DOCUMENT RESUME

ED 038 267 24 RE 002 715

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TITLE Covert Oral Behavior During Silent Reading. Final Report.
INSTITUTION Hollins Coll., Va.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO BR-7-1106
PUB DATE 30 Oct 69
GRANT OEG-0-8-001106-1877
NOTE 167p.

EDRS PRICE EDRS Price MF-$0.75 HC-$8.45
DESCRIPTORS *Behavior Patterns, *Covert Response, Feedback, Language Usage, Linguistic Performance, Listening, *Measurement, Oral Expression, *Reading Research, Reading Speed, Remedial Reading Programs, Silent Reading, *Task Performance, Verbal Stimuli, Writing

ABSTRACT

This final report gives the findings of a government research project, the broad objective of which was to determine the existence of heightened covert oral behavior in the performance of tasks in which the response class had not yet been empirically studied and to ascertain the function of the covert oral response. Areas covered by this report include covert oral behavior during the silent performance of language tasks and as a function of quality of handwriting, covert response patterns during the processing of language stimuli, the effect of increased reading rate on covert oral behavior, patterns of covert processes evoked by different classes of language stimuli, covert behavior as a direct measure of mediating responses, the effects of manipulating covert oral behavior during silent reading, and the effect of remedial reading on covert oral behavior. References are included. (NH)

BR-7-1106
PA 24

ED038267

Final Report

Project No. 7-1106
Grant No. OEG-0-8-001106-1877

Covert Oral Behavior During Silent Reading

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October 30, 1969

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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

Office of Education
Bureau of Research

RE002 715

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Abstract

Covert oral behavior is of considerable theoretical and technological importance, as indicated by the sizeable literature in which its relevance to "thinking" is considered and in which it is related to such educational practices as the teaching of reading. The broad objective of this project was to determine the existence of heightened covert oral behavior in the performance of tasks in which this response class had not yet been empirically studied, and to ascertain the function of the covert oral response. Specific goals are specified for each section of this report. The entire report is briefly summarized as follows.

Section II is entitled "Covert Oral Behavior During the Silent Performance of Language Tasks." All previous relevant research in which covert oral responses were recorded is summarized and evaluated. In early studies mechanical sensing devices were used while later research has exclusively employed electromyography. Three major criteria were used in evaluating research on the silent performance of language ("thinking") tasks, leading (in turn) to the conclusions that: a) covert oral behavior significantly increases over baseline; b) the increased covert oral behavior is accompanied by increased respiration rate and increased amplitude of electromyograms in the preferred (writing) arm, but appears to be relatively independent of other non-oral behavior; and c) covert oral behavior does not appear to typically increase during the performance of non-language tasks. A set of five directly relevant findings leads to the conclusion that covert oral behavior during the silent performance of language tasks serves a language function; mediational theories, built on overt behavior, help to suggest more precisely that the covert oral response facilitates the reception of external language stimuli and the internal processing

of that information. Physiological considerations indicate complex and rapid feedback loops between speech regions of the brain and the speech musculature. These loops may function in the process of internal communication.

Section III presents the results of three experiments in which Ss wrote words or engaged in comparable non-language (control) tasks. The handwriting of 117 and of 90 college female students were judged by 30 judges. From these, samples of Ss who had excellent and poor handwriting were selected for further work in the psychophysiological laboratory. It was found that covert oral behavior and breathing rate were significantly greater during the performance of the language task (writing words) than during the control tasks, but this was not the case for covert non-oral behavior. Furthermore, it was found that Ss who had poor handwriting emitted a significantly larger amount of covert oral behavior than did Ss whose handwriting had been judged to be excellent. The interpretation was that poor writers require enhanced feedback from the speech musculature during the performance of language tasks.

Section IV was a study of "Covert Response Patterns During the Processing of Language Stimuli," and built on results previously reported. In summary, three experiments were conducted in which Ss silently read, memorized, listened to prose, to music or to nothing. The findings confirmed those previously reported that during silent reading Ss significantly increase covert oral behavior (chin and tongue electromyograms), preferred forearm EMG and breathing rate. Furthermore, these increases are significantly greater than those that occur when listening to music or attentive listening to nothing. A similar pattern of responses occurs during memorization, though with increased amplitude. Preferred forearm EMG and breathing rate changes are significantly greater during the three conditions that involve language than for the non-language conditions. It is concluded that increased covert oral behavior, preferred forearm responses and breathing rate are associated with the processing of language stimuli.

Section V dealt with the effect of increased reading rate on covert oral behavior. The object was to administer objective reading tests and to record psychophysiological measures before and after a reading improvement course for an experimental group. Results were compared with those of two control groups -- one who took both pre and post tests but not the reading course, and one who took only post tests. The results showed that the experimental group improved their rate of reading by 149 words per minute, an increase that was significantly different from zero and significantly higher than that for the control group. The increased reading rate did not, however, result in decreased amplitude of covert oral behavior; rather, it appeared to produce <u>increases</u> in the most sensitive measure (tongue EMG), a mean increase that would have been significant beyond the .06 level. The experimental group also sizeably decreased the frequency of eye movements of the large kind that occur when one reaches the end of a line of prose, suggesting that <u>S</u>s learned to sometimes read more than one line simultaneously. These results are consonant with the hypothesis that covert oral behavior is beneficial in the performance of such language tasks as silent reading.

The research reported in Section VI was an effort to study patterns of covert behavior evoked by single words. Two words high and two words low in imagery evoking power were auditorally presented to the <u>S</u>s 32 times each, and reactions from various bodily regions were averaged by means of a PDP 8 I analog computer. More specifically, responses were recorded from the tongue, lips, neck, non-preferred arm, horizontal EOG and EEG from the parietal and occipital areas. Selected average curves are presented in Section VI, and it is concluded that further work on the project, based on this pilot investigation, is feasible. It seems likely that internal information processing does involve responses in a variety of bodily locations, and that the characteristics of the responses vary as a function of such stimulus parameters as meaningfulness (words) vs. meaningless (the white noise control stimuli used in this study) and class of language stimulus (high vs. low image evoking words).

An effort was made (Section VII) to obtain a direct measurement of the verbal mediating response. A verbal mediation paradigm was developed, based on that used by Tracy Kendler and with her cooperation, in which one group of Ss should exhibit heightened covert oral behavior during the mediation process. This verbal mediation group did in fact significantly increase the amplitude of tongue EMG from before the experiment until the phase in which the mediation test occurred. Furthermore, the increased amplitude of tongue EMG was significantly greater than for two other (control) groups. No other measure (EEG, EOG, right and left arm and right leg EMG) significantly changed for the verbal mediation group, nor was there a significant difference in these measures relative to the two control groups. It may well be that this heightened covert oral behavior was a direct measure of the verbal mediating response, as theoretically predicted.

Section VIII deals with the effects of manipulating covert oral behavior during silent reading. Briefly an operant paradigm was employed such that a mildly noxious stimulus (tone) would sound when S's covert oral behavior during silent reading exceeded baseline level by a certain (preset) amount. This mild punishment was followed by a negative reinforcer (cessation of the tone) when S decreased his response amplitude by a certain amount. Approximately 50 Ss were screened for further study. Five were selected on the basis that they exhibited rather pronounced subvocalization during silent reading and that they would cooperate by returning to the laboratory for repeated sessions (varying with S from 12 to 43).

Feedback is Effective in Reducing Amplitude of Covert Oral Behavior. In four of the five Ss feedback was effective in reducing amplitude of covert oral behavior when S was told that he was controlling the auditory feedback. One S was run for 20 sessions with feedback, but she was not aware that she was in control of the tone; under this condition amplitude of covert oral behavior did not decrease, indicating that S must be able to verbalize the response-contingency relationship in order to control his own behavior. However, the precise knowledge of the source of the feedback (e.g., chin EMG) is not necessary, since this S did reduce chin EMG in amplitude told only that she was in control; she apparently accomplished this by relaxing her entire body, including her speech musculature. The only S for whom the feedback paradigm was ineffective was an individual with brain damage. He also uniquely emitted heightened EEG activity from his temporal lobe (in contrast to that of other Ss and in contrast to his own occipital lobe).

Reduced Amplitude of Covert Oral Behavior Did Not Increase Reading Rate. In none of the four Ss was there a clear cut increase in reading rate accompanying the decrease in covert oral responding. In fact, there were several sections of curves for the Ss in which increased reading rate was accompanied by increased amplitude of covert oral behavior.

<u>The Reduced Amplitude of Covert Oral Behavior Produced by Feedback Is Not Permanent</u>. In all four <u>S</u>s for whom feedback was effective, removal of feedback in the final reading sessions resulted in an increase in amplitude of the behavioral region that produced the feedback. That is, when feedback was from chin EMG, removal of the tone when chin EMG exceeded the present amplitude resulted in an increase in chin EMG. Thus, even though <u>S</u>s spent many sessions and many hours reading under feedback conditions, and even though they were trying to "correct" a condition of subvocalization in themselves, the reduction in amplitude of covert oral behavior was only temporary, even in the laboratory environment.

A number of subsidiary findings are presented in Section VIII. It is clear that this is an exceedingly complex problem, but it is just as clear that the findings are not in accord with the traditional view that increased amplitude of covert oral behavior during silent reading is detrimental. It is important to study further the long term effects of reading under feedback, for reading under this condition may be inefficient due to the interference of the tone. But until it can be established that amplitude of covert oral behavior can be permanently reduced, effects on reading proficiency cannot be satisfactorily studied.

