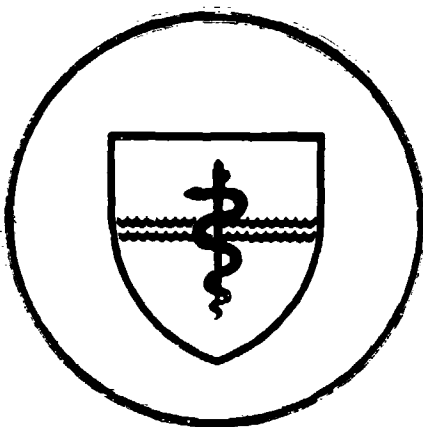


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THE EFFECTS OF BIMODAL PRESENTATION OF STIMULI AND NOISE ON TARGET IDENTIFICATION

by

S. M. Luria and Alan R. Jacobsen

Naval Medical Research and Development Command
Research Work Unit M0100.001-1022

Released by:

C. A. Harvey, CAPT, MC, USN
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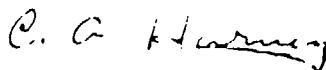
Saul M. LURIA and Alan K. JACOBSEN

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C. A. HARVEY, CAPT, MC, USN
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SUMMARY PAGE

THE PROBLEM

To determine if target identification on a sonar waterfall display is improved when target information is presented both visually and auditorially compared to either of these alone.

THE FINDINGS

Target identifications were made about 1 dB lower with bimodal than unimodal presentation of the target information.

APPLICATION

These findings support the use of bimodal presentation of information to operators of sonar, radar, ECM equipment, and the like.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Naval Medical Research and Development Command Work Unit M0100.001-1022. The present report is Number 5 on this work unit. It was submitted for review on 1 January 1986, approved for publication on 28 March 1986, and designated as NavSubMedRschLab Report No. 1072.

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ABSTRACT

Identification thresholds were measured for four targets which were presented on a CRT display or through earphones under 5 conditions: (1) auditory target with auditory noise; (2) visual target with visual noise; (3) auditory target with both visual and auditory noise; (4) visual target with both visual and auditory noise; and (5) both visual and auditory targets with both visual and auditory noise.

Both visual and auditory thresholds were better when the auditory and visual targets were presented together than when either was presented alone. This was true whether the two stimuli were being increased in intensity simultaneously or whether the secondary stimuli was set at a constant level 1 to 4 dB below the baseline threshold.



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THE EFFECTS OF BIMODAL PRESENTATION OF STIMULI AND NOISE ON TARGET IDENTIFICATION

Several studies have investigated the effects on an observer's ability to detect a stimulus in one modality when information has been presented simultaneously to a second modality. But, as Kobus, et. al. (1985) have pointed out, most studies of the interaction of two sensory modes have used such simple stimuli as flashes of light, clicks, and tones (Nickerson, 1983); moreover, they tend to use a method of directed or divided attention in which the subject must attend to one modality (e.g., vision) while another modality (e.g., audition) competes for attention.

The typical findings of such studies are that the bimodal presentation does not degrade performance (Colquhoun, 1975). Indeed, several studies have found that reaction time and signal detection are improved with bimodal stimulation (see Kobus, et. al, 1985). Apparently, individuals can divide their attention between two modalities quite effectively (Loveless, et. al., 1970; Keele and Neill, 1978), and information from one modality can enhance performance based on another modality (Hanson, 1981).

Few such studies have been done with complex tasks. Yet it is common for individuals to have to deal with information in more than one modality in most situations. Sonarmen routinely do so. Is their performance improved if target information is presented redundantly both visually and auditorially?

Kobus, et. al. (1985) and Lewandowski and Kobus (1985) studied the effects of bimodal presentation on the detection of sonar targets. They found that these thresholds were improved by bimodal stimulation. The present study investigated the effects of redundant bimodal stimulation on the more difficult task of classification, that is, identifying at near-threshold levels which of several stimuli is being presented.

EXPERIMENT 1

METHOD

Subjects. Three staff members of the laboratory and one sonarman volunteered to serve as subjects.

