MASKING AS AN INDICATOR OF NEURAL FATIGUE: A PRELIMINARY STUDY

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SUMMARY PAGE

PROBLEM

To determine whether or not the basic neural phenomenon of "masking" (the ability of a visual stimulus to inhibit the detection of another, target stimulus) can be used as an indicator of the state of fatigue or stress of an individual's nervous system.

FINDINGS

Fatiguing the visual system by prolonged viewing of a moving pattern results in the reduction of the apparent brightness of a moving line. The ability of the line to "mask" a target stimulus is also reduced, by the amount which occurs when the physical intensity of the line is lowered by an amount equal to the apparent decrease in brightness as a result of fatigue.

APPLICATION

These results suggest the possibility that the "masking" phenomenon may serve as a measure of the state of fatigue of the nervous system or of the effect of a variety of other stresses and may be an indicator of incipient disability of the individual.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MR041.01.01-0130BOKL - A Visual Test of Fatigue and Physiological Disturbances in Navy Divers and Submariners. The present report is No. 3 on that work unit. It was approved for publication on 23 May 1972 and designated as Naval Submarine Medical Research Laboratory Report No. 709.

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ABSTRACT

After prolonged viewing of a moving pattern, the apparent brightness of a moving line is reduced. As a result, the masking effectiveness of the moving line is also reduced. A reduction in the luminance of the moving line by an amount equal to the reduction in apparent brightness produced an equivalent reduction in masking effectiveness.

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INTRODUCTION

A search is currently underway for a simple and reliable test of impending physical disability in the face of environmental stress. When men must function in stressful situations or hazardous conditions, their performance frequently shows no decrement, even under extreme stress - at least for a limited period of time. Performance levels can often be maintained, but at additional physiological cost. Eventually, however, the body cannot sustain the extra effort, and performance begins to decline. Until that occurs, attempts made to monitor the condition of the body through various physiological and psychological tests often fail to reveal either a decrement in performance or the additional physiological cost of maintaining the performance. An indicator of the preliminary strain on the nervous system before the performance decrements begin to appear would thus be desirable.

One such indicator which has shown great promise is the evoked cortical potential[1]. This is a direct measure of neural activity in the cortex whose amplitude may either increase[2-4] or decrease[5-7] in response to a wide variety of environmental stresses. But it requires the attachment of electrodes to the individual and sophisticated equipment for its analysis. If a simpler measure of the functioning of the nervous system could be found, it might also prove very useful.

This report presents the results of a preliminary study of the phenomenon of "masking" as a possible measure of small decrements of functioning of the nervous system. Masking refers to the fact that under certain conditions the nervous system cannot process two stimuli arriving within certain temporal and spatial limits: One stimulus inhibits the detection of the second stimulus, and the observer is able to report the presence of only one stimulus. It seems reasonable to assume that a phenomenon which is so clearly based on fundamental processes of the nervous system should reflect any changes in the system resulting from such factors as fatigue or other stress. Specifically, changes in the functioning of the nervous system should appear as variations in the normal parameters of the masking phenomenon.

This phenomenon has been the subject of a very large number of investigations[8]. Virtually all of them have used stationary stimuli. In this laboratory, however, we have conducted several studies of masking stimuli which were moving[9,10]. Since then a great deal of information has been gathered about the effects of prolonged viewing of moving stimuli on the ability to see these stimuli; several studies have established that prolonged viewing of a moving pattern results in a reduction of the apparent brightness of that pattern - that is, some loss in the ability to see that pattern[11-13]. The nervous system apparently has lost part of its ability to respond to that stimulation. Since this decrement can be precisely measured, we can then ask what effect a given level of fatigue in the nervous system has on the ability of a stimulus to function as a "mask". If fatiguing the visual system results in a change in masking, this may serve as the basis for a relatively fast and simple test of the state of the nervous system and as an indicator of incipient disability.