In Section IX a brief summary of the effects of a remedial program on a single subject were studied. The program was successful in that it satisfactorily raised the <u>S</u>'s reading proficiency. Psychophysiological measures indicated that chin and tongue EMG were noticeably higher after the increase in reading proficiency than prior to the remedial course. The conclusion was that the increased amplitude of covert oral behavior may have been a basis for the improved reading proficiency.

While the results reported herein clearly invite follow-up research along a number of lines, they are generally consistent with the position that the covert oral response is beneficial during the performance of language tasks. As pointed out in the concluding portion of Section II, it is likely that feedback loops between the speech musculature and speech regions of the brain function to benefit the individual in a wide variety of "thinking" tasks. This research has concentrated on the peripheral mechanisms, but future efforts should coordinate these measures with central nervous system events to the extent possible.

COVERT ORAL BEHAVIOR DURING THE SILENT PERFORMANCE

OF LANGUAGE TASKS[1]

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Covert oral activity has long been implicated in "thought" processes or implicit language behavior (cf. Langfeld, 1933). The hypothesized functions of "inner," "silent," "implicit" or "subvocal speech" have been numerous, but twentieth century empirical investigations have largely been directed by the theorizing of Russian scientists (e.g., Pavlov) and Watson. Pavlov stated that the "basic component of thought... "consists of" ...kinesthetic impulses (which) pass from the speech apparatus into the cerebral cortex" (in Novikova, 1955, p. 210). Watson (1930) held that "the term, 'thinking' should cover all word behavior of whatever kind that goes on subvocally" (p. 243).

In response to these hypotheses, a number of empirical studies were conducted to directly record the activity of the speech mechanisms during the silent performance of language tasks that required "thinking". The purpose of this paper is to review and evaluate this previous work on covert activity of the speech musculature.[3] However, since the speech musculature may be activated for reasons other than the production of language, the more neutral term, "covert oral behavior" is used in place of terms like "silent speech" i.e., denoting increases in speech muscle activity by terms like "subvocal speech" prematurely assumes that a language function is being performed.

The primary assumption in previous theories and empirical investigations has been that localized changes occur in the speech musculature during the silent performance of language tasks.[4] There are three requirements for the test of this hypothesis.

(1) It should be demonstrated that covert oral responses actually occur -- that covert oral behavior changes from a resting, or baseline, level when

S is engaged in the language task.

(2) It should be shown that changes occurring in the speech musculature are relatively independent of other bodily changes by simultaneously recording a number of non-oral responses.

(2) It should be demonstrated that an increase in covert oral behavior from baseline level is a function of the language task and that similar changes do not occur under non-language conditions.

A number of additional control procedures should also be employed, depending on the nature of the particular experiment. For instance, where more than one task is presented, a control for order effects (e.g., counter-balancing) should be incorporated in the design. Similarly, at least dummy sensors should be attached to several body sites so that S's attention is not focused on his speech mechanism. The review of each study specifies the use of such controls, though the main purpose is to evaluate each investigation on the basis of the three major principles cited earlier. Table 1 summarizes the results for each of the three critical demonstrations.[5] Hence, "yes" in column 1 indicates that covert oral behavior increased during the performance of the task, while "?" indicates that response changes from baseline were not presented; "*" indicates that statistical tests were conducted, and it may be concluded that the increase over baseline was significant. "Yes" or "no" in column 2 indicates whether the change in covert oral behavior was or was not independent of other bodily activity sampled, while "?" indicates that other measures were either not taken or not reported on. Similarly, "yes" and "no" in column 3 indicates that an increase did or did not occur in covert oral behavior while S performed under a non-language condition, whereas "?" indicates that this control was not used.

Table 1

Summary of Evaluation of Previous Research on the Basis of Three Criteria

Experiment	Did the Covert Oral Response: (1) Increase from Baseline During a Language Condition?	(2) Occur Independently of Other Measures	(3) Occur Under Non-Language Conditions
Curtis (1900)	yes	?	?
Courten (1902)	yes	?	?
Wycozoikowska (1913)	?	?	yes
Reed (1916)	yes	yes (pneumogram)	?
Perky (1910)	yes	?	no
Clark (1922)	?	no (various)	?
Scheck (1925)	yes	?	yes
Thorson (1925)	yes	yes (pneumogram)	?
Rounds et al (1931)	yes	?	no
Jacobson (1932)	yes	yes (various EMG)	no
Basin et al (1955)	yes	yes (arm EMG)	?
Novikova (1955)	yes	?	?
Faaborg-Anderson et al (1958)	yes	?	?
Blumenthal (1959)	yes*	?	no
Edfeldt (1960)	yes*	?	?
McGuigan et al (1964)	yes*	no (respiration rate)	?
Hardyck et al (1966)	yes	?	?
Sokolov (1967)	yes	yes (GSR & EEG)	?
Sokolov (1969)	yes	yes (right finger EMG,etc.)	yes
McGuigan et al (1968)	yes*	yes (arm EMG) no (respiration rate)	no
McGuigan et al (1969)	yes*	?	?
McGuigan (in press)	yes*	yes (leg & chin EMG,EEG)	no
McGuigan (1967)	yes*	yes (arm EMG & no (respiration rate)	no
McGuigan & Bailey (1968)	yes*	no (preferred arm,EMG, (respiration rate)	no
Gould (1949, 1950)	yes	?	?
Roberts et al	no	?	?
McGuigan (1966)	yes*	yes (arm EMG)	?

Empirical Studies

Mechanical Sensing Devices. In 1895 Hansen and Lehmann (in Edfeldt, 1960) made an attempt to understand how "mind reading" works by placing Ss in a room with especially good acoustics and asking them to intently think of a number or word. They reported that Ss almost always produced unconscious whispering which could be heard by an observer, although neither the observer nor S could report lip movements. These results were used to implicate covert oral behavior during thinking and served to stimulate more objective experimentation, e.g., Curtis (1900) placed a tambour on the larynx, asked Ss to rest, silently read, silently recite, and to whisper one of the same passages. Kymograph records indicated increased laryngeal activity from baseline level during the silent language conditions for 15 out of 20 Ss. Curtis discounted the five "failures" since four did not show laryngeal activity during whispering and the fifth intentionally tried to suppress all movements. Courten (1902) employed a rubber bulb to monitor tongue movements, repeated Curtis' experiment and generally confirmed Curtis' findings with this different measure.

Wyczoikowska (1913) had Ss engage in such activities as thinking about words, remembering melodies that had words or no words, and listening to words and melodies. Her sensing device was a flattened glass placed about the end of the tongue. Responses were recorded on a kymograph. She concluded that every activity produced some movement of the tongue, and that thinking words, in contrast to hearing them, produced responses of comparable shape but reduced in amplitude. Wyczoikowska reported her data only in the form of sample tracings during a task. Since she did not report any baseline data, we cannot assume that the tongue responses were specifically related to the experimental conditions. Furthermore, since she obtained responses to melodies for which there were no associated words, it cannot be concluded that the tongue activity was specifically related to the language conditions.

Reed (1916) inserted a block into the mouth cavity, and had _Ss_ hold it in place by closing the lips and teeth on the block. The device included a thin rubber condom, from which a rubber tube emerged forming an air passage between the "speech receptor" and a tambour. Changes in air pressure within the mouth due to tongue movements and to breathing were recorded on a kymograph. Breathing curves were also recorded independently from the nose, and chest and abdomen. The tasks set for _Ss_ were: not to think of anything, to silently read, to silently write, to whisper, to read aloud, to silently count, and to solve arithmetic problems. Reed carefully compared breathing curves with his oral measures in an effort to separate inner speech from breathing _per se_. Summarizing results for 13 _Ss_, he states that from one-fourth to three-fourths exhibited inner speech during the various thinking tasks: "The first conclusion that appears from this is that inner speech is not a universal but an individual trait" (p. 380). In some instances Reed found that the curves from the mouth during silent reading corresponded in form to the curves obtained during whispering and overt reading, and that they were independent of the breathing curves. In the case of one _S_, he concluded that "... the objective certainty of inner speech in silent reading and in writing... is established" (p. 370). In assessing Reed's work, we can note that he obtained positive evidence of increased covert oral activity when some _Ss_ changed from a resting condition to the performance of the language tasks, and that the oral behavior was independent of the form of the abdominal pneumogram, but that he did not present non-language tasks to his _Ss_.

Perky (1910, in Experiment VIII) recorded laryngeal movements (by means of a Verdin Laryngograph) from three _Ss_ who were selected for their ability "to obtain auditory imagery". The _Ss_ first relaxed, then a signal was given following which one of a series of words was spoken. The appearance of an "auditory image" to the word was signalled by a minimal hand movement. Perky classified _Ss_' introspective reports according to whether they were "'images of memory'" or "images of imagination." The former were "...distinguished by particularity and personal reference" and the latter by "lack of particularity...in the sense of a particular sample, placed and dated...and absence of personal reference" (p. 436). The analysis indicated that laryngeal movements occurred in 84% of the 155 memory images, whereas 91% of the 214 imagination images were not accompanied by laryngeal activity. The experiment was repeated, she says, "with like result." In summary, it appears that Perky found an increase of covert oral activity from baseline level during the presentation of words and that amplitude of laryngeal activity varied directly with the degree of concreteness of the word. She did not record from other bodily regions, but she did indicate that the laryngeal response did not occur to the signal alone.

