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SUBVOCAL SPEECH DURING SILENT READING.

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DESCRIPTORS- *COVERT RESPONSE, *SILENT READING, *READING RESEARCH, *INNER SPEECH (SUBVOCAL), LISTENING, HANDWRITING, THOUGHT PROCESSES, LONGITUDINAL STUDIES, ELECTROMECHANICAL AIDS, PRIMARY GRADES, INTERMEDIATE GRADES,

COVERT BEHAVIOR HAS POTENTIALLY GREAT SCIENTIFIC AND TECHNOLOGICAL IMPORTANCE, THOUGH PRESENT KNOWLEDGE OF THIS RESPONSE CLASS IS MEAGER. SCIENTIFICALLY, COVERT BEHAVIOR HAS BEEN STUDIED FOR TWO REASONS--(1) BECAUSE OF ITS INTIMATE RELATION TO THE "THOUGHT PROCESSES," AND (2) BECAUSE IT IS PART OF THE REALM OF BEHAVIOR THAT THE PSYCHOLOGIST SEEKS TO UNDERSTAND--A SCIENCE OF BEHAVIOR THAT CONFINED ITSELF TO OVERT RESPONSES WOULD BE, AT BEST, INCOMPLETE. THE BROAD PURPOSE OF THE RESEARCH REPORTED HERE IS TO INCREASE THE UNDERSTANDING OF THE NATURE AND FUNCTION OF COVERT BEHAVIOR. THIS REPORT CONSISTS OF SIX SECTIONS. THE PROBLEM FOR EACH SECTION IS DEVELOPED SEPARATELY, AS ARE THE METHODS OF ATTACKING EACH PROBLEM, THE RESULTANT FINDINGS, THE DISCUSSION, AND CONCLUSIONS. THE REPORT DOCUMENTS THE OCCURRENCE OF HEIGHTENED COVERT ORAL BEHAVIOR IN A VARIETY OF SITUATIONS, AND THE FINDINGS STRONGLY SUGGEST THAT THIS KIND OF BEHAVIOR IS BENEFICIAL TO THE INDIVIDUAL IN SOME WAY. THE RESULTS ARE ENCOURAGING AND FORM THE BASIS FOR A MORE SUBSTANTIAL ATTACK ON COVERT BEHAVIOR. TABLES, FIGURES, AND BIBLIOGRAPHIES ARE INCLUDED. (AUTHOR/BL)

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U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

SUBVOCAL SPEECH DURING SILENT READING

Project No. 2643
Contract No. OE 5-10-073

Frank Joseph McGuigan

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Abstract

Covert behavior has potentially great scientific and technological importance, though our present knowledge of this response class is meager. It has been established that covert responses reliably occur under certain conditions, but we only speculate about the function that these responses serve. Technologically, for instance, teachers typically regard the covert oral behavior ("subvocal speech," etc.) that occurs during silent reading as an event that retards a pupil's reading proficiency and they, therefore, take steps to inhibit the response. Alternatively, it has been held that covert oral behavior during silent reading can facilitate a pupil's comprehension of the text being read. Scientifically, covert behavior has been studied for two reasons: 1) because of its intimate relation to the "thought processes," and 2) because it is part of the realm of behavior that the psychologist seeks to understand -- a science of behavior that confined itself to overt responses would, at best, be incomplete.

The broad purpose of this research was, therefore, to increase our understanding of the nature and function of covert behavior. To accomplish this purpose, efforts were made 1) to extend our knowledge of the conditions under which covert behavior occurs by attempting to record covert responses while subjects engage in a number of different tasks; and 2) to systematically manipulate the amplitude of covert oral behavior. The end result of this strategy will, if successful, tell us whether covert behavior is simply a concomittant or aspect of other events (e.g., that it is merely incidental "outflow" from the brain or merely part of a heightened state of arousal); or whether it serves some vital function in the receipt and processing of language stimuli and in "thought."

This report consists of six additional sections. The problem for each section will be developed separately together with the relevant references, as will be the methods of attacking each problem, the resulting findings, the discussion and conclusions. A brief summary of the remainder of the report is presented here.

In Section II an effort was made, based on a survey of the literature, to develope a guiding framework for research in the area of covert behavior. An integrating unit of behavior was suggested (Fig. 2, p. 10 b) in which an external language stimulus evokes two classes of behavior: 1) covert oral responses and 2) covert non-oral responses. These responses then lead to additional responses of both classes, and the chain may continue indefinitely. At crucial points in the chain a person can report on the nature of the responses, these crucial events constituting what we call "thougnts," "dreams" and the like. A number of implications of this analysis for further research in the area of covert behavior were suggested.

In Section III the amplitude of covert oral behavior during silent reading was studied in the same 16 children over a period of three years. These children were periodically called back to the laboratory for silent reading, and it was determined that the amplitude of covert oral behavior "naturally" decreased during the period studied. Nevertheless, the covert oral response persisted in them, though at a reduced level, posing the question of its possible function.

In Section IV an attempt was made to record several measures of covert behavior (chin, tongue, arm electromyograms, and breathing rate) while subjects engaged in several different tasks. The goal here was to measure these covert responses as a function of the tasks (memorizing, reading, listening to prose, listening to nothing, and listening to noise) in an effort to obtain comparable data under controlled conditions. For example, while we know that covert oral behavior occurs when subjects silently read, we do not know how amplitude of such behavior compares with that that occurs for other activities. Two experiments were conducted using 75 and 40 subjects respectively. Among other conclusions it seems clear that people are covertly more active when they memorize than for the other tasks.

In Section V an effort was made to systematically manipulate the amplitude of covert oral behavior during silent reading. Two experiments were conducted using 45 and 36 subjects respectively. It was found that the introduction of auditory stimulation increased the amplitude of covert oral behavior during silent reading, and that the amplitude was greatest when the stimuli were of a language nature. It was concluded that increased covert oral behavior is beneficial during silent reading, perhaps by facilitating the receipt and/or processing of the prose being read.

Section VI constituted an effort to record increased covert oral behavior while subjects engaged in cursive writing. Twelve subjects were selected according to quality of handwriting from a larger pool of 117 college students. It was found that these subjects significantly increased the amplitude of covert oral behavior during writing relative to that for a control condition (drawing ovals), leading to the interpretation that the covert oral response served a language function. The findings also suggested that amplitude of covert oral behavior was greater in poorer writers than in excellent writers.

Finally, in Section VII several children who emitted a large amount of covert oral behavior during silent reading were studied on several occasions. It was found that providing systematic feedback when the amplitude of the response was great resulted in a decrease in the amplitude of responding. However, the same effect was obtained for control subjects when the feedback was not provided. It appears that repeated reading sessions in the laboratory results in decreased subvocal speech, regardless of the auditory feedback and even though the subjects are not aware that they themselves are responsible for producing the feedback. This research thus leads to the question of what mechanism is responsible for reducing amplitude of covert oral behavior during silent reading, and invites further research.

In summary, this report documents the occurrence of heightened covert oral behavior in a variety of situations, and the findings strongly suggest that this kind of behavior is beneficial to the individual in some way. The results are thus encouraging and form the basis for a more substantial attack on covert behavior. Eventually, it is hoped, we will arrive at an advanced understanding of the function of the various kinds of covert behavior that occur during tasks (educational and otherwise) that require "thinking."

Toward an Understanding of Covert Language Behavior

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Abstract

The growing importance of the covert response is indicated by the increasingly large number of empirical and theoretical studies devoted to it. The progress of the empirical and theoretical approaches to covert behavior can no doubt be facilitated by establishing relationships between the findings of the former and the hypothetical constructs of the latter. As a first step, a classificatory system for the findings of our laboratory studies was suggested. Direct measures of covert behavior were then studied as a function of initiating language stimuli (e.g., as in "silent reading"), and, in the absence of initiating stimuli (e.g., as in "dreams" and "hallucinations") as a function of tacting responses. The resulting conclusions were then used as a basis for developing a provisional integrating framework. Finally, a tentative operational definition of covert language behavior was suggested, and the relationship between such behavior and the construct of a verbal mediating response was discussed.

Toward an Understanding of Covert Language Behavior

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The limited power of simple S-R laws to explain complex behavior has led to the postulation of an increasing number and variety of hypothetical constructs. Hull's (1952) $\underline{r_G}$, Osgood's (1953) mediating reaction, Schoenfeld & Cumming's (1963) perceptual response, and Underwood's (1965) implicit associative response are but a few examples. Within the recent past there has also been a dramatic growth in our laboratory efforts to directly measure a myriad of covert muscular and glandular events. As Ax (1964) reports, "Psychophysiology began its exponential growth in 1945 with about 45 articles. By 1960 there were over 300 per year being published in English" (p.1). Davis, Buchwald & Frankmann (1955) justify this increased empirical concentration on covert behavior when they point out that covert "...responses abound. One has but to observe them on a set of recording instruments to believe that they are by far the most numerous responses of the organism. It is clear that any overt response... is surrounded by a wide penumbra of them... In this sea of somatic response an occasional wave breaks into an external response" (p.1). Clearly there is an increasing amount of effort being devoted to both the theoretical and the empirical study of the covert response. Unfortunately, though, these two approaches have been essentially independent of each other. It is highly probable that the establishment of relationships between the directly measured empirical events of the laboratory and the hypothetical constructs of the theoreticians would benefit both enterprises. One strategy for establishing such relationships would be to commence with the empirical findings, form a framework for them, and to seek a set of low level laws. The results of an integrative attempt for the area of covert response measures may then be related to appropriate hypothetical constructs. At the same time the hypothetical constructs may help to guide the development of the empirical framework. For instance, the theoretical emphasis on constructs of verbal mediating responses suggests a priority for those kinds of covert behavior that involve language.

Taxonomy of Covert Behavior

The first step in arriving at a framework for laboratory studies is to develop a system that may be used for reviewing and classifying the important findings. In an exploratory way we shall first examine those kinds of responses that occur when a language stimulus is presented to a language-proficient organism. "Language stimulus" shall be broadly conceived (as in the sense of Morris' 1946 lansign-system) so that it includes words of a natural or artificial language, mathematical symbols, etc. The traditional (and approximate) distinction between overt and covert behavior shall be followed, *i.e.*, the latter is distinguished from the former in that it requires the use of specialized apparatus in order to make the event public.

Prior considerations of covert behavior, (*e.g.*, Skinner, 1957; Watson, 1919) suggest a potentially important subdivision of the realm of covert behavior, viz., a distinction between covert responses of the speech mechanism (tongue movements, laryngeal events, "sub-audible sounds," breathing changes, etc.) and of other parts of the body. We shall, therefore, study covert behavior according to whether it is muscular or glandular activity of the speech or of the non-speech regions of the body. Since the speech mechanism may also be used for non-language (or non-speech) responses, we shall prefer the more general term *oral* behavior; hence covert responses will be classified as either oral or non-oral in nature.

Finally, an overview of the relevant laboratory studies indicates that they may be categorized according to whether covert responses were recorded in the presence or absence of a directly initiating language stimulus. In the former case, behavior has been studied as a function of the stimulus input, and in the latter as a function of reporting behavior, an overt language response. Our strategy, therefore, will be to sample the literature in which various language stimuli have been presented and to classify the data according to whether the covert response was oral or non-oral; after this, we shall consider the problem of covert behavior that occurs in the immediate absence of such stimuli.

Covert Behavior as a Function of External Language Stimuli

Covert Oral Responses

Experiments in which external language stimuli (prose to be silently read, problems to be solved, etc.) were visually presented resulted in electromyographic (EMG) data that indicated modification of laryngeal muscle activity (Edfeldt, 1960; Faaborg-Andersen & Edfeldt, 1958), increased activity of the lips and chin (Basin & Bein, 1961; McGuigan, Keller & Stanton, 1964), and of the tongue (Novikova, 1961). Additionally, though individual differences among Ss were great, amplified sound recordings of subvocal speech ("whispering to one's self") obtained from children engaged in silent reading allowed the Es to understand portions of the text being read by some Ss (McGuigan, et al., 1964). Positive evidence of increased tongue and laryngeal activity as a result of visual presentation of language stimuli has also been reported using mechanical pickup and registration devices, though because of the crudeness of the experimental apparatus and methodology such studies are primarily of historical interest only (Curtis, 1900; Courten, 1902, Perky, 1910· Reed, 1916; Wyczoikowski, 1913, etc.). Modification of the pneumogram and associated measures has also been produced by the presentation of such external language stimuli as prose to be silently read and problems to be solved (McGuigan, et al., 1964; Morgan, 1916; Rounds & Poffenberger, 1931).

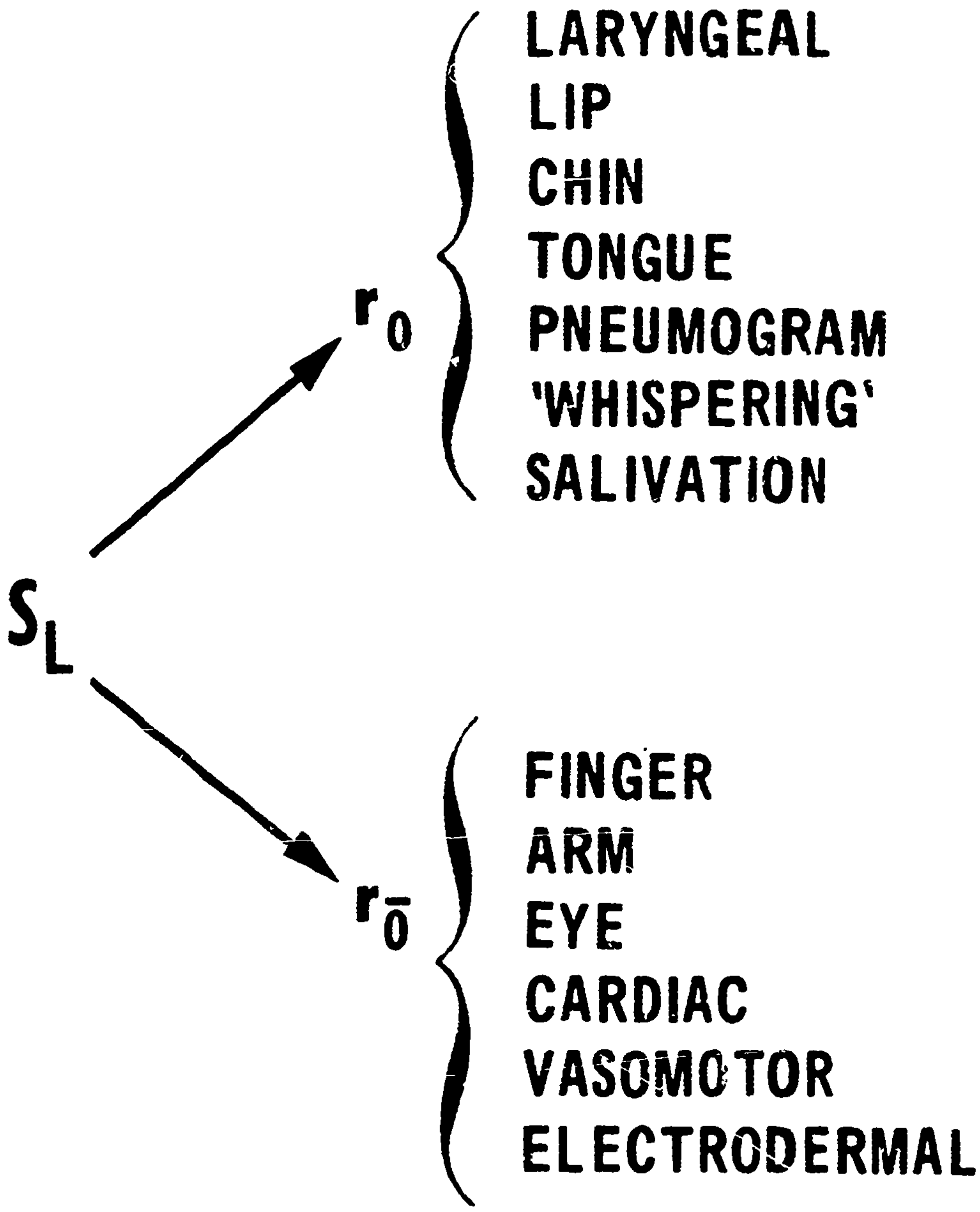
Experimentation in which language stimuli were presented orally has also yielded positive results; electromyographic techniques have indicated increased activity of the tongue (Blumenthal, 1959; Novikova, 1961), and of the chin (Wallerstein, 1954).

Jacobson's (1932) procedure was to agree with his subjects that a click of a telegraph key was to be the signal for imagining, recalling, etc. various predetermined activities. The presentation of this (substitute) language stimulus resulted in increased EMG activity of the upper lip and tongue.

Covert Non-oral Responses

Max (1935) has shown that various language stimuli (problems, instructions to imagine holding a live fish, telegraphing an SOS, etc.) resulted in heightened finger activity in both deaf mutes and normals (but more frequently for the former who use the fingers for overt language communication). Novikova (1961) also found that the visual presentation of arithmetic problems evoked considerable finger activity in deaf mutes and to a lesser extent in normal Ss. Of especial interest is Novikova's finding that Ss who were proficient in both oral and manual speech almost simultaneously yielded both covert oral and non-oral responses. Jacobson (1932) and Shaw (1940) recorded heightened EMGs of the arm to instructions to imagine lifting a weight. The presentation of a variety of other language stimuli, Jacobson (1932) also showed, results in unique covert non-oral responses such as increased EMG activity of the arm and of the eyes. Davis (1939) presented arithmetic problems and recorded unique activity of the right arm, a response presumably conditioned when one learns to count with his fingers. Ewert (1933) found that oral and non-oral language stimuli result in increased frequency of eye movements, and that the frequency during the original presentation and during a later recall is highly similar. As he concludes: "... eye movements are closely related to, or are a part of, the vocal recall pattern" (p. 79). Lorens and Darrow (1962) found that eye movement rate significantly increases during the presentation of an arithmetic problem and when an S is asked to imagine visual scenes. Additionally, the presentation of problems to be solved, etc. results in unique cardiac responses (Ford, 1953; and Blatt, 1961), and in various vasomotor changes (Day, 1924; Berry, 1960, McGinn, Harburg, Julius & McLeod, 1964). Razran

Fig. 1. The presentation of language stimuli (S_L) results in a class of covert oral (r_0) and a class of covert non-oral ($r_{\overline{0}}$) responses. Examples of members of these two response classes are indicated above.


LARYNGEAL
LIP
CHIN
TONGUE
r_0
PNEUMOGRAM
'WHISPERING'
SALIVATION
S_L
FINGER
ARM
$r_{\bar{0}}$
EYE
CARDIAC
VASOMOTOR
ELECTRODERMAL

(1939) reported that the visual presentation of words results in conditioned salivation, as has Volkova (1953). Volkova's findings were confirmed by Acker and Edwards (1964) where vasoconstriction was the conditioned response to language stimuli. And there is abundant evidence that the presentation of various words results in changes in electrodermal response (EDR) measures (e.g., Grings, Carlin & Appley, 1962; McCurdy, 1950). Furthermore, the EDR may occur uniquely to certain (conditioned) language stimuli (e.g., Crawford, Statts & Statts, 1962; Riess, 1940; Wylie, 1940).

An attempt to abstract general features from these studies is necessarily hazardous, and it is wise to remain as close as possible to the observational level. A provisional summary is offered in Fig. 1. Hence, we have noted that a variety of language stimuli have evoked the kinds of covert oral (r_O) and covert non-oral ($r_{\overline{O}}$) responses specified there. A more detailed analysis of behavior as a function of the different classes of evoking language stimuli would no doubt be enlightening, though it is interesting to note that similar response events occurred regardless of whether the stimulus was oral, visual, or even a substitute for natural language (a la Jacobson, 1932); obviously, a more systematic exploration of the effects of stimulus variation is called for.

