



Cortical evoked responses and detection efficiency in man.

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CORTICAL EVOKED RESPONSES
AND DETECTION EFFICIENCY
IN MAN

A Thesis Presented

By

Jay Isgur

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AND DETECTION EFFICIENCY
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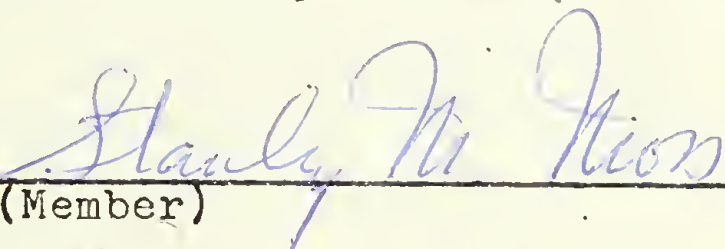
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Abstract

This experiment was an attempt to directly answer the following question: Do fluctuations in the amplitude of the brain's evoked bioelectric activity, recorded from the scalp, reflect merely long term changes in general arousal level, or do these amplitude fluctuations reflect also momentary fluctuations in attention?

Subjects were two adult males. Each subject was run for six vigilance sessions. Each session consisted of 30 minutes of continuous 16 Hz photic stimulation. The subject's task required a button-pressing response to signals which were randomly presented. A signal appeared to the subject as a slight dimming of the photic stimulation.

A narrow pass-band filter was used for recording bioelectric activity during vigilance sessions. Unlike a computer of average transients' (CAT) output, which reflects the bioelectric activity summed over a prolonged time period, the filter output reflects the moment to moment changes in amplitude of the bioelectric activity. The pass-band filter is thus a more useful monitoring device than the CAT for studying possible correlations between momentary bioelectric amplitude fluctuations and momentary attention fluctuations.

Results showed that day to day baseline changes in amplitude of evoked bioelectric activity were positively cor-

related with day to day baseline changes in detection efficiency. However, moment to moment fluctuations in amplitude did not correlate with moment to moment detection efficiency changes. If (1) day to day baseline changes in detection efficiency can be considered a legitimate measure of long term changes in general arousal level, and (2) momentary fluctuations in detection efficiency can be considered a legitimate measure of momentary fluctuations in attention, then it might be inferred that long term changes in amplitude of evoked bioelectric activity recorded from the scalp consistently reflect long term changes in general arousal level, but momentary amplitude fluctuations do not reflect momentary fluctuations in attention.

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Introduction

Haider, Spong and Lindsley (1964), utilizing computer averaging techniques, have shown that both (1) detection efficiency and (2) amplitude of visual, cortical evoked potentials decrease over time (i.e., over an approximately 90 minute vigilance task). From these findings, and from other observations which are not clearly interpretable, Haider et al. infer that there is a correlation between changes in attention and changes in amplitude of visual, cortical evoked potentials. However, Haider et al.'s data may be reinterpreted. By showing that both detection efficiency and visually evoked potential amplitude gradually decrease during a vigilance task of long duration, Haider et al. may be merely showing that amplitude is correlated with long term changes in general arousal level (possibly due to fatigue), rather than with moment to moment fluctuations in attention possibly due to distractions).

The present experiment was an attempt to directly answer the following question: Do fluctuations in the amplitude of the brain's evoked bioelectric activity, recorded from the scalp, reflect merely long term changes in general arousal level (from alertness to drowsiness to sleep), or do these amplitude fluctuations reflect also momentary fluctuations in attention?

In order to answer this question, it was necessary to

separate momentary fluctuations in attention from long term changes in general arousal. The present experiment was an attempt to accomplish this separation by incorporating three procedures not used in the Haider et al. study:

1) Sessions were short (30 minutes) so that there was little possibility of long term changes in general arousal level.

2) A narrow pass band filter was used for recording bioelectric activity. Unlike the computer of average transients' output (used by Haider et al.), which reflects the bioelectric activity summed over a prolonged time period, the filter output reflects the moment to moment changes in amplitude of the bioelectric activity. Furthermore, a type of data analysis was used which correlated these moment to moment changes in bioelectric amplitude with momentary fluctuations in detection efficiency.

3) The subjects were required to detect a signal whose magnitude was one thirtieth of the magnitude of the signal used in Haider et al.'s experiment. The smaller signal was expected to go undetected if the subject was not paying very close attention. The larger magnitude signal used by Haider et al. was more likely to be detected, even if the subject was not paying close attention; i.e., it was more likely to be missed only when there was a gross decrease in general arousal level. In short, the smaller magnitude signal was expected to be much more sensitive to slight moment to moment

attention fluctuations than was the larger magnitude signal.

Method

Subjects: Subjects were two adult males, S-P and S-I. Subject S-P was the laboratory technician; subject S-I was the author.

Apparatus: (See Figure 1-A.) A slide projector was used as the source of photic stimulation. The intensity of the photic stimulation was controlled by a set of cellophane filters mounted above and in front of the projector. When a solenoid closed, a filter was drawn down in front of the projector, thus decreasing the intensity of the photic stimulation and producing a signal (ΔS).