Golla (1921), attached one end of a small spring to the thyroid cartilage and the other end to a leather collar about the neck. A small button attached at a right angle to the spring, impinged on the membrane of a tambour. The vibrations of the tambour were pneumatically conveyed by a rubber tube to another tambour which actuated an optical lever. A beam of light was projected on the optical lever, so that magnified excursions were photographically recorded. The S was asked to sing up and down an octave, and then to think the notes of the octave. Similar ascending and descending curves were obtained under both conditions, as indicated by a sample record, though the amplitude of the curve for the thinking condition was about one-third of that for overt singing. No baseline data were reported, no other bodily measures were taken; it is not clear just what S did for the thinking condition, and records were not obtained for other tasks. Nevertheless, the remarkable similarity of the curves (from a single S) for the overt and covert conditions is striking.

In the fifth of a series of studies, Clark (1922) recorded respiration, arm volume, and laryngeal and tongue movements while four Ss solved a series of novel problems. A small cup-shaped object with a rubber membrane was attached to tne throat, and a mechanical system of levers registered horizontal and vertical laryngeal movements. Tongue movements were recorded by means of a small flat frame inserted into the mouth in such a way that a rubber membrane fit on top of the tongue. Though the Ss first relaxed, the results of the kymograph tracings are reported only during problem solving and only as follows: the total time spent in thinking was 513.3 sec. Tongue movements were present 34.7% of this time; vertical laryngeal movements were present 22.4% of the time that there were tongue movements, while the corresponding value for horizontal laryngeal movements were 12.4%. A complex of changes in the other measures occurred during the experimental session, indicating rather widespread bodily activity during thinking. It is difficult to reach any firm conclusions about oral behavior because of the above stated manner in which the results were reported.

Scheck (1925) inserted a small inflated rubber balloon into S's mouth such that it rested lightly on the top of the tongue. Tongue movements and thoracic pneumograms were recorded by a system of tambours and a kymograph. Records during rest were made, following which Ss wrote scientific prose dictated to them, read silently, listened to a march, a ballad, and a jig. Scheck reported results only on himself, regarding them as "typical" of those obtained from a small group of senior and graduate students. Visual observation of the sample records suggests that some noticeable tongue activity appeared during rest, that there were several periods of heightened tongue movement during writing and reading and that relatively little tongue activity occurred while listening to the ballad and to the march. Tongue movements were clearly greater while listening to the jig than during rest. From the data presented, it is difficult to justify Scheck's conclusion that "...tongue movements...are especially active under mental stress, and vary in rate and amount with the stimulus" (p. 391). We may conclude provisionally that tongue activity increased during writing and reading, relative to rest; but since pneumograms during these activities were not presented, no information is available about other bodily changes. The marked tongue activity during one non-language condition (listening to the jig) deserves note.

Thorson (1925) recorded thoracic respiration, and vertical and horizontal tongue movements on a kymograph. The tongue measurements were made by attaching a small suction cup to the tongue and, with a system of levers, she achieved amplification of X 3.5 or X 4.5. One purpose of the study was to determine whether "internal speech" during the performance of various language tasks produced curves similar in form to those that occur during the whispered performance of the same task. Using 18 Ss (14 faculty and graduate students, three undergraduates, and a 10-year-old boy), she carefully compared the tongue records under these two conditions. Her conclusion was in the negative: only "...4.4% of the total cases show some similarities ...between pattern of movement in thinking as compared with whispering" (p. 13). Because this conclusion is so frequently cited, it is valuable to note that the mean is based on 10 Ss, seven of whom showed zero percent similarity, and three who showed 29%, 15%, and 17% similarity. While one might accept Thorson's conclusion that tongue movements during thinking do not resemble those during whispering (but note the conclusions of Wyczoikowska, and Reed above), the generalized rejection of a motor theory of thinking should be re-examined. She concluded, for instance, that "Movements of the tongue are not universal in internal speech or verbal thought...(and)... are not so much dependent upon the content of internal speech as they are upon conditions of nervous irradiation and muscular tonus" (p. 27). This conclusion disturbed Watson (1930, p. 240) who criticized her experiment because of the lack of sensitivity of her apparatus. Her work, however, actually provides positive support for Watson's theory in that she did obtain heightened tongue activity during the performance of language tasks relative to tongue amplitude during control periods when Ss were told to keep their thoughts "blank". To understand this, note that Thorson rank ordered the various tasks according to relative amount of tongue movement during each as follows:

"1. Reciting silently the alphabet as rapidly as possible...

2. Thinking 'experimental psychology' while singing 'ah' and tapping the table...

3. Reciting silently the multiplication tables of 7s and 9s while singing 'ah' and tapping with the fingers...

4. Thinking following whispering...

5. Mental multiplication during filing distraction...

6. Reciting silently the multiplication tables of 7s and 9s after doing so under distraction...

7. Thinking 'experimental psychology' after doing so under distraction...

8.5 Writing a passage from dictation...

8.5 Thinking without any distraction and following no distraction...

10. Reading silently a Polish passage alternating with whispering of it...

11. Blank..." (p. 25)

It appears that little or no effort was made to achieve minimal resting levels between conditions, for S̲s evidently changed conditions rather rapidly and there were only three baseline periods in which instructions were to "keep their thoughts blank." It is thus remarkable that all tasks, on the average, resulted in more tongue movements than did the blank periods. Furthermore, Thorson demonstrated that distraction increased the amount of tongue activity (the first five tasks in rank order). Hence, rather than the typically cited negative conclusion, her following statement seems more appropriate: "...the records show continuous irregular movements of the tongue, varying in amount in different situations (p. 18)." The respiration records during thinking "showed no significant deviation from normal" (p. 18).

Rounds and Poffenberger (1931) placed a face mask on their S̲s and recorded variations in oral air pressure by leading a small tube to a tambour, and then to a kymograph. In this way, movements within the chest, larynx, tongue, etc., were recorded. Sample records were reported for an unspecified number of Ss during a resting period. The baseline records indicate uniform activity, but during mental work periods the curves are quite erratic and irregular, perhaps indicating the occurrence of covert speech reactions. As a control, records obtained on an individual who had been incapable of speaking since birth showed no noticeable change in covert oral activity during the silent addition period. It is in this sense that we affirmatively classify the Rounds and Poffenberger study according to the third criterion of Table 1.

As a general comment on these early studies it is quite apparent that controls, by today's standards, were inadequate, that the apparatus was quite crude, that findings were not evaluated statistically, that conclusions were often justified merely on the basis of selected sample traces, that small ns were often used, and so forth. In view of the lack of experimental sensitivity it is therefore surprising that positive evidence of increased oral activity ever was obtained.

Electromyographic Studies. Jacobson's extensive work in which he collected electromyographic (EMG) data relevant to a motor theory of consciousness was summarized in 1932. His Ss first received a prolonged training program in relaxation. During experimental sessions two signals (clicks of a telegraph key) were presented: the first to instruct S to engage in a particular "mental activity," and the second (occurring several sec. later) to relax any muscular tensions present. Needle electrodes were inserted into the tip of the tongue or into the upper lip. Electrodes were also placed elsewhere (see below), apparently during successive sessions. Signals from the electrodes produced vibrations of a string galvanometer. These deflections were photographically recorded, allowing the measurement of response amplitudes down to 1 μv. Tasks included "imagine counting," "imagine telling your friend the date," "recall a poem," "Multiply..." (certain numbers), "think of" (abstract matters such as "eternity," "electrical resistance," "Ohm's Law"). For five Ss, the overwhelming number of tests were positive in the sense that oral behavior noticeably increased following the first signal and then returned to baseline level following the second. Data on the sixth (see below) and seventh S (who was unable to relax) were not reported. Jacobson employed the control procedure of instructing Ss: "Upon hearing the first signal do not bother to think." Since the first signal produced no EMG changes under this condition it was concluded that the oral response did not occur merely because the click-signal was presented. In addition, Jacobson showed that no response changes occurred in remote ("irrelevant") bodily locations sampled when the above tasks were presented. For example, when S imagined lighting a cigarette, no change in tongue EMG occurred; instead, heightened EMG was recorded in the arm. Other control tests were similarly negative with regard to the tongue, e.g., "Imagine the Eiffel Tower in Paris" although this instruction evoked eye potentials. These findings indicate that covert responses are highly localized, are evoked as a function of the particular kind of stimulus, and occur in the part of the body that one would use should the response have been overtly made.

Two other findings by Jacobson are of interest. The above results were said to have been obtained in Ss not trained to relax (see S #6 above), indicating that the responses to the stimuli were "...not artifacts resulting from training." Second, when Ss were extremely relaxed (as indicated by minimal EMG levels) they reported an absence of"...mental activities involving words and numbers...." On the other hand, introspective reports while performing activities involving words or numbers indicated tenseness in the oral region (as also reported by Perky, 1910).