In considering Fig. 1, it may be further added that we are in no sense wedded to the oral vs. non-oral dichotomy, and should it not prove of value we need merely remove the subscripts for the rs. The emphasis on this distinction by Watson (1919) and others, however, suggests that it should be maintained at least until the data demand otherwise; as Watson (1919) put the matter "Vocal acts... do not become language habits until they become associated with arm, hand and leg activities..." (p. 319). Novikova's (1961) finding that language stimuli almost simultaneously resulted in increased EMGs from both the tongue (r_O) and fingers ($r_{\overline{O}}$) is an empirical case in point. Extensive documentation that unique covert oral and non-oral responses simultaneously occur to language stimuli would appear to be a priority research goal.

Finally, let us focus on the finding that, by monitoring Ss' amplified sound production, it was possible to comprehend, in some instances, the visually presented prose that was being silently read (McGuigan, et al, 1964); the Ss were, so to speak, acting as "involuntary" transducers, changing visual signals into auditory ones. The function of this exaggerated covert oral response is, unfortunately, little understood in spite of the prolonged attention given to it by educators and psychologists. The facts are few, but it is valuable to observe that such "whispering" was recorded only for children, never for college level Ss. Still, heightened chin and lip EMGs were recorded for both children and college Ss engaged in silent reading, indicating that oral activity generally increases during visual presentation of language stimuli, but it is more pronounced for the younger Ss. Might it be that, to speak loosely, children (at least in some instances) behaviorally reproduce an impinging language stimulus in order to comprehend it? And that a similar motor act occurs in the case of adults, though they abbreviate the reproduction by merely emitting representational responses?

Put more objectively, does an external language stimulus directly result in a covert oral response that is at least a partial reproduction (regardless of modalities involved) of that stimulus? The statement of such a possibility is, of course, not new; but intensive empirical study of it is. Liberman, Cooper, Harris and MacNeilage (1962) phrase the possibility this way: "... the perception of speech is tightly linked to the feedback from the speaker's own articulatory movements... what has been learned is a connection between speech sounds and their appropriate articulation... In time, these articulatory movements... come to mediate between the incoming acoustic stimulus and its ultimate perception." (p. 4: see also Lane's 1965 attack on the motor theory of speech perception). Determining the function of covert oral responses during the receipt of language stimuli is another important research goal; in the meantime we can merely observe that the findings of McGuigan et al (1964) are consonant with the motor theory of speech perception.

Covert Non-oral Responses as a Function of Covert Oral Responses

Our formulations to this point seem relatively straightforward; the historically perplexing areas of psychology, however, have been those concerned with covert behavior that occurs in the absence of immediately, directly specifiable external stimuli. There are some data bearing on this problem.

Laboratory conditioning studies have shown that a covert oral response (which had been evoked by a variety of external stimuli) can be systematically followed by several kinds of covert non-oral responses. That is, the subvocal saying (or "thinking") of various words and nonsense syllables has resulted in pupillary contraction and dilation (Hudgins, 1933, though this finding has never been confirmed), in heightened EDR (Henneman, 1941; Noble, 1950), in vasodilation and vasoconstriction (Menzies, 1937; Roessler & Brogden, 1943; also Skinner, 1938, though his initiating response was apparently depth of breathing, still a covert oral response by our definition), and pulse retardation (Kotliarevsky, 1936). Earlier, more casually reported findings are cited by Tuke (1884); Professor Beer, it seems, was able to contract or dilate his pupils by thinking (presumably a covert oral response) of a dark or light place; other "voluntary" language activities led to changes in cardiac rate and gastrointestinal responses.

Presumably, in these studies, the covert oral response resulted in internal stimulation that evoked the relevant non-oral response. But since we are now considering only directly observable events, we shall postpone the topic of a response-produced stimulus. The immediate importance of these findings is their relevance to the assumption made by behaviorists in "explaining" a wide variety of phenomena, viz., that all manner of complex chains of covert responses occur. While the data are more modest, they are sufficiently suggestive to encourage a more extensive search for kinds of r-r relations other than the r_0-$r_{\bar{0}}$ ones specified above. The increasing refinement of our laboratory measures may well establish that a covert non-oral response can result in a second clearly identifiable covert oral response, and that, in fact, interacting chains of these several classes of responses can continue indefinitely. The finding of Hefferline and Perera (1963) that a covert non-oral response (a slight thumb twitch) can produce, through operant conditioning procedures, a second non-oral (finger) response, provides additional support for this line of speculation.

Covert and Overt Responses

The general problem on which we have just been focusing is the case in which covert behavior occurs in the absence of immediate and directly specifiable external stimuli. We have seen that an external stimulus that evokes a covert oral response can lead to a covert non-oral response, and we have noted the possibility that complex chains of these covert responses may continue indefinitely. Should this be the case, the problem is: how to study these prolonged chains of covert responses when we do not have control over a relevant antecedent event? The kinds of continuous behavior, not directed by external stimuli, to which we have reference are called, in the vernacular, such things as "daydreaming," "thinking," "hallucinations," and "night dreams." Apparently, the only anchoring overt event for this case is a reporting response from S. There are two classes of studies in which efforts have been made to record covert responses and to relate them to overt responses.

The first is the study of night dreams. The pioneering work here was by Max (1935) where he reported that heightened finger movements of deaf mutes are strongly related to overt language reports of the presence of "dreams."

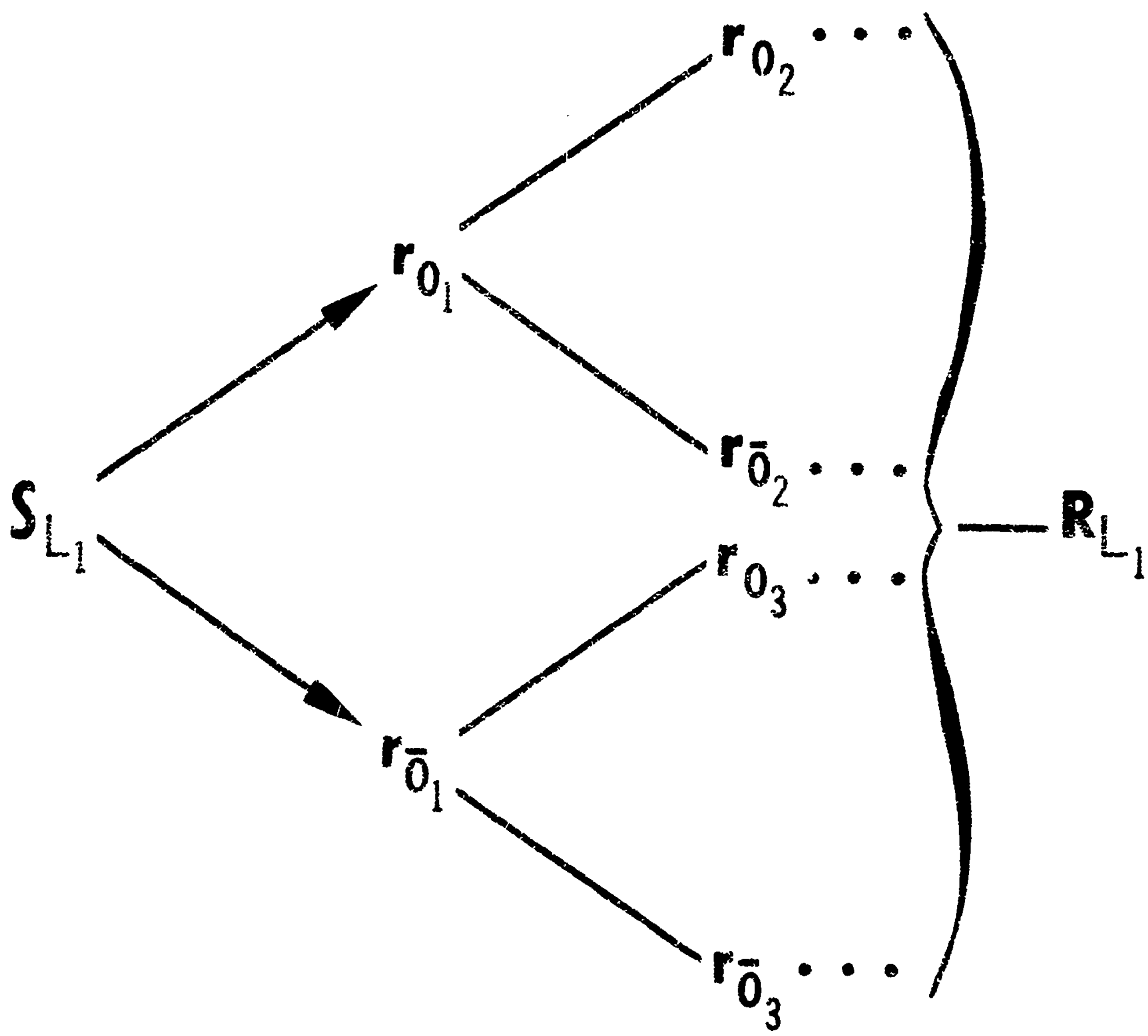
More recently an impressive flow of investigations (e.g., Dement & Kleitman, 1957; Dement & Wolpert, 1958) have demonstrated that rapid eye movements (REM) significantly often precede overt oral reports of dreams. A variety of other covert responses (changes in respiration, pulse rate, basal skin resistance, blood pressure) have also been related to the report of dreams (cf. Snyder, 1963). In a repetition and extension of Max's work, Stoyva (1965) found an increase in finger EMG during REM periods in both normal and deaf Ss. And Wolpert (1959, 1960) showed increased arm and wrist EMG associated with these REM periods. Apparently the only covert oral response related to the report of a dream is Berger's (1961) finding of decreased tonus in the extrinsic laryngeal muscles.

In addition to well-established relationships between these kinds of covert behavior and the presence of the dream episode, several features of covert responses are related to the specific content of the verbal reports. For example, horizontal REMs are related to reports of horizontal "dream activities," and vertical REMs to vertical "dream activities" (e.g., Dement & Kleitman, 1957); unique eye movement patterns are related to reports of unique dream episodes (Roffwarg, Dement, Muzio, & Fisher, 1962); and active and passive rapid eye movements relate strongly to dream reports that were judged, respectively, to be active and passive (Berger & Oswald, 1962). One specific example of the close correspondence between a specific covert behavior pattern and a unique overt oral language response vividly illustrates the point: during sleep one of Wolpert's Ss gave heightened EMG in the right arm, then in the left arm and then in a leg; his later oral report was that he dreamed of lifting a bucket with his right arm, transferred the bucket to his left arm, then proceeded to walk (Kleitman, 1960).

The second class of study of covert behavior that occurs in the absence of directly initiating external stimuli concerns reports of "auditory hallucinations" by psychotics. A hallucination is a phenomenon, it would appear, that is quite similar to a dream, and some limited data comparable to those obtained during dreaming are available. In particular, amplified recordings of subvocal speech and heightened EMG from the vocal musculature were related to overt oral reports of the presence (and to some extent the nature) of auditory hallucinations (Gould, 1949; 1950). While the generality of this finding has not been established, McGuigan (1965) reports similar results from a single psychotic; for this S significantly increased the amplitude of his chin EMG and pneumogram and emitted slight whisperings (that corresponded somewhat to the content of the hallucination) immediately before he reported "hearing voices." Furthermore, there was a tendency for his tongue EMG and quantified sound production to increase prior to the report of hallucinations. That this S's arm EMG did not noticeably change suggests that covert oral behavior was uniquely related to the oral report of hallucinatory activity. If, then, the covert oral response is interfered with, one might expect that a patient would fail to report an hallucination. Forrer (1960) presents evidence that is consonant with this prediction, i.e., he reports that when a patient engages in various kinds of oral activity such as brushing the teeth or swallowing, reports of hallucinations are eliminated or reduced in frequency.

Caution should be observed in interpreting these findings, for methodologically sound research in this area is extremely difficult to conduct, and the absence of suitable control measures is readily apparent. Nevertheless, these studies at least offer a starting place. For they suggest that the occurrence of some covert responses are strongly related to overt oral responses. For example, the occurrence of rapid eye movements, decreased laryngeal muscular tonus and heightened finger EMG precede overt oral reports to the effect that the subject has been dreaming. Furthermore, it has been shown that some of the covert response patterns are uniquely related to the content of the overt language response, allowing us to predict, to some extent, the characteristic of one from the other (as in Berger & Oswald, 1962; Dement & Kleitman, 1957;

Fig. 2. An arbitrary behavioral unit which is commenced when an external language stimulus (S_{L_1}) evokes a covert oral (r_{0_1}) and a covert non-oral ($r_{\bar{0}_1}$) response. Each covert oral and non-oral response results in an additional covert oral and non-oral response, the sequence continuing indefinitely. The unit is arbitrarily said to be terminated when an overt language response (R_{L_1}) occurs.


r_{o_2} . . .
r_{o_1}
$r_{\bar{o}_2}$ . . .
S_{L_1}
R_{L_1}
r_{o_3} . . .
$r_{\bar{o}_1}$
$r_{\bar{o}_3}$ . . .

Kleitman, 1960; Roffwarg, et al, 1962; etc.). Finally, the occurrence of covert oral responses apparently may lead to the report of auditory hallucinations. In short, it would seem that there occur unique organismic events that are either indicated by, or that actually consist of, complexes of covert responses; and these events (responses?) can be tacted. It is the task of future research to unambiguously specify these complex phenomena ("dreams," "hallucinations," etc.) in terms of unique response patterns (cf. Davis, 1957) and to thereby differentiate among them if the data so dictate.

An Integrative Attempt

Up to this point, we have surveyed a variety of data and classified them by employing a system which has suggested several low level empirical relationships. More than this, we have raised some questions about possible extensions of these relationships, questions that may help point out fruitful directions for further laboratory observation of covert behavior. In particular, the liberty that we have exercised in tentatively generalizing and extending the laboratory findings has resulted in the following possibilities: (1) the presentation of an external lar ge stimulus directly results in a covert oral and a covert non-oral response; (2) the occurrence of any such response may result in an additional covert oral and non-oral response; (3) complex interacting chains of these responses may continue indefinitely; (4) at least some of the resulting patterns of these responses constitute (or indicate) unique organismic events that may be overtly tacted. These considerations lead us to provisionally suggest an arbitrary behavioral unit, selected for analysis purposes out of a highly complex and continuous flow of behavior (Fig. 2). While further research may force us to modify the schema presented in Fig. 2, the reason would be that it contains only variables that are directly observable; for the antecedent and consequent events can be recorded by the classical methods of studying overt behavior, and the intervening responses are observable by the use of specialized apparatus.

On the Definition of Covert Language Behavior

One of our initial questions can now be phrased as follows: Does there exist a unique subclass of covert behavior that can justifiably and profitably be called language in nature? If there is, it is important that we properly define and study it. If there isn't, our analysis can stay at the more molar level depicted in Fig. 2. To approach this question we need to consider the additional question of why external stimuli evoke covert responses.

For one, there is a general, unlearned, arousal function of stimuli, regardless of their nature. Hence covert response changes that occur to any stimulus, be it language or non-language in nature, can safely be called non-language behavior for they are components of a general arousal state.

A second reason that covert responses are evoked by stimuli is to be found in the conditioning history of any given organism -- no doubt a wide range of language and non-language stimuli have acquired the capacity to evoke numerous covert responses. Our interest here has centered on those covert responses evoked by language stimuli, and it has been demonstrated that they may be either oral or non-oral in nature. The immediate question is whether those oral and non-oral responses are <u>uniquely</u> evoked by language stimuli. Unfortunately the available research, almost without exception, has not been designed to answer this question. The incorporation of language and non-language control conditions is indicated. For instance, one might present a variety of language and non-language stimuli, in addition to a specific language stimulus of interest. If a certain covert response occurs to the specific language stimulus, but fails to occur to the other stimuli, then that response would seem to qualify as a language response. A more demanding criterion would be the demonstration that a covert oral <u>and</u> a covert non-oral response <u>both</u> uniquely occur to a given language stimulus. Difficult as such a demonstration might appear, it is by no means impossible of accomplishment. The problem would be primarily a technological one, and the means are already available to solve it.

A more pressing, theoretical, matter concerns the relationship between a language stimulus and a stimulus object or event that may be denoted by it. It has been shown that when a covert response has been conditioned to a stimulus object for which there is an associated name, there is generalization to the name of the stimulus object; there is also generalization from an originally conditioned language stimulus to the corresponding object (cf., Cofer & Foley, 1942, for a summary of research on this topic.) Hence a given covert response may be evoked either by a language stimulus or by the stimulus object denoted by that language stimulus -- either may be the original conditioned stimulus and the response may occur to the alternative through generalization. Should, then, a covert response that is evoked by a stimulus object for which there is an associated language stimulus qualify as a language response? The answer to this question can only come by exploring the consequences of an affirmative and a negative answer. It is here proposed to explore the consequences of the former alternative and to thereby provisionally define covert language behavior as follows: If it can be shown that a covert oral and a covert non-oral response are both evoked by a certain language stimulus, or by a non-language stimulus denoted by that language stimulus, and that both of those responses do not occur when other language or non-language stimuli are presented, then those responses are language responses.

The extensive attention that has been given to the hypothesis that there _is_ a unique subclass of covert behavior that is language in nature strongly suggests that we should continue to assess its implications. Should it eventually be determined that such a subclass is in fact empty, or that covert language behavior can more profitably be defined otherwise, then at least our confidence in lines of attack alternative to that suggested here will be increased.

Covert Behavior as the Referent of Hypothetical Constructs

We shall here consider the problem of establishing relationships between direct measures of covert responses and mediating responses (hypothetical constructs) that are indirectly studied.

For illustrative purposes, let us consider Underwood's (1965) analysis of implicit verbal responses. The presentation of a verbal unit, he says, produces a response which is "the act of perceiving" that unit; this directly resulting response to verbal material Underwood calls, following Bousfield, Whitmarsh and Danick (1958), a representational response (RR). The stimulus properties of the RR then evoke a second response, the implicit associative response (IAR). And the evidence for the IAR is impressive indeed (see also Wallace & Underwood, 1964).

Referring to Fig. 2, the presentation of a verbal unit (S_{L_1}) evokes a response pattern containing a covert oral response component (r_{O_1}). It is r_{O_1} that is, in all likelihood, the RR. Then the directly resulting covert oral response (r_{O_2}) would constitute Underwood's IAR. In this example, we could expect that both responses would qualify as language responses. The problem of distinguishing between the actual, direct measures of r_{O_1} (e.g., the RR) and r_{O_2} (e.g., the IAR) will no doubt require considerable laboratory agility, but we can have confidence that the increasing sensitivity of our empirical response measures will be equal to the task. The successful recording of covert empirical referents for our hypothetical constructs will, when achieved, constitute a major theoretical and empirical advance. The work of Grice (1965) is a step in this direction.

Concluding Statement

We might here content ourselves with the bare mention of several additional problems suggested by this analysis and attempted synthesis. First is the question of how to incorporate into Fig. 2 a concept of a response-produced stimulus and still remain at a strictly observational level. One answer might be to behaviorally control such an internal stimulus by manipulating the initiating covert response, as in Hefferline and Perera (1963), and to simultaneously employ electrophysiological techniques for its direct measurement. An immediately following question is whether or not consideration of non-behavioral, EEG, data might facilitate our understanding of covert responses. Here one can envisage the eventual development of a set of laws of the type: $r = f(S_L, \text{EEG})$. Finally, we can anticipate reasons why, in some instances, we might expect covert responses to fail to occur. A concept of inhibitory stimuli, as demonstrated by Hernandez-Peon, Scherrer & Jouvet (1956), may also be incorporated into the schema of Fig. 2 such that this type of efferent discharge prevents the occurrence of a given response.

