AN ELECTROMYOGRAPHIC STUDY

OF

ATTENTIVE LISTENING

by

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HISTORICAL INTRODUCTION

Concerning Thought

Muscle activity may seem a topic far removed from that of attention. However, the recognition of motor phenomena during thought pervades the history of experimental psychology. In a recent review of this subject, Humphrey describes the recognition given to tensions in the muscles during thought by both the Wurzburg and Cornell group of introspective psychologists. Titchener's group, indeed, interpreted so-called "imageless thought" as kinaesthetic sensations proceeding from vestigial motor responses. Humphrey does not entirely agree with this extreme view, but his emphasis on effector processes during thought is clear: "Phylogenetically and ontogenetically adult human thinking is born in a matrix of action from which it never wholly escapes" (11, p. 188). Similarly, Woodworth has this to say on the introspective studies of attitudes: "Psychologists, so far as they have expressed themselves, are in pretty good agreement on the motor character of the typical conscious attitudes. The discovery of postural and gestural movements in silent thinking may be called one of the main achievements in this whole attempt to study thought introspectively" (32, p. 790).

Silent thinking may be examined in several aspects: persistence, complexity, and content. It is primarily the first two that concern our thesis. The persistive aspect of thought implies attention; complexity implies organization.

As to the understanding of attention, its importance to a systematic psychology was clear to the introspectionists. Titchener, for example, analyzed attention into attributes of degree, range, duration, and accomodation, for purpose of experimental study. Measurement of its degree was regarded as a major challenge: "The measurement of attention is one of the most pressing problems in experimental psychology. If we could measure a man's capacity of attention, and could discover at any moment what proportion of that capacity he was using...then we should have a result of the greatest scientific importance and of the utmost practical value" (28, pp. 293-294). For Titchener, of course, attention was to be measured in degrees of conscious clarity, introspectively determined. The difficulty here, aside from the validity of introspective analysis, is that even trained students of introspection have been unable to distinguish more than several degrees of clarity. More accurate measurement had to await objective methods; behavior analysis and physiological techniques were the answer.

The concept of organization is closely allied to that of meaning. Meaning has been discussed in the framework of learning theory by McGeoch and Irion, who regard meaning as a special case of transfer. Thus: "When one says that Material A is more readily learned than Material B because Material A is the more meaningful, one implies that A receives more advantage from transfer effects" (20, pp. 471-472). Three-letter words, for example, are learned more readily than corresponding nonsense syllables (19). To say that one word, sentence, or article is more meaningful than another, is to say that it arouses a greater number of previously learned associations. The greater the associative value of a stimulus situation, the more fully organized may be the consequent thought process.

In experiments on recall of completed and incompleted tasks (such as doing a jigsaw puzzle or drawing a vase), Zeigarnik found that her subjects recalled more interrupted than conpleted tasks (34). Assuming the completed task to have been more fully integrated by the performer, we might say that, for simple tasks at least, incomplete organization has a positive effect on memory. That organization, however, acts positively to a certain point was indicated by interrupted tasks being recalled more readily when the interruption occurred near the end of the task. This fits the general finding of a positive effect of meaningfulness on learning (20). But past a certain stage, memory may be negatively affected; tasks too familiar, like brushing one's teeth, are easily forgotten.

Miller and Selfridge (25) have studied the effect of meaning on recall, defining meaning in terms of verbal context. Subjects were presented verbal passages varying in degree of approximation to English. Higher-order approximations led to recall of a larger number of words. Words more fully integrated into a familiar language structure are more interdependent, selectively leading one into another. Thus, if a sentence is broken up, and the words presented in random order, the sentence will be better remembered; since in conformity with the language pattern, each word cuts down the number of possible words that will follow it.

Experiments dealing with effects of organization on learning and memory have been discussed; we shall later have occasion to describe work on the relation of muscle tension to integrative processes.

First, it may be instructive to digress and consider--though in rather limited extent--some views on thought in literature dealing with this concept from a psychological standpoint. Such consideration may help us to understand both the directive and integrative attributes of thought.

One definitive feature of thinking is its relative autonomy; thought cannot be entirely described in terms of sensory stimuli and motor responses. Humphrey's review (11) mentions this finding as a chief contribution of the Wurzburg introspectionists. Parts of thinking could not be reduced to images derived from external or kinaesthetic sensations. On the negative side, the discovery of "imageless thought" hastened the downfall of classical introspective methods, which were based on analysis of sensations and images. From a positive standpoint, it furthered new lines of research on the nature of thinking; these lines led away from analysis of thought elements, and towards investigation of the forces conditioning thought.

Introspective study of the conditions of thought was undertaken by Watt (cited by Humphrey, 11, pp. 66-72) by means of a partially constrained association technique. Thought was found to be directed. The directive influences were of two kinds: the task, Aufgabe, initiated by the experimenter's instructions; and the previously acquired associations initiated by the stimulus word. Recently, task-sets themselves were shown to result from prior learning. Harlow (9) found that rate of learning (in both monkeys and children) continuously increased with succeeding sets of problems; that is, already learned approaches (sets) to previous problems were more readily available for handling new problems.

An associated response to a stimulus word is usually elicited in a few seconds. Duncker (5) made a study of thinking during the course of problem-solving, where solution generally required several minutes. Subjects were presented with problems, and instructed to speak out all that came into their mind while they were solving these problems. By thus having his subjects "think out loud," and giving problems which took at least several minutes for the solution to be realized, Duncker was able to obtain much protocol material related to the course of human thinking--more specifically, human problem-solving. His experiments might be criticized for lack of statistical analysis and stringent controls; the poverty of experimentation directly bearing upon this topic, however, warrants consideration of Duncker's results. From analysis of the protocols, Duncker concludes that problem-solving consists of continuous reformulation of the problem--these restructurations being guided by the "essential" properties of the problem itself. As with reversible figures in the field of perception, new problem configurations may result from satiation of old patterns; thinking exhibits both anticipation and backtracking in constant flux. Although Duncker's monograph does not stress the point, the selective facilitation resulting from previous thinking as well as from the problem structure seems clear from the author's data.

So far we have discussed what psychology may have to say about thought; we may now inquire briefly what our understanding of thought processes has contributed to various fields of psychology. This brings us to examine the role of set in experimental psychology.

Gibson (7, 1941) undertook such an examination. The concept was found to play an extensive role in such diverse areas as classical conditioning, learning, and perception. In spite of ubiquitous use of the term set, the author could not discover a meaning for it common across a number of experimental areas. To illustrate, set in perception experiments may mean "expectation of the stimulus"; while in conditioning studies the concept may refer to "intention to react." However, on reading Gibson's review, one is impressed with the widespread use of terms like "expectancy," "conceptual schema," "intention," "tendency"--i.e., words denoting some central process. Gibson's inability to present a unified account of the role of set in psychology represents the failure of systematic theories to come to grips with central processes that selectively influence sensory stimuli and motor responses. Theoretical emphasis was on sensory-perceptual or conditioning-motor phenomena with set as an intervening variable. A systematic account bearing more directly on thought processes *per se* was yet to be undertaken.

Such an attempt has recently been made by Hebb (10), within the framework of neuropsychological theory. Through learning, certain brain cells set into operation by a specific stimulus (e.g., a corner of a triangle), interact to form a higher unit, called an assembly. Whole assemblies may also interact with one another, forming higher-order units (phase sequences). These assemblies and phase sequences, once established, may be set in motion by sensory stimulation or by preceding central neural activity (or both). Once activated, these units may persist independently for some time through self-stimulation (reverberating circuits). A single reverberatory assembly may lose strength quite rapidly (running itself out in a matter of seconds). But phase sequences can maintain themselves for longer intervals by virtue of more neural elements in reverberatory action. Systems of phase sequences are influenced by and modify incoming impulses, facilitating some impulses, inhibiting others; likewise, phase sequences activate specific motor responses. We thus have a postulated central neural schema--to some extent supported by contemporary neurohistology and neurophysiology--which may underlie a stream of thought. This schema is of particular interest to the present thesis, since muscle tension patterns may be recognized as part of the selective motor facilitation of central activity. Muscle activity, under appropriate conditions, may thus constitute an index (though certainly not a complete measure) of the thought process. It is time now to review some experiments on muscle tension, with a view towards gaining insight into the precise psychological conditions wherein muscle activity may reflect directed and organized thinking.

On Muscle Tension

Thus far, our thesis has implied that organized thought modifies muscle tension. But we are in fact handling a two-edged sword. For everyday experience and the psychological literature indicate that conflict and disturbance modify muscle tension. Further, both integrative and disturbing factors may result in changes in the same direction; namely, in increased muscle activity. The following sections describe representative experiments on stress, on mental work compared with periods of rest, and on muscle tension changes during mental work.

Stress

Luria (18), investigated irregularities of simple voluntary movements during experimentally elicited conflicts. His technique involved word-association combined with a simple motor reaction. Specifically, the subject sat comfortably, with each hand over a pneumatic bulb. Pressures on the bulbs were recorded on a kymograph. When the experimenter spoke a word, the subject was to respond with the first word that came to mind, and as he did so, to press the bulb under his right hand. Results typical under normal, non-disturbing conditions, showed minimal activity of both hands in the latent period following the stimulus word, ending in a specific pressure reaction of the right hand coincident with the response word. However, if the subject had committed (though not confessed) a criminal offense, then presenting key words related to the crime yielded distinct reactions and tremors from both arms during the latent period. Neutral words not related to the offence gave a normal response. Latency pressure responses to key words may be seen even when the subject shows no other sign of emotional disturbance (in facial expression, for example), and when the time taken for verbal response is normal. Luria believed that "motor tension" here constitutes an index of conflict. Low correlation between finger movement score and muscle potentials have been reported (22); which indicates caution in generalizing Luria's results to muscle activity. On the other hand, more recent investigations of muscle potentials have strongly suggested their direct participation during experimentally induced conflict (21, 23).

