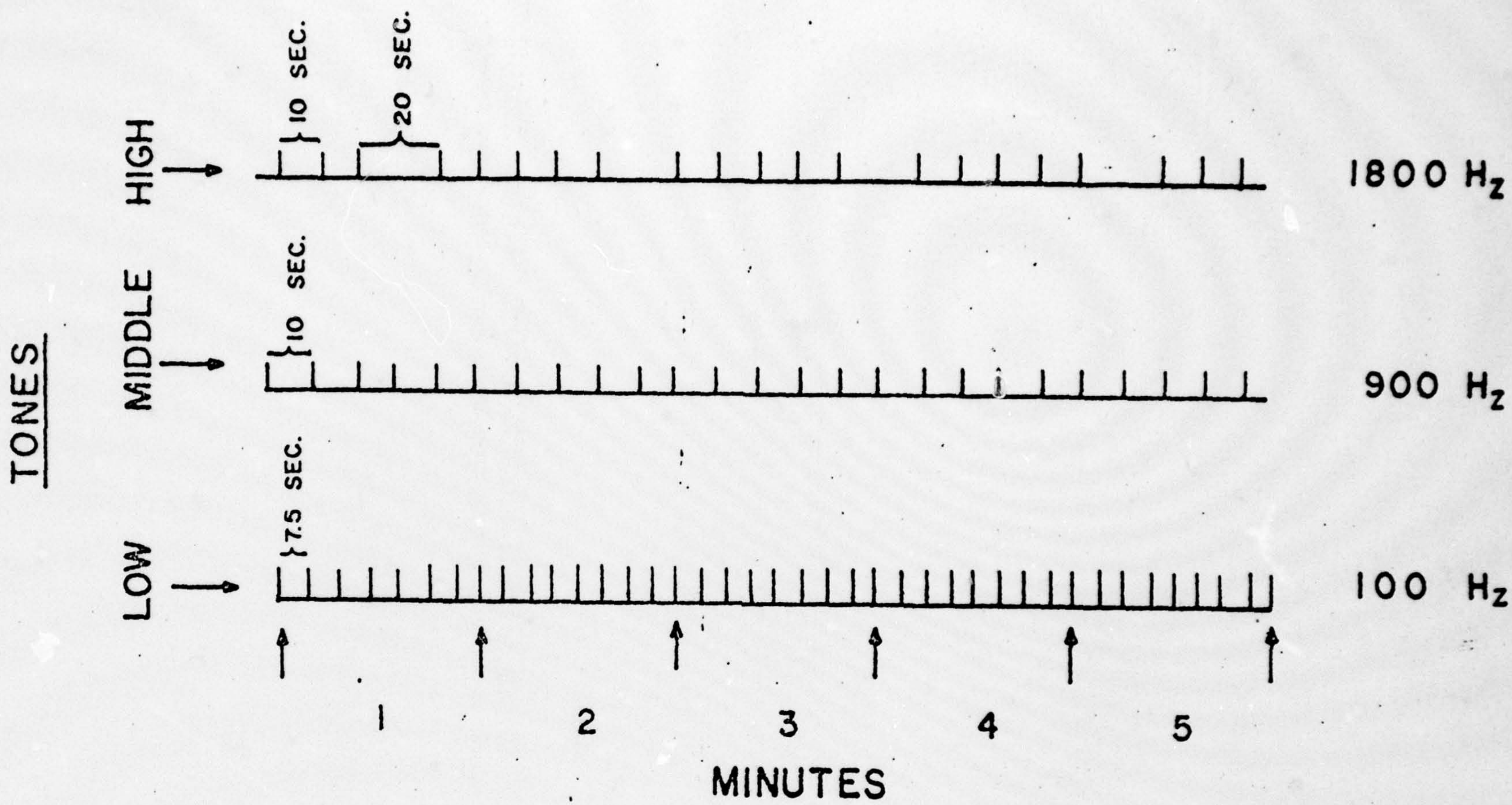

FIGURE 1. FIVE MINUTE SAMPLE OF TEMPORAL DISTRIBUTION OF TONES USED IN AUDITORY VIGILANCE TASK

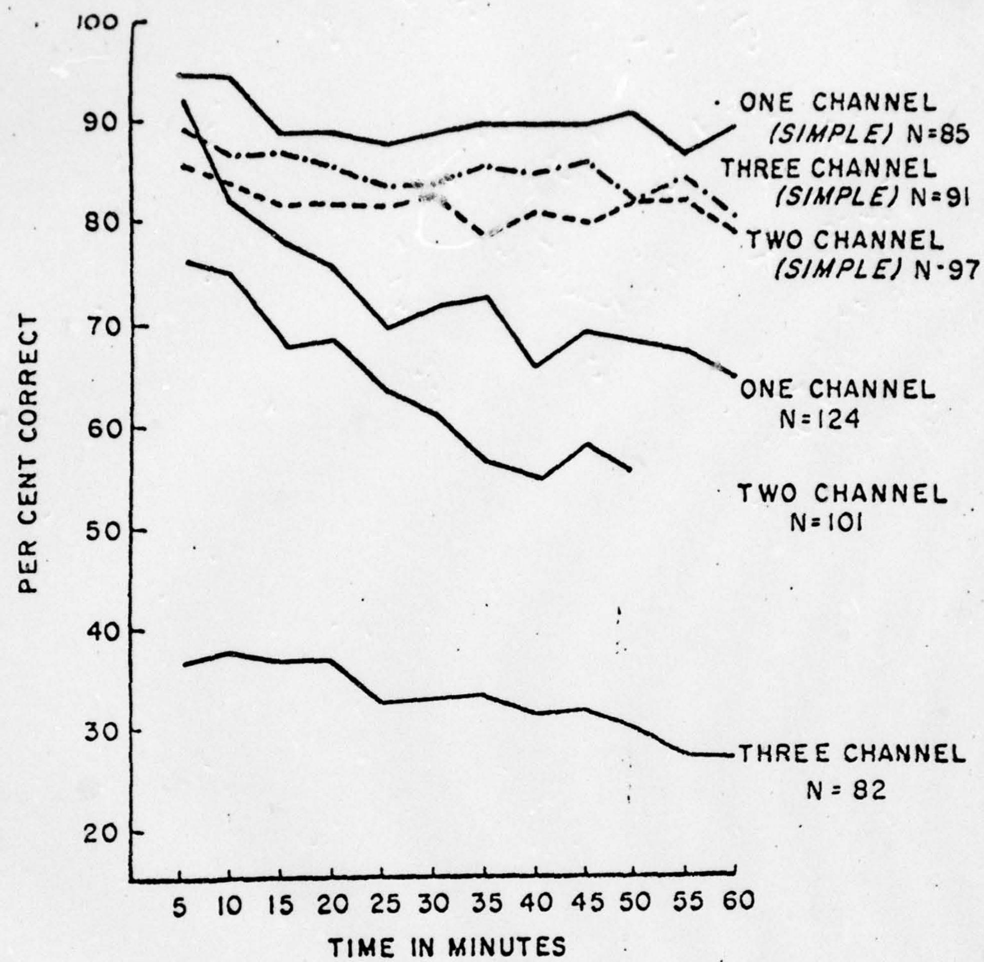