These considerations emphasize that the field of covert behavior is indeed a complex one in which to develop order. The provisional framework developed here will no doubt require considerable modification in the light of additional data. But in the meantime it is hoped that it has value for incorporating other findings and for pointing out some fruitful directions for new research. The effort has been a frankly exploratory one, though a necessary first step.

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A Longitudinal Study of Covert Oral Behavior During Silent Reading[1]

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While the importance of covert behavior has long been recognized (cf., Langfeld, 1933), it was the early behaviorists (e.g., Watson, 1919) who placed the greatest emphasis on it. One consequence of their speculations was a number of impressive laboratory demonstrations that implicate the covert response in "thinking" (e.g., Jacobson, 1931; Max, 1935). However, in spite of the array of evidence that supports a response interpretation of thinking (cf., McGuigan, 1966), it must be granted that the theorizing of the early behaviorists is, even today, justified more on enthusiastic than on empirical grounds. The issue is yet to be decided, and the decision will be reached only as the result of continued study of the covert response in a variety of stimulating conditions.

Of the many different approaches to the study of covert behavior, one that is receiving increasing attention is that in which such behavior is recorded during "silent reading" (e.g., Edfeldt, 1960; Faaborg-Andersen & Edfeldt, 1958; McGuigan, Keller & Stanton, 1964); this is so, perhaps, because "silent speech during silent reading" has technological, in addition to theoretical, significance (McGuigan, et al, 1964). While these efforts to understand the function of covert oral behavior during silent reading have yielded a certain amount of basic data, we still lack a complete and accurate description of the phenomenon. One common observation is that covert oral behavior is quite pronounced for young children, but that this is not the case for adults. The importance of a decrease in amount of covert oral behavior as a function of increasing age is twofold: (1) educators generally assume that reading proficiency increases largely because "subvocalization drops out;" and (2) early behaviorists, in assuming that "implicit speech" is necessary for thinking, had to explain the occurrence of "thoughts" in adults who, to all appearances, did not subvocalize -- this was typically accomplished by postulating that we "abbreviate action... in silent talking or thinking... the implicit processes... (become) shortcircuited and economized..." (Watson, 1919, p. 323). Objective data for the assumption that covert oral behavior decreases as a function of age are, however, meager, and, where they do exist, they have been provided by cross sectional experimentation. The findings of McGuigan et al (1964), for instance, are that children increased the amplitude of lip EMG by 1.03 units when they went from resting to silent reading; college students, however, only increased their lip EMG amplitudes by .33 units (still a significant increase). The purpose of this investigation was to measure the amplitude of covert oral behavior to language stimuli (in this case, prose to be silently read) in the same children over a period of several years.

Method

Subjects

The Ss were children who were originally studied by McGuigan et al (1964) in 1963. Three groups were unsystematically formed from their samples: Group I consisted of six children from their Experiment I, and they were retested in 1965 and 1966; Group II was composed of three children from their Experiment I, and they were retested in 1966; Group III consisted of seven children from Experiment II who were retested in 1965 and 1966. The second and third testings occurred approximately two and three years after the first. The general design and mean ages of the children are presented in Table 1.

Procedure

The apparatus and procedures specified in McGuigan et al (1964) were used for all three testings. Briefly, electrodes were placed on the chin

(Groups I and II) or on the lips (Group III), the pneumograph was attached, and a sensitive microphone was hidden in front of the lips for the 1965 testing. The S was asked to relax for a one min. prereading (control) period, then to open his eyes and read a story for a maximum of one min.; after this he closed his eyes and rested until it was time to read the next story. The first story read was one standardized for his grade level. For succeeding reading periods, the grade level of the material was advanced until his ceiling was reached or until he had completed the twelfth grade level. Each S received fifty cents for his cooperation.

The chin and lip electromyograms (EMG) and pneumograms were, after amplification, recorded on a Honeywell 906 C Visicorder, and signals from the microphone were recorded on an Ampex 601 Tape Recorder. The techniques for quantification, previously reported in detail (McGuigan et al, 1964), may be briefly summarized as follows: five sec. intervals on the Visicorder records were measured for the prereading and for the reading periods (the postreading periods were ignored in 1965 and 1966 since, in 1963, they coincided closely to the values for the prereading periods). Then the maximum amplitude of the EMG during each five sec. period was measured in centimeters, and a mean computed for the prereading period and for the reading period for each S. Group means for the prereading and the reading periods were next computed. If a S's score was missing for any test, he was discarded; consequently all reported values are for the same Ss for all testing periods.

Results and Discussion

The mean maximum amplitudes of chin and lip EMG are presented in Table 1. There we can see that the amplitude of covert oral behavior is always higher during reading than during the prereading (rest) period, regardless of the mean age of the children. To quantitatively study amount of covert oral behavior during silent reading, the mean values during the prereading

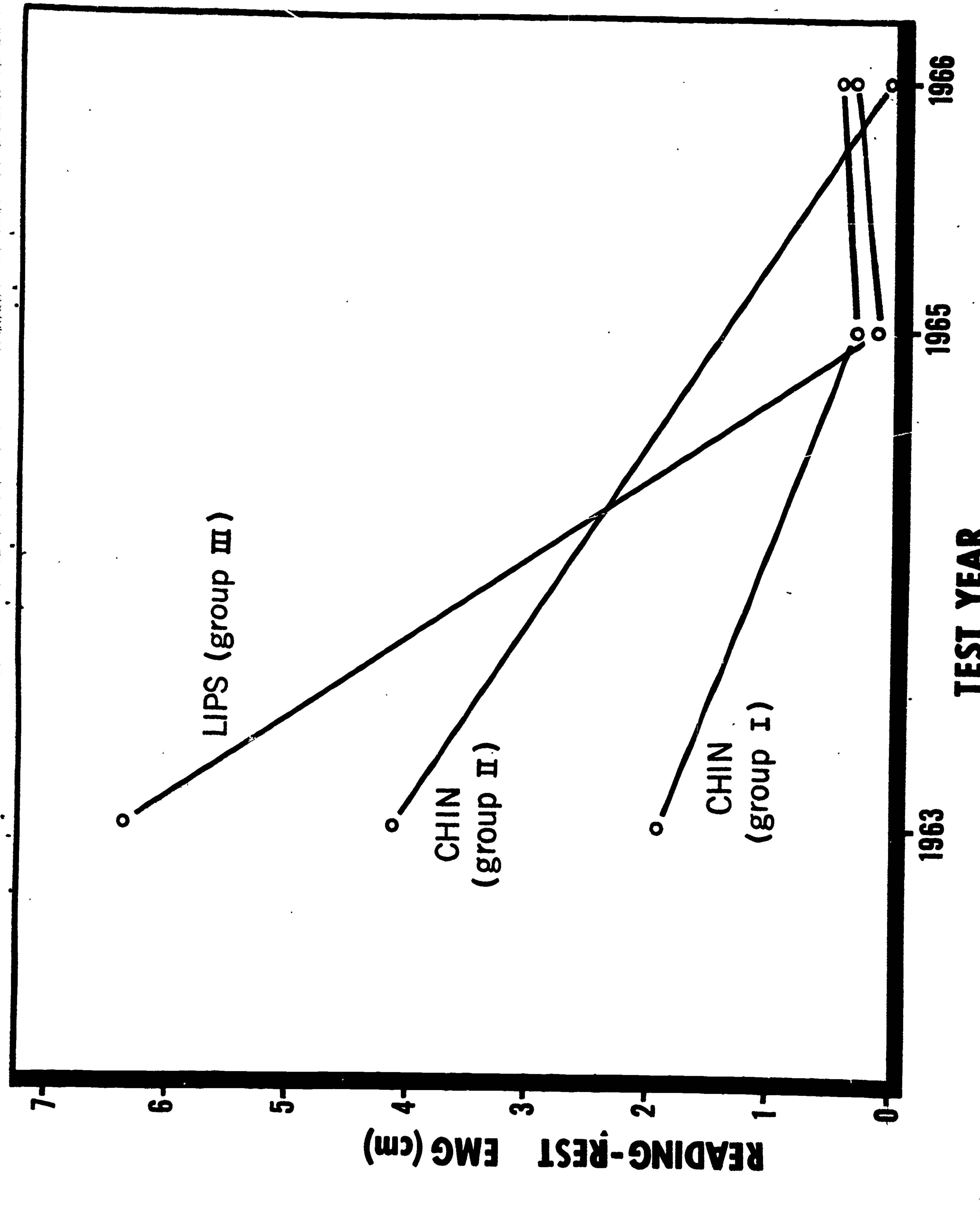
Table 1

Mean Maximum Amplitudes of Covert Oral Behavior (Centimeters) During Prereading and Reading Periods as a Function of Testing Period

			Test Year and Mean Age					
			1963 (10 yrs.)		1965 (12 yrs.)		1966 (13 yrs.)	
Group	Measure	n	Pre-reading	Reading	Pre-reading	Reading	Pre-reading	Reading
I	Chin EMG	6	3.56	5.47	1.22	1.50	2.75	3.21
II	Chin EMG	3	2.74	6.85	Not Tested		1.29	1.33
III	Lip EMG	7	5.84	12.18	1.97	2.10	2.71	3.07

Figure Caption

Fig. 1. Amount of covert oral behavior during silent reading over a three-year period. Vertical axis values are EMG differences between reading and rest.


LIPS (group III)
CHIN (group II)
CHIN (group I)
1963
1965
1966
TEST YEAR
0
1
2
3
4
5
6
7
READING-REST EMG (cm)

periods were subtracted from those during reading. The resulting differences are presented in Fig. 1 as a function of test year. The findings are consistent for all three groups -- the amplitude of the covert oral behavior markedly decreased from 1963 to the 1965 and 1966 testings regardless of whether the measure was lip or chin EMG.

Considering the 1963 testing first, the mean difference between pre-reading and reading for all three groups combined ($N = 16$) is 4.26 cm., a value that is significantly different from zero ($A = .155$, $P < .01$). In 1966 the mean difference is .34 cm.; this value is not significantly different from zero, but it is interesting to note that it is remarkably similar to that previously obtained for college students (i.e., .33 cm.) which, based on a larger number of Ss, was significant beyond the .01 level. To ascertain whether or not the decrease in level of responding from 1963 to 1966 was significant, the difference between the respective means for these years of 4.26 cm. and .34 cm. was tested; this difference is significant beyond the .01 level ($A = .168$). We may thus conclude that the Ss manifested a significantly large amount of covert oral behavior during silent reading in 1963, and that they significantly decreased their amplitude of responding within the next two years. This conclusion is further supported by the sound measures taken in 1963 and 1965, i.e., in 1963 the mean number of audible subvocalizations for the Ss from which the present groups were drawn was 1.53 and .43 (McGuigan et al, 1964). But not a single subvocalization was recorded in 1965.

One immediate methodological question concerns the effect of repeated testings on the measures taken. The fact that Group II, who was not studied during 1965, behaved in a manner similar to Groups I and III (who were tested three times) suggests that the effect is negligible. This conclusion is strengthened by noting the remarkable similarity, previously pointed out, between the last test results for the present Ss and those obtained for college students on their first exposure to the laboratory.

These findings, in short, document, by means of longitudinal methodology, the long-held assumption that covert oral behavior to language stimuli decreases in amplitude as children grow older.[3] Certainly, as Watson (1919) theorized, this important kind of behavior becomes "abbreviated," but the fact that it still occurs in adults (McGuigan et al, 1964) indicates that it does not vanish, become short-circuited, totally "recede into the central nervous system," or the like. The covert response remains, and thereby poses the most interesting problem of establishing its function in the receipt of language stimuli.

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Footnotes

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2. We especially thank William Ignatius Rodier III and Ronald D. Suiter for their help in conducting this research.

3. What happens to other measures over the years is an important and related question. Maximum amplitude of left arm EMG and breathing rate did not change significantly from the 1965 to the 1966 tests, but these measures were either not taken or there are insufficient data on them for the 1963 testing.

Covert Behavior as a Function of Type of Stimulus and Task

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Abstract

Increases in covert oral behavior during silent reading and listening have been reported in independent experiments, but there are apparently no comparable data under controlled conditions for other activities performed silently. To approach an understanding of the function of these covert oral responses it is proposed to compare a variety of response pattern changes as different kinds of stimuli and tasks are used in the same experiment. In this exploratory study Ss silently read, memorized or listened to a story, or they attentively listened to nothing or to music. Two experiments were conducted using a between and a within Ss design, respectively. Several methods of quantifying response measures were employed; it was found that the measures, as sampled, were reliable but that their intercorrelations were low. It was found that response measures were generally greatest for the memorization condition, followed in turn by the reading, nothing, listening to prose, and music conditions. Specific findings with regard to each measure (chin EMG, tongue EMG, arm EMG, breathing rate, and pulse rate) are reported, e.g., breathing rate significantly increased for all conditions, but it was significantly faster for the memorization and music conditions. It was suggested that the strategy employed here may eventually help to distinguish between response changes that are part of a state of general arousal and those that may be involved in the covert use of language.

Covert Behavior as a Function of Type of Stimulus and Task[1]

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There is ample evidence that electromyographic (EMG) activity of the speech muscles increases during silent reading (e.g., Edfeldt, 1960; McGuigan, Keller and Stanton, 1964) and during attentive listening to the auditory presentation of prose (e.g., Bartoshuk, 1956; Smith, Malmo and Shagass, 1954; and Wallerstein, 1954). The question entailed by such findings concerns the function of these covert responses. We know that when individuals change from a resting state to engage in various kinds of tasks in which language stimuli are presented they exhibit a heightened degree of general bodily activity. This arousal condition no doubt includes increases in covert oral behavior too, but are such increases in speech muscle EMG indicative of more than just a state of heightened arousal? For example, it has been argued that an _S_, when engaged in such activities, is making covert _language_ responses that are intimately related to his comprehension of the incoming stimuli, perhaps even necessary for such comprehension (cf., McGuigan, 1966). That there are numerous alternative interpretations of the covert behavior that occurs during "silent thinking" (e.g., Berlyne, 1965; Malmo, 1965) is indicative of the great need for basic data in this area. One approach that should facilitate our understanding of these covert oral responses is to simultaneously record a variety of events from different bodily regions as _S_s perform under different language and non-language task conditions. The resulting findings would, for instance, tell us something about the extent to which covert oral and non-oral responses change during silent reading and listening to prose relative to changes under other conditions, such as during memorization, listening to music or mere attentive listening to nothing. Eventually, perhaps, comparisons of response patterns as a function of the type of stimulus input and type of task in which S engages will establish the significance of this most interesting kind of behavior.

Method

Subjects and Designs. In Experiment I, 75 undergraduate female psychology students at Hollins College were randomly assigned to one of five groups. Each group silently engaged in one of the following activities: (1) reading a portion of Poe's *The Black Cat*; (2) listening to the story as presented on tape by Basil Rathbone; (3) memorizing a portion of the story; (4) listening to a selection of music from Vivaldi; or (5) listening to "nothing." For Experiment II, 40 Ss from the same population were all presented the same five conditions (repeated treatments), systematically randomized such that each condition occurred equally often for each order of presentation, and each S experienced each condition only once. The number of Ss available for each response measure is specified for Experiment I in Table 1; attrition was due primarily to apparatus failure, and the pulse and arm measures were added for only the final few Ss run.

Apparatus. Surface electrodes, for the EMG measures, led into two Tektronix 122 voltage preamplifiers placed in series for each channel, and thence to a Honeywell T6GA-600 Galvanometer Amplifier and to a Honeywell 906C Visicorder (voltage amplification = X 10,000; recording speed = 5 mm./sec.). Grass electrodes were used for chin and arm EMG (placement following Davis, no date) and specially constructed electrodes (held on by a vacuum source) were placed on the upper surface of the tongue approximately one in. from the tip, the pair being separated by approximately 3/4 in. Breathing activity was recorded by means of a bellows-type pneumograph which led to a Grass Model PT5A pressure transducer, to a Tektronix 122 preamplifier and finally to the Visicorder. The pulse transducer (Biocom), placed on the right index finger, led into a Tektronix 122 preamplifier, and recordings were made on the Visicorder. For Experiment II the three EMG measures were also recorded on three coordinated audio tape recorders.

Procedure. The S was seated comfortably in the subject room, she was assured that she was not going to be subjected to any discomfort, and the transducers were attached. Instructions were then given that the experiment involved thinking and listening and that close attention should be paid so that any information presented could later be recalled. Each S then relaxed for a one-min. prerest period during which time baseline measures were recorded. She then opened her eyes and engaged in one of the five activities for five min. The prose for the reading and memorization conditions were typed, double spaced, on white paper and placed on a reading stand in front of S. A tape recorder was used for the three listening conditions, i.e., story, music and nothing. For the nothing conditions, S listened to a blank tape with instructions to pay attention as she "may or may not hear something." For Experiment I only, the S closed her eyes and relaxed again at the conclusion of her activity period, thus rendering data during a postrest period.

Quantification of the Data. For Experiment I the EMG and breathing data were quantified as reported in McGuigan etal, 1964. Briefly, five sec. intervals were measured for the entire Visicorder record. The maximum amplitude of the EMG spikes in each five sec. period were measured in cm. and a mean of these values was obtained for the prerest, the postrest and each of five minutes of the activity periods. In addition, integrated values of the EMG measures were obtained for about half of the Ss (see Table 1), using an integrator modeled after that reported by Jacobson (1939). These integrated values were obtained for each one sec., approximately, the height of each trace was measured in cm., and averages were computed as above to obtain mean values for each of the seven periods. Pulse and breathing records were quantified as number per min., yielding rates for each.

The EMG measures for Experiment II were quantified as follows: the analog signal from the magnetic tape entered a Hewlett Packard 3400A RMS voltmeter, which gave out a DC level signal that could vary between 0 and -1 v. maximum; this value, which is proportional to the true RMS value of the input signal, was fed into a Hewlett Packard 3440A Digital Voltmeter that read the amplitude of the RMS signal instantaneously every five sec. The resulting amplitude was printed out on a Hewlett Packard 562A Digital Recorder, and mean values were computed for each S for the prerest and each of the five minutes of the activity periods. These values will be referred to as the sampled EMG amplitude. In addition, chin EMG was also quantified as follows: the output of the RMS voltmeter was fed into a Dymec 2210 Voltage Frequency Converter which converted the DC level to a proportional frequency. The output of the voltage to frequency converter, which could vary from 0 to 10,000 cps, was fed into a Hewlett Packard 5512A Electronic Counter which counted the frequency for each 10 sec. period. This frequency was then converted to a BCD signal that was printed out on the Digital Recorder. The result, thus, was an integrated RMS value of the wave form per unit time (10 sec.). In short, a mean value was obtained for each S for the prerest period and for each of five min. of activity for each measure.

Results

To study the effects of the five conditions on the several response measures, the mean value for the prerest period was subtracted from each of the other periods for each S. This yielded a mean change score for each min. of activity (and a similar difference between prerest and postrest for Experiment I) for each S. Group means for these five (or six) differences were then computed. The findings for each transducer placement will be discussed separately.

Fig. 1. Changes in Mean Maximum Amplitude of Chin EMG Spikes Throughout the Experimental Session for Each Condition (Experiment I). Changes for all Figures are Values During Activity Relative to Values During Resting.