Malmo, Shagass, and Davis (22) studied muscle potentials (muscle tension, electrically recorded), in psychiatric patients and normals. The forehead of each person was subjected to thermal stimuli of sufficient intensity to feel somewhat painful. Increased muscle potentials during stimulation were obtained from right forearm and neck muscles. Further, psychiatric patients showed higher level of arm tension during pain stimulation, and greater change in neck tension from rest to stimulation than did the controls; though the resting level of tension before stimulation was similar for both groups. Perceptual tests requiring rapid and difficult size discriminations for circles flashed on a screen gave like results. It appears that the muscle potentials increase as part of a disturbance resulting from pain stimuli or undue psychological pressure; and that this disturbance is more pronounced in subjects less well organized and more unstable; namely, in psychiatric patients.

Changes from rest to mental work

Freeman (6) recorded muscle volume (tension) changes of the forearm flexors and leg quadriceps, by photographing the movements of a system of levers resting on the belly of each muscle. On instructing his subject to do mental arithmetic, volume increases were seen in all muscles recorded. The pattern of activity was, however, quite unstable; for example, at one moment right flexors, at the next moment, left quadriceps might show maximum tension change. This constant flux was quite distinct from the specific and consistent tension increase obtained from the right flexors, on instructing the subject to respond with his right hand at a given auditory signal. Anticipation of movement thus involves greater muscle pattern specificity than does a task not related to particular overt movements. Also of interest here, is the finding that tension during anticipation of the same overt response spread over more muscles when the task difficulty was increased by making the auditory signal to react too weak to be easily perceived.

It should be noted, that the complicated system of mechanical recording that Freeman used required the subject to sit in a device "....resembling an ancient pillory or stock" (6, p. 480). It is possible that the distracting effect of the apparatus was a positive factor in the rise of muscle tension during mental arithmetic.

Davis (3) recorded muscle potentials from the extensor surface of the right forearm, in subjects doing several minutes of mental arithmetic, memorization of a difficult poetic passage, and multiplication. For mental arithmetic, a reliable increase from rest to work failed to obtain. Potentials during memorization and multiplication, however, rose significantly over their preceding rest periods. The author suggested that mental arithmetic may have been performed more easily and automatically than the two other tasks. Davis also correlated rest to work increases with performance scores. For all three tasks the correlations were negative. This finding was explained in terms of distraction and practice factors. The more distracted subject may become more tense and fails to perform as well. Indeed, when Davis distracted a working subject by playing a phonograph record of a "rhetorical exhortation," tension clearly rose in the distraction period. Davis also showed that with practice, both smaller increases from rest to work and better performance scores were obtained. However, he found that pretask potentials, correlated positively with performance scores, suggesting that higher readiness led to better performance. It therefore seems likely that factors other than distraction and practice enter the picture; like a stronger set to meet the task, for example.

Two experiments have been designed to study the relation between muscle potentials and degree of task difficulty. Davis (4) used five sets of number series problems, varying in difficulty. Amplitude of muscle potentials from right forearm and neck varied directly and regularly with order of task difficulty. Likewise, Hadley (8), using mental multiplication tasks and recording from left forearm, found higher potentials during more difficult problems. Of passing interest is Hadley's failure to note any changes with difficulty from simultaneous records of the left-occipital and right-precentral electroencephalograph (EEG). This suggests that muscle potentials and brain waves may to some extent reflect different aspects of the mental work process.

Changes during task activity

Recent studies of muscle activity have yielded results bearing more directly on the concept of integration. These investigations cover different tasks, but have one thing in common; analysis of what occurs within the course of task activity. We shall discuss them presently.

Smith (26) investigated the course of muscle activity in the active arm during mirror-drawing performance. From beginning to end of the task, a smooth, negatively accelerated rise of muscle tension was obtained. Since all subjects drew half the figures (circles and triangles) clockwise and reversed direction for the other figures, the intratask tension rise cannot be accounted for solely in terms of overt movements. These results were confirmed in a similar experiment by Bartoshuk (1), who in addition, found very regular increases in the passive arm, as well as rising (though less regular) gradients in the chin. These findings led to the hypothesis that muscle potential gradients represented the motor aspect of central neural events associated with progress in the task. This recalls Zeigarnik's finding of better recall with tasks closer to completion (34).

The question as to whether these rising gradients of muscle tension would occur during thought involving no overt movements, e.g., listening activity, has not been fully answered. So far, there has been one such study which has proved both equivocal and provocative. Smith, Malmo, and Shagass (27) had subjects listen to a six-minute recorded article with instructions to remember. Since the purpose was to induce stress, the playback was made difficult to hear in spots, by lowering the volume over a number of short, random intervals. Recordings from the chin and forehead muscles reached peak amplitude at the fourth minute and then declined. Left and right forearm muscles rose and declined more quickly and sharply. Comments of the subjects suggested a lack of interest in the presentation, rather than distress with its poor quality. The authors suggested that the rise and fall of the curves for the facial muscles may have been associated with the presence and decline of attentive listening. Although this interpretation may prove to be correct, factors of disturbance and difficulty cannot be ruled out entirely. A discussion of these variables in relation to attention may be instructive at this point.

Many of the experiments thus far reviewed have been concerned with or contaminated by factors of disturbance and difficulty. Few studies dealing explicitly with attention and integration have been examined. This is due in some part to the neglect of these problems in the experimental literature. On the positive side, however, the studies of distraction and difficulty may help clarify our understanding of attention and integration. Let us pursue this line of reasoning a little further.

If we observe a man in his home, comfortably reclining in an armchair beside a glowing fireplace, and reading a favorite novel--on seeing him thus absorbed for several minutes, we would say he is attending to his story. Suppose we observe the same man next morning. He may be seated at his desk, poring over a not too fascinating thesis upon which he is to pass judgment. Phone calls have been coming in with all too irritating frequency--yet he feels obliged to read this thing through. Again we would say this man is attending. But there is little sign of pleasant engrossment; instead there appears to be willful application to a task.

It is important to distinguish these two forms of attention in scientific as well as popular terms. One form suggests a natural absorption of a person into the characteristics of his environmental setting. The other points to attention by force of obligation; attention under difficulty; attention despite distraction.

Review of the recent psychological literature bearing on this distinction shows little explicit appreciation of this problem. Titchener, however, gives a lucid introspective analysis in his distinction between "primary" and "secondary" attention (28, pp. 265-276). He also extends our argument regarding continuous attention to include intense or novel events which attract us only momentarily. Closer examination of his analysis may prove enlightening at this point. An excerpt on primary attention follows. The author first describes the powerful effects of intense, sudden, and moving stimuli. He continues:

> Novelty, too, arrests the attention. The novel impression is, in psychological terms, the impression that finds no associates when it enters consciousness; that stands alone, in isolation. Such an impression, if it is at all intensive becomes clear in its own right; it is startling, just as the sudden stimulus is surprising and the moving stimulus is disturbing. And lastly, paradoxical as it sounds, impressions that are in a sense the reverse of novel claim the attention,--impressions that fit in with, are associated to, the present trend of consciousness (28, p. 269).

Again, on secondary attention:

> There are however many occasions when, so far from the impressions drawing and rivetting our attention, it seems that we are holding our attention by main force upon the impression. A problem in geometry does not appeal to us as a thunder-clap does. The thunder-clap takes unquestioned possession of consciousness. The problem has only a divided claim upon us: there is constant temptation to wander away from it and to attend to something else. We continue attending; but we have to make ourselves attend. In many of the psychological experiments that we have described, the object of attention--an obscure organic sensation, a minute qualitative difference--is something which of itself, so far from attracting notice, would seem to be eminently fitted to escape it. Attention to such an object is usually termed active or voluntary attention; we shall call it secondary attention (28, pp. 271-272).

The matter of the above described experiments on mental work and muscle tension is more pertinent to secondary attention. Many studies on momentary effects of primary attention--startle reactions to loud sounds, for instance--are to be found in the literature. But experimental psychology has yet to examine the continuous attention of the man comfortably reading beside his fireplace.

To anticipate somewhat, the present experiment seeks to determine (by means of muscle tension analysis under appropriate conditions) some changes which may occur during primary attention. Before doing so, a brief summary of some work on muscle tension as related to thought content is in order.

Though mainly concerned with persistence and complexity of the thought process, some effects of thought content will be discussed. The former operate on content, and are influenced by content. Also content _per se_ may affect muscle activity.

Jacobson has published a series of papers on the immediate influence of specific thoughts on muscle activity, electrically measured (13, 14, 15). Subjects were trained to relax their muscles to a point where electrical activity was reduced to zero, or very close to zero. His subjects were thus more relaxed, than those relaxed in the popular sense (who still show signs of muscle tension). The purpose of reducing the base line of muscle tension was to prevent masking of specific effects of thinking, however slight and fleeting these effects on muscle potentials might be.