FIGURE 2. A COMPARISON OF PERFORMANCES ON SIX AUDITORY VIGILANCE TASKS

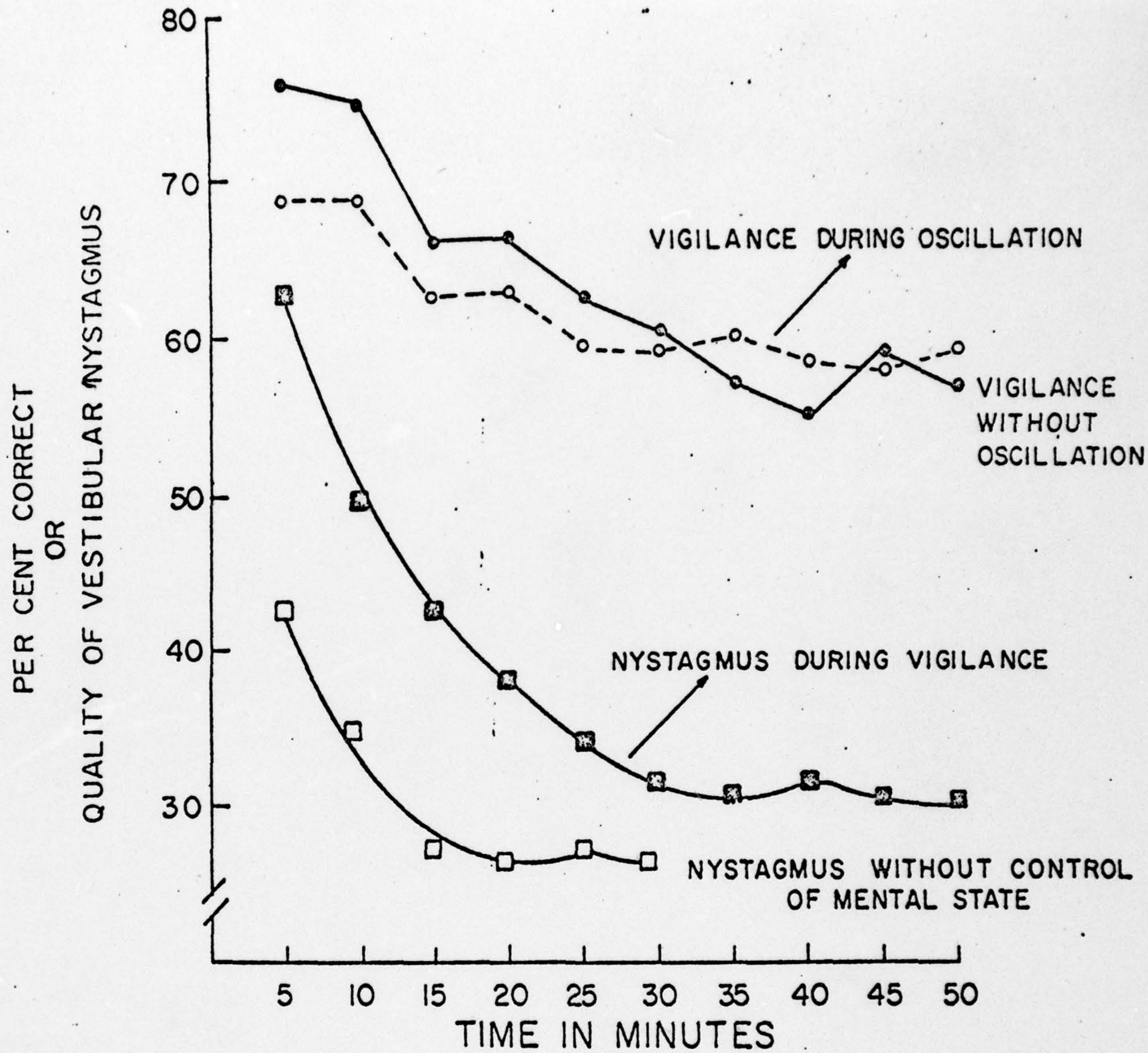

FIGURE 3. VESTIBULAR NYSTAGMUS AND VIGILANCE FOR