Apparatus. Three visual and auditory frequencies, 300, 1000, and 1600 Hz, were produced, each by a Wavetek function generator (Model FG 501). They were presented on both a monochromatic visual display unit (VDU) and Koss (PRO/4AM) headphones. The signal from each generator was split into two channels and fed through separate Hewlett-Packard attenuators (Model 350D) before being displayed. White noise was generated by a Grason-Stadler Noise Generator (Model 901B), also split into two channels, and routed through separate attenuators before going to the VDU and the headphones.

The VDU displayed the signal frequency along the x-axis and time along the y-axis. A horizontal line of pixels appeared at the top

of the display and moved down the screen in a "waterfall" fashion. Each line remained visible for 6.2 sec, and 16 lines were present at a time. The update time was thus 0.4 sec, equivalent to short-time averaging on these sonar displays. A signal appeared as an intermittent vertical line of dots of greater intensity than the background noise. The 1000 Hz signal appeared near the left and right edges of the screen, since the range of the display was from 0 to 2000 Hz. Intensity was coded as eight brightness levels. Noise appeared as lighted pixels varying randomly in position and intensity.

A target consisted of any two or all three frequencies presented together. There were thus four targets.

Procedure. Three categories of thresholds were measured. In the baseline condition, only one sensory modality was stimulated; target information and noise were both presented either as a visual display or through earphones. In the unimodal condition, the noise was presented both visually and aurally, but the target was presented in only one of the modalities, and separate visual and auditory thresholds were again obtained. In the bimodal condition, the same target information and noise was presented to both modalities at the same time.

Subjects were thus tested under five conditions: (1) auditory target with auditory noise (auditory baseline); (2) visual target with visual noise (visual baseline); (3) auditory target with both auditory and visual noise

(auditory unimodal); (4) visual target with visual and auditory noise (visual unimodal); and (5) both bisual and auditory target with both visual and auditory noise (bimodal).

The subjects first were given an extended training procedure during which they learned to identify the four targets. That is, the subject was required to state whether the target consisted of all three frequencies, or the high and low frequencies, etc. This proved to be rather difficult with the auditory targets for all the subjects except one, and training required about half a dozen sessions. The experiment began when the subject could identify each of the four targets, presented randomly, three times with no more than one error out of the 12 presentations.

Every session began with practice in identifying the four targets followed by the test procedure to ensure that they could identify the targets. Next, the baseline auditory and visual thresholds were measured twice for each target. After this, the unimodal and bimodal conditions were presented randomly, intermixed, until one threshold had been obtained for each target in each condition.

To obtain a baseline or a unimodal threshold, the target was simply presented below threshold and its attenuation decreased (that is, the intensity increased) by 1 dB every 10 sec until the subject identified the target.

To obtain a bimodal threshold, both the visual and auditory

targets were initially presented 5 dB below their mean baseline thresholds for that session, and their attenuation was decreased by 1 dB every 10 sec until the subject identified the target and reported the modality in which the target appeared. In most cases, only one modality was reported but there were instances in which the observer said that both modalities. In either case, these thresholds were compared with the unimodal ones.

At the end of the session, a few baseline thresholds were again measured to ensure that no significant threshold shifts had occurred. A session lasted about 45 minutes.

There were five sessions for each subject, resulting in five thresholds for each target in each condition.

RESULTS

Table 1 gives the mean attenuation in dB at which the four targets were identified in the various conditions. The higher the dB level, of course, the greater the observers' sensitivity. There was little change in the thresholds for the targets displayed visually. The baseline and unimodal thresholds were virtually identical; the bimodal threshold was improved by about half a dB, but none of these changes was significant, according to repeated measures analysis of variance ($F(2,6)=1.60$). The only statistically significant difference among the visual thresholds was that the threshold for the target composed of the

intermediate and high frequency was better than the threshold for the target composed of all three frequencies.

The mean auditory threshold, however, was improved by nearly three dB in the bimodal condition, a change which was significant, according to the analysis of variance ($F(2,6)=21.26$, $p < .01$). The bimodal threshold was significantly better ($p < .01$) than both the baseline and unimodal thresholds, according to the Newman-Keuls test.