The frequency of photic stimulation was regulated by a mechanical oscillating shutter mounted in front of the projector. The shutter was driven by an audio generator (Heathkit, Model AG-9A).

A fiber optic tube (Donner Electronics, type number ER 18072) conducted the photic stimulation to the subject. One end of the fiber optic tube was mounted in front of the oscillating shutter; the other end of the fiber optic tube was mounted in a face mask which the subject wore. The face mask was constructed so that the tip of the fiber optic tube was 1 cm from the closed left eyelid. The subject saw the photic stimulation only with his left eye through the closed eyelid.

A continuous EEG record was obtained for each session. Right occipital-midline parietal electrode locations (O_2-P_Z) were used in the first five sessions; midline vertex-right occipital placements (O_2-C_Z) were used in the sixth session. The raw EEG, its 16 Hz frequency component, and a continuous integration of the 16 Hz frequency component, were recorded simultaneously. The 16 Hz frequency component was obtained by passing the amplified cortical output through a narrow pass-band filter, Grass passive LC type, having a bandwidth of 1 Hz, and a fixed center frequency of 16.2 Hz ($Q=15.9$). Continuous integration of the 16 Hz frequency component was obtained by passing the 16 Hz frequency component through a Grass integrator (Model 7P10A). Photic stimulation was applied at a fixed frequency of 16 Hz. This frequency was precalibrated for peak output through the 16 Hz filter before each subject was run.

Procedure: Each subject was run for six vigilance sessions. Each of the first five sessions consisted of 30 minutes of continuous 16 Hz photic stimulation. The subject, reclining on a cot in a sound isolation room, was required to press a response button whenever he detected a signal. Signal duration was 5 seconds; intersignal interval varied from 5 to 45 seconds.

The signal appeared to the subject as a slight dimming of the 16 Hz photic stimulation. The magnitude of the dimming (ΔS) was determined for each subject in the following

manner. Different ΔS s were presented to the subject, each ΔS being presented four times in succession. When a ΔS was found which was detected at least once, and not more than three times out of its four successive presentations, then this ΔS was used as the signal.

The ΔS turned out to be the same for both subjects; i.e., dimming the photic stimulation from its baseline of 327.50 millilamberts to 204.38 millilamberts ($\Delta S = 123.12$ millilamberts) met the above criterion for both subjects. (Brightness measurements were taken with a MacBeth Illuminometer, Leeds and Northrup, model 6800.)

To reduce the possibility that, from time to time, the subject might change his criterion as to what constitutes a signal, he was told that false responses would not be held against him, but that a signal would be considered detected only if he responded within 1 second of signal onset; all other signals would be considered undetected. Therefore, the subject was told that the best strategy was to respond as quickly as possible to even the "slightest feeling" that a signal had been delivered.

Before each session the subject was given a 10 minute warmup. Approximately 15 signals were delivered, and the subject was told whether or not he was correctly detecting these signals. At the end of this 10 minute warmup, the 30 minute session proper was begun.

To test the generality of the results, the sixth session

differed in four ways from the first five:

1) Instead of the midparietal-right occipital electrode placements used in the first five sessions, midline vertex-right occipital placements were used.

2) The signal magnitude of 152.67 millilamberts was greater than the 123.12 millilambert signals of the first five sessions.

3) Subjects were run for 90 minutes. (The first five sessions were 30 minutes.)

4) The sixth session was run three months after the first five sessions.

Results

1. CAT-Filter Correlation

It has been consistently observed that the amplitude of bioelectric activity, recorded over the occipital area of the scalp and filtered through a narrow pass band filter set at the frequency of photic stimulation, is greater when the photic stimulation is presented than when no stimulation, or stimulation at another frequency, is presented (Trehub, 1965). This corresponds to the fact that the amplitude of the average visual evoked response, as recorded by a computer of average transients (CAT), is greater when photic stimulation is present than when it is absent. It seems reasonable to assume, therefore, that (1) a narrow pass band filter (set at the frequency of the photic stimulation) and (2) a CAT

will give highly correlated measures of bioelectric amplitude fluctuations.

To check this assumption, one subject (S-P) underwent a 90 minute session (during which, as usual, 16 Hz photic stimulation was presented to the subject, who was asked to detect randomly delivered signals). Eight 25 second periods were randomly chosen from the 90 minute session. An average evoked response for each of the 25 second periods was computed by a Nuclear-Chicago Data Retrieval Computer (Model 7100). Also, for each of the 25 second periods, the bioelectric activity was filtered through the 16 Hz narrow pass band filter, and the filtered output was integrated. In short, for each 25 second period, there was an average evoked response and an integrated filter output. A product moment correlation (PMC) of the results showed that the peak to peak amplitude of the average evoked response and the amplitude of the integrated filter output positively correlated over the eight 25 second sessions ($r = +0.8104$, $\alpha = .007$).¹

Because of the high positive correlation, it is apparent that a narrow pass band filter, set at the frequency of the photic stimulation, can be used to measure peak to peak bioelectric amplitude changes in the same way as the computer

¹All reported significance levels are for one-tailed tests.

of average transients has been used; also, the pass band filter has an added advantage in that it can monitor moment to moment changes in bioelectric amplitude. It is this advantage which makes the pass band filter a more useful monitoring device than the CAT in the present experiment; that is, the pass band filter is ideal for studying possible correlations between momentary bioelectric amplitude fluctuations and momentary attention fluctuations.