THREE GROUPS OF NAVAL AVIATION PERSONNEL

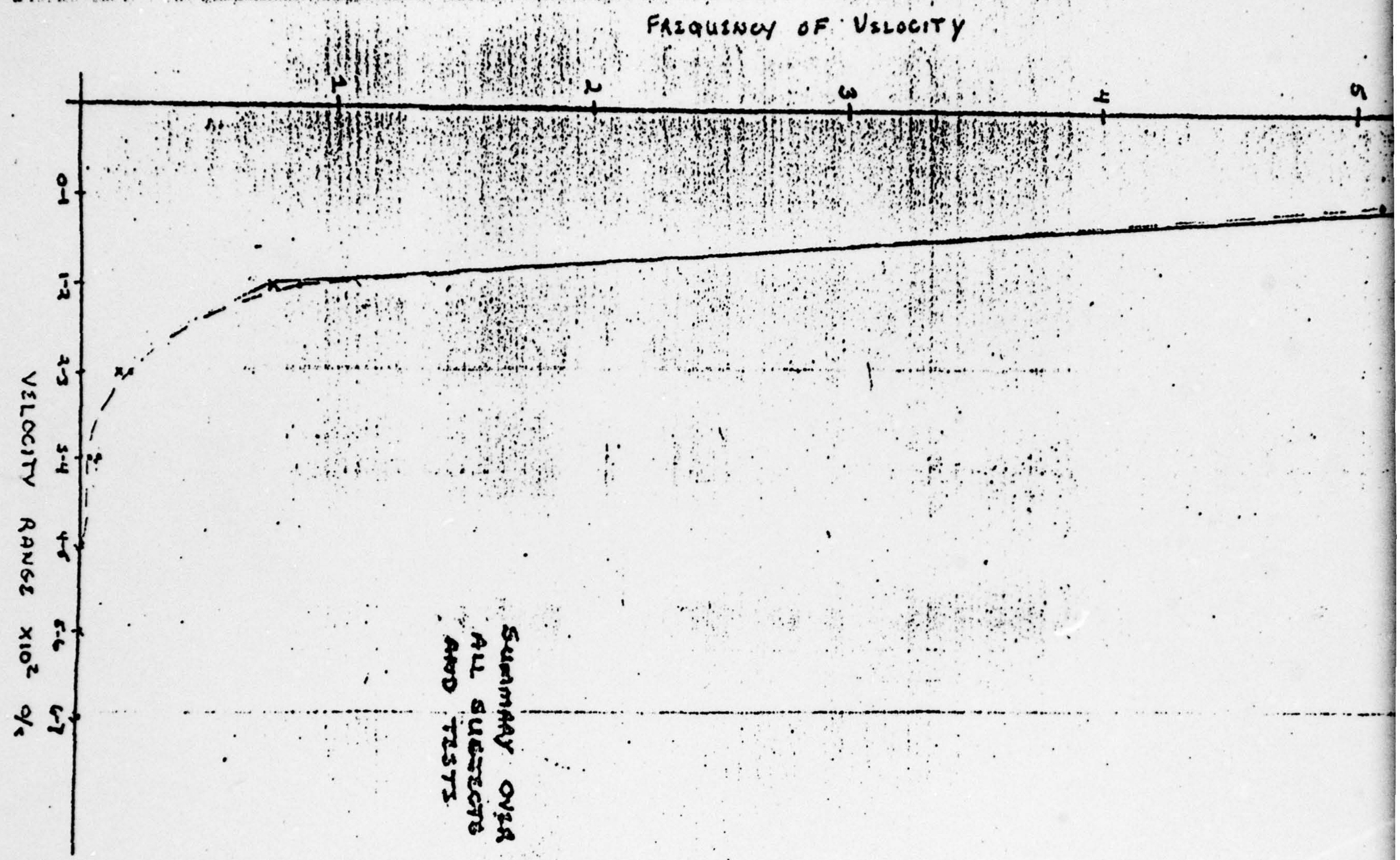

FIGURE 4. SPECTRAL DENSITY OF EYE MOVEMENT VELOCITIES OVER SIX SUBJECTS