After relaxation had been induced, the subject was instructed to image or recall, at a given signal, some specified event.

Some examples are: "Imagene lifting a ten-pound weight with your right arm"; "imagene the Eiffel Tower"; "think of infinity." As the subject carried out these instructions, small but distinct potentials were recorded by deflections of a sensitive string galvanometer. Furthermore, the increase of muscle activity was specific to the muscle functionally related to the overt counterpart of the imagined event: imagining weight-lifting yielded activity in the right biceps; imagining the Eiffel Tower, resulted in ocular muscle activity; thinking of infinity (abstract concept) involved potentials from the tongue (speech) musculature. Again, the pattern of muscle activity observed, corresponded, though not identically, to the relevant overt movement: instruction to "imagine reading this morning's newspaper" gave an ocular muscle pattern similar to that effected by actually moving the eyes to the right (though the overt response was of shorter latency and higher magnitude). In reviewing Jacobson's work, Humphrey (11) feels that these results may be an artifact of Jacobson's relaxation technique, which requires intensive concentration on particular muscles (16). Jacobson, however, reports similar results (though not as clear cut) from a few untrained subjects. Also, Max (24) obtained like findings with untrained subjects (deaf-mutes and normals, selected for ability to relax naturally); imagined "typewriting" brought activity to the flexors of right and left arms. Though such activity failed to be seen in every case, kinaesthetic imagery clearly involved the appropriate musculature in a majority of instances. Of special significance is the finding that abstract thinking, e.g., working out syllogisms or mental multiplication, produced action potentials in the arms of deaf-mutes more frequently than in the arms of hearing subjects. Since the former had learned to speak with their hands, it again appears that abstract thinking particularly activates the muscles of speech. Evidence further showed fewer responses from legs (gastrocnemius) as compared with arms of deaf-mutes. To establish a high degree of speech muscle specificity would, of course, require simultaneous muscle recordings from many widely distributed bodily areas.

The findings of Jacobson and Max strongly suggest that diverse thought contents specifically activate diverse muscle patterns. Though of some concern to an investigation of sustained attention, it is worth noting that the tension changes generally last a few seconds only; no longer than the given thought. During activity lasting for several minutes or longer, attentive and integrative aspects may play a dominant role.

Continuous thought may be regarded as a broad stream of activity, shifting fleetingly from object to object, yet on the whole maintaining a steady course. Take the example of a spectator watching an exciting game:

> Not for an instant does his mind wander from the game. For all that, his attention is as nimble as ever. His eyes follow the movements of the players. He keeps pace with the

game which is certainly mobile and changing. Sustained attention, then, is not rigid and motionless but consists rather in movement within a certain field of interest. It does not wander outside that field nor yield to distractions. The livelier it is within its proper field, the more surely it resists allurements to wander outside (33, p. 407).

EXPERIMENTAL

Purpose

The present experiment was designed, broadly, to demonstrate the application of electromyographic technique to the study of thought. More specifically, it was hoped that muscle potential analysis would throw light on central neural events during sustained attention.

The problem

In view of the data on muscle potential changes during task activity, a working hypothesis was put forward. It may be stated in this way. Continued attentive listening will be reflected in regularly rising gradients of muscle tension.

In addition, a study was made of: 1) materials differing in ease of comprehension; 2) repetition of the materials--with particular reference to their influence on muscle tension.

Method

Materials.--A situation was arranged in which a subject was to listen to some recorded material. A hospital bed with foam-rubber mattress was provided. This bed was adjusted for each subject. Two selections were used: a detective story and a philosophical essay. The story--"Coroner's Inquest"--was written in dialogue form, and was therefore recorded by two voices.[1] An excerpt from Emmanuel Kant's Critique of Pure Reason was recorded by the person who played the major part in the story.[2] Both selections were 10 minutes long. Each was presented three times.

A questionnaire concerning the subject's attention and feelings was devised, to be filled out when the session ended. A sheet was also prepared for noting movements during testing, and their time of occurrence.

A Magictape recorder (Utah Electronics) was used both for original recording and playback. Paper-backed "Scotch" magnetic tape was the recording medium.

Subjects.--Nineteen male subjects heard the detective story. Of these, 15 were university students, three were RCAF personnel, and one was a university graduate. Sixteen male individuals listened to the essay; this group consisted

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[1]Marc Connelly, "Coroner's Inquest." In the Ellery Queen edition To the Queen's Taste. Boston: Little, Brown, 1946. Pp. 472-477.

[2]Emmanuel Kant. Critique of Pure Reason. In C.J.Friederich (Ed.), The Philosophy of Kant. New York: Modern Library, 1949. Sections I and II. Pp. 24-27.

of 15 university students and one RCAF man. All the RCAF recruits had some secondary school training. The group who heard the story ranged in age from 18 to 31 years, with a mean age of 21.6 years. Ages of the "essay" group ranged from 18 to 25, with a mean of 20.9 years.

Recording apparatus.--Muscular tension was measured in terms of electromyographic potentials between bi-polar electrodes, continuously amplified and recorded on an Edin ink-writing electromyograph. An ink-writing integrator, designed by J.F. Davis (2), continuously averaged these potentials over half-second intervals. Both devices were equipped with appropriate time and signal markers.

Surface leads were placed over muscles of the forehead (frontalis), chin, and over both forearm extensors. The electrodes were 1.5 cm cubes of cellulose sponge, soaked in thin electrode jelly with the end of the lead wire passed through once and doubled back. All lead placements were secured with lastonet bands. The precise locations of the placements were as follows:

Frontalis--one electrode was placed 1.5 inches to the right of a line drawn through the center of the forehead from nasion to hairline. This electrode was approximately one inch above the eyebrow. The other electrode was placed in the same position, but to the left of the dividing line. Hence, both leads were in the horizontal plane of the forehead, three inches apart. Placement in the horizontal axis of the muscle cuts down artifacts from the vertically directed eyeblink potentials.

Chin--the first electrode was placed 3/4" above, the second electrode 3/4" below the point of the chin, on the midline. This placement records from a complex of muscles--mainly from depressor-labii inferioris, genio-glossus, digastric, and platysma--which function in such diverse activities as speech, facial expression, and swallowing.

Right and left forearm extensors--the forearm was placed on a table, palm down. The first electrode was on a point one-third of the distance from the lateral humeral epicondyle to the styloid process of the ulna. A point two inches distal to the first, marked the placement of the second electrode. Maximum palpation of the muscle with extension of the middle finger was obtained at this point.

An electromyographic and integrator record was taken from all four muscle leads. In addition, throat movements were electrically transmitted to a separate channel of the electromyograph by means of a double-carbon throat microphone, (secured by a loose-fitting cloth band). Muscle potential artifacts (particularly from chin) produced by swallowing, or coughing, could thus be accounted for.

The subject was connected to ground through a 10 cm square German silver plate strapped to the right wrist; this helped to reduce electrical interference.

<u>Procedure</u>.--The subject was prepared for recording and tested in one part of a double-room suite, the other room being reserved for recording purposes. Information as to what would follow was informally given by the experimenter. (In all cases, the present writer placed the leads and served as experimenter.) The subject was told that the purpose of the experiment was to investigate the electrical activity of his muscles while he listened to some recorded material to be presented him. Assurance that there would be no shock from the equipment was also given. The leads were then placed, their resistance checked; and the subject made comfortable on an adjustable bed[3] and connected to the amplifiers. Before starting the test proper, a sample of the subject's muscle potentials and throat movements were taken on the EMG to insure against loose leads and other defects making for poor recording.

The experimenter now told the subject about what kind of material he was soon to hear, (a detective story or philosophical essay), its approximate length, and that a rest period would precede and follow its presentation. This was not a test of intelligence, memory, or the like. The subject was merely to lie quietly, relax and listen, as he would to a radio program. He would be asked to close his eyes when the test commenced--in order to reduce dis-

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[3]Five subjects rèclined in a leather-cushioned arm-chair.

traction, as well as eyeblink and eye-movement artifact. The experimenter was to stay in the same room to run the playback machine; and also to keep a record of the subject's movements, which should be minimal. Formal instructions to this effect would be announced when the test proper began. It should be noted that the experimenter tried to present these instructions in a cheerful (though not too casual) manner.

Having indicated his understanding of what was expected, the subject was asked to close his eyes. Recording of muscle potentials (EMG) commenced and formal instructions played on the tape: "You are about to hear a story, told by two voices. An interval of silence will precede this recording, so we may get a record of your resting condition. The story will be followed by a rest period. Please do not talk, move, smile, or swallow. Remember to keep your eyes closed. Just relax, and listen carefully."

If the essay was to be played, the first sentence of the instructions read: "You are about to hear a selection from an essay on philosophy." The remaining instructions were identical with those above, except that "essay" was substituted for "story."

These instructions were followed by a one-minute rest interval; the story or essay then presented (10 minutes);

and the presentation ended with a two-minute rest period. For convenience, these periods will sometimes be designated as Pre, Listening, and Post. During the listening period, the playback machine was operated by the experimenter, who also watched the subject to note if and when any movement occurred. Facial expressions and postural tone, e.g., whether the subject appeared "serene," "stiff," "peaceful," and so on, were recorded; but this impression of the subject might well have been colored by the experimenter's own feelings at the time. Lastly, the experimenter activated signal markers at start and end of instructions, beginning of article, end of article, and end of test. The signals appeared on both the EMG and integrator records, which were handled by another operator. Since this equipment was in a separate adjoining room, running noise was minimal.