2. Correlations Between Bioelectric Amplitude And Detection Efficiency

A. Within-Session Correlations

1) Product Moment Correlations: A study was made of the relationship between bioelectric amplitude fluctuations and detection efficiency (% detected signals) fluctuations within individual sessions. Since it was not known if detection efficiency would best correlate with bioelectric amplitude quite close to signal onset in time, or with bioelectric amplitude relatively distant from signal onset in time, four different product moment correlations were performed for each session: (See Figure 2-A for the following explanation.) (1) A PMC was performed between detection efficiency and amplitude at the point of signal onset (i.e., between changes in detection efficiency over successive 5 minute intervals and changes over the same successive 5 minute intervals in the average of all filter output amplitudes occurring at the points of signal onsets). (2) A PMC

was performed between detection efficiency and the amplitude integrated over the 1 second preceding signal onset (i.e., between changes in detection efficiency over successive 5 minute intervals and changes over the same successive 5 minute intervals in the average of all the 1 second integrated filter output amplitudes just preceding signal onsets).

(3) A PMC was performed between detection efficiency and the amplitude integrated over the 5 seconds preceding signal onset (i.e., between changes in detection efficiency over successive 5 minute intervals and changes over the same successive 5 minute intervals in the average of all the 5 second integrated filter output amplitudes just preceding signal onsets). (4) A PMC was performed between changes in detection efficiency over successive 5 minute intervals and changes in total 5 minute integrated amplitudes over the same successive 5 minute intervals.

The results of the PMCs can be seen in Table 1-B. For subject S-P, only 5 out of the 24 PMCs were significant at better than the .05 level; similarly, for subject S-I, only 2 out of the 24 PMCs were significant at the .05 level.²

²The sixth session, as previously discussed, differed slightly from the first 5 sessions in recording site, signal magnitude and session length. The PMCs, however, were quite similar to the PMCs of the first 5 sessions.

2) Wilcoxon Matched-Pairs Signed-Ranks Tests of Combined Results: For subject S-P, although only 5 out of the 24 correlations were significant at better than the .05 level, all 24 correlations were positive. Running Wilcoxon Matched-Pairs Signed-Ranks Tests of Combined Results (Trehub and Heilizer, 1962; Siegel, 1956) for each of the four amplitude analyses (5 minute, 5 second, 1 second and signal onset amplitudes) gave significance at the .025 level (Table 1-B). In other words, for subject S-P, there was a positive correlation between detection efficiency and bioelectric amplitude; moreover, this positive correlation was found whether the amplitude was the amplitude measured at the point of signal onset, the amplitude measured over the 1 second preceding the signal onset, the amplitude measured over the 5 seconds preceding the signal onset, or the amplitude measured over the whole 5 minute period in which the signal was found.

For subject S-I, although only 2 out of the 24 correlations were significant at better than the .05 level, 18 out of the 24 correlations were negative.³ Running Wilcoxon tests for each of the four amplitude analyses gave significance at the .05 level for both the 1 second and 5 minute

³It is not unusual to find a negative correlation between attention and evoked potential amplitude. See, for example, Horn (1960), Jane et al. (1962) and Satterfield (1965).

amplitude analyses. Moreover, both the 5 second and signal onset amplitude analyses showed a strong tendency toward negative correlations (Table 1-B). For the 5 second amplitude analysis, 5 out of the 6 correlations were negative; and for the signal onset amplitude analysis, the 3 negative correlations were more significant (average $\alpha = .117$) than the 3 positive correlations (average $\alpha = .261$). In other words, for subject S-I, there was a negative correlation between detection efficiency and bioelectric amplitude. This negative correlation was significant whether the amplitude was measured over the 1 second preceding the signal onset, or over the whole 5 minute period in which the signal was found. And there was a strong tendency toward significant negative correlations when the amplitude was measured over either the 5 seconds preceding the signal onset or at the point of signal onset.

3) Binomial Test: The fact that the Wilcoxon tests showed significance (i.e., that all the PMCs for subject S-P were positive, although only 5 were significantly positive at the .05 level, and that 18 out of the 24 PMCs for subject S-I were negative, although only 2 were significantly negative at the .05 level) might mean that the PMCs would have been significant at the .05 level if more data points had been utilized in the PMC analysis. (On the average, the PMC analysis of a single session was based on only five pairs of points.)