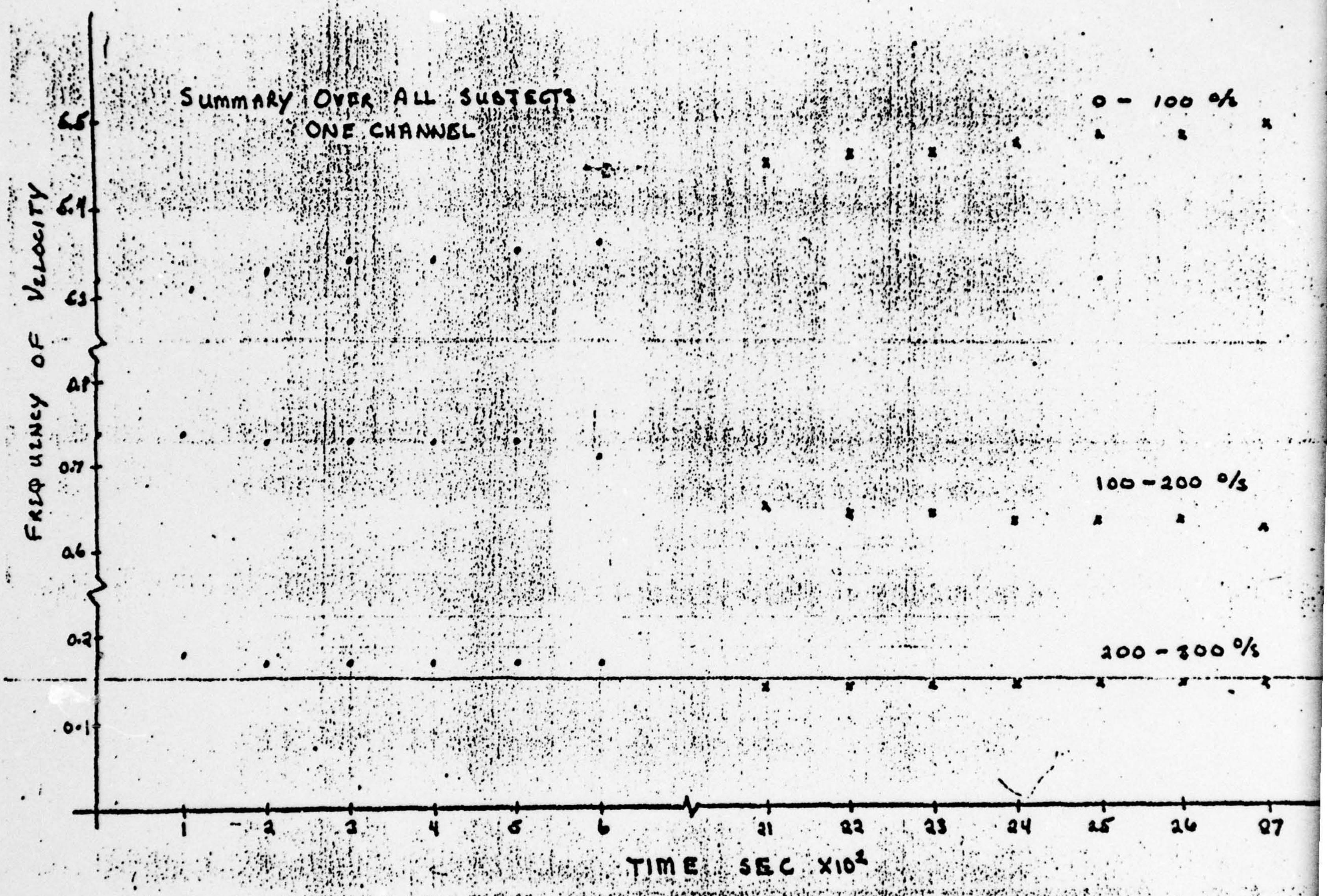

FIGURE 5. A COMPARISON OF EARLY AND LATE EYE MOVEMENT VELOCITY CATEGORIES IN ALL VIGILANCE TASKS COMBINED

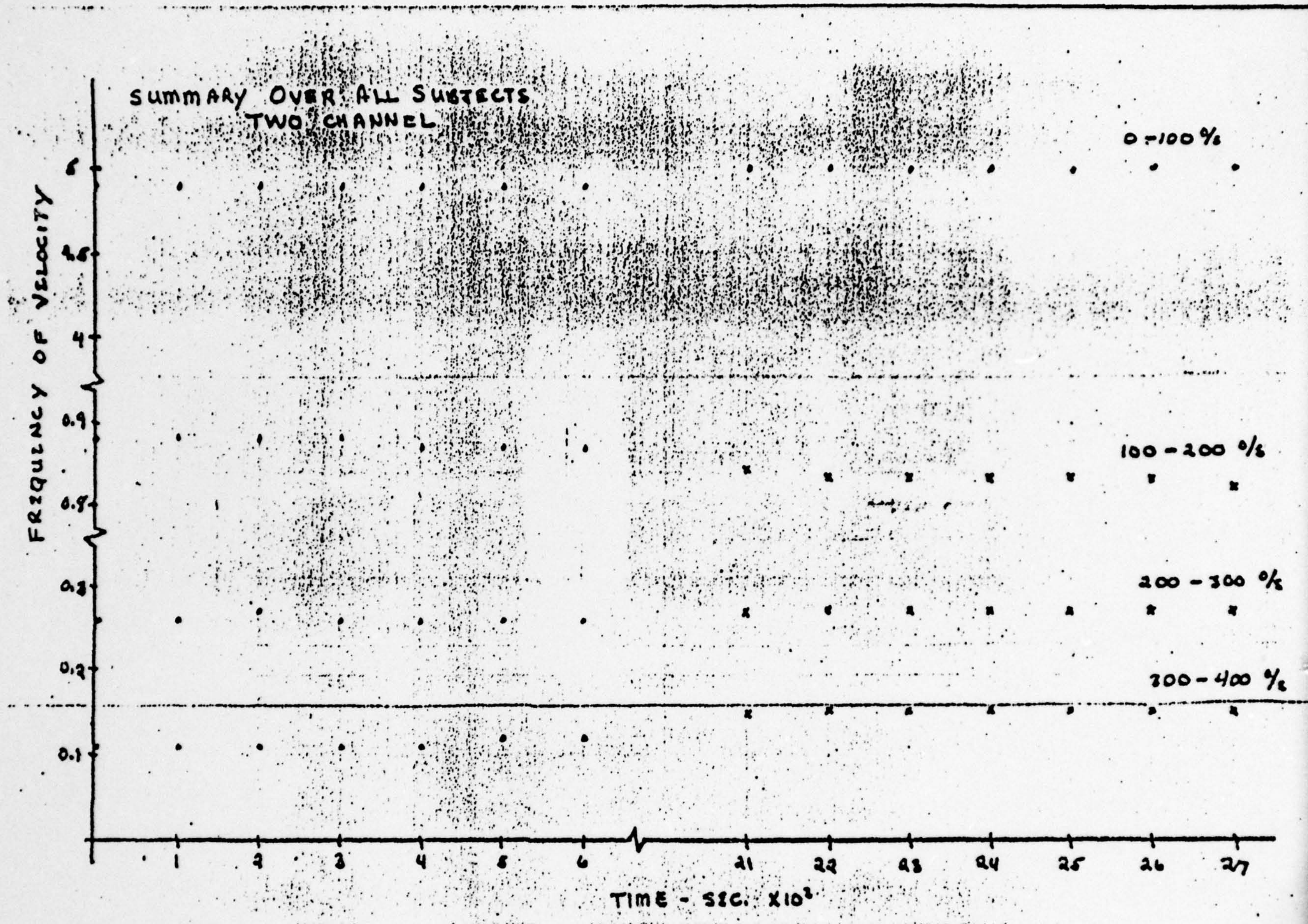