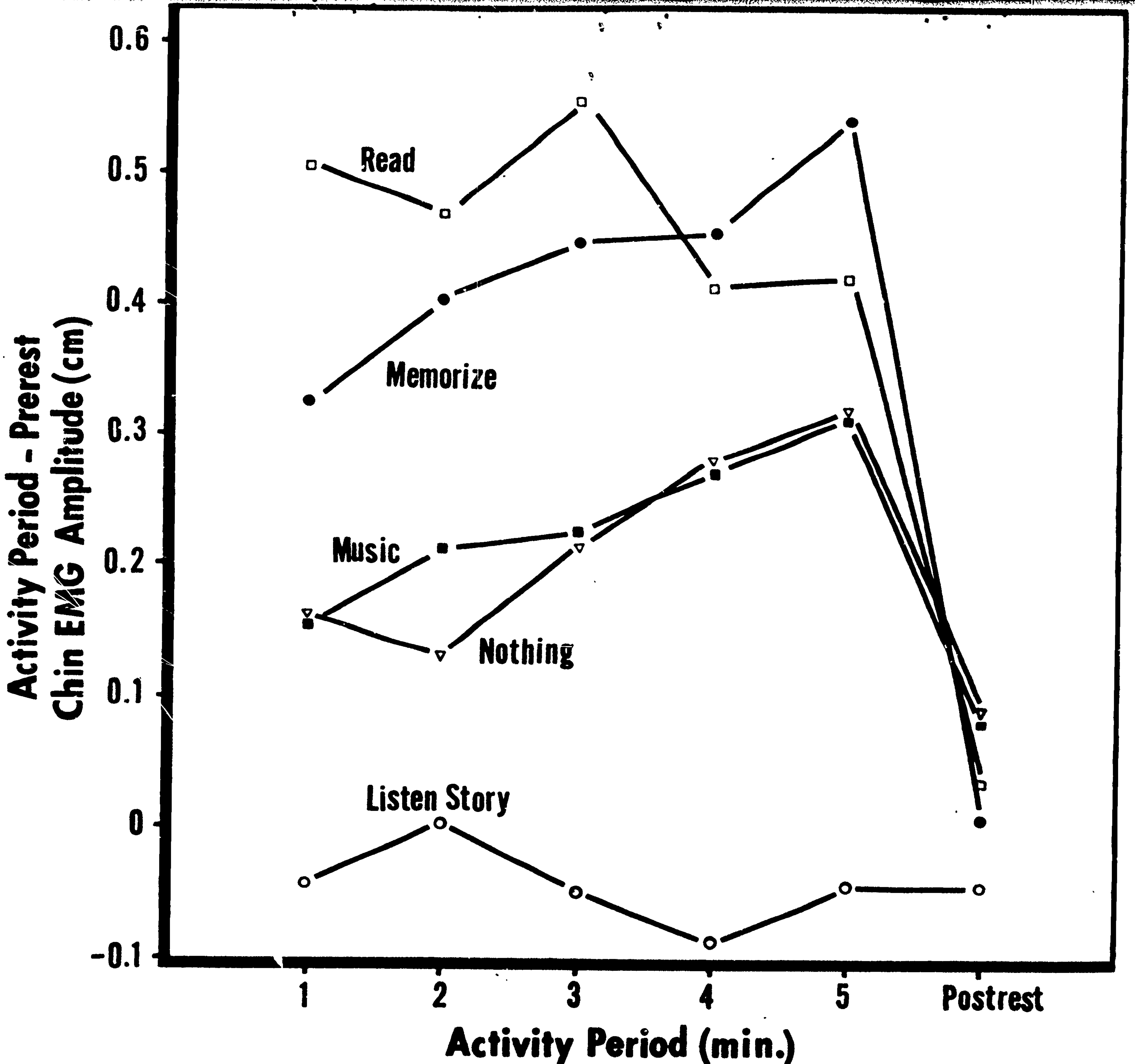

Read
Memorize
Music
Nothing
Listen Story
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
Activity Period - Prerest
Chin EMG Amplitude (cm)
1
2
3
4
5
Postrest
Activity Period (min.)

Table I

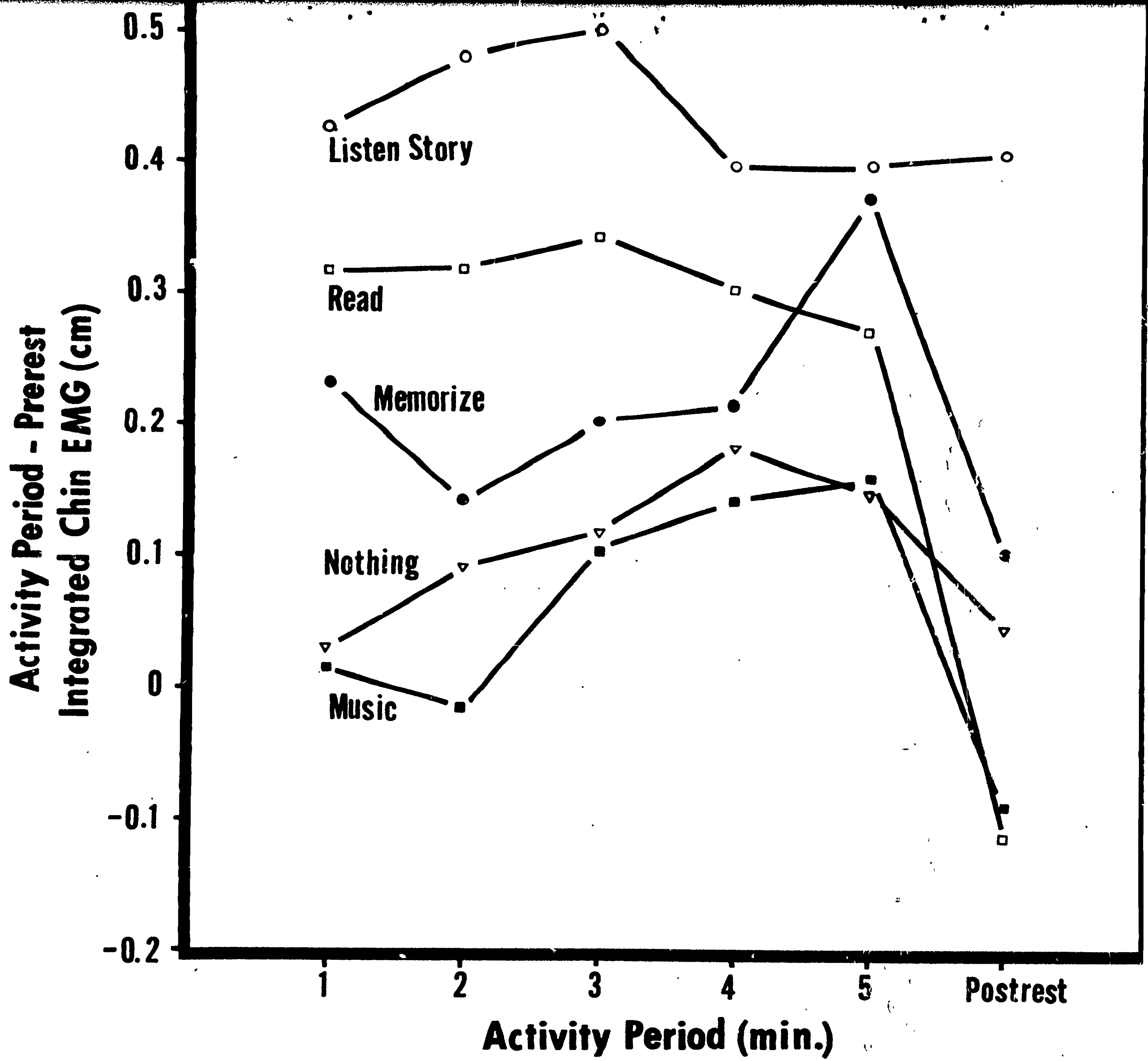
Mean Changes in Five Covert Response Measures for Five Conditions (Experiment I)

Condition

Measure		Reading	Memorize	Listen Story	Listen Nothing	Listen Music
Chin	$\bar{X}$	.47	.45	-.05	.22	.24
Amplitude	n	15	12	12	12	13
(cm.)	A	.133*	.343		.219*	.309
Chin	$\bar{X}$	.31	.23	.44	.11	.08
Integrated	n	8	7	7	8	6
(cm.)	A	.290	.62	.896	.525	.827
Breathing	$\bar{X}$	1.58	3.93	3.35	1.21	4.15
Rate	n	15	11	12	12	13
	A	.197*	.140*	.112*	.261*	.137*
Arm	$\bar{X}$	.18	.48	.03	-.04	.02
Amplitude (cm.)	n	6	4	4	4	6
Pulse	$\bar{X}$	.50	2.08	.31	.27	.08
Rate	n	2	2	4	3	4

*$P < .05$

Fig. 2. Changes in Mean Amplitude of Integrated Chin EMG Throughout the Experimental Session for Each Condition (Experiment I).


Listen Story
Read
Memorize
Nothing
Music
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
Activity Period - Prerest
Integrated Chin EMG (cm)
1
2
3
4
5
Postrest
Activity Period (min.)

Chin EMG. In Fig. 1 we can study the change in the mean maximum amplitude of chin EMG (Experiment I) as a function of time in the experimental condition (activity). The greatest increase during the first min., for example, occurred for the reading condition, followed in turn by memorization, nothing, music and listening to the story. The levels of activity for this measure can be similarly studied for the succeeding four min. of activity until the postrest period where values for the four conditions that are above zero fall dramatically.

Subtraction of the mean prerest value for each *S* from the mean of each of the five activity scores yielded five difference scores. The mean of these five difference scores was computed for each *S* and group means were then obtained (Table 1). Each group mean was then tested to determine whether it differed significantly from zero. Still looking at the maximum amplitude of chin EMG in Table 1, we can see that, by the *A* test, only the values for the reading and nothing condition significantly increased during the five min. of activity, relative to the prerest level.[3] The results of Duncan's Range Test, applied to test for significant differences between conditions, were as follows:

Listen Story	Nothing	Music	Memorize	Read
-.05	.22	.24	.45	.47

We may thus conclude that both the reading and memorization conditions led to higher mean maximum amplitude of chin EMG than did listening to a story, but that no other pairs of conditions differed significantly.

The curves for integrated chin EMG (Experiment I) are presented in Fig. 2, and the resulting group means are in Table 1. None of the means are significantly different from zero, though it may be noted that there was a reduced

Table 2

Mean Changes in Five Covert Response Measures for Five Conditions

(Experiment II)

Measure		Reading	Memorize	Listen Story	Listen Nothing	Listen Music
Sampled Chin	$\bar{X}$	.6	27.1	8.8	12.2	14.2
EMG (μv)	A	5.747	.205*	.559	.516	.146*
Integrated	$\bar{X}$	21.2	46.2	14.8	83.2	29.6
Chin EMG (μv)	A	1.403	.422	1.314	.134*	.606
Sampled	$\bar{X}$	32.3	68.9	18.5	18.4	6.9
Tongue EMG (μv)	A	.108*	.062*	.405	.194*	2.447
Breathing	$\bar{X}$	1.26	2.62	1.57	.80	1.88
Rate	A	.146*	.057*	.082*	.294	.052*
Sampled	$\bar{X}$	22.3	50.9	5.6	11.9	-13.9
Arm EMG(μv)	A	.155*	.129*	1.142	.302	.267

*$P < .05$

Note. The laboratory did not include equipment for calibrating amplitude of the EMG measures. Hence, the data reported here should be regarded only as approximations to the absolute values. Regardless, our interest is only in relative values, i.e., amount of change from rest to activity.

Fig. 3. Changes in Mean Sampled Amplitude of Chin EMG Throughout the Experimental Session for Each Condition (Experiment II).

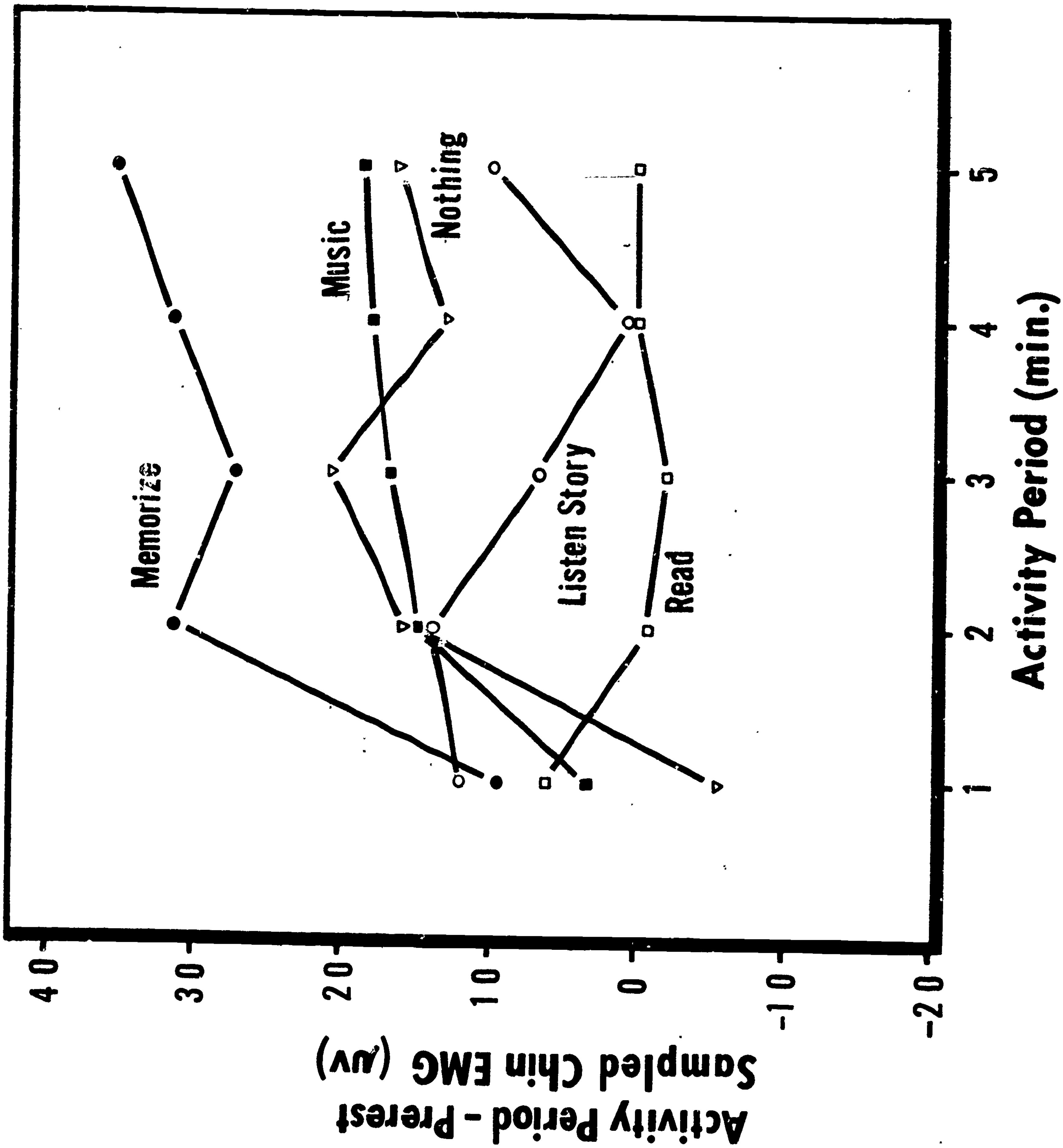

Memorize
Music
Nothing
Listen Story
Read
40
30
20
10
0
-10
-20
1
2
3
4
5
Activity Period (min.)
Activity Period - Prerest
Sampled Chin EMG (μv)

Fig. 4. Changes in Mean Amplitude of Integrated Chin EMG Throughout the Experimental Session for Each Condition (Experiment II).

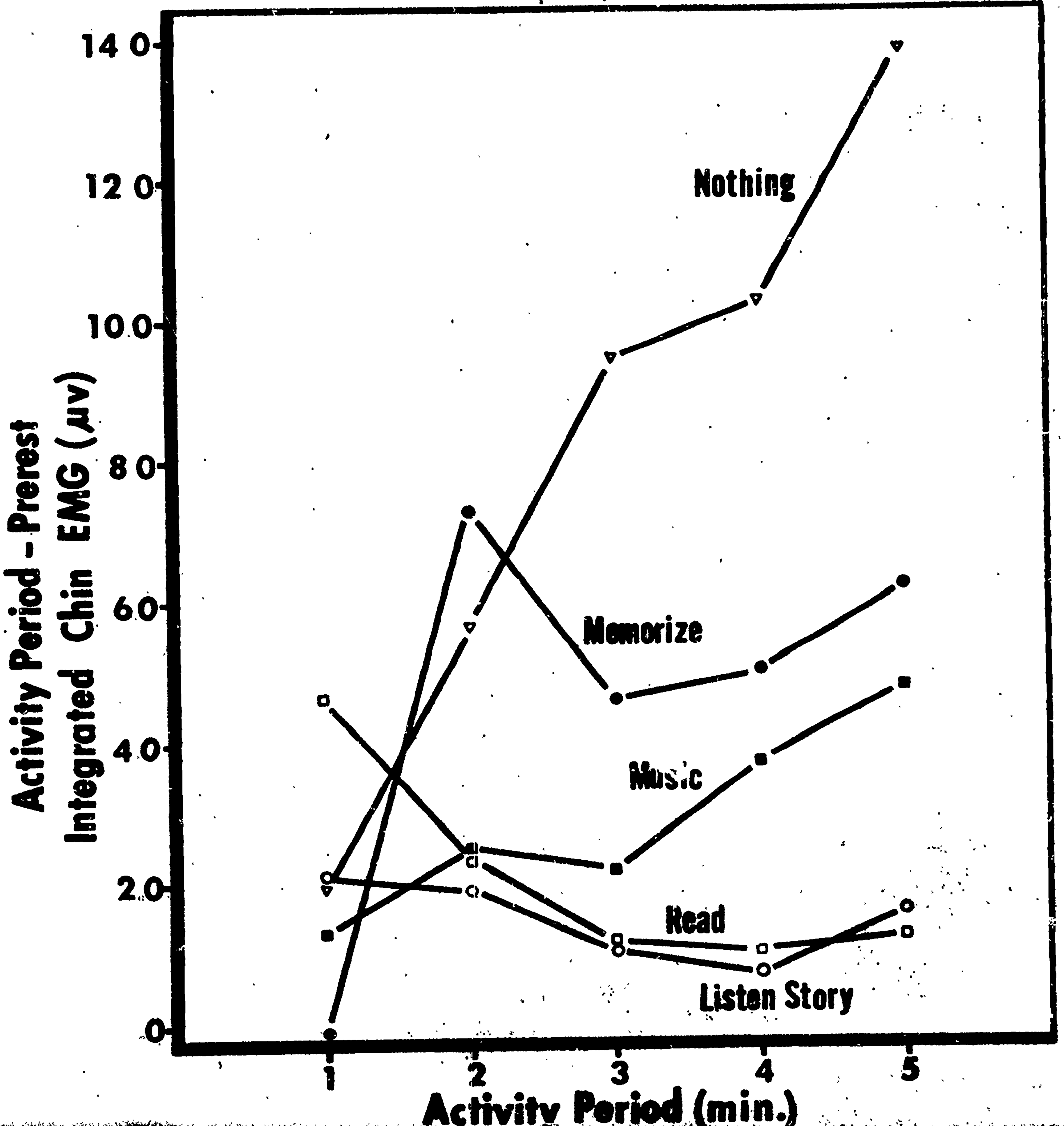

Activity Period - Prerest
Integrated Chin EMG (μv)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
Nothing
Memorize
Music
Read
Listen Story
1
2
3
4
5
Activity Period (min.)

Fig. 5. Changes in Mean Sampled Amplitude of Tongue EMG Throughout the Experimental Session for Each Condition (Experiment II).