In order to utilize all the data of each session, a binomial test (National Bureau of Standards Applied Mathematics Series 6, 1949) was run in which success for subject S-P was classified as either a detected signal whose preceding amplitude was above the median amplitude value, or as an undetected signal whose preceding amplitude was below the median amplitude value; success for subject S-I was classified as either a detected signal whose preceding amplitude was below the median amplitude value, or as an undetected signal whose preceding amplitude was above the median amplitude value.

When binomial tests were performed on each session (Table 2-B), the results tended to support the hypothesis of a positive correlation between amplitude and detection efficiency for subject S-P (especially for the 5 second amplitude analysis, where four out of the six sessions were significant at better than the .02 level); but the results did not support the hypothesis of a negative correlation for subject S-I; i.e., no sessions showed significance at better than the .28 level.

B. Between-Session Correlations

A study was made of the relationship between mean bioelectric amplitude changes and mean detection efficiency (mean % detected signals) changes across sessions. When the mean detection efficiency and mean amplitude for each session were calculated, and a PMC was run between these two variables across all sessions, both subject S-P and subject

S-I showed highly significant positive PMCs. PMCs varied from +0.8493 to +0.9600; α s varied from .025 to .005. (For example, see Figure 3-A.)

In short, detection efficiency and bioelectric amplitude were positively correlated across sessions; moreover, this positive correlation was found whether the amplitude was the mean session amplitude measured at the point of signal onset, the mean 1 second amplitude of a session, the mean 5 second amplitude of a session, or the total integrated amplitude of a session. Finally, it was noted that on sessions where mean detection efficiency and mean bioelectric amplitude were very low, subjects reported that they felt they had slept during part of the session.

3. Short Term Fluctuations In Detection Efficiency And Bioelectric Amplitude

In order to study momentary fluctuations in attention, a type of data analysis was used which emphasized only momentary fluctuations in detection efficiency. Whenever an instance occurred in which a detected signal was immediately followed or preceded by an undetected signal (as in the second 5 minute period shown in Figure 2-A), the amplitudes (5 second, 1 second and signal onset amplitudes) immediately preceding the detected signal were compared to the amplitudes immediately preceding the undetected signal. A binomial test was performed to determine if, within a single session, there were a significant number of instances in which

the amplitudes preceding the detected signal were (1) greater than the amplitudes preceding the immediately adjacent undetected signal (as would be expected for subject S-P, since his PMCs between amplitude and detection efficiency were consistently positive) or (2) less than the amplitudes preceding the immediately adjacent undetected signal (as would be expected for subject S-I, since his PMCs between amplitude and detection efficiency were consistently negative).

When binomial tests were performed (Table 3-B), the results for both subjects showed a complete lack of significance (except for subject S-P's 5 second amplitude analysis, where 3 out of the 6 sessions were significant at better than the .05 level). In other words, the amplitudes preceding a detected signal did not differ significantly from the amplitudes preceding an immediately adjacent undetected signal.

Discussion

Day to day baseline changes in evoked bioelectric activity, recorded from the human scalp and filtered at the frequency of the photic stimulation, positively correlated with day to day baseline changes in detection efficiency (Results' Section 2B). But this significant correlation broke down within sessions (Results' Sections 2A(1) and 2A(3)), although there was a strong tendency toward correla-

tion (Results' Section 2A(2)). Finally, when the most detailed analysis was used to study moment to moment fluctuations in detection efficiency and amplitude, absolutely no correlation was detected; i.e., moment to moment fluctuations in amplitude did not correlate with moment to moment detection efficiency changes (Results' Section 3).

If (1) day to day baseline changes in detection efficiency can be considered a legitimate measure of long term changes in general arousal level, and (2) moment to moment fluctuations in detection efficiency (manifested as a pair of signals closely adjacent in time, one of which is detected, the other undetected) can be considered a legitimate measure of momentary fluctuations in attention, then it might be inferred that long term changes in evoked bioelectric amplitude recorded from the scalp consistently reflect long term changes in general arousal level, but that momentary amplitude fluctuations do not reflect momentary fluctuations in attention.

The results of the present experiment are compatible with the results of Haider et al. (1964) if the following facts are considered:

- 1). It is not surprising that Haider et al. found significant rank-order correlations between bioelectric amplitude and detection efficiency within sessions, while in the present experiment no significant within-session PMCs were found. Since, as the results of the present experiment in-

dicade, bioelectric amplitude changes reflect only long term changes in general arousal, and since it is much more likely that long term changes in general arousal (probably due to the fatigue effects of a prolonged vigilance task) would occur over 90 minutes than over 30 minutes, it is therefore much more likely that a correlation between bioelectric amplitude changes and long term changes in general arousal would be seen in the 90 minute Haider et al. sessions than in the 30 minute sessions of the present experiment.