Jacobson's work has been variously criticized. For instance, with regard to the condition in which S is told to not bother to think, Humphrey (1951) has stated: "But the understanding of the instructions is just as much a mental process as the understanding of the former instructions ...there should have been some peripheral action corresponding to the content of the instructions..." (p. 216). Max (1937) criticized the procedure of announcing Ss problem in advance: "Such a method entails the subject's awareness of the problem throughout the foreperiod, which therefore is not truly a 'control' for the subsequent thinking response" (pp. 303-304). In evaluating such criticisms of Jacobson's work, one should not lose sight of how thoroughly relaxed his Ss were. Jacobson's extensive relaxation program probably produced the most relaxed Ss in the history of this kind of psychological research. One would expect, with Humphrey, peripheral activity sometime during the "Do not bother to think" test. But, recognizing the possibly fleeting nature of the covert response, particularly in such well relaxed Ss, such a minute event could easily be missed. The fact is that Jacobson's research, conducted with such apparent carefulness, yielded remarkable results, and the appropriate criticism of it should only be found in countering data.

Smith, Malmo and Shagass (1954) had 22 Ss with pathological behavior and 11 college Ss listen to prose as the volume was decreased at intervals, so that the sound was periodically almost inaudible. EMGs were continuously recorded from the forehead, neck, chin and both forearms. They report that chin EMG and EMG from both forearms significantly increased from a baseline level during listening, but that forehead and neck EMG were unaffected. The patients had a significantly higher level of chin EMG during listening than did the normal Ss, with no other response measures differing between groups. It is possible that the increase in chin EMG was produced by listening to the prose, but is may also have been caused by the Ss "straining" when the volume was reduced. Two similar studies were also conducted in the same laboratory, these without a reduction in volume (Wallerstein, 1954; Bartoshuk, 1956); however, no data are reported for comparing covert oral behavior during listening with a baseline level. The main purpose in all three of these investigations, though, was to study gradients from the first through the tenth minute of listening (cf. Malmo, 1965). Consequently the results are not directly relevant to the present problem.

Basin and Bein (1955) recorded EMG from the lower lip and distal part of one arm using "more than" 50 Ss. They recorded a baseline level, following which Ss engaged in a "simple verbal task" (e.g., silent arithmetic). Only sample tracings are reported, but it is apparent that during the performance of the verbal task there are slight increases in lip EMG with no readily apparent changes in (an unspecified) arm EMG. Increasing the difficulty of the task (reading a list of jumbled words and letters) greatly increased the amplitude of lip EMG. Basin and Bein also studied a number of pathological speech Ss and concluded that a considerable increase in lip EMG occurred if S was asked to perform a verbal task that involved his defect. If the task is beyond S's powers, there may be a reduction in lip EMG with a marked increase in right hand EMG, e.g., Ss with hysterical mutism produce normal baselines for the lip and right hand, but when asked to mentally pronounce a word that they are unable to overtly say, there is a dramatic increase in right arm EMG, indicating that Ss were " ...using writing as a method of compensation for a speech defect" (p. 200).

Novikova (1955) placed electrodes on the tongue and on the dorsal surface of the right forearm of 11 normal Ss. Sample records indicate that tasks such as silently reciting the months, days of the week, and a poem, or memorizing figures and words, all led to increases in tongue EMG, relative to a baseline level. As the difficulty of the verbal task was increased, amplitude of tongue EMG proportionately increased. Increase in tongue EMG while listening to instructions is also reported. During the solution of a difficult arithmetical problem, depression in "electrical activity of the cerebral cortex...could be seen to coincide with the period of activity of the tongue" (p. 215). Three illiterate Ss showed especially high tongue EMG, relative to literate Ss. No results on arm EMG are reported for normal Ss. Novikova also presented sample records on deaf mutes, and concluded that Ss who knew both oral and manual speech showed EMG increases in both regions while performing arithmetical tasks. The same phenomenon was demonstrated in normal Ss who were proficient in manual speech, and it was noted that tongue EMG increased prior to the onset of an increase in arm EMG. Novikova concluded that a single functional system develops which includes control of both fingers and tongue.

Faaborg-Andersen and Edfeldt (1958) inserted needle electrodes in three locations in the laryngeal musculature, viz., the vocal, the posterior cricoarytenoid and the mylohyoid muscles. They recorded EMGs and sound records when Ss rested, read silently and read aloud. The Ss read their native prose (Danish) and foreign prose (Swedish). Though they studied 10 Ss, only sample records of two are presented. Their conclusions were: (1) vocal and mylohyoid EMG increased during silent and overt reading of both Danish and Swedish prose, but posterior crico-arytenoid EMG was inhibited; (2) EMG was substantially greater for Ss unaccustomed to reading foreign prose during the reading of that foreign prose then when reading their native language, but this effect was not present for Ss accustomed to reading the foreign text; and (3) EMG activity started .3 to .5 sec. before onset of an audible signal during overt reading.

Blumenthal (1959) pretested 81 Ss and selected 11 who evidenced noticeable tongue EMG during thinking. The Ss were required: to rest; to listen to each of a series of words, and upon hearing each word to think of saying the word back to E; to imagine licking a postage stamp, and to suck a lemon; to listen to words, but to try to keep the tongue relaxed and still; to listen to a bell, but to do nothing. Among the results, Blumenthal reported that maximum magnitude of tongue EMG when thinking of words was significantly higher than during the two control conditions of resting and when listening to a bell; furthermore, mean tongue movement was significantly greater for lingual than for labial words.

Tongue movements during the two control conditions did not differ significantly. The motor imagination tasks of licking a postage stamp and sucking a lemon resulted in significantly greater tongue activity than during the control conditions, and also than when hearing and thinking of saying words. The response inhibition condition of keeping the tongue relaxed and of merely listening to words did not result in significantly different amounts of tongue activity. Blumenthal's purpose in selecting his Ss was to enhance the possibility of discovering specific relationships between class of vocal movements and word class (as in the lingual vs. labial difference). Nevertheless, this selection obviously limits the extent to which the findings can be generalized.

Edfeldt (1960) used 84 Swedish college Ss who had indicated an interest in possible improvement of their reading ability. He first administered a battery of objective tests. During the experiment, 30-sec. relaxation periods were alternated with five 30-sec. reading periods. Edfeldt varied the difficulty of the text ("easy" vs. "difficult"), the clarity of the text ("clear" vs. "blurred"), and classified his Ss according to whether they were "good", "medium" or "poor" readers. Laryngeal EMG (recorded from needle electrodes in the mylohyoid muscle) was continuously integrated and amplitude was sampled during relaxation and during silent reading; amount of silent speech was measured by comparing EMG amplitude during reading with baseline levels. Edfeldt reported that "good" readers engage in significantly less silent speech during silent reading than do "poor" readers; that the reading of an easy text results in significantly less silent speech than does the reading of a difficult text; and that the reading of a clear text produces significantly less silent speech than does the reading of a blurred one. Edfeldt (1960) concludes "...that silent speech cannot be a habit which is, in itself, detrimental to the reading performance....it appears likely that... silent speech actually constitutes an aid toward better reading comprehension..." (p. 154). Furthermore, he claims that silent speech occurs in the reading of all persons.

McGuigan, Keller and Stanton (1964) reported two investigations using children (N = 36 and 60) and one using college Ss (N = 24). They found that mean maximum amplitude of lip and chin EMG was significantly greater during silent reading than during rest periods for both kinds of Ss. Increased EMG occurred in the college Ss regardless of whether they read English or a foreign language (French). Pneumograms were also recorded, and it was found that respiration rate significantly increased from a resting level during silent reading for children, and for college Ss when reading both native and foreign prose. A sensitive sound and magnetic tape system allowed the Es to record subvocalization during silent reading, and they report means of 1.53 and .43 audible subvocalizations per minute for the two samples of children, but none for the adult Ss. The authors also attempted to record arm EMG, but apparatus failure prevented the attainment of useful data on this measure.

Hardyck, Petrinovich and Ellsworth (1966) selected 17 Ss from a college reading improvement class on the basis that they subvocalized during silent reading. They placed electrodes on the throat, and transduced the electrical signals to provide S with auditory feedback that varied with EMG amplitude. The S was asked to relax and then to read while attempting to keep the EMG feedback to a minimum. Only sample records of one S are reported, but Hardyck, et al., indicated that EMG increased during reading, relative to the relaxation period, and that "In all cases one session of the feedback was sufficient to produce complete cessation of subvocalization. Most of the subjects showed a reduction of speech muscle activity to resting levels within a 5-min. period... after 3 months...none of the subjects gave any evidence of subvocalization..." (p. 1468). Contrary to the conclusions of Edfeldt, these authors regard subvocal speech as detrimental to reading proficiency and thus regarded the feedback condition as therapeutic: "This treatment resulted in immediate and long lasting cessation of the subvocalization...(and)...should prove valuable in treating some reading problems" (p. 1467, italics ours). Unlike Edfeldt, no quantitative data are reported on EMG activity, nor for the reading proficiency of their Ss before or after "treatment." McGuigan (1967) conducted a study similar to that of Hardyck, et al., and reported that one S who silently read with feedback from chin EMG decreased the amplitude of chin EMG. However, similar decreases in chin EMG were obtained with control Ss who read for more than one session in the absence of feedback. This finding casts doubt on the conclusion of Hardyck, et al., that feedback was the specific variable that produced reduction of speech muscle EMG, particularly since McGuigan used sensors in several locations and his Ss were not able to verbalize the response-feedback contingency.

Luria (1966) placed great emphasis on the role of verbal kinethesia in intellectual functions, but because his data are either clinical in nature or were collected under conditions of speech interference, we shall not dwell on them. Yet, Luria's work is sufficiently important to observe that he offered such interesting hypotheses as that aphasia may be due to impaired kinesthesis of the speech musculature.