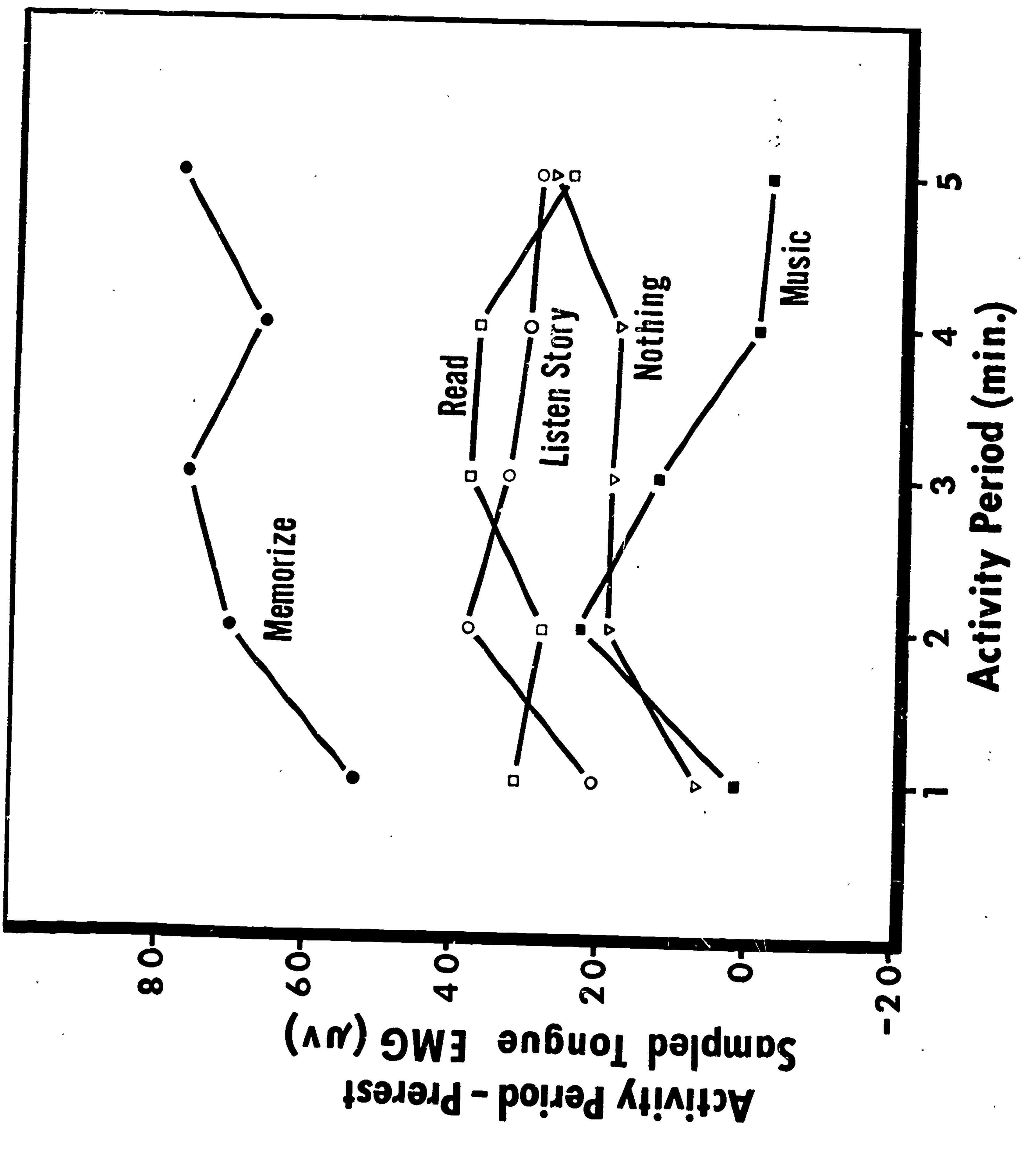

Activity Period - Prerest
Sampled Tongue EMG (μv)
80
60
40
20
0
-20
Memorize
Read
Listen Story
Nothing
Music
1
2
3
4
5
Activity Period (min.)

Fig. 6. Changes in Mean Breathing Rate Throughout the Experimental Session for Each Condition (Experiment I).

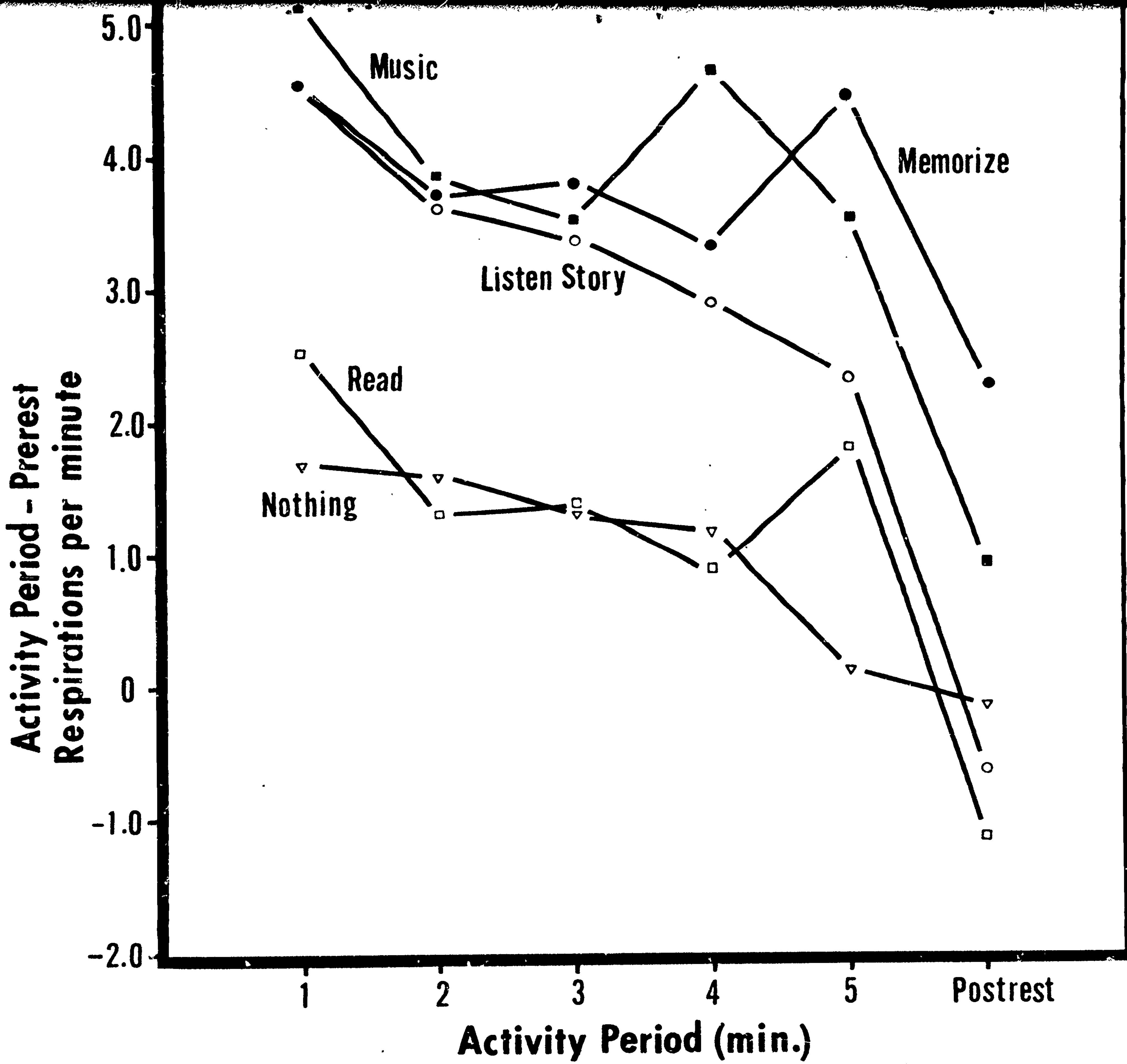
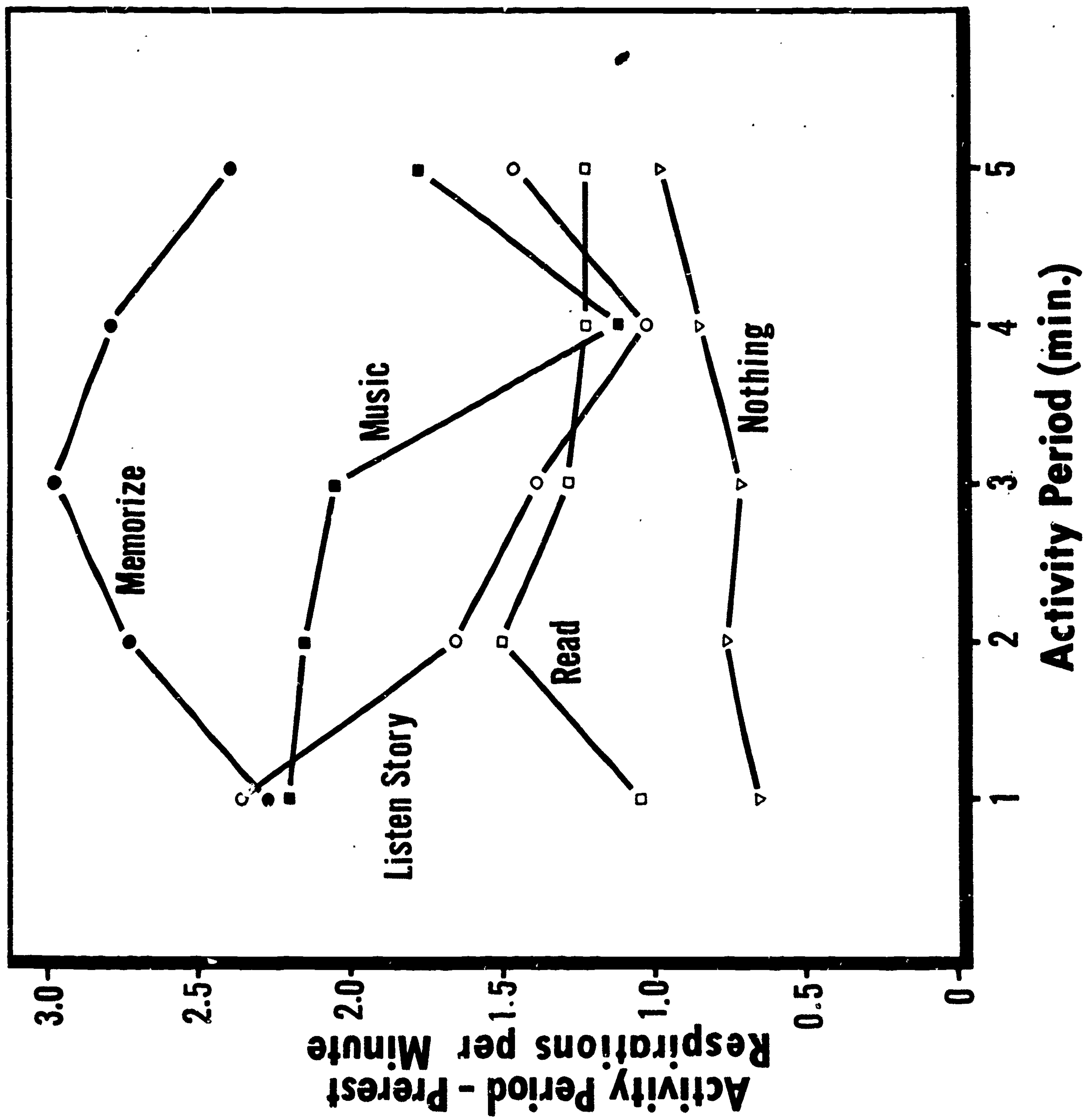

Music
Memorize
Listen Story
Read
Nothing
5.0
4.0
3.0
2.0
1.0
0
-1.0
-2.0
Activity Period - Prerest
Respirations per minute
1
2
3
4
5
Postrest
Activity Period (min.)

Fig. 7. Changes in Mean Breathing Rate Throughout the Experimental Session for Each Condition (Experiment II).


Memorize
Music
Listen Story
Read
Nothing
Activity Period (min.)
1
2
3
4
5
Activity Period - Prerest
Respirations per Minute
0
0.5
1.0
1.5
2.0
2.5
3.0

number of _Ss_ available for this measure. Similarly, a Duncan's Range Test indicates that there is no significant difference between any pair of conditions. These limited data are included only because of the interesting finding that, by this measure, the three conditions in which language stimuli were presented resulted in the higher response values.

Turning now to sampled chin EMG for Experiment II, we can study the curves for the five conditions in Fig. 3. The group means over the five min. of activity are presented for Experiment II in Table 2, where we can note that only the memorization and music conditions are significantly greater than zero. Paired _t_ tests were run between all possible pairs of conditions and, by this measure, the only significant difference occurred between the memorization and reading conditions ($t = 2.09$). These same data were also quantified using the integrated EMG measure for Experiment II. The resulting curves are presented in Fig. 4. Only the nothing condition was significantly different from zero, and there were no significant differences between groups.

Tongue EMG. The means of the sampled values for this measure are presented in Fig. 5 and summarized in Table 2. The means for the memorization, reading and nothing conditions are significantly greater than zero, and the memorization condition led to a significantly greater increase than all other conditions, no other pairs differing significantly (Memorization vs. listening to the story, $t = 3.11$; Memorization vs. music, $t = 4.18$; Memorization vs. reading, $t = 2.62$; Memorization vs. nothing, $t = 3.28$).

Respiration Rate. The changes in this measure as a function of time are presented in Fig. 6 (Experiment I) and summarized in Table 1. All conditions, it may be noted, led to significant increases.

The results of Duncan's Range Test on these means is as follows:

Nothing	Read	Listen Story	Memorize	Music
1.21	1.58	3.35	3.93	4.15

Fig. 8. Changes in Mean Maximum Amplitude of Arm EMG Spikes Throughout the Experimental Session for Each Condition (Experiment I).

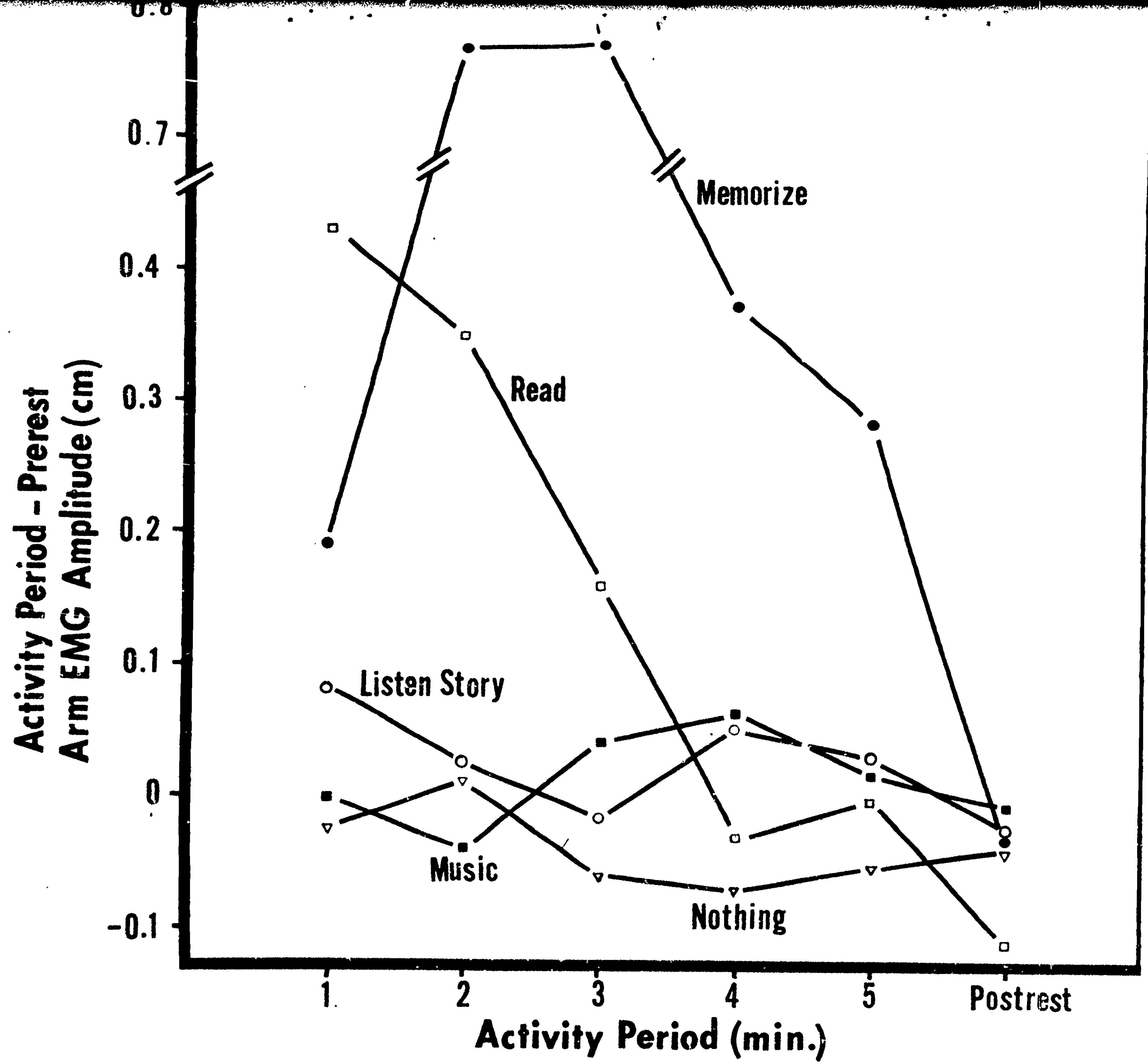

Activity Period - Prerest
Arm EMG Amplitude (cm)
0.8
0.7
0.4
0.3
0.2
0.1
0
-0.1
Memorize
Read
Listen Story
Music
Nothing
1
2
3
4
5
Postrest
Activity Period (min.)

Fig. 9. Changes in Mean Sampled Amplitude of Arm EMG Throughout the Experimental Session for Each Condition (Experiment II).