2) Haider et al. (pp. 181-182) make the following statement:

"In addition to these overall trends showing a correspondence between vigilance decrement and evoked-potentials (over the 90 minute session), there were briefer concurrent fluctuations in detection performance and evoked potentials which were very pronounced in some experimental sessions. Frequently, in adjacent 5-minute periods there were contrasting increases in amplitude of evoked-potentials and performance efficiency. These relatively short-term fluctuations in detection performance and in evoked-potentials to nonsignal stimuli appear to reflect changes in the subject's attentive state."⁴

Apparently, there was some concern on the part of the experimenters that only gross arousal changes were correlated with bioelectric amplitude; their statement appears to be an attempt to show that not only gross arousal changes, but also momentary attention fluctuations, were correlated with

⁴Bracketed words are my own.

bioelectric amplitude changes. However, the statement is a purely non-statistical description of the data; since no statistical significance levels were given, it can only be inferred that Haider et al. found no significant number of briefer concurrent fluctuations in detection performance and evoked-potentials. This result is compatible with the within-session correlation results of the present experiment; i.e., although there was a tendency toward a within-session correlation between detection efficiency and bioelectric amplitude (Results' Section 2A(2)), there was no significant correlation (Results' Sections 2A(1), 2A(3) and 3).

In summary, the data of both the present experiment and Haider et al.'s experiment support the same conclusion: there is a significant correlation between long term changes in general arousal level and long term changes in amplitude of evoked bioelectric activity recorded from the scalp, but not between momentary fluctuations in attention and evoked bioelectric amplitude. However, Haider et al. conclude that there is not only a correlation between long term changes in general arousal level and evoked bioelectric amplitude, but also a correlation between momentary fluctuations in attention and bioelectric amplitude. The results of the present experiment indicate that this conclusion is erroneous. By incorporating three procedures not used in the Haider et al. study (See Introduction), the present experiment has been an attempt to achieve a separation of momentary fluctuations in

attention from long term changes in general arousal. Results indicate that bioelectric amplitude changes significantly correlate with long term changes in general arousal, but not with momentary attention fluctuations.