In a general theoretical article, Sokolov (1967) presents sample tracings and briefly summarizes some of his empirical findings. During the solution of an arithmetical problem, there was a tonic increase in lip EMG from baseline level, with bursts of phasic activity; "Tongue electromyograms always show increase in integrated electrical activity of 150-180% in comparison with 'background level (rest state)'" (p. 12). During the writing of familiar material (S's name) Sokolov demonstrated that there was no increase in lip EMG from baseline level, but that there was a dramatic increase in tonic and phasic activity when S wrote an unfamiliar word. When S listened to a story for 260 sec., there was a gradual increase in tonic lip EMG (similar to findings summarized by Malmo, 1965), again with individual (phasic) bursts of electrical activity. Citing previous findings that the GSR and alpha-rhythm depression are indicators of general activation of the cortex by the brain stem reticular formation, Sokolov states that comparisons of speech electromyograms with GSR and alpha depression "... allows for a fairly precise differentiation in the electromyograms between the general tonic and the special speech components." (p. 11). This independence of covert speech activity during the performance of language tasks led Sokolov to attribute a unique function to the covert oral response, as we shall see later.

In a later translation, Sokolov (1969) summarized a series of studies in which _S_s were given both verbal and nonverbal (visual) tasks, under the following conditions. The _S_s (school children, students, and laboratory assistants) underwent preliminary extinction of orienting responses to the electrical apparatus, were relaxed to obtain baseline levels, and simultaneous recordings were taken from various areas of the speech and non-speech musculature. Sokolov presents a variety of individual records, one to illustrate each of his general conclusions. The various tasks included counting to oneself, thinking about previous events, solving arithmetic problems, silent reading of native and foreign prose, listening to phrases and then recalling these phrases, solving Raven Matrices, and so forth. The general finding is that speech motor activity increases from baseline level during the performance of these tasks, regardless of whether they are language or non-language. Furthermore, response amplitude increases as the difficulty of the task increases, and decreases as the task becomes more automatic and its solution becomes stereotyped.

McGuigan and Rodier (1968) conducted two experiments in which college _S_s (N = 45 and N = 36) first rested, then engaged in a listening condition, and finally read silently while the listening condition continued. The listening conditions were silence, prose, prose played backwards, and white noise, presented in counter-balanced order for each S. EMGs were recorded from the chin, tongue and forearm, and breathing rate was quantified. Of 14 comparisons of the listening-only conditions with baseline level, only two significant differences occurred: chin EMG and breathing rate significantly increased while listening to prose. Hence, there is some indication that covert oral behavior and breathing rate increase during the auditory presentation of language stimuli. With regard to oral EMG during reading, the findings "...confirm those previously reported (McGuigan, et al.,1964), and we can confidently conclude that covert oral behavior and breathing rate significantly increase during silent reading, relative to rest" (p. 651). As to the effects of auditory stimulation, it was found that "...the auditory presentation of prose and of backward prose during reading leads to a significantly greater amplitude of covert oral behavior than occurs during silence, but noise does not have this effect. It is concluded that the increased covert oral behavior is beneficial to S, perhaps by facilitating the reception and/or processing of language stimuli in the presence of auditory interference; or alternately, that Ss simultaneously respond to visual and auditory (language) stimuli" (p. 649).

McGuigan and Bailey (1969) selected 16 children who showed pronounced covert oral behavior during silent reading from the Ss used by McGuigan, et al., (1964), and retested 13 of them after two and after three years; .ree Ss were retested only after three years. During the original test, the 16 Ss exhibited a significant amount of covert oral behavior (lip or chin EMG) during silent reading, relative to a baseline period. The mean amplitude of the covert oral response noticeably decreased from the original to the second and third tests; amplitude after three years was significantly lower than during the original test; and at that time was approximately of the same value as for college Ss who had been tested but once. Furthermore, no subvocalizations during silent reading were detected during the second test, in contrast to the means of 1.53 and .43

subvocalizations per min. reported in the original study. It was concluded that covert oral behavior during the performance of a language task "naturally" decreases in amplitude with age, but that it still persists at a significantly high level in the adult.

McGuigan (1967) selected a group of college Ss who had excellent handwriting (n = 7) and a group who had poor handwriting (n= 4), from a larger group of 117. The Ss wrote a list of words, and drew ovals with a rest period preceding each task. EMG from the tongue, chin and non-writing arm were recorded, as was respiration rate. The group mean of tongue and chin EMG for all 11 Ss significantly increased from rest while writing words, but not when drawing ovals. The amount of increase while writing words was significantly greater than when drawing ovals. Arm EMG did not significantly increase during either experimental condition, nor was there a significant difference between the amount of increase in arm EMG while writing or while drawing ovals. Respiration rate significantly increased under both conditions, but the amount of increase between conditions was not significant. The increase in amplitude of covert oral behavior during writing, relative to that while drawing ovals, was greater for the poor writers than for the excellent writers, but the difference was not significant; only minor differences between groups occurred for the arm and respiration measures. The experiment was repeated (McGuigan, in press), using eight excellent writers and eight poor writers, selected from a larger group of 90 college Ss. Groups of eight Ss each were also formed according to whether Ss said that they did or did not subvocalize during cursive writing. The same measures as those employed in the 1967 study were taken, except that lower leg EMG was substituted for arm EMG, and EEG was recorded from the right motor area. The Ss wrote words and drew ovals in counterbalanced order with relaxation periods preceding each task. Considering all Ss together, it was found that tongue EMG was significantly higher while writing words than while drawing ovals. Respiration rate increased over baseline significantly more while writing than for the oval condition, but no other differences as a function of condition were significant. An analysis as a function of quality of writing indicated that tongue EMG was significantly higher in amplitude for the poor writers than for the excellent writers, that the difference for chin EMG approached significance, but that differences for the other three measures were minor and non-significant. No differences between the groups who said that they did or did not subvocalize were significant. A third, control, study was conducted using six Ss who wrote words, drew ovals or drew clefs in counterbalanced order. The n was too small to allow statistical tests of significance to be meaningfully conducted, but the amplitude of tongue EMG was noticeably greater while writing words than while drawing clefs or ovals. Among the conclusions were the following: (1) amplitude of covert oral behavior increased significantly more during cursive writing than during a non-language task, but that this was not the case for the non-oral processes sampled; (2) amplitude of covert oral behavior during writing varies inversely with the quality of one's writing; (3) respiration rate increased significantly during the performance of the language and the non-language task, but it increased above baseline significantly more during the former. The results for this study were quantified using the ratio of Lykken, Rose, Luther and Maley (1966) so that the affirmative answer in column #1 of Table 1 uses response amplitude during the oval condition as the "baseline." Similarly, the "no" in column #3 is given because the amplitude is greater under the writing than under the baseline condition.

McGuigan and Bailey (1968) had their Ss silently read, memorize prose, listen to the auditory presentation of prose, listen to music, and attentively listen to "nothing" (a blank tape on a tape recorder), with relaxation periods before each task. The experiment was repeated three times (N = 36, N = 40 and n = 25). Measures taken were EMG from the chin, preferred forearm, tongue, breathing rate, and EEG from the right motor area. It was found that chin and tongue EMGs during silent reading and memorization significantly increased from baseline level, and that the amounts of these increases were significantly greater than for the two non-language conditions (listening to music and to nothing). Respiration rate and preferred forearm EMG significantly increased from baseline level during silent reading, memorization and listening to prose, and the increases for these three language conditions were significantly greater than for the two non-language conditions. EEG amplitude significantly decreased during attentive listening to "nothing." Covert oral behavior increased in all three experiments while listening to prose, but in no case was this measure significantly higher than baseline. It was concluded that increased covert oral behavior, preferred forearm responses and breathing rate are associated with the processing of language stimuli.

Auditory Hallucinations

While this phenomenon cannot properly be classified as a language task, the successful recording of subvocal speech during auditory hallucinations is directly relevant to the general topic of this paper. The first work was by Gould (1949, 1950). He studied psychotics who emitted subvocal speech, selecting them by means of a stethoscope or sensitive microphone placed in front of their lips. Gould (1949) reports that "...there was marked correspondence between the subvocal speech as heard by the investigator and the voices as heard by the subject" (p. 425), and numerous examples of this correspondence are given. One patient was asked to think a story and to imagine lecturing; Gould reports that the amplitude of EMG from the vocal organs increased from a sustained resting level of 27.5 μv to 66.0 μv and 50.5 μv, respectively. A second patient showed an increase to 66.0 μv and 55.0 μv from a resting level of 27.5 μv when asked to imagine that she heard her husband calling her and hearing someone recite a poem, respectively.

Roberts, Greenblatt and Solomon (1951) studied six psychotics who experienced auditory hallucinations during the test, four who did not hallucinate during the test, and three nonpsychotic control Ss. EMGs were recorded on an inkwriting polygraph from the anterior neck, chin, and temporo-mandibular joints on both sides. The Ss relaxed and then signalled the beginning and ending of an hallucination by raising and lowering the little finger. Records were taken for 10 min. No relevant gross EMG changes were noted for the seven non-hallucinating Ss. The six remaining Ss reported a total of 43 hallucinations. The amplitude of EMG records were quantified by milimeters of pen deflection into three classes ("slight," "moderate" or "marked"). Nineteen instances of moderate to marked EMG occurred, but only four of these instances coincided with the raising of the finger, leading to the conclusion that auditory hallucinations are "...not consistently accompanied by vocal myographic discharges ... " (p. 914). These relatively negative findings might be tempered by the fact that EMGs were recorded by means of relatively insensitive equipment (viz., an inwriting polygraph that apparently registered only 19 responses from four body locations of six Ss during 10 min. which is amazingly low even for a normal S during a total of 240 min. of records), and that the criterion of the occurrence of a hallucination was unobjective. That is, one cannot be sure that the Ss in fact hallucinated when (and only when) they raised their fingers.