At the end of the presentation, informal questions were put, concerning the subject's comfort and attention to the material. Minor adjustments, e.g., of bed incline or pressure of electrode attachments, were made if required. This intermission took approximately five minutes.

The procedure was repeated. Before running through a third time, the subject was informed that this would be the final presentation.

After the third repetition, the leads were removed and the subject was seated at a table. He then formally rated his own attention and feelings during the three presentations on a given questionnaire. Finally, he was asked to write a brief summary of what he had heard. As the subject was previously told that no test of memory was involved, the experimenter did not press the subject to recall as much as possible; he was just to put down what easily came to mind.

Treatment of data.--The primary (EMG) record was used only to gain general impressions and to determine artifacts. All quantitative measurements were made on the integrator records.

Since an integration occurred every half-second, there were 120 pen deflections per minute. For the instructions, and for each consecutive minute thereafter, the average height (in mm) of the middle 20 seconds (i.e., 40 spikes) was marked off and calculated. All four integrated muscle channels were treated this way. Thus, the 20-second sample from the 20th to 40th second represented the one-minute Pre period. Likewise, 10 successive 20-second samples represented the 10 continuous minutes of presentation; and similarly for the two-minute Post period.

The calculations were made in the following way: determination of the area of each sample by means of a compensating polar planimeter; then division by the base line, giving an estimate of the average sample height in millimeters. This height was converted to its correct microvolt value by reference to standard calibration curves. (These curves were obtained by feeding into the integrator a 45-cycle sinusoidal wave at different voltage levels, generated by a Hewlett-Packard audio-oscillator, and controlled by a microvolter.) So that from each subject, one microvolt value for the Pre, 10 values for the presentation, two values for the Post period--for each of the three presentations and for every channel, was obtained.

Results

Events on each of the four muscle channels will be discussed in turn. Any event with a probability of a chance occurrance less than five times in one hundred is regarded as statistically significant. Also, the terms muscle potentials and muscle tension are used interchangeably.[4]

Frontalis (Table 1, Figs. 1 and 2).--For both materials heard and for all hearings, there obtained a significant rise from first to last minute of listening. The increases were consistent and regular from minute to minute.

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[4]Under isometric conditions, the electrical activity as measured by electromyography parallels the muscle tension as measured by pull on a strain gauge (12).

Comparing the last minute of listening with first minute of postrest, a significant fall occurred after every hearing of the story; whereas no significant fall obtained for any hearing after the essay was presented. Indeed, for the second and third presentations of the essay, there was practically no change of potential level with termination of listening.

A small but significant rise from prerest to initial minute of listening occurred for each curve.

The essay and the story groups showed a consistent fall in prerest tension from first to second to third hearings. The drop from first to third hearings was statistically significant for both groups. It is pertinent to note here that the rising gradients during listening failed to decrease from first to third hearings; and that the gradients during the essay in fact showed an orderly (though not significant) increase with repeated listening.

If corresponding hearings of the story and essay were directly compared for size of increase from first to last minute of listening, larger gradients appeared during the story. Though none of these comparisons are significant, that for the second hearing may be regarded as suggestive ($P<.10$).

Two subjects fell asleep during the third presentation of the story. Their tension changes are illustrated in Fig. 3.

Note the fairly regular fall of tension beginning some time before the approximate onset of sleep. No other subjects tested ever showed a fall of such magnitude.

Chin (Table 2, Figs. 4 and 5).--A rise from first to last minute of listening to the story occurred during each presentation. This rise was close to significance for the first hearing ($P<.10$), and reached significance during the second and third hearings. Listening to the essay, on the other hand, yielded only slight and insignificant changes from beginning to end; except for the third presentation, where a substantial and significant increase was obtained. When corresponding hearings of essay and story were directly compared, a significant difference was found for the second presentation: chin tension rose more when listening to the story ($P<.05$).

In general, the gradients given by chin were not as consistent and regular from one minute to the next as were those shown by frontalis. As was previously mentioned in the section on lead placement, the chin records exhibit activity from a complex of muscles, some of which partake in swallowing. Although records of hearings containing gross swallow-related tension changes were omitted from group analysis, finer instabilities of this sort may conceivably have made for more irregularity in the group curves. Data from the subjects whose prerest chin tension was lower than average lends support to this conception: for both materials and all presentations, a significant increase appeared from first to last minute of listening.

Coming back to the group as a whole, no significant chin tension differences were observed from last minute of listening to first minute of postrest. But a tendency to drop occurred after all three presentations of the story, whereas the essay showed a slight rise after both first and second hearings.

There was only one significant change from prerest to initial minute of presentation: a rise with the first minute of the story.

A fall in prerest tension of the chin from first to third hearings was found for story and essay, reaching statistical significance for the latter group. Again, as with frontalis, the rising gradients during listening failed to decrease. There took place instead an orderly increase from first to third presentations of the story; and as already indicated, the essay group rose significantly within the last hearing only.

One of the subjects failing to keep awake showed a continuous decline of chin tension, starting before the onset of sleep and continuing to the end of the record. The curve for the other subject was more irregular--due, perchance, to rather vigorous snoring.

Right and left extensors.--Inspection of the electromyographic records gave the following overall impressions:

(1) Low tension (under three microvolts) present at the start and persisting through to the end of the record.

(2) Sharp increases of muscle tension lasting anywhere from one second to a minute or more, then falling just as abruptly back to a low background.

(3) Appreciable individual differences in the number, magnitude, and duration of these tension bursts.

Considering that these bursts might have resulted from slight arm movements, as in small shifts of position on the bed, the decision was made to analyse a hearing of any subject, only if the hearing showed minimal burst activity.

Results for right arm are given in Table 3. Skewed distributions indicated the use of medians rather than means, as estimates of central tendency. For the same reason, significance of differences was tested by a non-parametric technique for paired replicates (31). Almost no significant differences of any kind appeared. (An exception was the rise from prerest to initial minute of the first essay presentation.) These negative results were further attested by the flat, low, and somewhat irregular curves of Fig. 6.

Left extensor showed essentially negative results, similar to those from right extensor (Table 4, Fig. 7).

In summary, the muscles recorded from yield the following picture. Rising gradients from beginning to end of listening occur in frontalis and chin. The magnitude of the gradients is larger when listening to the story, especially for the first two hearings. Such gradients do not appear in right and left extensors.

Retrospective data from the questionnaire.--Twenty-four subjects reported being most sleepy on the third playing of the material, whereas only five were most sleepy during the second, and three during the first presentation. The probability of such an answer pattern occurring by chance is less than one in a 1000 (χ =25.1, with two degrees of freedom). Also, the decrease in alertness (or increase in sleepiness) is orderly; a majority of subjects estimating themselves less alert during the second hearing, and still less during the third hearing. Both story and essay groups follow this pattern.

The material listened to does, however, affect other aspects of thought: such as interest, attention, anticipation. Table 5 indicates that when story and essay are compared, these aspects occur to a stronger extent at later hearings for the essay. In other words, it requires more hearings to produce maximum interest, etc., for the essay, than it does for the story.

Memory.--From the experimenter's crude impression of the written summaries, the detective story was judged to have been better comprehended than the philosophical essay; a fact not surprising to any lover of Sherlock Holmes.

The materials were compared more objectively by counting the number of words and sentences written. Average number of words written in recall was 150 for the story and only 65 for the essay ($P<.001$). Recall of the story also yielded more sentences--8.3, as compared with a mean of 5.7 for the essay ($P<.10$). Again, the average sentence length for the story (18.1 words) was significantly higher than the mean of 10.5 words for the essay ($P<.001$).

Thus, the retrospective and recall evidence indicate: 1) More intense listening to the story during earlier, and to the essay during later presentations. 2) Better memory for the story. 3) For the group as a whole, decreasing alertness with repetition.

One final note. The subjects were asked to rate the first presentation of story or essay for degree of interest. Seven subjects rated themselves as uninterested, 28 as interested. Now, from the retrospective evidence obtained in the listening experiment of Smith et. al., previously described, seven subjects were classed as uninterested and only four as interested (27, and personal communication).

DISCUSSION

The occurrence of regularly rising gradients in frontalis and similar, though less regular, increases in chin, would appear to confirm our hypothesis--namely, that continuously rising muscular tension, occurring under nonstressful hearing of organized verbal material, indicates a state of continued attention. This rather hasty statment must be clarified, which returns us to the consideration of certain historical questions: to the distinction between primary and secondary attention, and to the problem of organization.

Let us regard the findings of the present experiment in the light of results obtained by Smith and his co-workers (27). On presentation of poorly recorded and rather dull material, which the subjects were instructed to remember, significant changes occurred in the muscles of right and left arms. Both extensors rose abruptly, reached their peak in two or three minutes, and then declined. Our investigation, on the other hand, failed almost entirely to show such changes when the story or essay came through. It seems, therefore, that in a comfortably positioned subject, increased arm tension with onset of verbal material reflects application to a dull and difficult task, i.e., secondary attention. Such a conclusion is further supported by the single arm change from prerest to listening that does obtain in our study: a significant increase of right extensor potentials with first presentation of the essay. No increase occurs for the second and third presentations, where the essay is presumably easier to take and where most subjects report greater interest.