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APPENDIX A

FIGURE 1-A. SCHEMA OF APPARATUS ARRANGEMENT

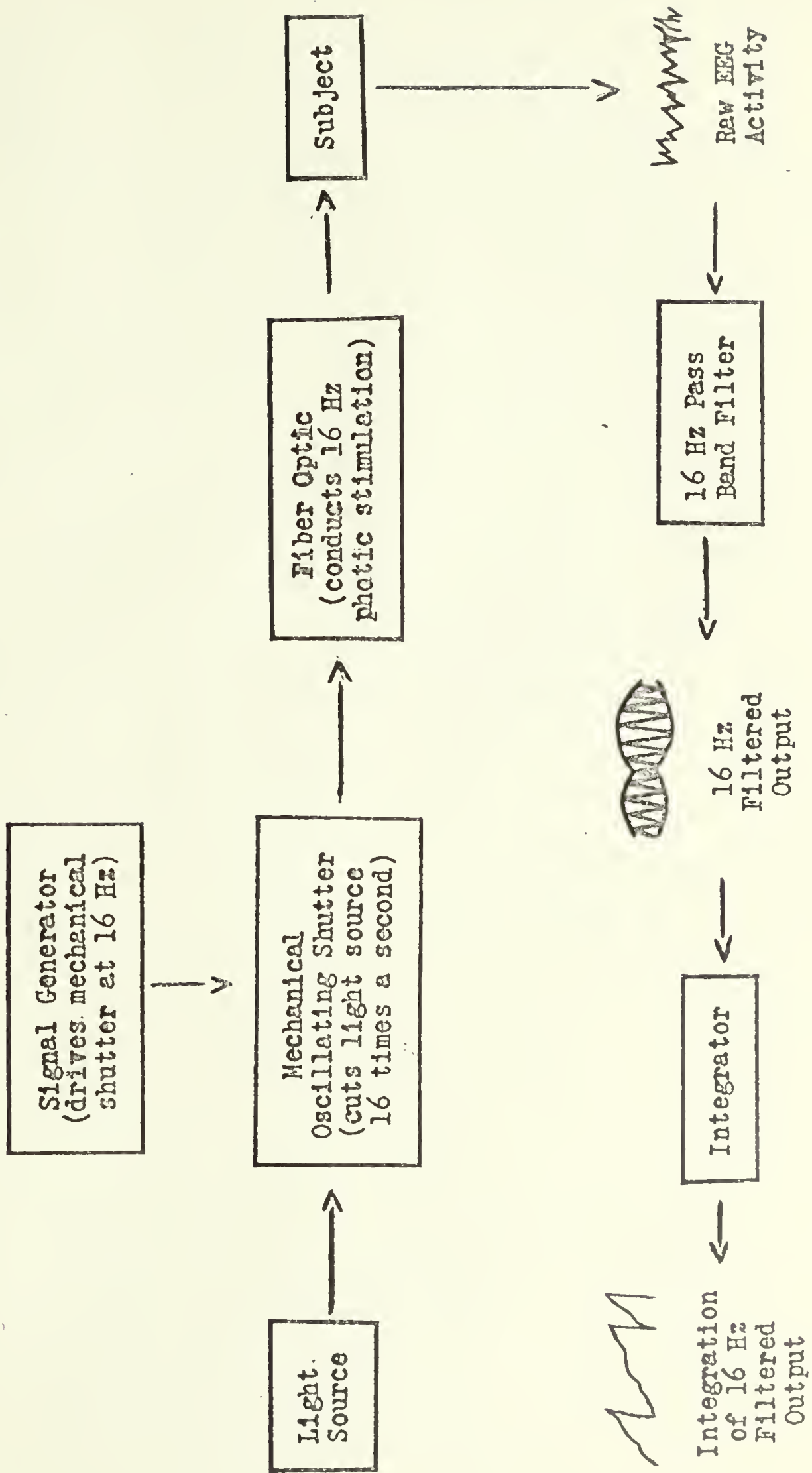