FIGURE 6. A COMPARISON OF EARLY AND LATE EYE MOVEMENT VELOCITY CATEGORIES IN THE ONE CHANNEL VIGILANCE TASK

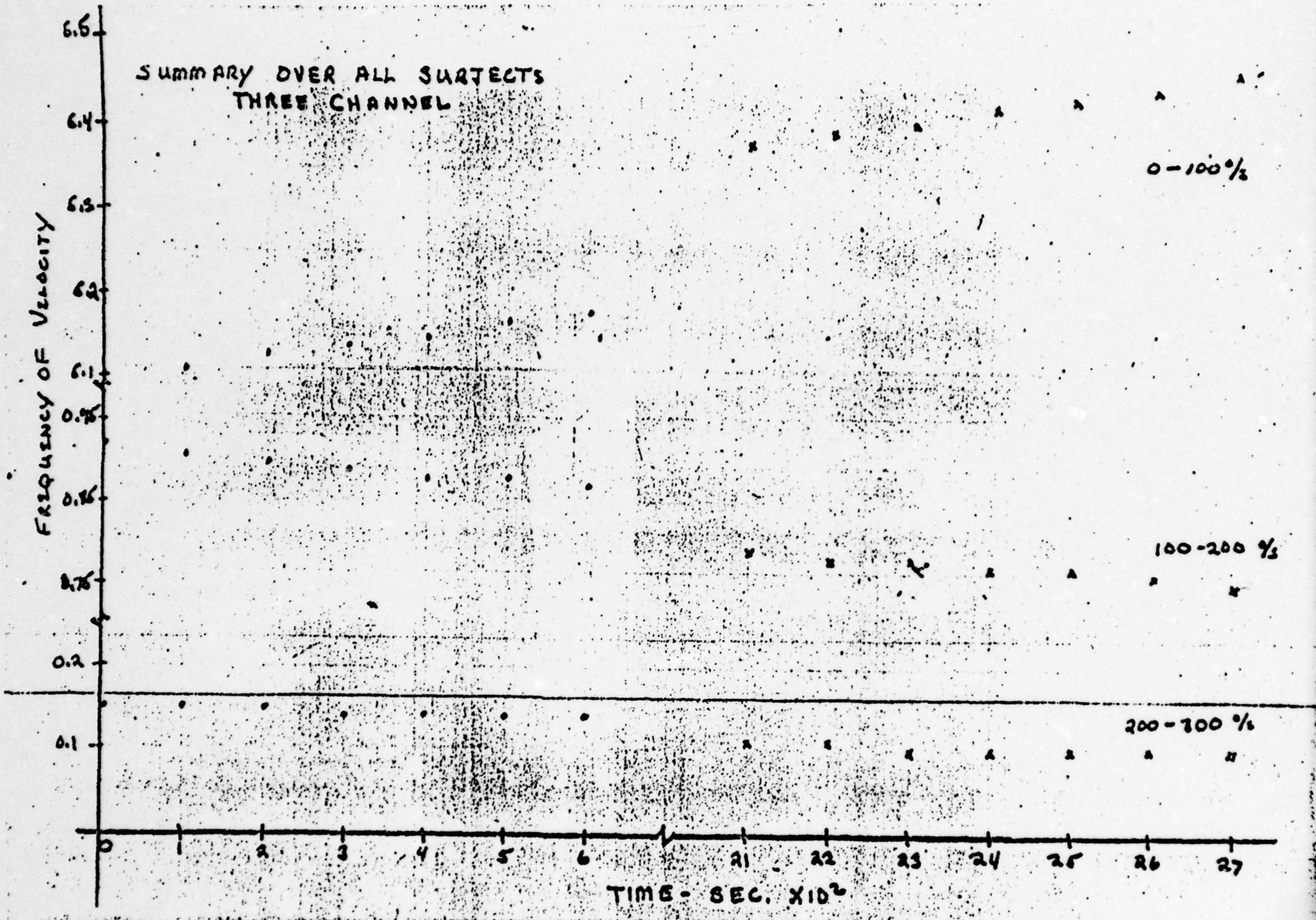