From both chin and frontalis, Smith and his co-workers obtained a rising gradient to the fourth minute of listening, then a fall to the end of their six-minute article. Interpretation presented, was that the subjects attended for a few minutes; this attention being reflected by continuously rising muscle potentials. After the fourth minute, the individuals became bored and tension fell. This view was supported by some retrospective reports of boredom and sleepiness setting in before the article finished. Frontalis and chin curves in the present study showed a rise throughout listening; and our subjects failed to report a loss of interest during the record. Again one might say that continuous attention was reflected by rising gradients in particular muscles. But why should this be so?

It may be that sustained thought per se, i.e., attention by itself, would lead to increasing muscular activity. Such an occurrence might conceivably take place if a person were deliberately persisting along certain lines of thought, despite increasing difficulty, distraction, or fatigue. The gradients would thus represent compensatory effort for decreasing efficiency in carrying through a task. Though such a possibility cannot be entirely ruled out, its likelihood is questionable. Distraction was minimal, and the subject was not forced to listen; witness two subjects who fell asleep. As for difficulty, one might expect listening to the story to yield gradients of smaller magnitude; in fact, these were larger. Further, the size of the gradient showed an orderly (albeit small) increase from first to last hearing of the essay. Finally, only the last presentation yielded a significant gradient on the chin when the essay was listened to. It would appear that ease rather than difficulty is a positive factor here. Greater familiarity with and comprehension of the material seems to make for larger increases of tension during the course of listening. (All this, admittedly, within the narrow range of our experiment; only three successive hearings may not have allowed for extreme familiarity to take place.) Now terms like comprehension bring us to grips with the organizing functions of the thought process. But to face this aspect more fully, a slight digression is in order.

So far, we have considered the persistive aspect of thought; keeping one's mind on a problem, or one's ear tuned to a recorded program. We have seen, when tuning in is difficult because of poor recording, a relatively abrupt increase of muscular activity in the arms. The more gradually rising slopes of frontalis and chin, on the other hand, do not appear to reflect difficulty--rather, they show greater prominence when subject and material are more compatible or synchronized.

This puts forward the question of what happens when an adult human being is tuned to a recording. An observer, preferably one who has known this person for some time and has a thorough knowledge of his likes and dislikes, might say either of two things: the program is heard by the subject; or the subject is listening to the program. Analysis of these two alternatives may enlighten our understanding of what is meant by organization.

The term <u>hearing</u> implies passive reception of the incoming auditory stimuli; the term <u>listening</u>, active integration of these stimuli. In our experiment, these stimuli, organized into an already learned language structure, constitute items of information. The present thesis holds that these items did not merely impinge on the subject's auditory receptors; but were actively selected and organized by the subject. The individual's attention involved a set to understand, that is, to integrate the information. As the record played on and the number of items increased, the extent of the subject's organization also increased. Rising gradients of tension from chin and frontalis muscles may thus reflect increasing complexity of psychological organization.

We now arrive at the question of mechanism. By what means does the unity between particular thought processes and muscular processes take place? To attempt an answer leads one into neuropsychological theory.

As partly described in the introductory history, such a frame of reference has recently been propounded by Hebb (10). Through learning (especially during early life) numbers of nerve cells interconnect to form distinct groupings (assemblies) more or less permanent. A single assembly may denote a simple item in physical space--a triangle, for example. These simple items become organized into larger units, through sequential action of a number of assemblies firing in proper phase. A phase sequence might underlie a patterned geometrical mosaic, composed of simpler assembly units like triangles, circles, and squares. Now for our present thesis, the discrete stimuli are not concrete objects, but word symbols. Word items referring to simple objects or events are corresponded by cell-assemblies. Patterns of such items, i.e., higher-order structures like sentences and paragraphs, involve higher-order neuronal action, viz., phase sequences. Through reverberation (self-stimulation) these units may maintain a course independent of sensory stimulation and motor response. This process is, however, only relatively autonomous. Central and sensory processes may reinforce each other or come into conflict. Similarly, central and motor components interact, leading to central facilitation or inhibition of muscular and overt action. A directed system, involving a degree of central independence in congruence with a degree of central-peripheral interaction, may constitute the thought process. Increasing complexity of such a system may constitute increasing organization of the thought process.

Lest the sight of our problem be lost in speculation, we shall once more return to our half-forgotten subject, secure in a hospital bed--and attempt to state, in neuro-psychological terms, what the subject is doing.

First, the subject is asked to listen to a recording of a certain kind, which will soon be presented. Such instructions set into motion a number of previously acquired cell-assemblies and phase sequences related to listening; and more precisely, listening to detective stories of philosophical essays. So that the recorded material does not begin to play on a diffused system. The subject is already set to listen.

Onset of the material, since it is clearly audible and in a language familiar to the subject, immediately strengthens this set. A sensory-central interplay begins. Items of information, more or less congruent with this listening set, keep flowing in and reinforcing it. The greater this congruence, the greater the unity of the phase sequences and the larger number of assemblies controlled. In other words, the more the subject listens, the more organized his listening becomes.

Finally, the material comes to an end; the stream of information ceases. Losing their sensory support, the phase sequences tend to lose direction, and become more random.

All through this, our electromyograph has recorded from the frontalis muscle: a rise of tension with onset of listening, a continuous increase with the course of listening, and (for the detective story) a decline of tension with end of listening. The frontalis muscle may thus constitute a motor aspect of the phase sequence, reflecting its rise, organization, and decline. Chin muscle activity has supported this picture, whereas muscles of the forearms have proved negative. It may well be, that during thinking, muscles of facial expression and speech are particularly prone to direct central facilitation. Close connection of thought and speech is favored by early cultural conditioning, though social conventions (and the wish to maintain friends), often keep an adult from thinking aloud. Myographic examination of tongue activity during thought might gain considerably through study of the more voluble child. As for facial expression, changes with emotion have long been taken for granted. We must not overlook, however, alterations that often occur during thought, e.g., a tendency to knit the brows.

Before leaving the discussion of directed listening, one other finding deserves inspection. We have said that the phase sequence tends to become more random when sensory reinforcement ceases. This appears only partly true in the light of obtained results. Frontalis tension falls the minute after completion of the story, but not upon completion of the essay. The poorer memory scores and smaller gradients suggest that the essay was not as well understood. When an interested subject does not fully comprehend the material listened to, he may continue thinking about it after it has ended. Whereas more fully understood material may fail to occupy his attention to the same degree. Neuropsychologically, the better organized phase sequence "short-circuits" more rapidly (10, pp. 227ff).

This brings to a close the consideration of our main problem: the neuromuscular basis of directed and organized thought. We might well adjourn discussion but for some interesting results on what may be another aspect of the thought process: the "wakefulness" aspect, or the state of alertness.

The results have shown an orderly decrease in level of frontalis tension from first to third hearings during the prerest period. Frontalis tension gradients during listening failed to show a similar decrease. Also, retrospective reports indicated an orderly decrease of alertness from one hearing to the next. These same reports, however, did not show a similar decrease of interest, attention, and anticipation.

It may therefore be that changes in the prerest level of frontalis activity reflect changes in wakefulness; that differences in magnitude of the rising gradients reflect changes in the attentive and anticipatory states--and that within the major limits of our experiment these two states are independent.

Not within the entire limits, however; as indicated by the two subjects who failed to keep awake, and the frontalis tension decline prior to actual onset of sleep. Falls of frontalis potentials preceding sleep have previously been reported by Travis and Kennedy (29), whose subjects also showed poorer motor and reaction-time performance with decreasing frontalis activity (17, 29, 30). It might be that attention and anticipation are more intimately bound to alertness when a subject is nearing sleep, and less so when he is wide awake.

At present, however, this distinction between waking level and the more directive aspects of thought is only suggestive, and awaits the test of further research.

SUMMARY

An experiment was designed to investigate muscular activity during sustained attention, in a situation which kept overt movements, distraction, and difficulty to a minimum. This was done by requesting subjects to listen to some recorded material, while reclining comfortably in a quiet room, and under no obligation to memorize the material.

Nineteen subjects listened to a detective story, and 16 to a philosophical essay. Each presentation lasted 10 minutes, and was given three successive times. Potentials from forehead, chin, and both forearms were recorded and integrated electromyographically. At the end of the session, each subject answered a questionnaire about his interest in, and alertness during the successive hearings.

Results from frontalis showed a continuous minute-to-minute increase of potentials from first to last minute of listening. These tension gradients held for both essay and story, and for the three successive hearings. The story tended to yield gradients of greater magnitude, during listening, than did the essay--and the rise of tension for the essay appeared to persist into the postrest period.

Results from chin also showed gradients during listening, but were less smooth and occurred less consistently than

those obtained from frontalis. A rise from first to last minute of listening was found during all presentations of the story, but only for the third presentation of the essay. This may be related to the fact, that most subjects who heard the essay, reported greater interest and anticipation during later presentations; in contrast with subjects listening to the story, where maximum involvement was reported during earlier presentations.

As with frontalis, chin gradients tended to be steeper during listening and to fall more sharply after listening, when the story was heard.

Unlike frontalis and chin, the forearm muscles did not show clear variations of tension during listening.

It was suggested that the tension gradients are associated with increasing organization of incoming verbal material--organization which may occur during continuous attentive listening. Such an association was considered in terms of neuropsychological mechanisms.