EXPERIMENT 2

The presentation of target information visually and auditorially at the same time clearly improved the subjects' ability to make an auditory identification of the targets, but it had very little effect on the identification of the visual targets. The explanation appeared to be that the variability in the visual thresholds was very small, and the apparent confidence with which the observers made their judgments was very high. There was, on the other hand, much more variability in the auditory thresholds, and the observers were much more hesitant in their judgments. The auditory threshold, therefore, was open to improvement by any additional visual cues. The confidence with which the visual judgments were made, however, left little room for improvement, and the addition of auditory cues had little effect.

The relative variability of the auditory thresholds was, however, a weak link in the procedure. Although it was possible to say

Table 1. Mean Attenuation at Identification Threshold (dB)

<u>Target</u>	<u>Base</u>	<u>Visual</u>		<u>Auditory</u>		
		<u>Uni</u>	<u>Bim</u>	<u>Base</u>	<u>Uni</u>	<u>Bim</u>
LM	18.25	18.15	18.57	57.22	56.78	59.35
MH	18.27	17.70	18.08	56.00	56.35	59.69
LH	18.07	18.35	19.08	57.85	58.85	60.22
LMH	17.59	17.65	18.38	57.10	57.55	59.82
Mean	18.04	17.96	18.52	57.04	57.38	59.77

with considerable confidence what the visual threshold was for a given observer and, therefore, to present the visual signal at 5 or 2 dB below that threshold, the same could not be done with the auditory thresholds. We could not be certain that we were a given number of dB below that threshold and that the visual and auditory signals being presented simultaneously were perceptually equivalent.

Experiment 2 attempted to solve this problem by presenting the ancillary signal at a series of constant intensities during the determination of the threshold of interest.

METHOD

Subjects. Four volunteers again participated, three staff members and one sonarman. One of the staff members had participated in Experiment 1; the others were new subjects.

Apparatus. The same apparatus was used as in Experiment 1.

Procedure. Each session again started with practice in identifying the four targets. Next, the baseline thresholds were measured for each of the four targets both visually and auditorially. A threshold was the mean of several determinations. If these showed little variability, then only three were taken; if the variability was enough to cast doubt on the threshold value, then as many as 10 determinations were made.

After this, the visual and auditory thresholds for the four targets under the five conditions

were measured in random order. The subject thus did not know whether the threshold being measured was visual or auditory, unimodal or bimodal. In this experiment, when a threshold was being measured for one modality, the stimulus in the other modality was either not present or was presented at a constant intensity level of either 1, 2, 3, or 4 dB below the baseline threshold measured at the start of that session.

While the signal in the ancillary modality was kept at a constant intensity, the signal in the modality whose threshold was being measured was first presented at some random intensity below threshold and increased by 1 dB every 10 sec until the subject correctly identified the target. He also reported whether he had heard or seen the target.

The threshold in each condition was measured once during each session. There were five sessions for each subject, resulting in five threshold determinations for each condition. A session lasted between 60 and 90 minutes.

RESULTS

Both the visual and auditory thresholds were measured without a stimulus in the other modality as well as with a stimulus presented from 1 to 4 dB below its threshold measured at the start of the session. Table 2 gives the differences between the unimodal threshold and the thresholds in the presence of stimulation in the other modality.

For example, the mean visual threshold for the "LM" target was

Table 2. Difference in attenuation (dB) at threshold between the unimodal and bimodal stimulation. A negative number indicates less sensitivity in the bimodal condition.