FIGURE 7. A COMPARISON OF EARLY AND LATE EYE MOVEMENT VELOCITY CATEGORIES IN THE TWO CHANNEL VIGILANCE TASK

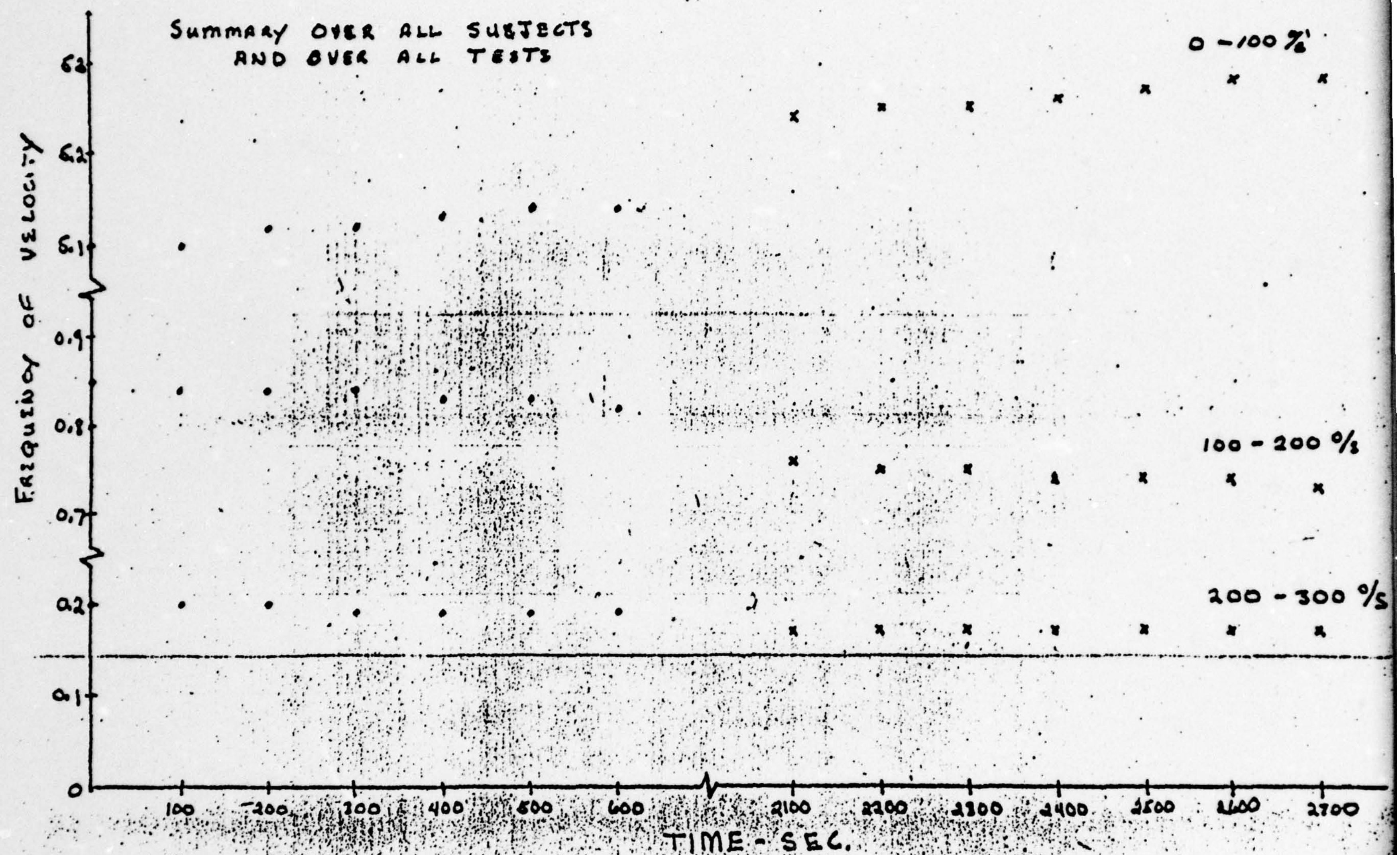

FIGURE 8. A COMPARISON OF EARLY AND