TABLE 1

Mean Change of Frontalis Potentials (microvolts) with Start (1'-Pre) Duration (10'-1') and End (10'-11') of Listening

	Hearing	N†	Pre	(1'-Pre)	(10'-1')	(10'-11')
Story Group	1st	18	8.3	0.8*	2.1**	0.8*
	2nd	18	7.6	0.7*	2.6**	0.6*
	3rd	16	6.4	0.6**	2.4**	0.6*
Essay Group	1st	15	7.5	0.9 **	1.2**	0.5
	2nd	14	6.7	0.3‡*	1.4**	0.1
	3rd	13	6.3	0.7**	1.8**	-0.1

Note.--Probabilities determined by t test.

† Variations in N, result from omissions due to recording artifacts, and two subjects falling asleep during third hearing of story.

‡ Distribution skewed. Probability determined by non-parametric test for paired replicates (31).

*$P < .05$

**$P < .01$

TABLE 2

Mean Change of Chin Potentials (microvolts)
with Start (1'-Pre) Duration (10'-1')
and End (10'-11') of Listening

	Hearing	N†	Pre	(1'-Pre)	(10'-1')	(10'-11')
Story Group	1st	15	8.3	1.2*	2.5	0.3
	2nd	16	11.2	-0.3	3.9**	1.1
	3rd	12	7.3	1.8	4.7*	2.5
Essay Group	1st	14	10.9	-0.1	0.8	-0.5
	2nd	13	10.9	-0.9	0.4	-0.2
	3rd	13	8.8	-1.5	3.5**	0.5

Note.--Probabilities determined by t test.

† Variations in N, result from omissions due to recording artifacts, and two subjects falling asleep during third hearing of story.

*$P < .05$

**$P < .01$

TABLE 3

Median Change of Right Extensor Potentials (microvolts) with Start (1'-Pre) Duration (10'-1') and End (10'-11') of Listening

	N†	Hearing	Pre	(1'-Pre)	(10'-1')	(10'-11')
Story Group	9	1st	2.0	0.0	1.4	1.4
	8	2nd	1.4	0.6	1.1	1.3
	10	3rd	1.4	0.0	0.3*	-0.1
Essay Group	9	1st	1.3	1.0**	0.9	1.4
	9	2nd	2.0	-0.2	0.0	-0.7
	9	3rd	1.8	-0.3	-0.5	0.0

Note.--Probabilities determined by non-parametric test for paired replicates (31).

† Variations in and reduced size of N, result from omissions due to recording artifacts, two subjects falling asleep during third hearing of the story, and burst-like activity.

*$P<.05$

**$P<.01$

TABLE 4

Median Change of Left Extensor Potentials (microvolts) with Start (1'-Pre) Duration (10'-1') and End (10'-11') of Listening

	N†	Hearing	Pre	(1'-Pre)	(10'-1')	(10'-11')
Story Group	11	1st	1.7	0.1	1.0	0.6
	10	2nd	1.6	0.2	0.7	0.7
	10	3rd	1.8	-0.2	0.1	0.2
Essay Group	9	1st	1.2	0.0	0.3	0.3
	7	2nd	1.5	-0.3	0.1	0.1
	10	3rd	1.2	0.1	-0.1	-0.1

Note.--Probabilities determined by non-parametric test for paired replicates (31), fail to show any significant differences.

† Variations in and reduced size of N, result from omissions due to recording artifacts, two subjects falling asleep during third hearing of the story, and burst-like activity.

TABLE 5

Subjective Comparisons of Successive Hearings along some Dimensions of Thought

Number of subjects more interested	Story	Essay
in 1st hearing than in 2nd:	12	3
in 2nd hearing than in 1st:	5	12
Story vs. Essay $\chi^2 = 8.19$; $P < .01$		
Number of subjects more attentive	**Story**	**Essay**
in 1st hearing than in 2nd:	13	3
in 2nd hearing than in 1st:	5	10
Story vs. Essay $\chi^2 = 7.29$; $P < .01$		
Number of subjects thinking ahead more	**Story**	**Essay**
in 2nd hearing than in 3rd:	14	5
in 3rd hearing than in 2nd:	5	8
Story vs. Essay $\chi^2 = 3.97$; $P < .05$		

Note.--Particular hearings compared are those splitting the reports most closely into equal groups.

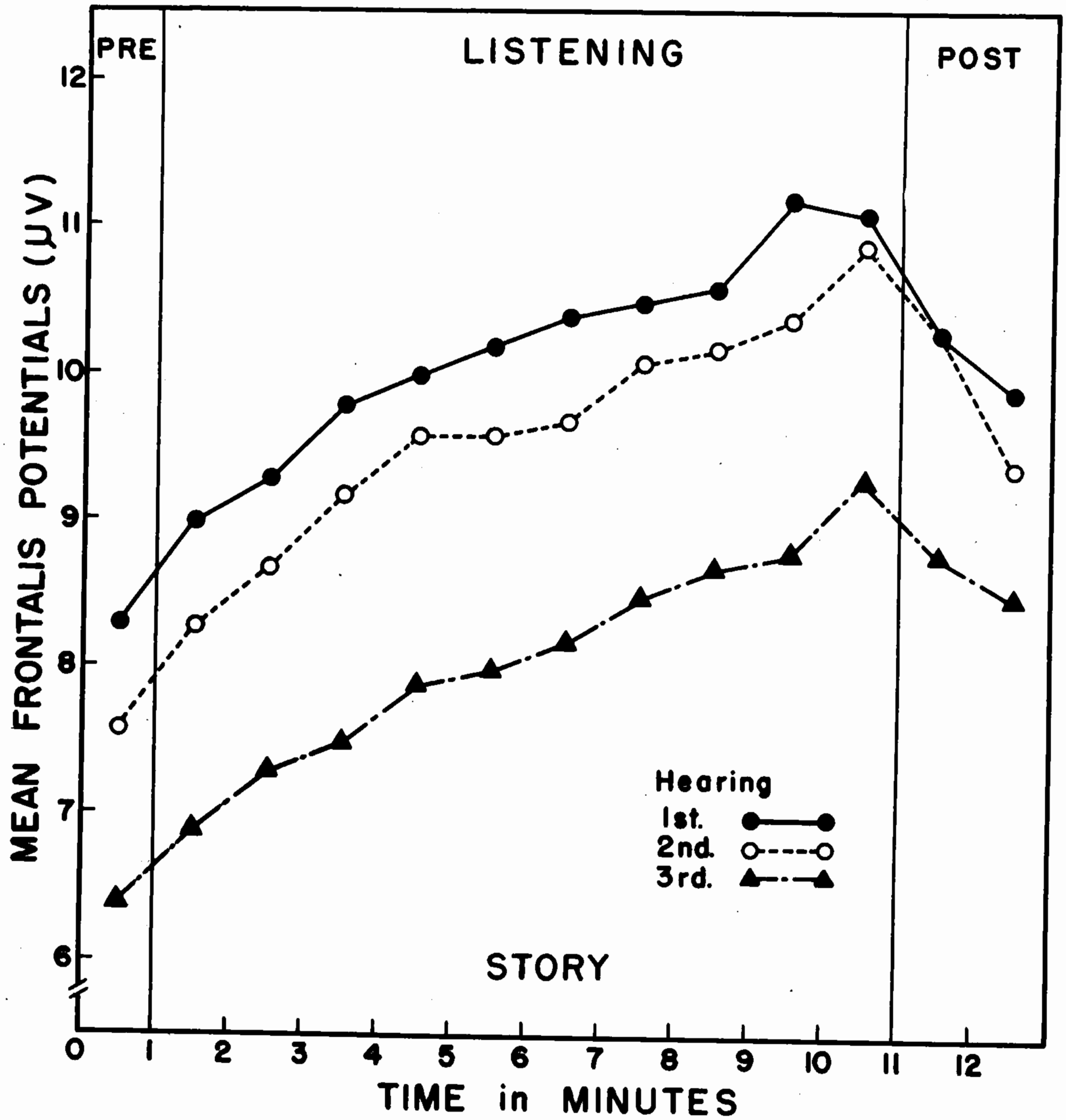

Fig. 1. Effect of listening to a detective story on frontalis muscle tension. Approximately five minutes intervened between each presentation.