McGuigan (1966b) had a schizophrenic S relax and depress a button each time that voices were heard. Pneumograms, sound production (from a sensitive microphone placed before the lips), and EMG from the chin, tongue and (non-pressing) arm were continuously recorded. For 15 of the reported hallucinations, S was asked to remain silent after their occurrence; for the remaining ten, S was asked to report the content of the hallucinations. It was found that chin EMG and breathing amplitude significantly increased during a 2-sec. interval just prior to the report of hallucinations, relative to a comparable time interval 6-sec. prior to the button press, while there was no noticeable change in arm EMG. Slight whisperings were detected significantly often immediately before the hallucinations were reported; in two instances, the whisperings were sufficiently clear that they could be identified as part of the content of the overtly reported hallucinations. Control measures were taken prior to overt speech and pressing the button; these curves showed no resemblance to those obtained for actual hallucinations. (An unpublished study by Malmo, personally communicated, closely resembled that of McGuigan, with similar results.)

Discussion

Evidence for Covert Oral Behavior. The results summarized under column #1 of Table 1 lead to the firm conclusion that covert oral behavior increases over baseline during the covert performance of a wide variety of language tasks. It would appear, from column #2, that increased respiration rate and preferred (writing) arm EMG also increase from baseline during the covert performance of language tasks; however, it has not been established that systematic changes occur in various other measures and, in fact, the indication is that such behavior as non-preferred arm EMG and leg EMG do not significantly increase over baseline levels.

Column #3 summarizes rather inconclusive evidence that covert oral behavior may not significantly increase under non-language conditions. The following set of possible interpretations of the phenomenon of increased covert behavior during the performance of language tasks may be offered:

(1) Such covert behavior has no special significance or consequence in itself -- it may be: a) simply one aspect of a widespread state of heightened bodily arousal evoked by essentially any form of stimulation; b) merely "motor leakage" from critical brain processes; and so forth. This interpretation

follows from extreme centralist theory which holds that information processing, thinking and other cognitive processes occur exclusively in the brain.

(2) While the covert response may have no language function, its occasional occurrence may produce neural feedback to the central nervous system which, in turn, evokes some critical brain events and helps to guide the flow of ongoing central activity. This centralist interpretation thus grants some limited value to peripheral events, but holds that central events are far more significant.

(3) A less extreme centralist position holdsthat each critical central event results in efferent discharge which produces a (peripheral) response. Hebb (1949), for example, hypothesized that the firing of each cell assembly results in a (covert or overt) response. The response, as in interpretation (2) above, then may set off additional cell assemblies. But, in contrast to interpretation (2), this theory states that there is a one-to-one correspondence between central and peripheral events; hence, the measurement of a response may be used as an indirect index of the important central event (cf., McGuigan, 1966a, p. 295).

(4) The covert response is part of an arc in which efferent neural impulses produce a response which in time sets off afferent impulses back to the brain. Each of the three aspects of this sequence is necessary (though not sufficient) for the performance of language tasks. This is the standard motor theory of thinking (or consciousness), and holds that covert responses serve some critical language function.

(5) "Man Thinking Is Simply Man Behaving" (Skinner, 1957, p. 452);"language habits (are) habits which when exercised implicitly behind the closed doors of the lips we call thinking" (Watson, 1930, p. 225). This is an extreme peripheralist position in which neurological events (central, afferent and efferent impulses) are considered psychologically irrelevant or unimportant, and are thus largely ignored. Hence, response events (primarily oral behavior) are both necessary and sufficient for the performance of language tasks; they, in fact, define the "cognitive" process.

It is immediately apparent that the results of research conducted to date do not allow us to decide among the above five interpretations. The paucity of information relative to Criteria #2 and #3 indicates that additional research should be conducted using the implied paradigm of Table 1. In this way it might eventually be possible to specify patterns of covert processes concomitant with oral changes as a function of language and non-language conditions. Comparisons of these two classes of patterns would help to implicate critical events in the various bodily systems during the reception, processing, coding and decoding of information. Coupled with physiologically oriented research, such findings should eventually lead to a decision with regard to the above interpretations (cf., McGuigan, 1966a, pp. 293-294).

Covert Oral Behavior and Information Transmission. In essence, Watson (1930) defined covert language behavior as covert oral behavior that has become associated with non-oral responses (in the arms, hands, legs, etc.). Several findings are directly relevant to the question of whether covert oral behavior serves a language function: (1) preferred (writing) arm EMG increases significantly more under various kinds of language conditions than under non-language conditions (Davis, 1939; McGuigan & Bailey, 1968); (2) tongue and finger responses occur together during the covert performance of language tasks in individuals proficient in both oral and manual speech (Novikova, 1955); (3) heightened covert oral EMG during silent reading and during auditory hallucinations are accompanied by slight "whisperings" (subvocalizations) that can be understood as English words by the Es (Gould, 1949; Gould, 1950; McGuigan, et al., 1964; McGuigan, 1966c); (4) recognizing that the breathing mechanism is intimately associated with the production of speech, it may be noted that breathing rate increases during the performance of language tasks, (e.g., McGuigan, et al., 1964) and that the increase is significantly greater under language conditions than during non-language tasks (McGuigan & Bailey, 1968; McGuigan, in press);

$$S_L \begin{array}{l} \nearrow r_0 \left\{ \begin{array}{l} \text{LARYNGEAL} \\ \text{LIP} \\ \text{CHIN} \\ \text{TONGUE} \\ \text{PNEUMOGRAM} \\ \text{'WHISPERING'} \\ \text{SALIVATION} \end{array} \right. \\ \\ \searrow r_{\bar{0}} \left\{ \begin{array}{l} \text{FINGER} \\ \text{ARM} \\ \text{EYE} \\ \text{CARDIAC} \\ \text{VASOMOTOR} \\ \text{ELECTRODERMAL} \end{array} \right. \end{array}$$

and (5) variation of the conditions under which Ss have performed language tasks has led to the conclusion that the covert oral response is beneficial (e.g., Edfeldt, 1960; McGuigan & Rodier, 1968; McGuigan & Bailey, 1968; McGuigan, in press).

These findings lead to the conclusion that the covert oral behavior recorded during the performance of language tasks qualifies as language behavior. The next step is to specify more precisely just what is meant by "covert oral language behavior," i.e., to identify the function of a covert oral language response.

The traditional behavoristic analysis of language behavior holds that an external language stimulus produces a complex chain of intraverbal responses Applied to the present problem, and taking into account our preceding conclusions, we can more precisely state that the presentation of a specific external language stimulus (S_{L_1}) directly results in a covert oral (r_o) and a covert non-oral ($r_{\bar{o}}$) response (Fig. 1). We can assume on good grounds that the occurrence of any such response may result in additional covert oral and non-oral responses, and that complex interacting chains of these covert responses may continue indefinitely. The chain may, arbitrarily, be said to terminate when an overt language response (R_{L_1}) occurs. R_{L_1} may, for example, be the overt report of the solution of the problem posed by the initiating language stimulus. If the initiating stimulus is not specifiable, R_{L_1} may be a tact of a unique pattern of covert processes that, in everyday language, is referred to as a hallucination (as in McGuigan, 1966c), a dream (as in Dement & Kleitman, 1957), etc. The sequence that commences with S_{L_1} and ends with R_{L_1} may thus be considered to be an arbitrary behavioral unit selected, for analysis purposes, out of a highly complex and continuous flow of behavior. The unit, as presently specified, contains only behavioral variables that are directly observable: 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.

Now, consider that the covert responses of Fig. 1 are language responses e.g., the increased tongue, lip, and chin EMG that occurs during the performance of language tasks may be complex examples of the class r_o while increased EMG of the preferred forearm may be a complex example of the class $r_{\bar{o}}$. To hold that these covert responses are linquistic in nature must mean that they have some internal communication function, that they serve in the transmission of information. The various theories concerning mediating responses (conceived of as hypothetical constructs) deal, in part, with the problem of internal information transmission. For illustrative purposes, let us consider Underwood's (1965) analysis of implicit verbal responses: The presentation of a verbal unit produces a response which is "the act of perceiving" that unit; this response which directly results from the presentation of verbal material is termed a representational response (RR). The stimulus properties of the RR then evoke a second response, the implicit associative response (IAR). The IAR "...may be another word which is associated with the actual word presented..." (p. 122). The evidence for the existence of the IAR is the impressive (see also, for example, Wallace & Underwood, 1964).

In terms of Fig. 1, S_{L_1} would be the verbal unit that evokes RR which would, in all likelihood, be the pattern of r_{o_1} and $r_{\bar{o}_1}$. Then, the directly resulting IAR would probably be a complex pattern consistently of units of r_{o_2}, $r_{\bar{o}_2}$, r_{o_3}, and $r_{\bar{o}_3}$. These considerations, in short, are at least somewhat representative of how mediational theories, applied here, would hold that information is internally transmitted -- that covert language responses function to facilitate perception of external stimuli, and that the later members of the response chain function to produce rich verbal associations with the impinging verbal unit. A major advance may come when direct empirical covert referents are recorded for our hypothesized mediational constructs.