LATE EYE MOVEMENT VELOCITY CATEGORIES IN THE THREE CHANNEL VIGILANCE TASK

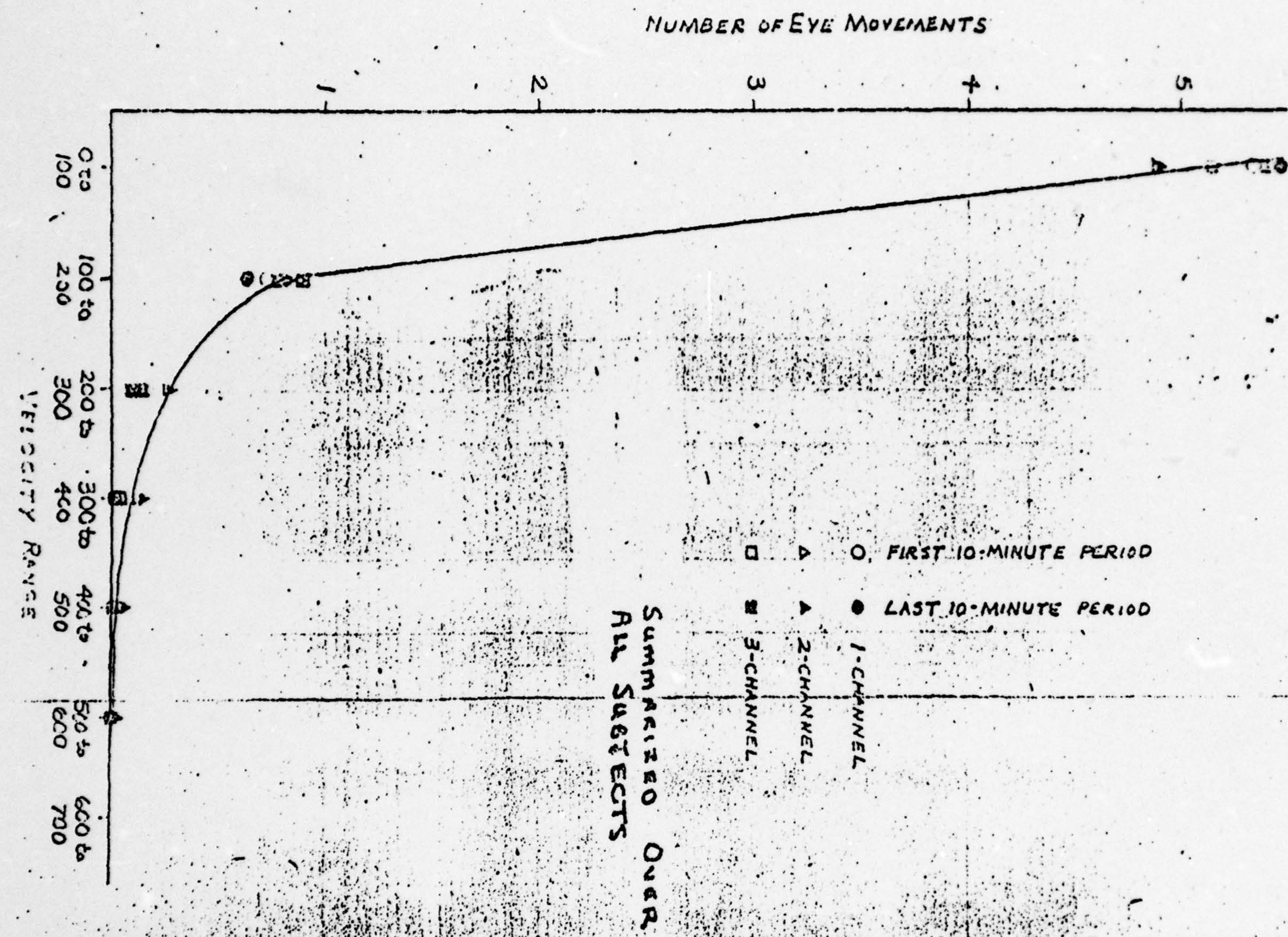

FIGURE 9. A COMPARISON OF EARLY AND LATE EYE MOVEMENT