In this experiment, then, a subject first viewed a moving pattern of lines for an extended period in order to fatigue the nervous system and the resulting loss of apparent brightness was measured. Then the masking ability of the moving line was measured to determine if there was also a loss in the ability of the moving line to prevent the detection of a target stimulus.

APPARATUS

Two pieces of apparatus were used, one to present a continuously moving pattern of lines with which to adapt the eye and another to present the moving masking stimulus and the test stimulus.

The continuously moving pattern was produced by an endless strip of opaque, black paper revolving on two vertical rollers. Both the direction and speed of the movement were controlled by a 2T 60 Motor Controller made by G. K. Heller Co. A series of vertical strips were cut in the paper which subtended 4.6° visual angle in height, and 6 min in width and separated by 2.35° from each other. An aperture in front of the roll restricted the visible movement of the pattern to a distance of 4.6°. A pinlight, covered with red plastic (cutoff at 590 nm) and placed 1° to the right of the right edge of the movement, served as the fixation point. The pattern was back-lighted by an incandescent lamp whose current was controlled by a General Radio Variac. Between the lamp and the paper stood a sheet of diffusing glass. The luminance of the slits as measured by a Spectra Brightness Spot Meter was 2 ft-L. The distance from the observer to this apparatus was 74 inches.

The apparatus produced the moving masking stimulus and the test stimulus has been described in detail elsewhere[9]. Essentially, it presents a vertical line of light at various luminances which can be moved either from right to left or from left to right (as it was in this experiment) at various speeds. The test stimulus, which appears at any set position, can be flashed at any luminance and at any desired time during the traverse of the moving line. In this study the height of the moving stimulus was 4.5°, its width was 4 min, and its extent of movement was 4.6°. Another small red light, again set 1° to the right of the point where the moving line disappeared, served as a second fixation point. The moving line, thus, was almost identical to each line in the adaptation pattern in terms of dimensions, extent of movement, and area of retinal stimulation. The direction of movement was left to right - toward the test stimulus. Its luminance was 2 log units above absolute threshold. The speed was 10° per second. (Fig. 1).

The test stimulus was 8 min wide and 26 min high and located at the point where

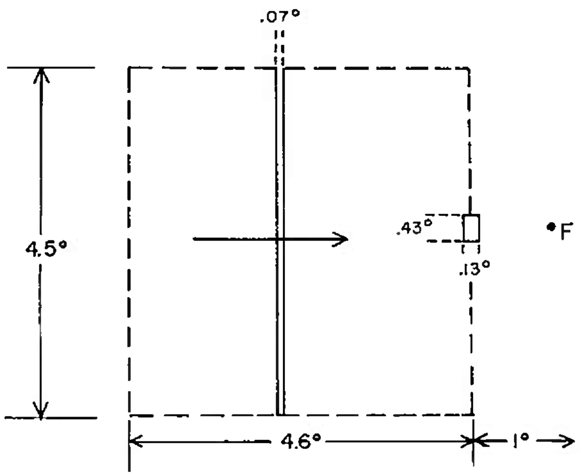

Fig. 1. Diagram of the viewing screen, showing the location of the fixation point (f), the rectangular test stimulus 1° to its left and the masking line with its area of traverse. The diagram of the adaptation pattern would be similar except that there would be no test stimulus and two moving lines are visible at any given moment.

the moving line disappeared. Its duration was 150 msec, and its timing was such that it appeared while the moving line was making its traverse and then it and the line disappeared simultaneously.

The adaptation apparatus was set to the left and slightly lower than the screen on which the masking stimuli were projected. The visual angle between the two fixation points was about 30°. The subject's head was positioned by a chin and forehead rest which swiveled around easily so that he could quickly change his direction of gaze.

PROCEDURE

The experiment consisted of three parts. The first measured the effect of adaptation to the moving pattern on the visibility threshold for the masking line. The second measured the reduction in the masking effect when the masking line was actually dimmed by the amount equivalent to apparent dimming produced in the first part. The third compared the masking effect of the line after adaptation to movement in the same direction as that of the masking line with that obtained after adaptation to movement in the opposite direction.