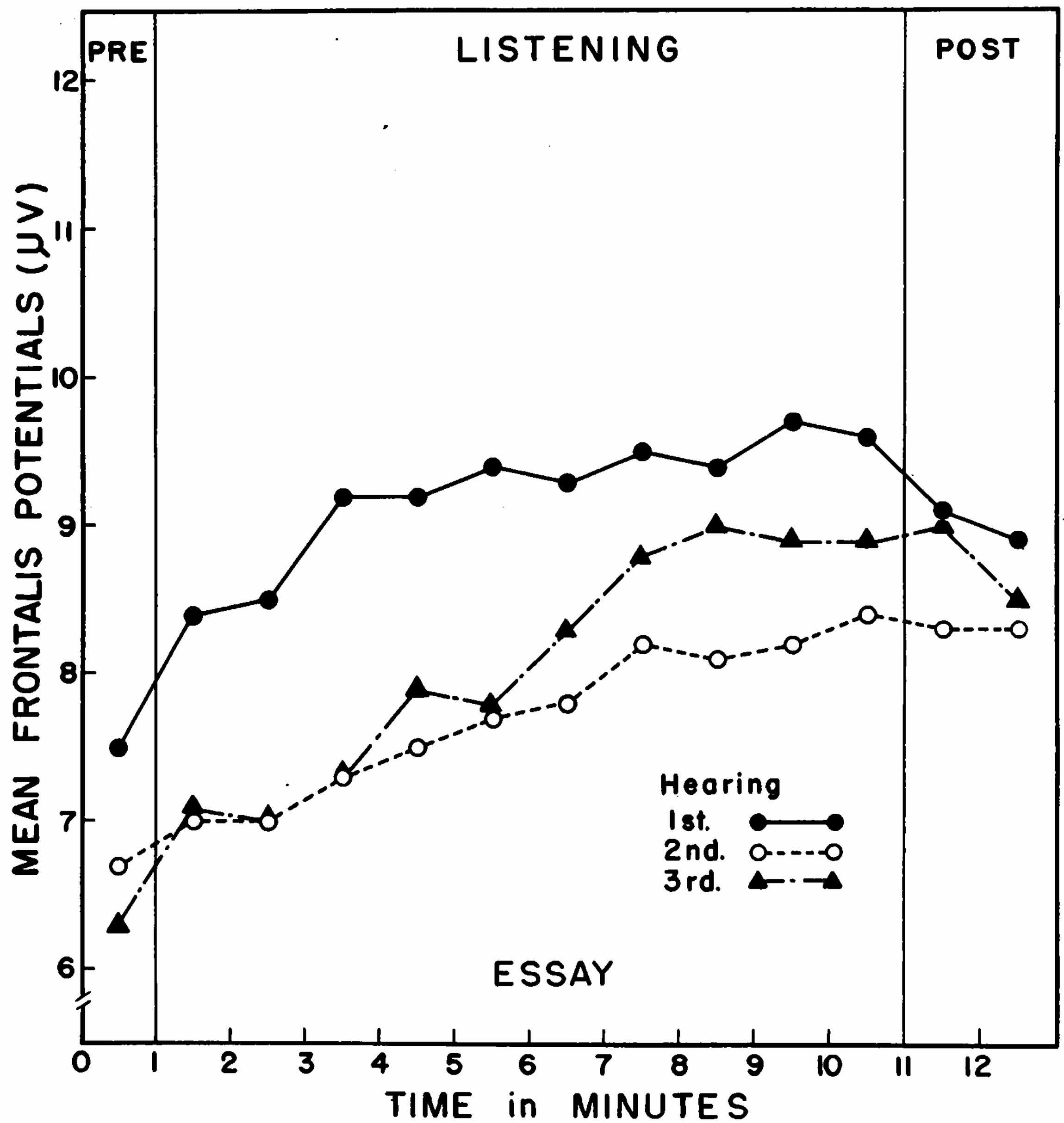

Fig. 2. Effect of listening to a philosophical essay on frontalis muscle tension. Approximately five minutes intervened between each presentation.

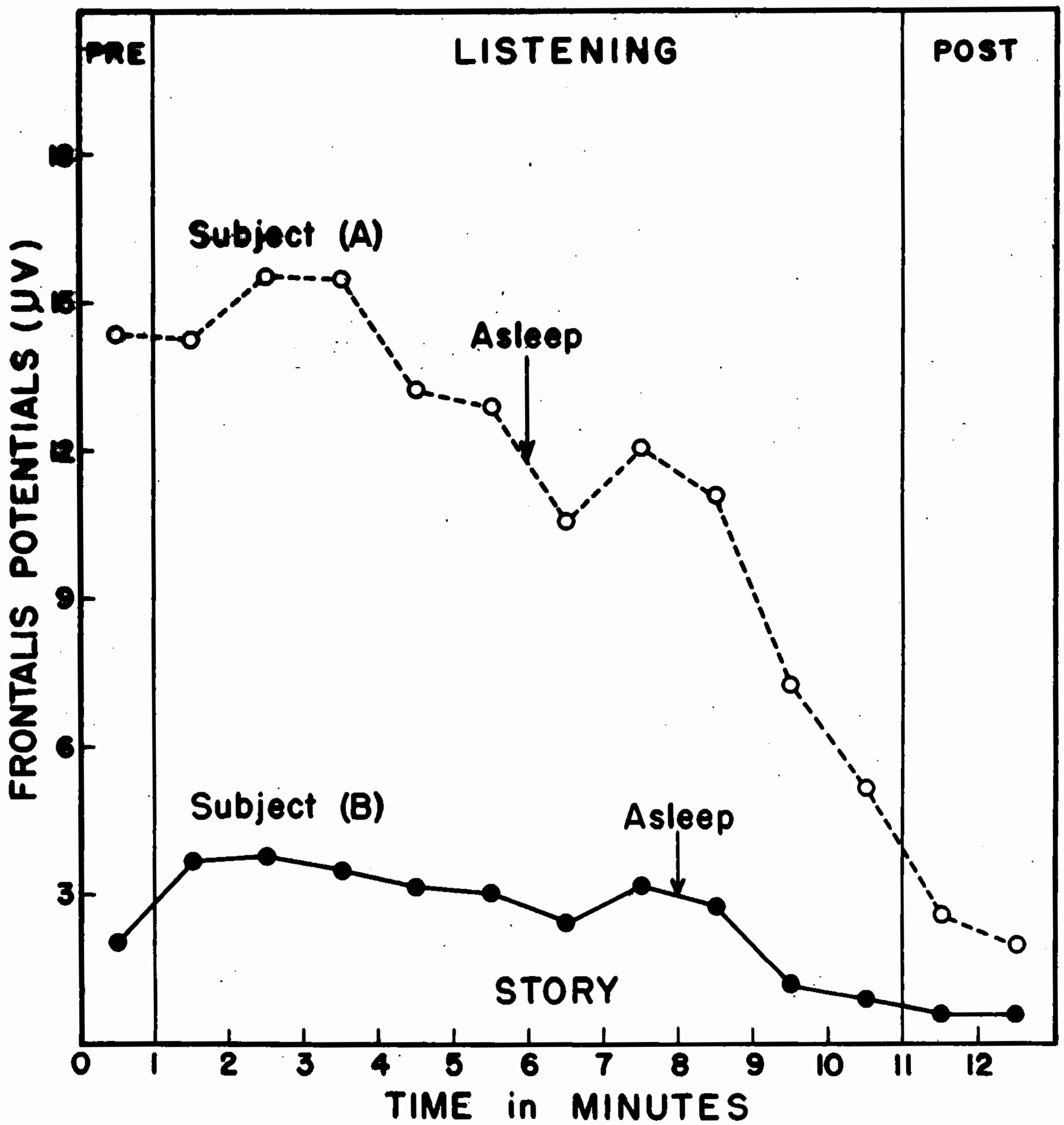

Fig. 3. Changes of frontalis muscle tension in two subjects who fell asleep, during the third hearing of a detective story.

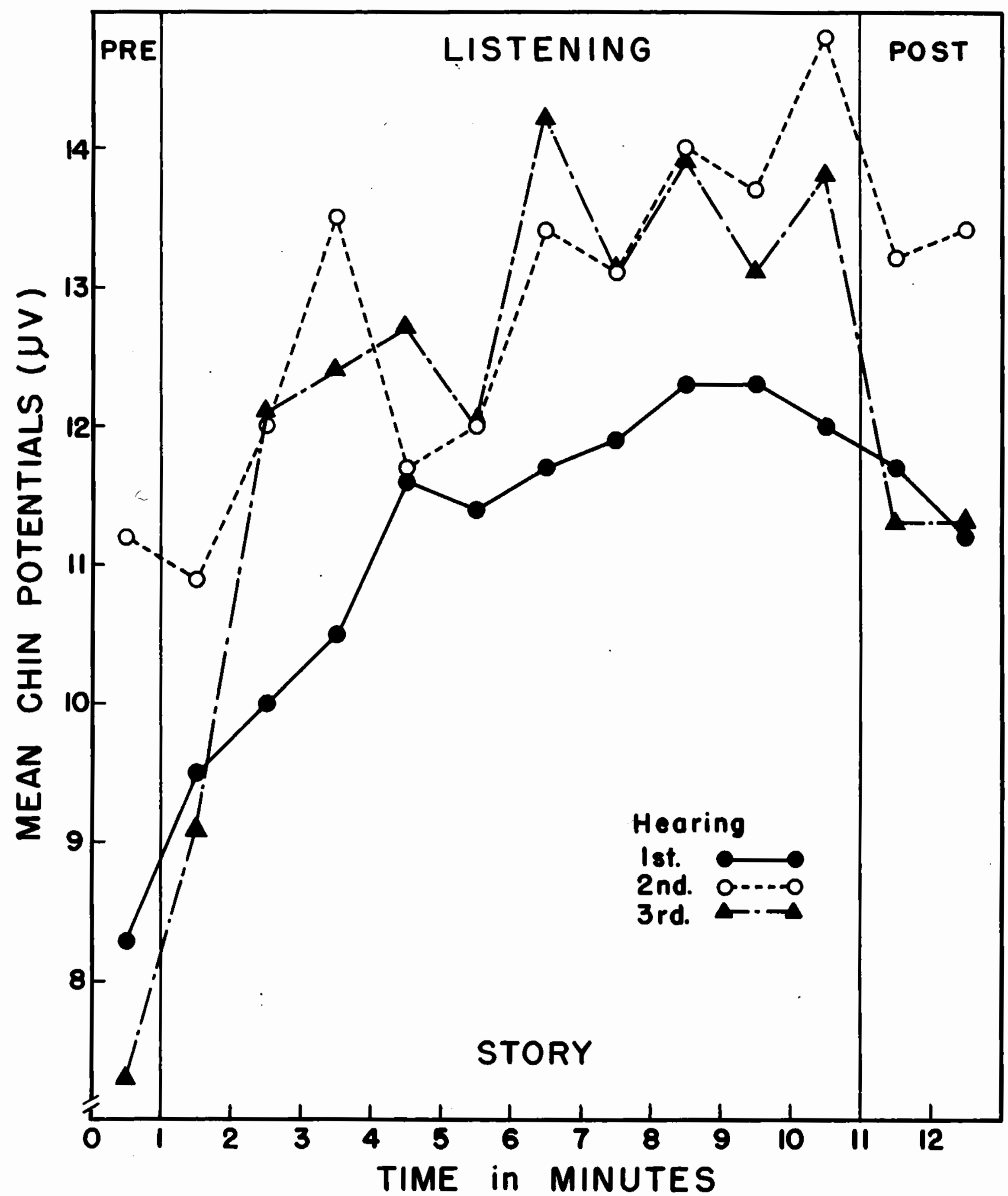

Fig. 4. Effect of listening to a detective story on chin muscle tension. Approximately five minutes intervened between each presentation.