FIGURE 2-A. ILLUSTRATION OF RAW DATA ANALYSIS

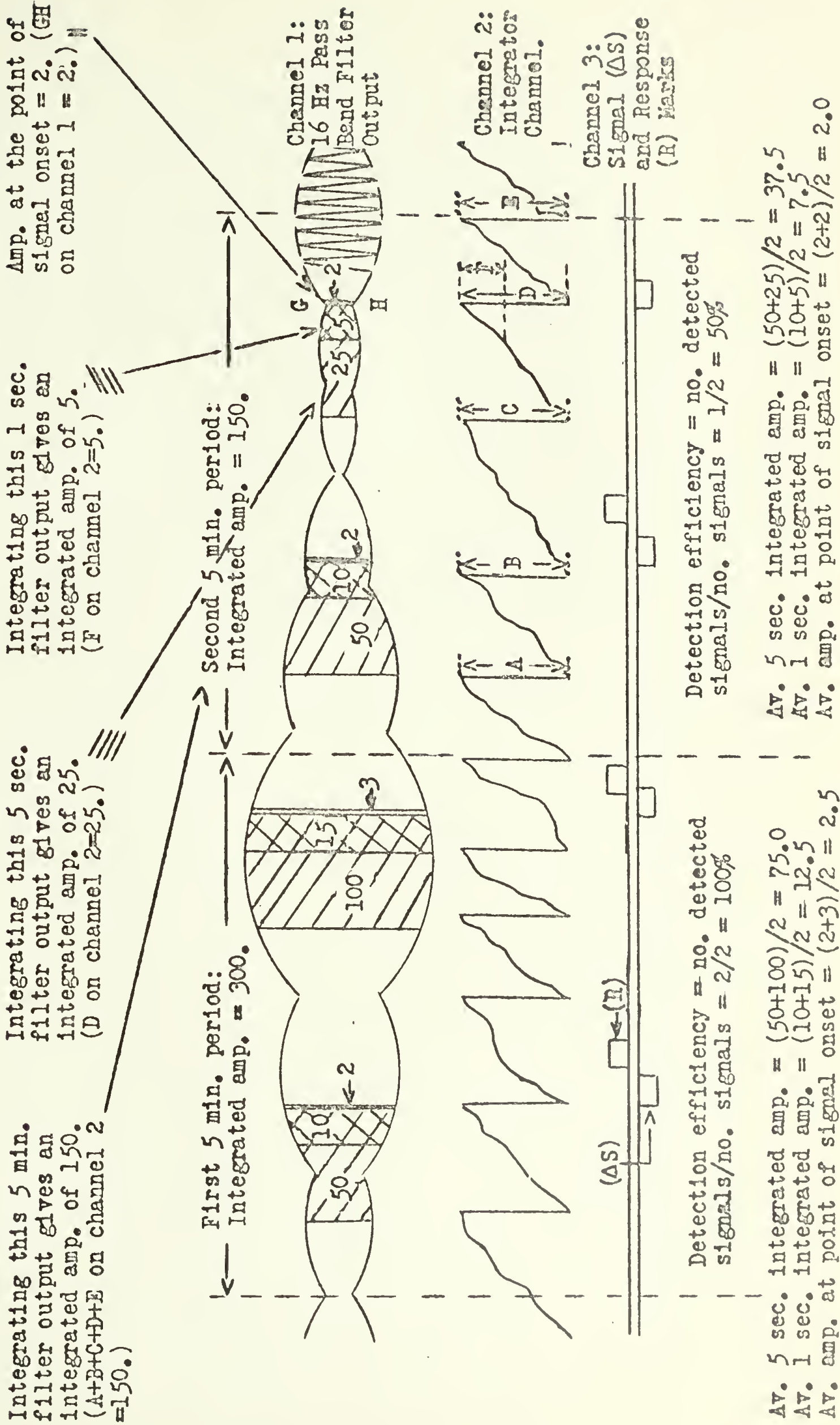
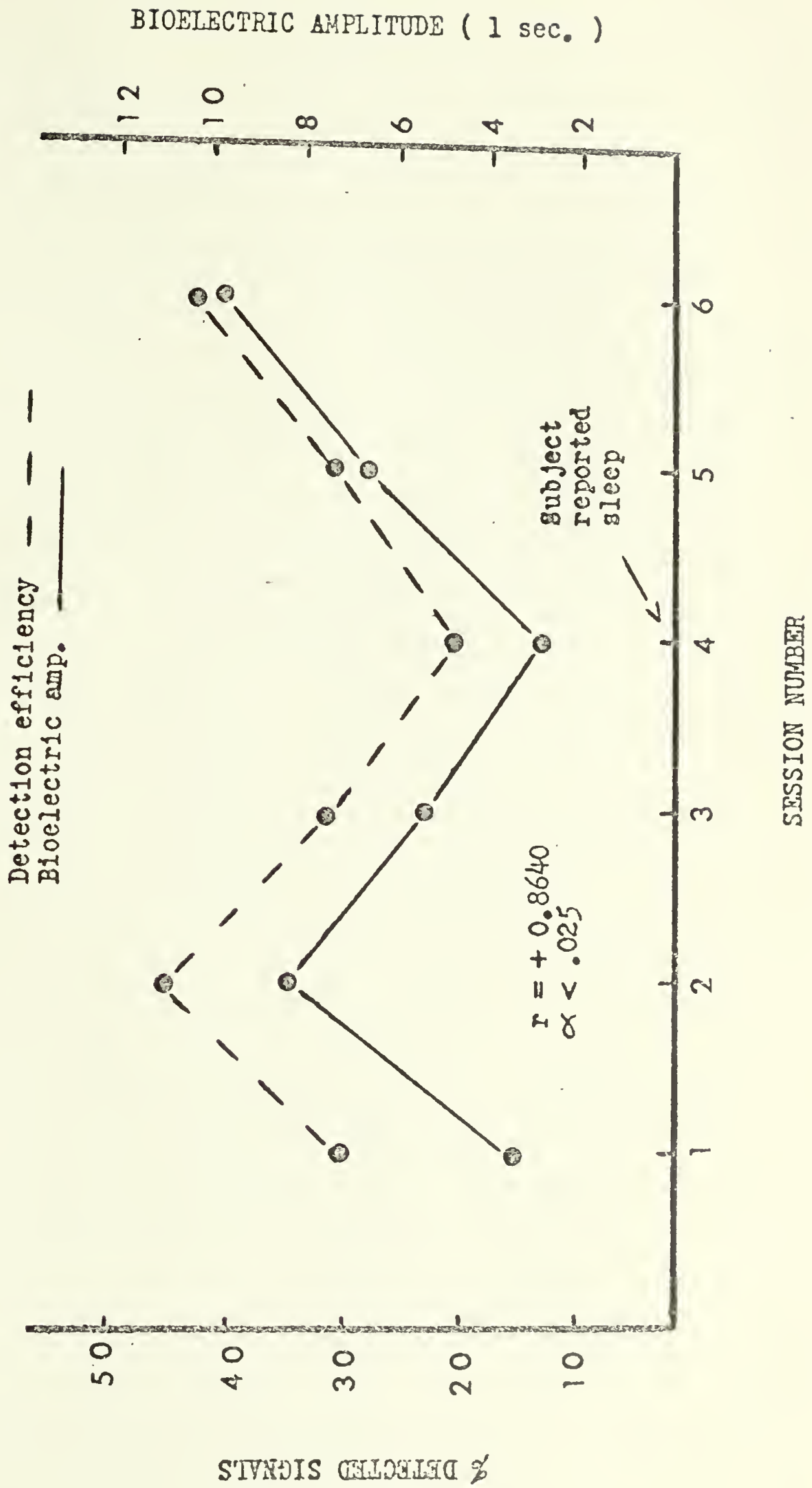