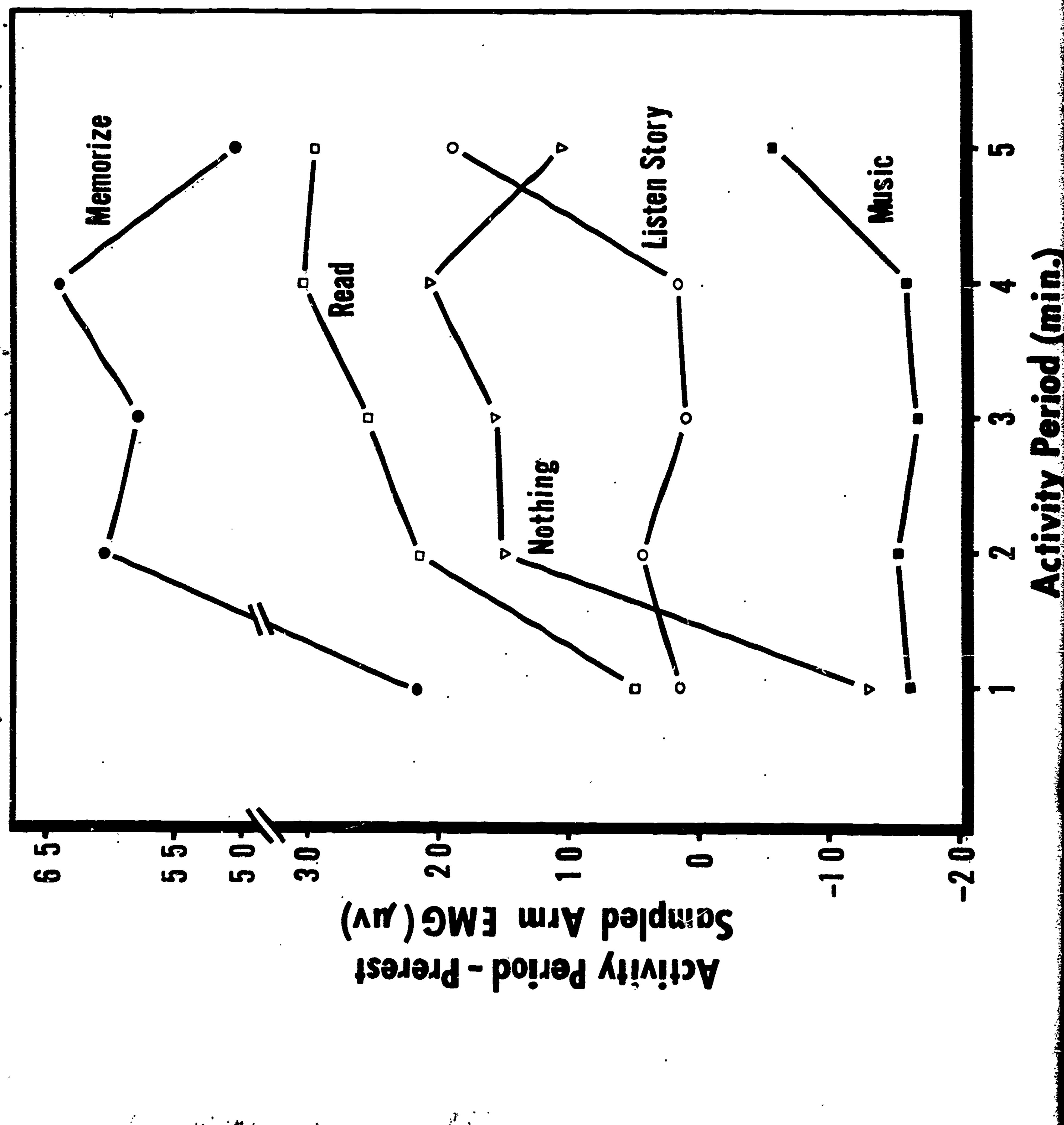
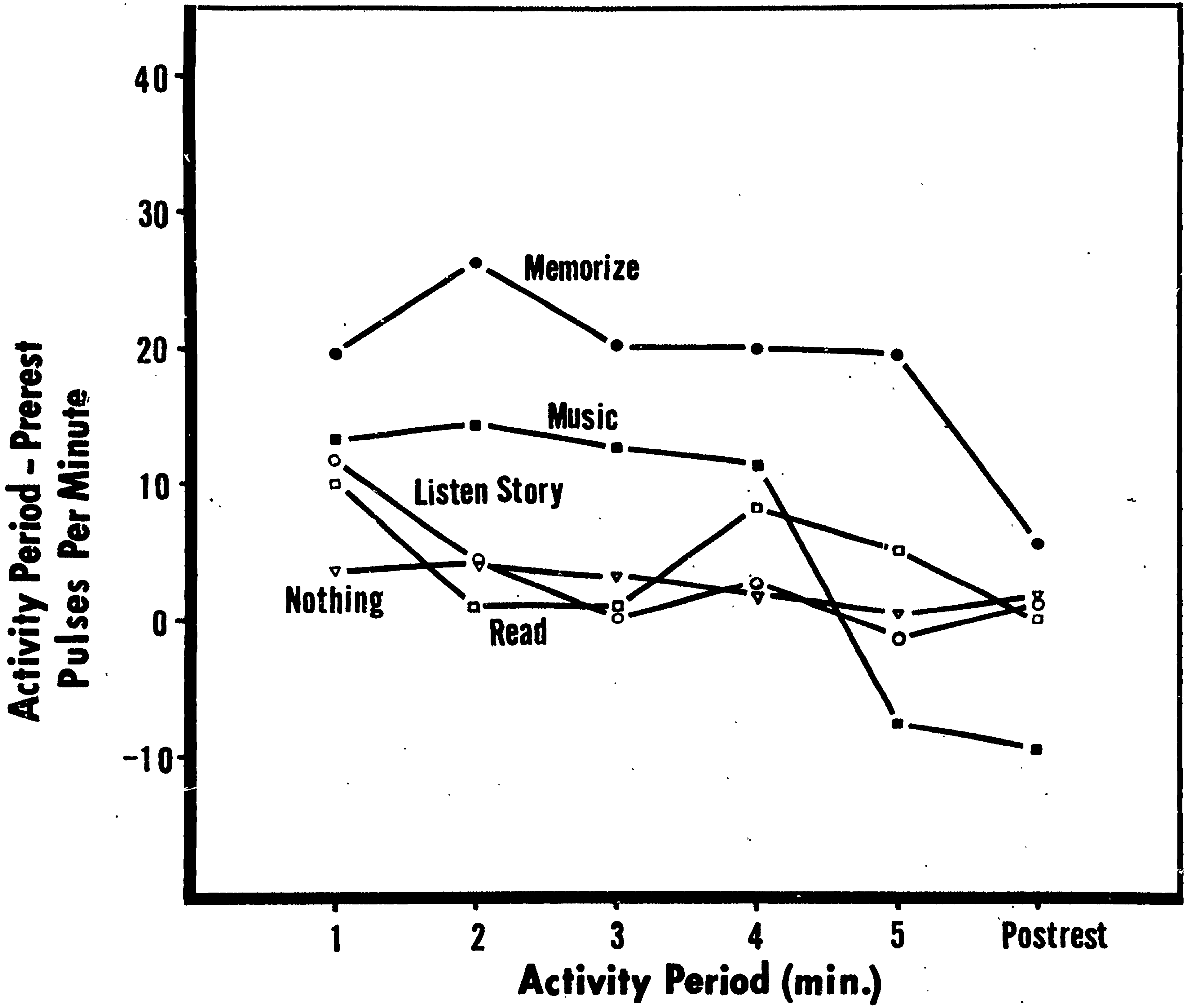

Memorize
Read
Nothing
Listen Story
Music
1
2
3
4
5
Activity Period (min.)
65
55
50
30
20
10
0
-10
-20
Activity Period - Prerest
Sampled Arm EMG (μv)

Fig. 10. Changes in Mean Pulse Rate Throughout the Experimental Session for Each Condition (Experiment I).


Memorize
Music
Listen Story
Nothing
Read
40
30
20
10
0
-10
Activity Period - Prerest
Pulses Per Minute
1
2
3
4
5
Postrest
Activity Period (min.)

The increase in breathing rate is thus significantly greater for both the music and the memorization conditions than it is for the reading and nothing conditions. No other pairs of means differ significantly.

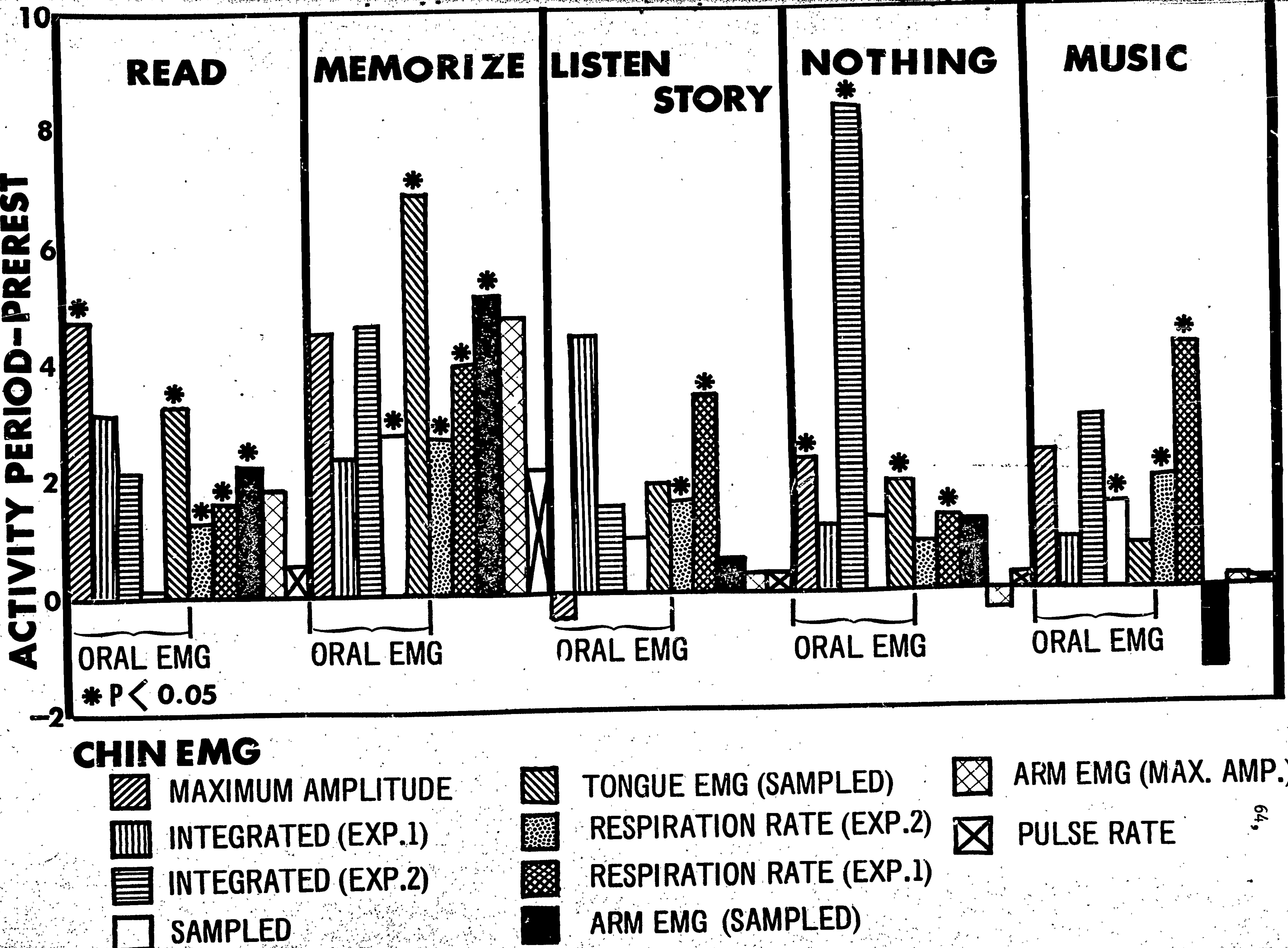
Strikingly similar results, as far as group means are concerned, were obtained in Experiment II (Fig. 7 and Table 2). All conditions led to a significant increase in this measure, with the exception of the nothing condition that would have been significant beyond the .07 level. The increase due to the memorization condition was significantly greater than for all other conditions except the music condition (Memorization vs. listen to story, $t = 2.86$; Memorization vs. reading, $t = 2.63$; Memorization vs. nothing, $t = 3.03$). The music condition led to a significantly greater increase than the nothing condition ($t = 2.37$), no other differences being significant.

Arm EMG. The curves for the mean maximum amplitude for this measure based on very few Ss of Experiment I, are presented in Fig. 8. Comparable curves for sampled EMG (Experiment II), are shown in Fig. 9; Table 2 shows that only the memorization and reading conditions led to significant increases above the prerest level. t-tests indicate that all conditions are significantly higher than the music condition (music vs. listen to story, $t = 2.70$; Music vs. nothing, $t = 2.62$; Music vs. reading, $t = 3.67$; and Music vs. memorization, $t = 3.29$). Furthermore, the memorization condition was significantly higher than all other conditions except reading (Memorization vs. nothing, $t = 2.25$; memorization vs. listen to story, $t = 2.94$). No other pairs differed significantly.

Pulse Rate. The curves for this measure, taken on very few Ss of Experiment I, are presented in Fig. 10. Again, it is interesting to note that the memorization is the highest.

Response Reliability. Because of the exploratory nature of this research, we have studied a variety of responses that were quantified in several different ways. By thus examining different response measures we should eventually be able to select those quantification techniques that lead to the most lawful stimulus-response relationships. In recognizing that the results within and between the two experiments were, on occasion, inconsistent, we can well ask about the reliability of the several response measures. Correlations of the measures using the raw data of Experiment I indicate that the measures are reliable, but that their intercorrelations are low. For example, the mean of the correlations between each minute of activity were as follows: chin amplitude, r = .89; chin integrated, r = .99; breathing rate, r = .80; and pulse rate, r = .99. On the other hand, the mean of the intercorrelations between each minute of activity for different response measures yielded the following: between chin integrated and chin amplitude, r = .04; between chin amplitude and breathing rate, r = -.08; between chin integrated and breathing rate, r = -.24; between chin amplitude and arm amplitude, r = -.01; and between breathing rate and arm amplitude, r = .15. Similar values were obtained by correlating the prerest period with the postrest period, and the prerest period with the five activity periods. Hence, the apparent inconsistencies may actually be due to the fact that different events are being measured, but this possibility can only be confirmed by further research. In the meantime, we can note that there are a number of other factors that require consideration. For example, a within subjects design was employed in Experiment I, while a between subjects design was used in Experiment II; or that the use of audio tape recorders in Experiment II did not allow recording of low frequency spikes (below 30 cps or so), while they were quantified in Experiment I.

Fig. 11. Mean Response Pattern Changes for All Measures for All Conditions. Values Read On the Vertical Axis Should be Modified as Follows: For EMG Measures for Experiment I a Decimal is Understood Before the Numbers: For EMG Measures for Experiment II, a Zero is Understood After the Numbers (See Tables 1 and 2).


READ
MEMORIZE
LISTEN STORY
NOTHING
MUSIC
ACTIVITY PERIOD-PREREST
10
8
6
4
2
0
-2
ORAL EMG
ORAL EMG
ORAL EMG
ORAL EMG
ORAL EMG
* P < 0.05
CHIN EMG
MAXIMUM AMPLITUDE
INTEGRATED (EXP.1)
INTEGRATED (EXP.2)
SAMPLED
TONGUE EMG (SAMPLED)
RESPIRATION RATE (EXP.2)
RESPIRATION RATE (EXP.1)
ARM EMG (SAMPLED)
ARM EMG (MAX. AMP.)
PULSE RATE

Discussion

The results have been presented with two general questions in mind: (1) Which conditions led to significant changes in which response measures? and (2) Which response measures differentially changed as a function of experimental condition? To consider these questions we can observe a summary of the findings, obtained by plotting the means of Tables 1 and 2, in Fig. 11. The general impression, substantiated by the results of the various statistical tests presented in the preceding section, is that individuals are generally the most active (covertly) under the memorization condition. In particular, the memorization condition generally led to the highest amplitude of oral EMG, to the greatest increase in respiration rate, (with the possible exception of that for music) to the highest amplitude of arm EMG, and to the greatest increase in pulse rate. The next most active conditions, considering all measures, were the reading and the nothing conditions, while the two listening conditions in which prose or music were presented led to the relatively most relaxed behavior.[4] Still, it is interesting to observe that all conditions generally led to increases in covert responding.

The only measure that increased significantly for all conditions was that for breathing rate. That the rank orders for the means for this measure are so consistent in the two experiments deserves comment: memorization and music led to greater increases than did listening to the story, with the reading and nothing conditions leading to the smallest increases. This finding, viewed along with the general response patterns (Fig. 11), again indicates that the Ss were in a heightened state of activation for the memorization condition, but the same cannot be said for the music condition -- that people increase their breathing rate when listening to music is a unique phenomenon among the response measures. We are left with the question of why listening to music affects breathing rate when the other response measures change so little.

That arm EMG increased to the greatest extent for the memorization and reading conditions again suggests that the Ss were relatively the most active when engaged in these activities. To understand the reason for the increase here one would like comparative data from some other non-oral portion of the body, such as from the leg. The fact that the arms and hands are used so often when people speak (even the left arm, as here sampled) leaves open the possibility that these covert responses were language in nature, and not just an index of general bodily arousal.

The difficulty of distinguishing language responses from general arousal responses becomes even more apparent when we turn to the several measures of oral activity. Oral EMG generally increased for all conditions, and at least to some extent these increases must be accounted for in terms of heightened general bodily activity. Here we can again observe that the greatest general increase was for the memorization condition, followed in turn by the reading and the nothing conditions. That the Ss who engaged in silent reading generally increased their level of oral responding is consistent with previous findings (e.g., Edfeldt, 1960; McGuigan, et al, 1964). But when we view this increase along with similar increases for other conditions, we are left with the question of the extent to which these responses are unique to activities like reading and memorization. That is, is the relatively large increase in covert oral behavior during memorization and reading an indication that these responses are language in nature? If so, one might expect similar noticeable increases during the other conditions in which language stimuli were presented, but there is relatively little increase when Ss listen to a story, a finding that is at first glance inconsistent with the results reported by others (Bartoshuk, 1956; Smith et al, 1954; Wallerstein, 1954). Perhaps this apparent inconsistency will be resolved by further experimentation under more refined conditions in which the modest increases in oral behavior when Ss listen to a story would turn out to be significant. In this case, the music condition, in which no language stimuli are presented, might serve as something of a baseline -- the increases due to listening to music could be an approximation of the extent to which oral EMG increases are part of the state of general arousal. But we would still have to face the question of why the most interesting increases for the nothing condition? Note here that the curves for this condition all start off in the first activity period at a low level, but that they all show a consistent increase throughout the remaining four minutes of activity (Figs. 1-5); the increasing gradient is especially remarkable in Fig. 4.[5] Do Ss under this condition become increasingly tense and expectant? Or do they start to wander from their task and engage in self stimulated covert oral activity that is perhaps language in nature ("thinking of other things?").

Our considerations to this point suggest that we can provisionally classify the increases in responding into two classes: (1) measures that change regardless of the experimental condition. These measures can be considered an index of a heightened state of activity that occurs when a person is alerted and instructed to "pay attention". (2) response changes that are unique to a given experimental condition or some combination of experimental conditions -- this class is more complex and potentially consists of at least two subclasses: (a) those response changes that are measures of general activity, but they indicate that a person is more active under some conditions than under others; and (b) those response changes that are uniquely evoked by the kind (class) of stimulus that impinges on the person.

Breathing rate increase is the only measure taken here that belongs to class 1. It also belongs to class 2a. Other members of class 2a are arm EMG, oral EMG and perhaps pulse rate, for all four of these measures are, in general, greater for memorization than for the other conditions. The question is which of these measures also belong to class 2b, for these are not mutually exclusive categories. It is reasonable to assume that some covert responses have become naturally conditioned to various kinds of stimuli; some responses, for instance, should be expected to be evoked by language stimuli and some by non-language stimuli. Because individuals in the same culture have had common conditioning histories we can expect language stimuli to evoke some covert responses especially of an oral kind. If covert language responses are to be identified, they would fall within class 2b.

In short, our provisional interpretation of these findings is as follows: Ss exhibited a state of general arousal for all conditions (increased breathing and pulse rates). The arousal was greatest for the memorization condition, followed in turn by the reading, nothing, listening to a story, and music conditions. The relatively greater increase in oral and arm EMG for the memorization and reading conditions allows us to investigate these responses further in an effort to identify language behavior, responses that are uniquely evoked by language stimuli.

At this point it may be advantageous to ask just what it means when we say, for instance, that the increase in amplitude of tongue EMG is greatest for the memorization condition. The answer apparently is that, since muscle cells obey the all or none law, any such cell does not increase its amplitude of responding but rather that more cells are contracting more frequently for this condition than for others. The indication is that the entire body is more active for memorization than for the other conditions, but the fact that the muscle cells used for oral activity are firing at a greater rate and/or in greater number is one point of especial interest. For these are the ones that one would expect to most prominently be involved in covert language behavior.

The general strategy initiated in this study may be expected, at least eventually, to dissect out those responses that are language in nature from those that merely occur because of a heightened state of alertness. To accomplish this we need to record a greater variety of covert oral and non-oral responses to a greater variety of stimulation and task conditions.

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Footnotes

1. The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program.

2. We wish to especially thank William I. Rodier, III, Carole Dickenson, Lindsay Ogle, Ailleen Lewisohn for their contributions to this research.

3. α was set at .05 throughout, though many of the results reported here would have been significant at the .01 or at the .001 level, had these levels been preselected.

4. This rank order was also established in two other ways. While it is not strictly speaking legitimate to pool scores from the different measures, rank scores were computed for each measure and combined. Similarly, a mean of standardized scores was also computed. In both cases, the ranks are as specified and clearly indicate what is apparent by close scrutiny of Fig. 1, viz, that the Ss under the memorization condition were by far the most active.