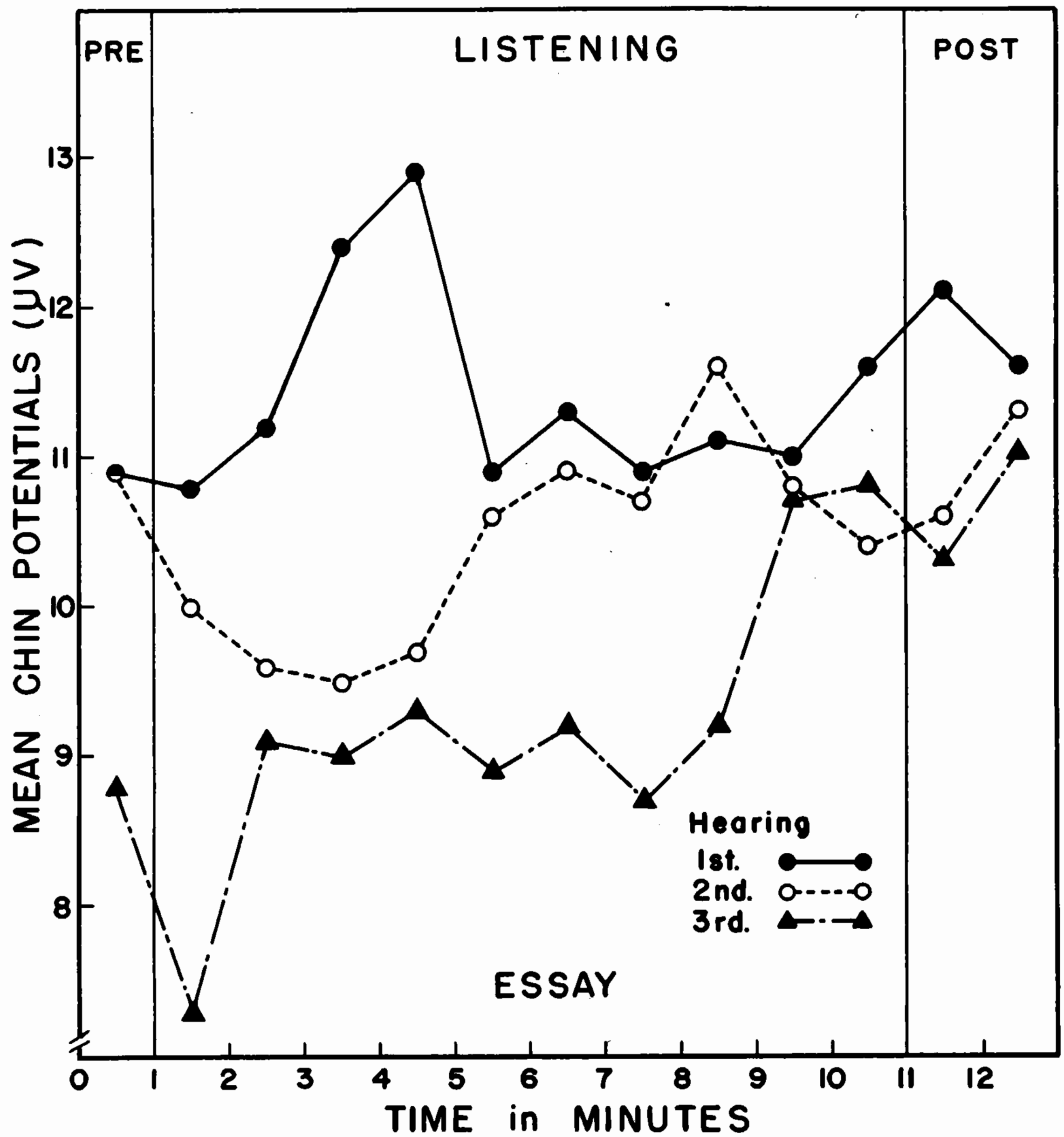

Fig. 5. Effect of listening to a philosophical essay on chin muscle tension. Approximately five minutes intervened between each presentation.

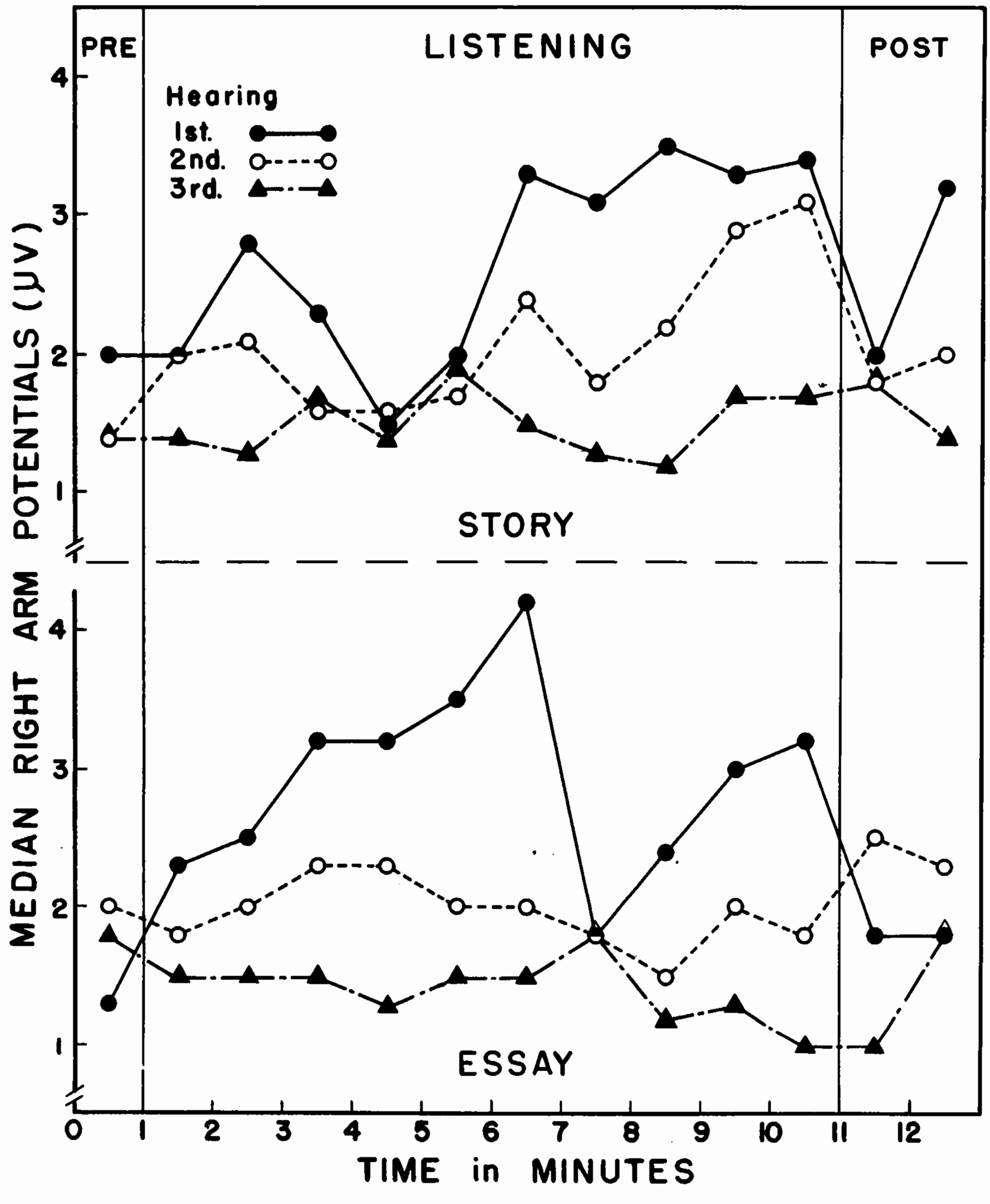

Fig. 6. Effects of listening to a detective story and philosophical essay on right extensor muscle tension. Approximately five minutes intervened between each presentation.

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