FIGURE 3-A. MEAN DETECTION EFFICIENCY AND MEAN 1 SECOND BIOELECTRIC AMPLITUDE ACROSS SESSIONS FOR SUBJECT S-P



APPENDIX B

TABLE 1-B. PMC BETWEEN BIOELECTRIC AMPLITUDE AND DETECTION EFFICIENCY OVER SUCCESSIVE 5 MINUTE PERIODS

PMC and significance level α for subject S-P when bioelectric amplitude is the:

PMC and significance level α for subject S-I when bioelectric amplitude is the:

| Session no. | Av. amp. at point of signal onset | | Av. 5 sec. integrated amp. | | Av. 1 sec. integrated amp. | | Av. 5 sec. integrated amp. | | Av. 5 min. integrated amp. | | | | | | | |
|-------------|-----------------------------------|-----|----------------------------|-----|----------------------------|-------|----------------------------|-----|----------------------------|------|---------|-----|---------|-----|---------|-------|
| | α | | α | | α | | α | | α | | | | | | | |
| 1 | +0.9028 | .02 | +0.6970 | .10 | +0.4565 | .22 | +0.4789 | .20 | +0.4412 | .23 | -0.3314 | .30 | -0.3595 | .28 | -0.5514 | .16 |
| 2 | +0.6779 | .10 | +0.5426 | .17 | +0.1067 | .44 | +0.1442 | .41 | -0.8839 | .025 | -0.6795 | .10 | -0.6492 | .12 | -0.6345 | .12 |
| 3 | +0.5922 | .14 | +0.4898 | .20 | +0.9140 | .015 | +0.6582 | .12 | +0.3427 | .28 | -0.2691 | .33 | -0.5770 | .16 | -0.6545 | .12 |
| 4 | +0.6965 | .10 | +0.8606 | .03 | +0.7678 | .06 | +0.7296 | .08 | -0.8332 | .08 | -0.7351 | .13 | -0.3327 | .32 | -0.8367 | .08 |
| 5 | +0.6642 | .11 | +0.7634 | .06 | +0.9781 | <.005 | +0.8922 | .02 | +0.3811 | .26 | +0.3157 | .30 | +0.5790 | .15 | +0.1265 | .42 |
| 6 | +0.1046 | .34 | +0.1219 | .31 | +0.2887 | .12 | +0.2541 | .16 | -0.1748 | .24 | -0.3459 | .08 | -0.3670 | .06 | -0.7706 | <.005 |

α for Wilcoxon Matched-Pairs Signed-Ranks Test of Combined Results

| | | | | | | | | |
|------|------|------|------|-----|------|-----|------|-----|
| .025 | .025 | .025 | >.05 | .05 | >.05 | .05 | >.05 | .05 |
|------|------|------|------|-----|------|-----|------|-----|

TABLE 2-B. BINOMIAL TEST OF DETECTION EFFICIENCY--
BIOELECTRIC AMPLITUDE RELATIONSHIP

| Session no. | Subject S-P | | | Subject S-I | | | | | | | | |
|-------------|-------------------------------|------------|------------|-------------------------------|------------|------------|----|-----|----|-----|----|-----|
| | Amp. at point of signal onset | 1 sec amp. | 5 sec amp. | Amp. at point of signal onset | 1 sec amp. | 5 sec amp. | | | | | | |
| | %S* | α | %S | α | %S | α | | | | | | |
| 1 | 57 | .20 | 55 | .28 | 45 | .80 | 53 | .39 | 51 | .50 | | |
| 2 | 59 | .13 | 48 | .61 | 52 | .50 | 52 | .50 | 52 | .50 | | |
| 3 | 62 | .08 | 66 | .02 | 78 | .00007 | 44 | .80 | 48 | .61 | 54 | .39 |
| 4 | 59 | .13 | 63 | .04 | 67 | .01 | 50 | .61 | 52 | .50 | 50 | .61 |
| 5 | 60 | .13 | 63 | .04 | 60 | .13 | 53 | .39 | 50 | .61 | 43 | .87 |
| 6 | 59 | .13 | 57 | .20 | 68 | .01 | 56 | .28 | 54 | .39 | 52 | .39 |

* %S = $\frac{\text{total number of successes in a session}}{\text{total number of signals in a session}}$

X 100%; a success for subject S-P (S-I) = a detected sig-

nal whose preceding amplitude magnitude is greater (less) than the median amplitude magnitude, or an

undetected signal whose preceding amplitude magnitude is less (greater) than the median amplitude.

TABLE 3-B. SHORT TERM FLUCTUATIONS IN DETECTION EFFICIENCY AND BIOELECTRIC AMPLITUDE

| Session no. | Subject S-P | | | | Subject S-I | | | | | | | |
|-------------|-------------------------------|------------|------------|-------------------------------|-------------|------------|-------------------------------|------------|------------|-----|----|-----|
| | Amp. at point of signal onset | 1 sec amp. | 5 sec amp. | Amp. at point of signal onset | 1 sec amp. | 5 sec amp. | Amp. at point of signal onset | 1 sec amp. | 5 sec amp. | | | |
| %S* | α | %S | α | %S | α | %S | α | %S | α | | | |
| 1 | 50 | .58 | 50 | .58 | 75 | .01 | 33 | .96 | 33 | .96 | 38 | .90 |
| 2 | 45 | .73 | 27 | .99 | 41 | .86 | 36 | .96 | 44 | .79 | 64 | .11 |
| 3 | 93 | .0005 | 80 | .02 | 87 | .004 | 43 | .79 | 36 | .91 | 43 | .79 |
| 4 | 50 | .64 | 25 | .96 | 75 | .14 | 58 | .27 | 54 | .42 | 38 | .92 |
| 5 | 52 | .50 | 64 | .11 | 64 | .11 | 36 | .92 | 54 | .42 | 31 | .98 |
| 6 | 55 | .28 | 64 | .04 | 72 | .002 | 50 | .61 | 49 | .61 | 44 | .80 |

% S = $\frac{\text{total number of successes in a session}}{\text{total number of instances where a detected and undetected signal are adjacent}}$ X 100%; a success for subject S-P (S-I) = an instance

in which the amplitude preceding a detected signal is greater (less) than the amplitude preceding an adjacent undetected signal.