5. The interest of Malmo (1965) and his associates in increasing gradients as a function of activity period deserves comment here. With the exception of the tongue EMG for the music condition, there is a clear increasing gradient (Figs. 1 - 5) for all five measures of oral activity for the memorization, music and listening conditions; but there is no such clearly defined gradient for any of these measures for the listening to a story or for the reading condition. Furthermore, with one exception, none of the conditions produced an increasing gradient for breathing rate (Figs. 6 and 7) nor for pulse rate (Fig. 10). The increasing gradients of arm EMG for all five conditions of Experiment II stand in contrast to the results for Experiment I; this is perhaps due to differences in measurement techniques or in designs, as previously discussed.

Effects of Auditory Stimulation on Covert Oral Behavior During Silent Reading

F. J. McGuigan and William I. Rodier, III

Abstract

This was an effort to advance our understanding of the function of the covert response by adding to our identification of stimulus and organismic variables with which amplitude and kind of covert behavior varies. In this research, covert behavior during silent reading was studied as a function of several classes of auditory stimuli. Two experiments (N = 45 and 36, respectively) were conducted in which all Ss were presented all conditions in a counterbalanced order. In Experiment I, the Ss listened to auditorily presented prose, to backward prose and to nothing; then they silently read while these three conditions of auditory stimulation continued. The same procedure was followed for Experiment II, except that white noise was substituted for backward prose. The findings, in general, included the following: (a) covert oral behavior (chin and tongue electromyograms -- EMG) and breathing rate significantly increased while reading under all conditions for auditory stimulation; (b) covert oral behavior and breathing rate were significantly greater while reading during auditory stimulation than during auditory stimulation alone; (c) auditory stimulation during reading, regardless of whether it is prose, backward prose or noise, led to significantly faster breathing rate than occurs while reading during silence; (d) auditory presentation of prose and of backward prose during reading leads to a significantly greater amplitude of covert oral behavior than occurs while reading during silence, but noise apparently does not have this effect; (e) the above statements are apparently not true for a measure of covert non-oral behavior (arm EMG). It thus seems likely that the increases in amplitude of covert oral behavior are

beneficial, in some way, to the Ss; it may be that they facilitate the reception and/or processing of language stimuli (prose being read) in the presence of interfering auditory stimuli; or it may be that Ss are simultaneously responding to language stimuli that are being visually and auditorily presented.

Effects of Auditory Stimulation on Covert Oral Behavior During Silent Reading[1]

F. J. McGuigan and William I. Rodier[2]

Hollins College

There is ample evidence that individuals emit covert oral responses to a wide variety of stimuli and while engaged in a number of different tasks, but the function of these responses is the source of some controversy (cf., McGuigan, 1966). One task in which an increase in covert oral behavior has been particularly well documented is silent reading (e.g., Edfeldt, 1960; Hardyck, Petrinovich & Ellsworth, 1966; McGuigan, Keller & Stanton, 1964). Similar response changes have also been demonstrated during attentive listening to the auditory presentation of prose (Bartoshuk, 1956; Smith, Malmo & Shagass, 1954; Wallerstein, 1954). Edfeldt (1960) has shown that the amplitude of covert oral behavior during silent reading increases as the difficulty and "blurriness" of the prose being read increases. Morgan (1916) concluded that breathing changes (an index of articulation) occurred when such auditory stimuli as music, prose or a bell were presented during the performance of a complex "mental" task. Such findings suggest that the amplitude of covert oral behavior during the performance of one task, such as silent reading, can be increased by the simultaneous presentation of other stimuli. It was, therefore, the purpose of this research to systematically introduce several kinds of auditory stimuli during silent reading and to study the effects on several measures of covert behavior. Continuous experimentation of this kind should increase our understanding of this response class by establishing the stimulus and organismic variables with which amplitude and kind of covert behavior varies.

Method

<u>Subjects</u>. Forty-five women students from undergraduate psychology classes

at Hollins College were used for Experiment I and 36 served as Ss for Experiment II.

Apparatus. The laboratory includes two adjacent, sound deadened rooms, one for the Ss and the other for E and the recording equipment. A double plate glass window between the rooms allows observation of the Ss by E. Grass disc electrodes were used to pick up electromyograms (EMG) from the left forearm and from the chin following the placements of Davis (no date), and specially constructed vacuum type electrodes were positioned about one in. from the tip of the tongue separated by about 3/4 in. Each set of electrodes led into two Tektronix Type 122 low level preamplifiers placed in series (amplification X10,000) and recordings were made on a Honeywell 906c 12-channel Visicorder running at a paper speed of 5 mm.per sec. Pneumograms were recorded by means of a bellows-type pneumograph placed about the chest and abdomen which led to a Grass PT5A Volumetric Pressure Transducer and thence to a Tektronix 122 amplifier and to the Visicorder. For Experiment II, the three EMG signals were also recorded on three coordinated audio tape recorders.

Procedure. Each S was first introduced to the experimental situation with assurances that she would in no way be harmed. The transducers were then attached and the Ss were told: 1) that they would read silently and 2) that auditory stimuli would be introduced during the session.

The reading material consisted of three sections from Bronstein, Krikian and Wiener (1947) entitled "Religion and Theism," "Religion and Pantheism," and "Religion and Materialism," typed on white 11 in. x 8 in. paper, double spaced, and presented on reading stands, resting on a table, placed at a comfortable reading distance. Instructions and listening materials were auditorally presented by means of a tape recorder, the sound stimuli consisting of a portion of Peter Ustinov's "The Loser" (which describes the hero's near escape from an auto wreck and his later reflections on life) and white noise. The Ss first relaxed for a three min. pre-control (resting) period, during which time baseline measures were obtained. Following this one of three stimulus conditions was presented during Experiment I:

Silence: Listening for 1.5 min. to blank tape run on the tape recorder; the Ss then read for two min. during which time the blank tape continued.

Prose: Listening for 1.5 min. to "The Loser" presented by the tape recorder; the Ss then read for two min. while the prose from the tape recorder continued.

Backward Prose: Listening for 1.5 min. to "The Loser" played backwards; then the Ss then read for two min. while the backward prose continued.

At the conclusion of one of the above stimulus conditions, S relaxed for 30 sec. of silence following which a second of the above stimulus conditions was presented. On conclusion of a second stimulus condition, S rested for 30 sec. and then the third stimulus condition was presented. The order of presenting the three stimulus conditions was such that each condition was presented equally often at each stage of practice; order of the three reading selections was similarly (and independently) counterbalanced. The results of a pilot study indicated that there was essentially no difference in amount of transfer from any one condition to any other condition. After each S had been presented all three stimulus conditions, a one min. rest (post-control) period was instituted and the session was concluded by tests to insure that all channels were properly functioning. The same procedure was followed for Experiment II except that a tape of white noise was substituted for the Backward Prose condition.

Quantification of the Data. The Visicorder records were quantified for Experiment I essentially as previously reported (McGuigan et al, 1964). Briefly, 30 sec. periods were specified at the end of the pre-control period, at the end of the auditory stimuli-only periods, during the last of the first minute of reading, and during the last of the second minute of reading. All of these 30 sec. periods were then divided into five sec. sub-periods. The maximum amplitudes of the arm, chin and tongue EMGs were measured for each five sec. sub-period in cm. of galvanometer deflection and a mean was computed for each 30 sec. period for each S.

The EMG measures were quantified in Experiment II as follows: the analog signal from the magnetic tape entered a Hewlett Packard 3400A RMS voltmeter, which emits a DC level signal that can vary between 0 and -1 v. maximum; this value, which is proportional to the true RMS value of the input signal, was fed into a Dymec 2210 voltage to frequency converter which converted the DC level signal to a proportional frequency. This output, which could vary between 0 and 10,000 cps was fed into a Hewlett Packard 5512A electronic counter which counted the frequency for each 10 sec. period. The resulting value was converted to a BCD signal and printed out on a Hewlett Packard 562A digital recorder. The result is a mean integrated value (μv) for each 10 sec. and mean values were computed for each S for each 30 sec. period, as for Experiment I.[3]

Results and Discussion

To ascertain response changes as a function of the various conditions of auditory stimulation, the mean value of each measure during the resting period was subtracted from the corresponding value during each listening condition for each S. Group means were then computed and tested (by the A test) to determine whether they were significantly different from zero. The results for both experiments are presented in Table 1. There is a suggestion that breathing rate and the two measures of covert oral behavior (tongue and chin EMG) generally increased during auditory stimulation (Backward Prose, Prose and Noise) compared to the mean values during silence, but this is not the

Table 1

Mean Response Changes During Listening Conditions Relative to Rest

Condition	Response Measure			
Experiment I	Chin EMG	Tongue EMG	Arm EMG	Breathing Rate
Silence	.09	-.10	.02	-.21
Backward Prose	.08	.13	.06	.26
Prose	.10*	.09	-.06	.14
Experiment II				
Silence	19.68	-8.76	-15.24	-.05
Noise	63.33	28.50	-30.00	.46
Prose	31.08	31.26	.66	.88*

*$P < .05$

case for the measure of covert non-oral behavior (arm EMG). The increase during the presentation of prose was significant ($\alpha = .05$) for chin EMG during Experiment I and for breathing rate during Experiment II. Previous findings of increases in covert oral behavior during attentive listening to prose (Bartoshuk, 1956; Smith et al, 1954; and Wallerstein, 1954) thus receive some limited support. But the inclusion of control stimuli (backward prose and noise) in the present study indicates that the problem is a complex one: while it may well be that language stimuli evoke a larger amplitude of covert oral behavior than do non-language stimuli, such a conclusion must be based on the resul's of future research.

To study response changes while reading during the various conditions of auditory stimulation, mean resting values were subtracted from mean reading values for each S, as above. The resulting group means are presented in Table 2 for the first and the second minutes of reading. We can note rather sizeable (and generally significant) increases in chin EMG, tongue EMG, and breathing rate while reading under all conditions.[4] In only one of 12 instances did arm EMG significantly increase during reading. These findings thus confirm those previously reported (McGuigan et al, 1964) and we can rather confidently conclude that covert oral behavior and breathing rate significantly increase during silent reading, relative to rest.

For each S, the difference was computed for each measure between resting and each of the two minutes of reading, as noted above; a difference between these two differences was then determined and the group means were tested for significant differences from zero. In only one of these 24 comparisons was a significant difference found (in Experiment II breathing rate was faster during the second minute of reading during silence than it was during the first minute), though in 17 of them the mean . gher during the second minute of reading (cf., Malmo, 1965).

Table 2

Mean Response Changes During the First and Second Minutes of Reading Relative to Rest

Condition		Response Measure			
Experiment I		Chin EMG	Tongue EMG	Arm EMG	Breathing Rate
Silence	(1)	.15*	.07	.11*	.97
	(2)	.16*	.07	.09	1.53*
Backward Prose	(1)	.21*	.23*	.04	1.78*
	(2)	.18*	.26*	.06	2.13*
Prose	(1)	.35*	.26*	.02	2.20*
	(2)	.31*	.38*	.10	2.50*
Experiment II					
Silence	(1)	37.41	104.16*	16.92	.96*
	(2)	28.02	104.67*	25.26	1.54*
Noise	(1)	73.41	149.16*	37.17	1.87*
	(2)	77.82	132.33*	39.75	2.23*
Prose	(1)	52.83	246.51*	57.33	2.17*
	(2)	46.17	269.76*	57.57	2.46*

$*P < .05$

There is some evidence, we have noted, that auditory stimulation by itself results in increases in covert oral behavior and in breathing rate, but does auditory stimulation during silent reading lead to further increases in these measures? Values during auditory stimulation were subtracted from those that obtained during reading, e.g., mean amplitude of tongue EMG while listening to noise was subtracted from mean amplitude of tongue EMG while reading during noise. The resulting group means are presented in Table 3. In every case breathing rate is significantly faster during reading than it is during the corresponding pre-reading condition of auditory stimulation. While not so striking, the same general effect can be observed for tongue and chin EMG, but not for arm EMG.[4] We may thus conclude that, in general, covert oral behavior and breathing rate is greater while reading during auditory stimulation than it is during auditory stimulation alone.

The question of the effects of auditory stimulation is pursued in Table 4. These means were obtained as follows: the difference between reading (first minute) during each condition of auditory stimulation and resting was computed for each S; then the difference between these differences was obtained and the group means were tested for significance. We can note that breathing rate is significantly faster while reading during the auditory presentation of backward prose, prose and noise than it is while reading during silence. While breathing rate is faster during the prose condition than it is while reading during backward prose or noise, these differences were not significant. Amplitude of tongue EMG is greater while reading during prose than during silence; backward prose had the same effect, but noise did not. The only significant difference for chin EMG occurred for the prose-silence comparison, and there only in Experiment I. These findings thus lead to the following conclusions: (1) auditory stimulation during reading, regardless of whether it is prose, backward prose or noise, leads to a significantly

Table 3

Mean Response Changes During the First and Second Minutes of Reading Relative to Prereading Listening Conditions

Condition		Response Measure		
Experiment I	Chin EMG	Tongue EMG	Arm EMG	Breathing Rate
Silence (1)	.06	.17*	.09	1.18*
(2)	.07	.17*	.07	1.73*
Backward Prose (1)	.13*	.10	-.02	1.52*
(2)	.10	.13	.00	1.87*
Prose (1)	.25*	.17	.08	2.06*
(2)	.21*	.29*	.16	2.43*
Experiment II				
Silence (1)	17.73	112.92*	32.16	1.01*
(2)	8.34	113.43*	40.50*	1.59*
Noise (1)	10.08	120.66*	67.17	1.41*
(2)	14.49	103.83*	39.75	1.77*
Prose (1)	21.75	215.25*	56.67	1.29*
(2)	15.09	238.50*	56.91	1.58*

*P<.05

Table 4

Comparisons of Mean Response Changes During First Minutes of Reading Relative to Rest

Condition	Response Measure			
Experiment I	Chin EMG	Tongue EMG	Arm EMG	Breathing Rate
Backward Prose -Silence	.06	.16*	-.07	.81*
Prose - Silence	.20*	.19*	-.09	1.23*
Prose - Backward Prose	.14	.03	-.02	.42
Experiment II				
Noise - Silence	36.00	45.00	20.25	.91*
Prose - Silence	15.42	142.35*	40.41	1.21*
Prose - Noise	-20.58	97.35	20.16	.30

*P<.05

faster breathing rate than occurs while reading during silence; (2) in general, auditory presentation of prose and of backward prose during reading leads to a significantly greater amplitude of covert oral behavior than occurs while reading during silence, but noise apparently does not have this effect; (3) while the data suggest that auditory stimulation (especially prose) during reading, and in fact reading during silence, results in an increase in covert non-oral behavior (arm EMG), such an effect is slight, relative to comparable changes in oral behavior. The inference is that changes in behavior during reading, both under conditions of silence and auditory stimulation, occur primarily in the speech mechanism, if in fact they are not localized there.

These findings, taken as a whole, thus rather clearly indicate that auditory stimulation during silent reading results in heightened covert oral behavior, relative to amplitude while reading during silence. Two interpretations present themselves. The first is that auditory stimulation is distracting (interfering) to the Ss while they are concentrating on reading; in this case, the increase in covert oral behavior may be useful in that it helps them to receive and/or process the language stimuli that constitute the text being read. It may be that the more similar the auditory stimulation is to the text, the greater its interfering effects, and the larger the amplitude of covert oral behavior required to "comprehend" the text.

The second interpretation is somewhat more radical. It is that the Ss are simultaneously responding to both the visual and auditory stimuli. That is, the heightened covert oral behavior while reading and listening to prose is actually a complex of language responses simultaneously occurring to both classes of language stimuli. If we can take tongue EMG as the more sensitive measure, we can note in Table 4 that the amplitude for this measure is significantly greater while reading during prose (language stimuli) and backward prose (approximations to language stimuli) than during silence, but not during noise (non-language stimuli). The fact that tongue EMG was of a noticeably greater amplitude while reading during prose than during noise (viz., 97.35μv) is especially interesting in that it is consonant with the interpretation that covert oral behavior serves a language function. This difference, which would have been significant beyond the .07 point (t = 1.55), certainly invites further study. Regardless, however, of the specific interpretation of these findings, the point that amplitude of covert oral behavior was systematically varied should be emphasized -- it is quite likely that this class of behavior is beneficial to the individual in some way and it is important that we attempt to more precisely establish its function.

Breathing rate is the most lawful measure recorded here, but its function too remains to be more precisely established. The fact that the breathing mechanism is part of the speech apparatus complicates the issue. It seems likely that increases in breathing rate occur during any condition of activity. But does the fact that breathing rate is fastest for the prose condition mean that the S is relatively more aroused, that he is covertly receiving and processing language stimuli, or both?

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Footnotes

1. The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education and Welfare, under the provisions of the Cooperative Research Program.

2. We wish to express our appreciation to the following for their contributions to this research: Susan A. Crandell, Ronald D. Suiter, and Susan N. Stokely.

3. The laboratory did not include equipment for calibrating the absolute values of the EMG signals. Hence these response measures should be regarded as approximations. Regardless, our interest is in relative values, i.e., changes in response measures as the Ss went from a resting state to the various experimental conditions.

4. That chin EMG failed to significantly increase during Experiment II (note also Table 3) in contrast to Experiment I may be due to the difference in measuring techniques. For instance, the use of audio tape recorders in the second experiment presumably did not allow recording of very low frequency responses (below 30 or so cps), while such were quantified in Experiment I. The laboratory has since been expanded to remove this limitation on data collection techniques.

Covert Language Behavior During Handwriting[1]

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There has been successful recording of covert oral responses to language stimuli in a sufficiently large number and variety of studies to suggest that the phenomenon is universal in language proficient individuals (cf., McGuigan, 1966). On the basis of this hypothesis one would predict that covert oral behavior also occurs when Ss engage in the writing of prose, but apparently the only relevant research was that conducted by Lepley (1952). This experimenter found that the handwriting of Ss who report that they engage in "implicit speech" during cursive writing is of a poorer quality than those who do not report the occurrence of implicit speech. Though this finding is based on the relatively crude criterion of S's tact of a covert event, it suggests that covert oral responses do occur during cursive writing and that the phenomenon is exaggerated in poorer writers. Handwriting thus offers us another opportunity to directly record covert oral behavior with the possible consequence that positive results, in a task different than those that have heretofore been studied, might be useful in ascertaining the function of this response class. The purposes of this study were, therefore, 1) to directly record covert behavior during cursive writing, and 2) to ascertain the amplitude of covert behavior as a function of handwriting quality.

Method

Subjects and Procedure

The procedure reported by Lepley (1952) was adhered to except as modifications and extensions are specified. Briefly, 117 female Ss from introductory psychology classes at Hollins College were asked to write a list of 10 words; 93 samples satisfied Lepley's criteria. Thirty judges then assigned the 93 samples to one of five categories (excellent to poor) according to amount of rhythm, harmony and smoothness of coordination. Based on the pooled ratings, seven Ss who had the best (Group E) and seven who had the poorest handwriting (Group P) were selected for further study. Two Ss from Group P refused to cooperate and one failed to follow instructions.

The Ss were individually brought to the laboratory where they were assured that they were not going to be subjected to any discomfort or pain. Grass electrodes were placed on the left (non-writing) forearm and on the chin; specially constructed vacuum type electrodes were placed on the tongue (approximately one in. from the tip, separated by about 3/4 in.) and a bellows type pneumograph was attached about the chest (see McGuigan, Keller and Stanton, 1964, for details). The electromyographic (EMG) measures were recorded on three coordinated audio tape recorders, and the pneumograms were recorded on a Honeywell 906C Visicorder (as also were the other measures).