In all three, the general procedure was similar. Each session began with a 15-minute period of dark-adaptation. Next followed 15 minutes of adaptation to the moving pattern. Then came the threshold measurements of either the masking line or the test stimulus (masking effect). The actual procedure was as follows. When the adaptation period was completed, the pattern continued to move but the light in the adaptation apparatus was extinguished. This served as the signal to the subject to shift his gaze to the fixation point for the threshold measurements. About two seconds after the light was extinguished, the moving line was presented. The subject immediately signalled his response (yes or no) with a buzzer, the adaptation light was turned on, and the subject looked back at the fixation light for the adaptation pattern until the adaptation light was again extinguished.

A judgment was taken every 20 seconds. Between presentations of the masking line, the subject thus continued to adapt. The time taken up in shifting fixation points, presenting the test stimulus, and making a judgment took three or four seconds; there was thus about 16 seconds of adaptation between each judgment.

Thresholds were measured by the method of limits; the run was always begun with the test stimulus (or the moving line) clearly visible. The luminance of either the masking line or the test stimulus was varied in 0.1 log unit steps until the subject changed his judgment; that luminance level was recorded. Then a run was taken in the opposite direction. The threshold was the mean of 20 such determinations, 10 in each direction.

Two thresholds were measured in each session. For example, to assess the effect of adaptation to the moving pattern on the absolute threshold for the moving line, the threshold was measured after adaptation to movement in opposite directions. Depending on which part of the experiment was involved, a session lasted about 60-80 minutes.

SUBJECTS

Complete data were obtained only for the writer. The conditions, however, were sampled with another subject; in no case did his data fail to conform with the results presented in this report.

RESULTS

A. Effect of adaptation to the moving pattern

The effect of adaptation to the moving pattern on the absolute threshold for the masking line was assessed by comparing the threshold after adaptation to movement in the same direction as that of the masking line with the threshold after adaptation to movement in the opposite direction. Six thresholds were obtained for each condition; in three sessions, thresholds were first obtained after adaptation to the same direction of movement, and in three other sessions, thresholds were first obtained after adaptation to the opposite direction of movement. Following the first threshold there was a short rest period, after which the procedure was repeated beginning with 15 minutes of adaptation, etc.

Table I gives the results. In every case, the threshold of the moving line was higher after adaptation to a pattern moving in the same direction. The mean threshold after "same: movement was 1.25 μL, whereas the threshold after adaptation to movement in the opposite direction was 0.69 μL. This is a ratio of 1.82, equivalent to a difference of 0.26 log unit, a typical value for such experiments[14]. These results completely conform to the many experiments demonstrating threshold changes as a result of such adaptation and, therefore, confirm the effectiveness of the apparatus and procedure.

B. Effect on masking of changes in luminance of the masking line

Having successfully replicated the effect of adapting to a moving pattern on the threshold for a moving line, the next question was whether a decrease in the luminance of the masking line of only 0.26 log unit would produce a measurable change in the magnitude of masking.

Table I. Thresholds (μL) for the masking line after adaptation to movement in either the same or the opposite direction

	Same [a]	Reverse [a]
	1.33	0.79
	0.89	0.54
	1.29	0.73
	1.49	0.70
	1.26	0.73
	1.21	0.65
Mean	1.25	0.69

[a] Adaptation to "same" direction occurred first during the session for the first three sets of thresholds.

The second part of the experiment compared the masking effect of a moving line at a reference luminance two log units above threshold with the effect of the line dimmed by 0.28 log unit, the closest filter match readily available.