	<u>Visual</u>				<u>Auditory</u>			
	(Auditory setting)				(Visual setting)			
Target	-1dB	-2dB	-3dB	-4dB	-1dB	-2dB	-3dB	-4dB
LM	1.7	1.9	0.8	1.1	1.0	1.6	0.5	0.3
MH	0.5	0.8	0.7	0.2	0.4	-0.04	0.4	0.8
LH	0.5	0.6	0.2	0.7	0.8	0.8	1.3	0.9
LMH	1.1	1.2	1.0	0.1	1.8	1.7	2.0	1.9
Mean	0.95	1.1	0.7	0.5	1.0	1.0	1.0	0.8
N	28	30	45	52	103	101	100	95
p-value	.02	NS	.01	.01	.001	.001	.002	.0025

at an attenuation of 17.1 dB. In the presence of the auditory stimulus presented 1 dB below the baseline threshold, the subjects reported seeing that target at an attenuation of 18.8 dB, an increase of 1.7 dB.

Table 2 shows that in virtually every condition, the subjects identified the targets, either visual or auditory, at a greater attenuation -- that is, with increased sensitivity -- in the presence of the bimodal stimulation. The degree of enhancement declined only slightly as the level of the ancillary stimulation decreased. The mean differences were all significant, according to the Sign Test (Siegel, 1956), except for the visual threshold in the presence of the auditory stimulus 2 dB below its threshold. Once again, the enhancement of the auditory thresholds was greater than that of the visual thresholds.

Table 2 also shows the number of thresholds for each condition. It is obvious that more auditory than visual thresholds were obtained. This resulted from the fact that many times the subjects reported hearing the target when it was kept at 1 to 4 dB below the baseline threshold as the visual signal was being increased. This happened much less often with the visual thresholds. It was these things which produced the unequal number of thresholds in the various conditions. Again, this supports the statement that the auditory thresholds were much more variable than the visual thresholds.

DISCUSSION

In both experiments, the observers identified the targets at lower intensity levels with redundant bimodal target information. The enhancement was more effective for the auditory than the visual stimuli. This enhancement was fairly consistent as the intensity of the stimulation in the other modality decreased through the range used in Experiment 2, particularly for the auditory modality.

When the target intensity is low, the observers are, of course, unsure as to the identity of the target. But they have some ideas. The availability of additional information, even in the form of stimuli which are "below threshold", improved their ability to make the identification.

The reason, of course, is that the threshold is not a definite point, but rather a somewhat indefinite zone; at the lower end of this zone, the signal may be identified only 10% of the time; at the upper end of the zone, it may be identified 90% of the time. Thus, although we set a signal 2 dB below the measured threshold, we must expect it to be seen a certain proportion of the time. Moreover, the zone is always changing from moment to moment. Although we established a baseline threshold for both the visual and auditory stimuli at the beginning of each session, this undoubtedly was constantly changing to some extent during the session. When we set a stimulus 1, or 2, or 4 dB below that threshold, it is difficult to know if it was, in fact, where it was supposed to be. Thus, there may have been times when a stimulus set at -1 dB, or even -4 dB, was,

in fact, above the observer's threshold at that moment.

But there can be no question that a stimulus at -4 dB was, on average, less perceptible than one at -3 or -2 dB, and was quite likely below threshold a good part of the time. Yet identification of these stimuli increased significantly compared to when they were presented unimodally. It appears that the observers were using not just the best information but rather were using all the information available to them when attempting to identify the targets. Even the stimuli which were below threshold provided some information. Apparently, even a limited amount of information is useful when added to other information in another modality. It is likely that what is happening is this. The subject may, for example, be sure that he hears the high and low frequencies but be uncertain as to whether or not he hears the middle frequency. The visual display, although unclear, may be enough to convince him that the middle frequency is being presented.

And when the stimuli are presented for extended periods of time, fluctuations in threshold level increase the probability that the target will be above threshold (or closer to threshold) for some period of time. One would expect that the less the secondary information, the less the threshold enhancement. As the secondary stimulus was set further below threshold, the amount of enhancement was reduced surprisingly little. This suggests that the enhancement is not simply a matter of probability but rather that

observers are adept at extracting information from highly degraded stimuli, and that small amounts of information enhance the confidence and accuracy of target identification.

If the auditory information can be so enhanced by processing that it is brought to the same threshold level as is now done for the visual information, then it would be most to the advantage of the operator to have both presented simultaneously. This is not to say, of course, that auditory information is currently useless; certain signals such as transients even now are best detected by ear.

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