The S was asked to assume a comfortable (seated) writing position, a reading stand holding a series of 5 in. x 8 in. cards was placed on a table in front of her, she was instructed to keep her opened eyes directly on the reading stand during the entire experiment, and she was asked to write words or draw ovals as they were serially exposed on the cards. She wrote each word (or drew ovals) over each preceding one on a blank card, this so that she would not move her arm. There were eight periods: (1) write three words and draw several ovals about the same height as the words (practice); (2) rest; (3) draw ovals; (4) rest; (5) write words; (6) rest; (7) draw ovals; (8) rest. Period (2) was two min. long, while all others were one min. long. The E told S what she was going to do during each period and each period was commenced by removing the top card from the series on the reading stand, revealing a blank card (for rest periods), a card with words (writing period), or cards with ovals, as appropriate. The ten words used by Lepley were incorporated with an additional 18 of the same general character for period (5);

Quantification of the data

The EMG measures were quantified as follows: the analog signal from the magnetic tape entered a Hewlett Packard 3400A RMS voltmeter, which emits a DC level signal that can vary between 0 and -1 v. maximum; this value, which is proportional to the true RMS value of the input signal, was fed into a Hewlett Packard 3440A Digital Voltmeter that read the amplitude of the RMS signal instantaneously every five sec. The resulting amplitude was printed out on a Hewlett Packard 562A Digital Recorder, and mean values were computed for each S for each period. Respiration rate was quantified as number per min. (cf., McGuigan et al, 1964).

Results and Discussion

The initial question concerns the relative amplitude of the several response measures during writing and while drawing ovals. To answer this question, the mean response amplitude during the pre-writing rest period (Period 4) was subtracted from the mean response amplitude during the writing period (Period 5) for each S. A group mean of these differences was then obtained for all 11 Ss for each measure, and similar values were obtained by subtracting the second pre-oval rest period (Period 6) from the second oval period (Period 7).[2] The resulting means are presented in Table 1 where it can be seen that the amplitudes for the tongue and chin responses significantly increased during writing, but they did not significantly increase during the drawing of ovals. Arm EMG (of the non-writing arm) did not significantly increase during either writing or during the drawing of ovals, but breathing rate significantly increased during both periods.

To interpret these findings we may safely assume that all measures of covert behavior change when a person moves from a resting state to one in which he engages in any task, be it writing prose, drawing ovals or whatever. The increase in amplitude of responding during a state of general arousal

Table 1

Mean Increases in Response Measures while Writing and Drawing Ovals Relative to Pre-activity Rest Periods (N = 11)

Measure	Writing-Rest		Ovals-Rest	
	$\bar{X}$	A	$\bar{X}$	A
Tongue EMG (μv)	95.0	.147***	52.7	.313
Chin EMG (μv)	38.7	.193**	3.8	3.537
Arm EMG (μv)	27.3	.965	11.1	1.29
Respiration (per min.)	2.7	.147***	1.4	.234*

*$\underline{P} < .05$

**$\underline{P} < .02$

***$\underline{P} < .01$

Table 2

Mean Differences Between Response Increases

During Writing and During Drawing Ovals

Measure	Group E (n=7)		Group P (n=4)		Total (N=11)	
	$\bar{X}$	A	$\bar{X}$	A	$\bar{X}$	A
Tongue EMG (μv)	31.2	.559	62.0	.521	42.3	.270*
Chin EMG (μv)	27.9	.222*	47.1	.565	34.9	.194**
Arm EMG (μv)	19.2	2.48	10.9	3.08	16.2	1.60
Respiration (per min.)	1.3	.656	1.2	1.320	1.3	.388

*$\underline{p} < .05$

**$\underline{p} < .02$

may be estimated, for this experiment, by noting the means for the oval condition (Table 1). If, on the other hand, there is a greater amplitude of covert oral behavior during cursive writing than there is when a person engages in similar motor activity that is not language in nature (drawing ovals), one could ascribe a language function to that behavior. The appropriate test here is to subtract the increase during the drawing of ovals from the increase during writing for each _S_; the resulting group means are presented in the "Total" column of Table 2. There we can note that the increases in tongue and chin EMG were significantly greater during writing than during the drawing of ovals, but this was not the case for arm EMG or for respiration rate. In short, while _Ss_ generally increase the amplitude of their covert responses when actively engaged in a non-language task similar to writing prose, there is a further increase in their level of covert oral behavior when the task involves language. The fact that the language stimuli (words) to which _S_ responds uniquely results in increases in oral behavior, compared non-oral behavior (arm EMG), may be taken as evidence that the oral behavior is actually language in nature. If respiration rate may be taken as a measure of general arousal, the lack of a significant difference between the increase during writing and while drawing ovals further indicates that the significantly greater increase in oral behavior during writing occurred because that oral behavior had a language function.

Having concluded that the _Ss_ make unique covert oral _language_ responses to language stimuli, the next general task is to establish variables of which this class of behavior is a function. The attempt here is to pursue the hypothesis that amplitude of covert oral language behavior varies inversely with the quality of a person's handwriting. The relevant results are presented in Table 2 where we can note that Group _P_ manifested a greater increase in the two measures of oral behavior during writing (compared to drawing ovals) than did Group E. The reverse was the case for non-oral behavior (arm EMG). t-tests, however, indicate that the differences for oral behavior are significant. That is, the t between the means of Groups E and P for tongue EMG was .72 ($P > .05$), and for chin EMG it was .62 ($P > .05$). In short, while the direction of the means for this small sample of Ss is that specified by Lepley's hypothesis, the results of the statistical analysis do not allow us to confirm that amplitude of covert oral behavior varies inversely with the quality of a person's handwriting. The findings are, however, sufficiently encouraging to invite follow up research. The fact that Ss do emit covert oral language responses when engaged in language tasks raises the question of the role that these responses play. Perhaps they are useful, or even crucial, for the interpretation of language stimuli (McGuigan, 1966). It is by specifying the major stimulus and organismic variables with which covert oral language behavior varies that the precise function of this class of behavior will eventually be established.

Footnotes

1. The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program.

2. The second session for drawing ovals was used for comparison with the writing period because of the possibility that S was still adapting to the laboratory situation during the first oval drawing period. Even so, essentially the same results were obtained by using the first oval drawing period for comparison. This finding, incidentally, indicates that order effects, if such existed, were negligible.

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Feedback of Speech Muscle Activity during Silent Reading: A Methodological Question

Abstract

Hardyck et al report that auditory feedback from speech muscles results in the cessation of subvocalization during silent reading. A similar effect appears in findings reported here but additional control data indicate the same result in the absence of feedback. Methodologically sounder research is required before it can be asserted that the auditory cue is responsible for the reduction in covert oral behavior.

Feedback of Speech Muscle Activity during Silent Reading

A Methodological Question

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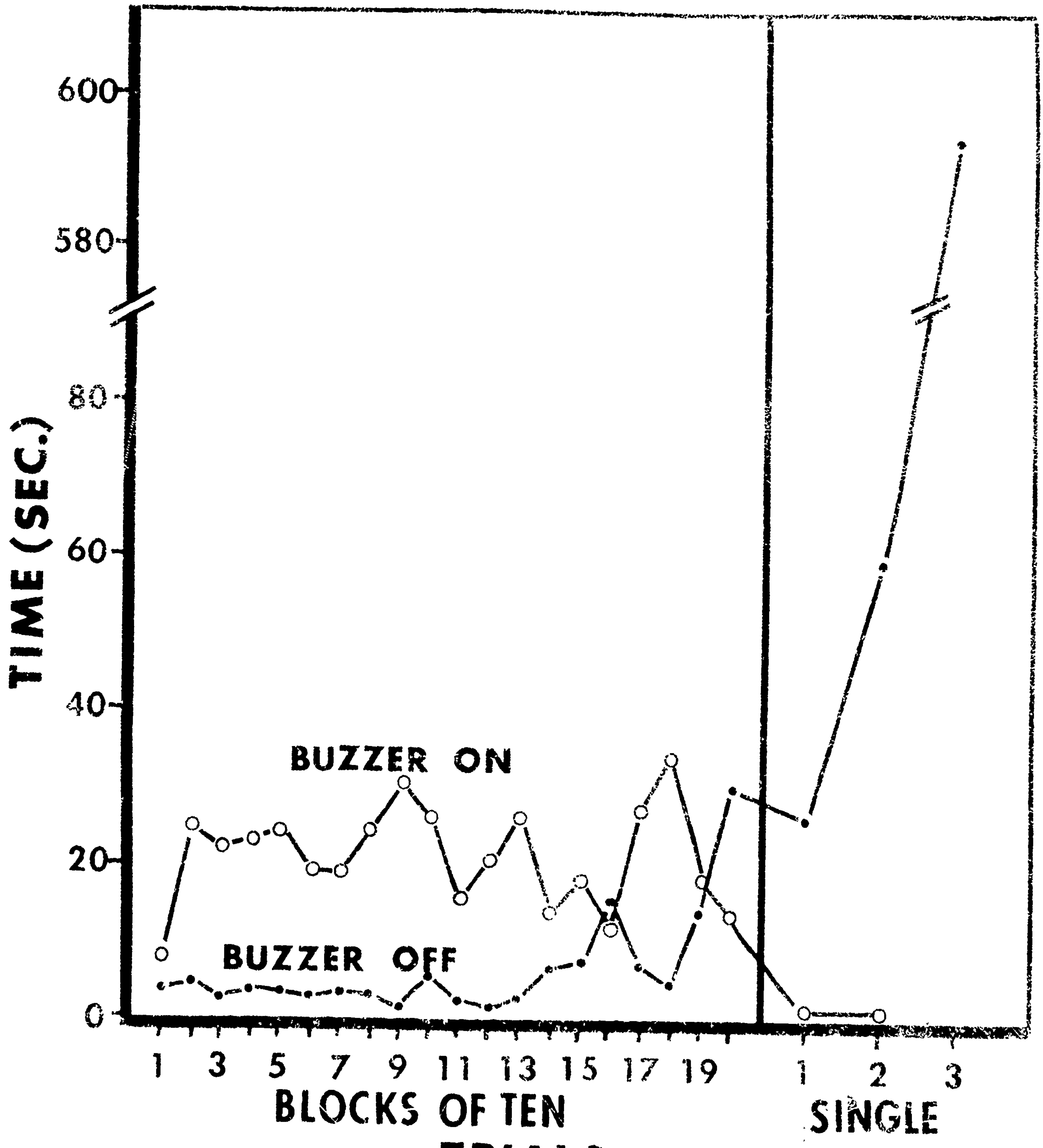
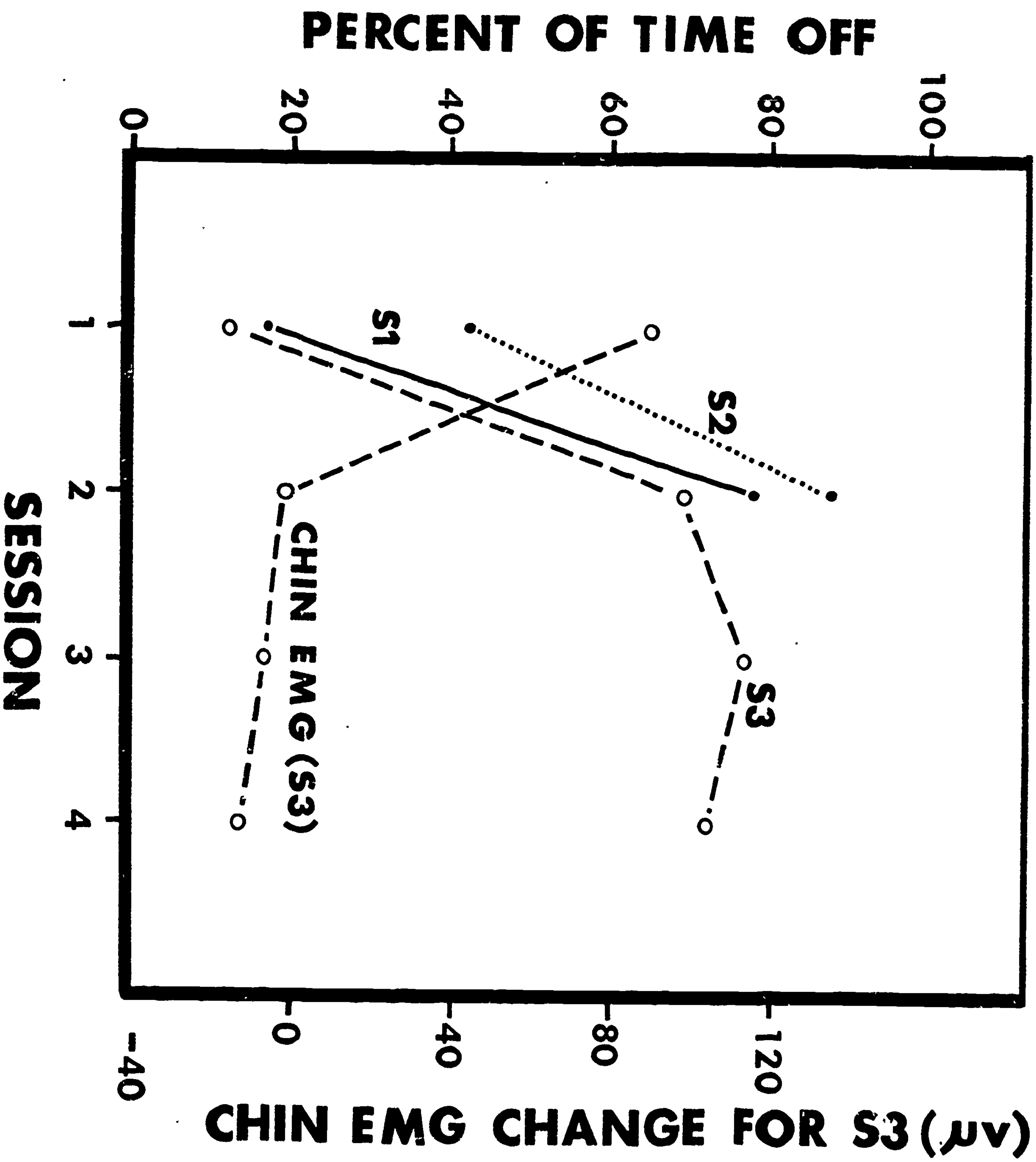
Hardyck, Petrinovich and Ellsworth report that the presentation of auditory feedback from the speech muscles produces a "...long-lasting cessation of the subvocalization..." that occurs during silent reading (1). The auditory cue is effective, they conclude, because it allows subjects to make fine motor adjustments in their speech musculature. While this conclusion is consonant with other findings (e.g., 2), the lack of systematic control data weakens the strength of the inference that auditory feedback is the critical variable. It is possible, for instance, that the complex of giving the subjects a set to the effect that their subvocalization will be reduced, the placing of electrodes (apparently) only on the throat, and a variety of other extraneous variables, all of which focus attention on the speech mechanism of individuals who clearly subvocalized, played at least a role in the reduction of the response amplitude. To amplify on this methodological question, consider the results presented in Fig. 1. The subject (S1), an 11 yr. old girl who manifested heightened covert oral behavior during silent reading, read in the laboratory at Hollins College for two 45 min. sessions on successive days. The procedures previously reported (3) were used, with the extension that the amplified signal from the chin electrodes entered a meter relay that was activated at 15 and 25 (arbitrary units). These levels were selected in accordance with the amplitude of the chin response during silent reading such that when the amplitude exceeded 25 a noxious buzzer (a potential punisher) automatically started in the subject room. When the response amplitude fell below 15, the buzzer ceased (a potential negative reinforcer). The length of time that the buzzer was on was automatically recorded, as was the time that it was off. Each buzzer change (on or off) was defined as a trial. We can observe that the subject decreased the amount of

Figure Captions

Fig. 1. Amount of time that chin EMG was of a sufficiently great amplitude to produce the noxious stimulus (Buzzer On) or of a sufficiently low amplitude to remove the noxious stimulus (Buzzer Off) as a function of trials (S1).

Fig. 2. Percentage of time that the buzzer was off as a function of number of sessions (S1). For S2 and S3 the left vertical axis is a measure of percentage of time that the buzzer would have been off. The right vertical axis is change of amplitude of chin EMG as S3 went from resting to silent reading for each of four sessions.


600
580
80
60
40
20
0
TIME (SEC.)
BUZZER ON
BUZZER OFF
1 3 5 7 9 11 13 15 17 19
1 2 3
BLOCKS OF TEN TRIALS
SINGLE


PERCENT OF TIME OFF
0
20
40
60
80
100
S1
S2
S3
CHIN EMG (S3)
SESSION
1
2
3
4
-40
0
40
80
120
CHIN EMG CHANGE FOR S3 (μv)

time that the buzzer was on (reduced her response amplitude) as trials progressed, and that the response stabilized at a low amplitude level for the last 10 min. of reading until the session was terminated, even though she was later unable to verbalize the fact that the buzzer event was contingent on her own behavior. One is tempted to conclude that the feedback from the covert oral response resulted in a reduction of response amplitude.

The total amount of time that the buzzer was off was determined for each of the two reading sessions and a percentage, relative to total time that the buzzer was on, was calculated. This summary of the data presented in Fig. 1 is shown for the subject in Fig. 2 where the sharp increase in the percentage of time that the buzzer remained off (read on the vertical axis) can be noted.

Two additional subjects who "subvocalized" during silent reading were run under control conditions: S2 (a 10 yr. old boy) read for two 45 min. sessions on two successive days, while S3 (an 11 yr. old girl) read for four sessions on four successive days. These two subjects were treated the same as was S1 except that the buzzer was never presented. The amount of time that the buzzer would have been on (and off) had it been presented was automatically recorded, just as for S1. The precentage time that the buzzer would have been off during each reading session (vertical axis) is plotted for the two control subjects in Fig. 2. The curves for all three subjects are remarkably similar for the first two sessions -- they all show sharp rises that indicate relatively rapid reduction in the amplitude of chin EMG.

Signals from the chin, arm eye and pneumograph transducers were recorded for S3 on magnetic tape. The analog signal from the former three entered an RMS voltmeter which yielded a DC level signal that could vary between 0 and -1 v. maximum. This value, which is proportional to the true RMS value of the input signal, entered a voltage to frequency converter which could vary between 0 and 10,000 cps., and thence to an electronic counter which counted the frequency for each 10 sec. period. The resulting frequency was converted to a BCD signal that was printed out on a digital recorder; this value is a mean integrated voltage for each 10 sec. period. A mean voltage was computed for the pre-reading rest period, and for the reading period. The former was subtracted from the latter for each session, and the results for chin EMG are plotted in Fig. 2. The curve for this measure, it can be observed, is an approximate mirror image of that for the first measure for S3 -- a direct recording of covert oral behavior also shows that the amplitude of the response is sharply reduced. The results for the arm, eye and respiration measures are not germane to the present discussion, but it is important to emphasize that transducers were placed in a variety of regions of the body.

These exploratory data, in short, indicate that subjects relatively rapidly decrease their amplitude of covert oral behavior in the absence of experimenter arranged feedback. Furthermore, in contrast to the procedures of Hardyck et al, this effect occurred without calling the purpose of the study to the subject's attention, and without them being able to verbalize the response-contingency relationship (4). While the effect that Hardyck et al report may well be a real one, the assertion that it is must await the results of research that rests on a methodologically sounder basis.

References and Notes

1. C. D. Hardyck, L. F. Petrinovich and D. W. Ellsworth, Science, 154, 1467 (1966).

2. J. V. Basmajian, Science, 141, 440 (1963).

3. F. J. McGuigan, B. Keller and E. Stanton, J. Educ. Psychol., 55, 339 (1964).

4. The modification of behavior occurred for all subjects in spite of the fact that none were "aware" of this relationship, including a college student who read for nine sessions while we were merely observing how the procedures worked.

5. The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare, under the provisions of the Cooperative Research Program.