Twelve thresholds were obtained for each luminance, one threshold for each per session. The two luminances were presented in random order during the session until 12 pairs of runs were given for each luminance. It was impossible for the subject to tell whether the brighter or dimmer line was being presented. Prior to the threshold measurements and also between judgments, the subject adapted to the grid pattern moving at a speed of 0.2° per second in a direction opposite to that of the masking line. Thus, the same degree of light adaptation was maintained, although such a slow speed of movement (as well as being in the opposite direction) has little effect on the subsequent visibility of the masking line.

Table II gives the threshold values. The mean threshold of the test stimulus in the presence of the "bright" masking line was 10.17 μL. When the line was dimmed by 0.28 log unit, the mean threshold of the test stimulus fell to 9.32 μL. This decrease in threshold occurred in 10 of the 12 sessions ($p < .05$, Wilcoxon Sign Test, one-tailed).

C. <u>Effect on masking of adaptation to moving pattern</u>

The second part of the experiment showed that there was a small, but statistically significant, decrease in the masking effect of the moving line when its luminance was reduced. The final step was to determine whether or not adaptation of the visual system to a moving pattern, which reduces the apparent brightness of a moving line, also reduced the ability of that line to mask the test stimulus by an amount comparable to that produced by actually reducing the physical intensity of the line.

Twelve thresholds were obtained for each direction of adapting movement, one threshold for each per session. In six of the sessions, the first adapting movement was in the same direction as that of the masking movement; in six of the sessions, the first adapting movement was in the opposite direction as

Table II. Thresholds (μL) for the test stimulus in the presence of the masking line at each of the two luminances

	Bright	Dim	Ratio (B/D)
	7.35	8.10	0.91
	11.09	9.69	1.14
	9.47	9.37	1.01
	10.02	9.58	1.05
	8.63	8.18	1.06
	7.98	9.81	0.81
	12.27	9.47	1.30
	9.47	9.26	1.02
	9.90	8.74	1.13
	10.33	8.73	1.18
	14.75	10.57	1.40
	10.82	10.42	1.04
Mean	10.17	9.32	1.09

that of the masking movement. There was first a 15 min period of adaptation followed by the threshold measures; after a brief rest period, there was another 15 minute adaptation period to the other direction of movement, followed by the second set of thresholds.

Table III gives the threshold values. The mean threshold for the test stimulus in the presence of the moving line after adaptation to movement in the same direction as that of the line was 8.52 μL. After adaptation to movement in the opposite direction, however, the threshold for the test stimulus rose to 9.21 μL. Such a rise occurred in 9 of the 12 sessions ($p < .03$, Wilcoxon, one-tailed), and produced virtually the same ratio between the two sets of threshold as in Table II as well as virtually the same range of thresholds for the 12 sessions.

DISCUSSION

These experiments have, first of all, replicated the now well known phenomenon of reduced visibility of a moving line as a result of adaptation to that speed and direction of movement. Further, they have shown that reduction in actual luminance of a moving line by an amount equivalent to the apparent reduction in brightness reduces the masking effectiveness of the moving line. Finally, they have shown that adaptation to the same direction and speed of movement as that of the masking line produces that same reduction in masking effectiveness.

Table III. Thresholds (μL) for the test stimulus after adaptation to two directions of movement

	Same [a]	Reverse [a]	Ratio (R/S)
	7.34	8.83	1.20
	8.52	8.61	1.01
	7.97	8.62	1.08
	8.27	9.07	1.10
	7.98	9.16	1.15
	13.15	14.86	1.13
	8.50	9.90	1.16
	7.56	10.66	1.41
	8.07	7.82	0.97
	7.35	7.56	1.03
	8.41	7.36	0.88
	9.04	8.19	0.90
Mean	8.52	9.21	1.08

[a] Adaptation to "same" direction occurred first in the session for the first six sets of thresholds.

Fatigue of the nervous system, accomplished by prolonged inspection of a moving pattern, results in a measurable reduced ability to mask a test stimulus. It is thus conceivable that the general phenomenon of masking may serve as an indicator of the state of fatigue of the nervous system. We propose therefore that masking be studied under various kinds of environmental stress.

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13. ABSTRACT

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