Efforts to conceptualize such complex processes as the internal transmission of information must necessarily be misleading in that they categorize bodily events in a discrete manner. A much more realistic picture would be one in which there is continuous, extremely complex and rapid feedback among the central nervous system, receptors and effectors. The feedback between (and within) these three systems must perform valuable coordinating functions, in addition to carrying specific information. Sokolov (1967), e.g., provides a most interesting hypothesis about the interrelations of covert oral responses and brain events. Following Pavlov, he embraces a principle of dynamic functional localization in which there are two-way neural connections among all the speech zones of the brain. The cortical speech areas are excited by afferent impulses, following which speech impulses are transmitted along the efferent speech-motor pathways to the speech musculature which may result in "...covert, soundless articulation ('inner speech')" (p. 6). Covert articulation then generates currents of reverse, proprioceptive afferentation. This proprioceptive (reverse) afferentation from the speech organs is a mechanism of the formation of the verbal code that enters all cerebral speech structures, and regulates cognitive activity. With this emphasis on the importance of the covert oral response, he concludes from electromyographic research that in "...the process of mental activity ... there is a gradual strengthening of muscle tonus -- not only in the speech musculature, but elsewhere as well (for example, in the musculature of the forehead, arms, and hand)... (with)... 'bursts' or 'volleys' of speech motor discharge separated by considerable intervals..." (p. 8). Hence the electromyogram reveals a "... tonic component (that) can be looked upon as a relatively generalized 'tuning' of the speech mechanisms, while the phasic component is more probably linked with 'specific' (local) speech activity (soundless word articulation)... In one degree or another all of these forms of electrical activity of the speech musculature are represented in all forms of mental activity... (though)... in reasoned thought bursts and volleys of electrical activity are more frequently observed... " (p. 9).

Sokolov's analysis is consonant with traditional and contemporary behavioristic theories of the importance of the covert oral response and is particularly valuable in that it proposes a specific relationship with brain events.

In conclusion it seems that the covert oral response serves a unique language function, and that it occurs along with a variety of other bodily events. The function of the covert oral response will be more clearly established as we continue to record EEG and response patterns as a function of stimulus, task, and organismic variables.

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Footnotes

[1]Work on this article was supported in part by a contract with the United States Office of Education, Department of Health, Education and Welfare, under the provisions of the Cooperative Research Program.

[2]Special thanks to Joseph Germana, Charles Osgood, and Sherman Ross for their suggestions.

[3]We are excluding experiments in which covert oral behavior was intentionally interfered with by E in an effort to ascertain reduced problem solving proficiency.

[4]It should be recognized that Watson (1930) and others also hypothesized that localized changes occur in non-oral regions of the body during thinking. We are, however, restricting our attention to the possible function of the oral response.

[5]A glance at these early studies reveals that a number of decisions of Table 1 must necessarily be based on limited information. Furthermore, even though the term "language tasks" is broadly conceived, the processing of language stimuli is but one indicator of thinking (cf., McGuigan, 1966a, p. 3). The relationship between behavior as a function of class of stimulus is a complex one that requires condiderable additional research. We know, for instance, that there is semantic generalization from non-language stimuli to their corresponding words, and vice versa (e.g., Cofer & Foley, 1942), but there is a dearth of information about response parameters as a function of language stimuli, non-language stimuli for which there are corresponding language stimuli, and non-language stimuli for which there are no corresponding language stimuli.

Covert Oral Behavior as a Function of Quality of Handwriting*

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There is considerable evidence that Ss emit covert oral responses when engaged in a variety of tasks that require the reception and processing of language stimuli. For instance, heightened levels of electromyograms (EMG) from several oral regions (tongue, lips, or chin) have been recorded when Ss silently read prose that was visually presented,[2] when Ss listened to auditorally presented prose,[3] when Ss solved problems,[4] and when Ss thought about abstract terms such as "electrical resistance".[5]

Handwriting, however, is a language task that has not been extensively studied as far as covert behavior is concerned. The implication from the findings during the performance of other language tasks is that Ss would emit heightened covert oral behavior during cursive writing, too. Furthermore, since it has been found that poor readers emit a higher amplitude of covert oral behavior during silent reading than do good readers,[6] it can be hypothesized that amplitude of covert oral behavior during handwriting is greater for poor writers than for excellent writers. This is, in fact, precisely the conclusion that Lepley reached, though Lepley did not use a direct measure of covert oral behavior during writing.[7] Rather, he classified Ss according to whether or not they said that they subvocalized when writing words. He found that those Ss who said that they subvocalized had a poorer quality of writing than did those Ss who said that they did not subvocalize during writing.

Lepley's interpretation of his findings was that when "...implicit speech accompanies cursive writing, the motor rhythm and harmony thereof are disturbed...", though he recognized that the influence may be in the reverse direction -- "... that individuals deficient in motor coordination may attempt to support and guide their acts of skill with symbolic action."[8] Lepley's quandary is typical of those who are concerned with covert oral behavior during the performance of language tasks, and there is considerable controversy about the function of this class of behavior.[9] In addition to the possibilities (1) that covert oral responses are detrimental to the performance of a language task, and (2) that they facilitate the reception and processing of language stimuli, it is also possible that (3) covert oral responses are merely one aspect of a heightened state of general arousal. It is, therefore, important to ascertain response amplitudes during cursive writing relative to amplitudes when Ss perform a comparable motor task that does not involve the use of language, such as the drawing of ovals. Furthermore, relative changes in oral and non-oral behavior during the performance of a language task should also be studied in order to ascertain the possible involvement of the speech mechanism. If covert oral behavior has a greater amplitude during the performance of a language task than during a comparable non-language task, and if covert response increases during the language task are localized in the speech (oral) region, then it seems likely that those covert oral responses serve a language function.

It was, therefore, the purpose of this research to test the hypotheses, based on the above cited work of Lepley and others, that: (1) Ss increase the amplitude of their covert oral behavior during cursive writing; (2) amplitude of covert oral behavior during cursive writing varies inversely with the quality of handwriting; (3) amplitude of covert oral behavior increases more during writing than during the performance of a comparable non-language task; and (4) changes in covert behavior during writing are primarily localized in the oral region. The results of two experiments and one minor control study will be reported.

Experiment

Method

Subjects. The handwriting of 117 females in Introductory Psychology classes at Hollins College was rated by 30 judges. Seven Ss who had excellent handwriting were assigned to Group E, and seven who had poor handwriting to Group P. Inability of cooperate eliminated three Ss in Group P.

Procedure. Lepley's procedure was adhered to except as extensions are specified.[10] The Ss were individually brought to the laboratory and the following sensors were attached: Grass electrodes on the left (non-writing) arm and on the chin, following Davis[11]; specially constructed vacuum electrodes on the tongue; and a bellows pneumograph about the chest. Each S then assumed a comfortable writing position and was told to always keep her eyes on a reading stand placed in front of her. The Ss briefly practiced writing words and ovals prior to the experimental session. There were three experimental periods of 1 min. each: the first was for drawing ovals, the second for writing words, and the third for drawing ovals again.[12] Cards containing words or ovals to be copied were exposed (as appropriate) on the reading stand by removing a blank card before each period. Rest sessions of 1 min. preceded each experimental period, and Ss were instructed immediately prior to each period to write words or ovals, as appropriate. So that S would not move her arm, she wrote the words or ovals directly over each other during each period; the spatial length of hand movement was the same for both conditions. The 10 words used by Lepley were incorporated with an additional 18 of the same character for the writing period.

Apparatus. The laboratory was unshielded and consisted of two adjacent sound-deadened rooms, one for the S and one for observation and for the recording apparatus. Each sensor led into two Tektronix 122 amplifiers and a Honeywell Galvanometer amplifier, all placed in series to provide X 10,000 amplification. All signals were recorded on a Honeywell Visicorder, and the EMG measures were also recorded on three coordinated audio tape recorders.

Quantification of the data. The analog EMG signals from the magnetic tapes entered a root mean-square (RMS) voltmeter which emits a direct current signal that can vary between 0 and -1v. maximum; this value, which is proportional to the true RMS value of the input signal, was fed into a digital voltmeter that read the amplitude of the RMS signal instantaneously every 5 sec. The resulting amplitude was printed out on a digital recorder. Values obtained 5 sec. before and after each set of instructions were discarded and mean values were computed for each S for each period and each rest session. Respiration rate was quantified as number per minute (for details see the second experiment of McGuigan and Rodier).[13]

Results

To determine whether Ss, regardless of their group, emitted heightened covert oral behavior during writing, the mean response value for each S during the (pre-writing) rest session was subtracted from the mean value during writing. A group mean of these differences was then determined for each measure. Similar group mean differences were obtained by subtracting values during rest from the corresponding values during the oval periods. The resulting group means are presented in Table I where it can be seen that the amplitudes of the tongue and chin responses significantly increased during writing, but these responses did not significantly increase while drawing ovals. For example, the mean difference between rest and writing for tongue EMG was 95.0 μv ($p < .05$ --α was set at .05 throughout), but for drawing ovals this measure only increased by 52.7 μv ($p > .05$).