VELOCITY CATEGORIES ON THREE DIFFERENT VIGILANCE TASKS

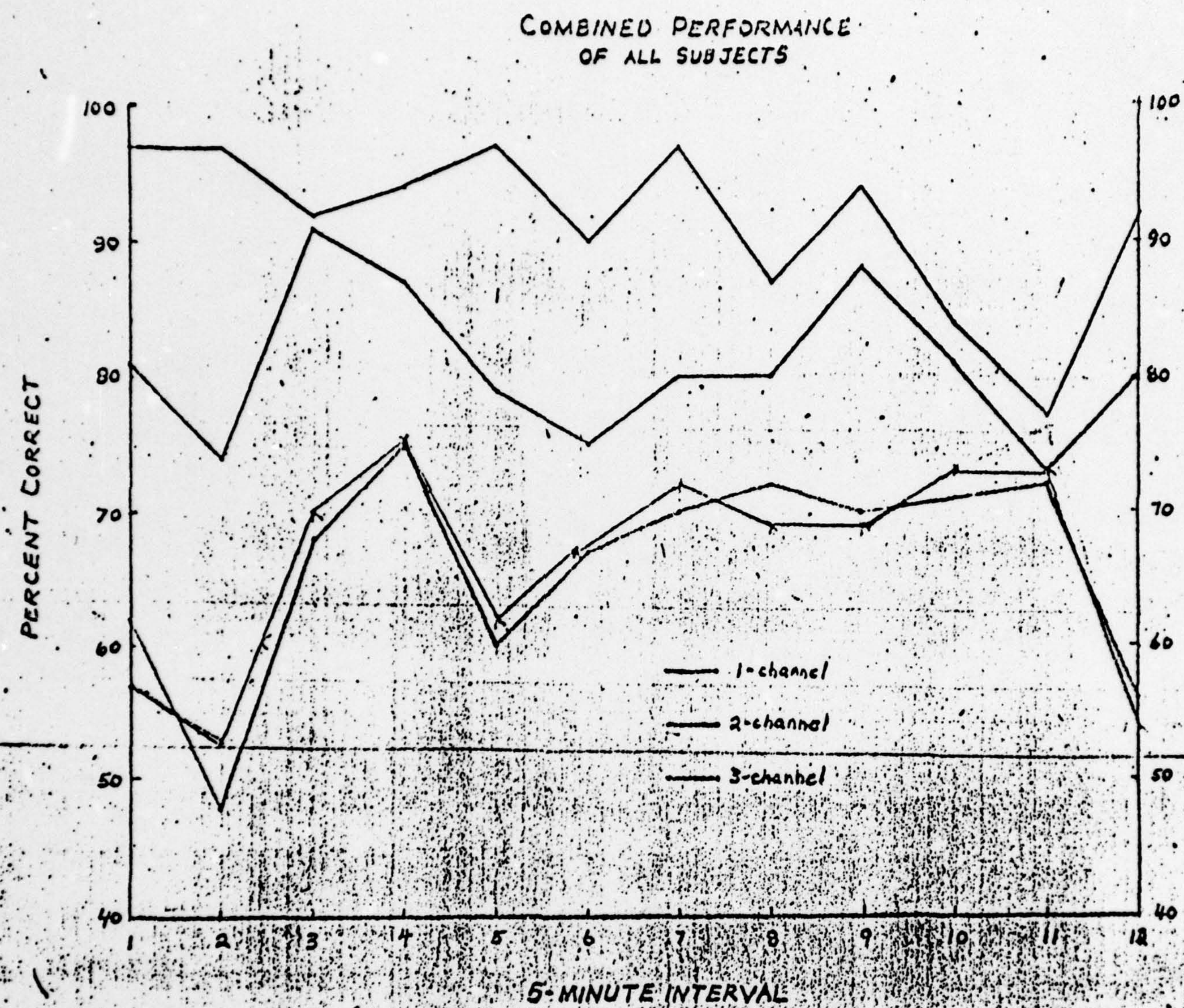

FIGURE 10. PERFORMANCE IN PERCENT CORRECT ON THREE DIFFERENT VIGILANCE TASKS