Table I

Mean Response Increases During Experimental Periods

Relative to Rest (N = 11)

Measure	Writing-Rest $\bar{X}$	Writing-Rest A	Ovals-Rest $\bar{X}$	Ovals-Rest A	Difference $\bar{X}$	Difference A
Tongue EMG (uv)	9.5	.147*	5.3	.313	4.2	.270*
Chin EMG (uv)	3.9	.193*	.4	3.537	3.5	.194*
Arm EMG (uv)	2.7	.965	1.1	1.29	1.6	1.600
Respiration (per min.)	2.7	.147*	1.4	.234*	1.3	.388

*$p < .05$

The mean EMG of the non-writing arm did not significantly increase during writing or during the oval period. Breathing rate, on the other hand, significantly increased during both periods.

To determine whether the increase in each response measure was greater during handwriting than while drawing ovals, the latter values for each S were subtracted from the former and the means appear in the "Difference" column of Table I. For instance, the mean increase in chin EMG during writing was 38.7 μv, during the oval period it was 3.8 μv, and the difference between these two values is 34.9 μv ($p \leq .05$). These results indicate that Ss increased the amplitude of their covert oral responses (tongue and chin EMG) significantly more during the writing than during the oval period. On the other hand, the measure of covert non-oral behavior (arm EMG) did not increase significantly more during handwriting than while drawing ovals; nor was there a significant difference in breathing rate change as a function of experimental condition.

To test the hypothesis that amplitude of covert oral behavior varies inversely with the quality of a person's handwriting, the results in the difference column of Table I were analyzed according to whether S's handwriting was judged to be excellent or poor. We can see in Table II that the means for the two measures of oral behavior (tongue and chin EMG) are higher for Group P (poor writers) than for the excellent writers (Group E); however, t-tests indicate that the differences were not significant ($t = .72$ and $t = .62$ for the tongue and chin measures respectively). The differences in the arm and respiration measures between Group E and Group P are minor and do not approach significance.

Experiment II

Method

Subjects. Groups P and E contained eight Ss each, selected from a

Table II

Mean Difference Between Response Increases

While Writing and Drawing Ovals as a Function of Quality of Handwriting

	Group E (n = 7)		Group P (n = 4)	
Measure	$\bar{X}$	A	$\bar{X}$	A
Tongue EMG (uv)	3.1	.559	6.2	.521
Chin EMG (uv)	2.8	.222*	4.7	.565
Arm EMG (uv)	1.9	2.48	1.1	3.08
Respiration (per min.)	1.3	.656	1.2	1.320

* $p < .05$

larger group of 90 female college Ss as in Experiment I. Two additional (overlapping) groups of eight Ss each were also formed such that one group consisted of Ss who said that they subvocalized and one group said that they did not.[14]

Procedure. The order of the writing and the oval periods was counterbalanced for each group, so that half of each group wrote words before they drew ovals while the remaining half drew ovals before they wrote words. The same covert response measures were recorded as for Experiment I except that leg EMG was substituted for arm EMG, and electroencephalographic (EEG) measures from the right motor area (C-4) were taken. All other procedures of Experiment I were effected, including rest sessions prior to each experimental period.

Apparatus. The laboratory consisted of three subject rooms and a central apparatus (control) room, all shielded with high permeability steel and with a magnetic liner to provide maximum shielding for radio frequency and low frequency signals. The amplifiers were the same as for Experiment I, but all signals were recorded on an eight-track data tape recorder.

Quantification of the data. The analog EMG and EEG signals from the tape recorder entered an RMS voltmeter, as before; the resulting signals entered a voltage-to-frequency converter which could vary between 0 and 10,000 counts/sec., and thence to an electronic counter which counted the frequency for each 10-sec. period. The resulting frequency was converted to a binary-coded decimal signal that was printed out on a digital recorder; this value is a mean integrated voltage and provides the amplitude of each measure for each 10-sec. interval of the experiment. The values of the first and last 10 sec. of each experimental period were discarded, and means for each period were computed using the remaining values. At the conclusion of the experiment, each S was requested to make overt responses involving each measure being recorded; the maximum value for a 10-sec. interval during the experiment was ascertained, this usually when S made the overt response. Similarly, the minimum value for a 10-sec. period was determined for each S. These data were then used to compute a ratio for each S as follows:[15]

$$\text{Ratio} = \frac{\bar{X} - \text{minimum}}{\text{Maximum} - \text{minimum}}$$

For example, the mean tongue amplitude ($\bar{X}$) was computed for the writing period for an S, and the minimum tongue amplitude during the entire experiment for that S was subtracted from that mean; the resulting value was then divided by that S's maximum value for a 10 sec. interval subtracted from that S's minimum value. The result is a ratio that can vary between 0 and 1.0 such that the higher the value, the greater S's response amplitude. Lykken et al., have shown that this ratio corrects for individual differences in S's range of response values, and thus yields a more meaningful dependent variable value than that typically used.[16]

In short, then, a mean ratio was computed for each EMG and EEG measure for the writing and for the oval periods for each S. Pneumograms were quantified by determining respirations per min. during the resting sessions and during the experimental periods for each S.

Results

Group mean ratios based on all Ss were computed for each experimental period for the EMG and EEG measures and entered in Table III. We can note, for example, that the mean ratio of tongue EMG for all Ss was .439 while writing words and that it was .293 while drawing ovals. The difference between these two means (.146) was tested to determine whether the value during writing was significantly different from the value during the oval period. As can be observed, Ss yielded a significantly higher amplitude of tongue response when writing words than when drawing ovals, thus confirming the results of

Table III

Means During Experimental Periods. Respiration is Rate Increase Relative to Rest. Others are Ratios (*N* = 22).

Measure	Words	Ovals	Difference	*A*
Tongue	.439	.293	.146	.101*
Chin	.430	.362	.068	.558
Leg	.377	.345	.032	3.440
EEG	.397	.385	.012	23.500
Respiration	3.82	2.60	1.22	.162*

* $p < .05$

Experiment I. While chin EMG was noticeably higher during the word period this difference was not significant. Neither difference in the non-oral measures (leg EMG or EEG) was sizeable or significant. Respiration rate, on the other hand, increased significantly more during the writing period than it did during the oval period. The differences between rest and experimental periods for mean integrated EEG were minor and not significant (for words the mean increase was .10 $\mu\underline{v}$ and for ovals it was .25 $\mu\underline{v}$).

To study the results as a function of quality of handwriting the difference scores in Table III were classified according to whether the S was a member of Group P or E. That is, the ratio for each S while drawing ovals was subtracted from the S's ratio while writing words, and means of these differences for Groups P and E were computed. It can be observed in Table IV that the mean tongue EMG for Group P was .243 higher while writing words than while drawing ovals; the difference for Group E was only .061. The difference between these two differences (.182) was significant allowing us to conclude that the poor writers yielded a greater amplitude of tongue EMG during writing (relative to drawing ovals) than did the excellent writers. Group P's increase in chin EMG is also noticeably higher than is Group E's, but the difference fails to be significant. There are only minor and non-significant differences between groups for leg EMG, EEG and breathing rate. It may be concluded that poor writers emit a significantly greater amplitude of covert oral behavior when writing words than do excellent writers, but they do not differ significantly as far as covert non-oral behavior, EEG or breathing rate are concerned.

The results presented in Table V were computed just as for Table IV, except that the classification is for Ss who said that they do or do not subvocalize. The question here is whether individuals who say that they subvocalize during cursive writing emit a larger amplitude of covert oral behavior during writing than do Ss who deny that they subvocalize. No behavioral differences between these groups approach significance.

Table IV

Differences Between Means While Writing and Drawing Ovals as a Function of Quality of Handwriting (n = 8).

	Quality			
Measure	Group P	Group E	Difference	t
Tongue	.243	.061	.182	2.36*
Chin	.148	.002	.146	1.33
Leg	.061	.009	.052	.38
EEG	-.030	.110	.140	.78
Breathing	2.19	1.38	.82	.76

* $p < .05$

Table V

Differences Between Means While Writing and Drawing Ovals

as a Function of Self Report of Subvocalization ($\underline{n}=8$).

Measure	Subvocalizers Yes	No	Difference	$\underline{t}$
Tongue	.170	.099	.071	1.01
Chin	.036	.124	-.088	.72
Leg	-.031	.141	-.172	1.30
EEG	-.060	.180	.240	1.85
Breathing	.84	1.12	-.28	.25

Discussion

The major findings of Experiments I and II may be summarized as follows. With regard to covert oral behavior (tongue and chin EMG), it may be concluded that: (1) Ss significantly increase the amplitude of their covert oral responses during writing; (2) they do not during a control (non-language) task; (3) the amplitude of covert oral behavior during writing is significantly greater than during the performance of the non-language task; and (4) amplitude of covert oral behavior during writing varies inversely with the quality of a person's handwriting.

With regard to covert non-oral behavior (arm and leg EMG), Ss do not significantly increase the amplitude of their responses during writing or during the drawing of ovals, nor is there a significant difference in behavior as a function of these tasks.

These findings suggest the following conclusions. First, the fact that increased covert behavior during writing occurred in the oral but not in the non-oral regions that were sampled suggests that these responses were not widely distributed throughout the body; therefore the heightened covert oral behavior was apparently not merely an aspect of general arousal of the entire body, but was relatively localized in the speech mechanism. Second, the findings that covert oral behavior was significantly greater in amplitude during writing than during the performance of a comparable non-language task indicates that these responses were intimately associated with the performance of a language task;[17] the question is, in what manner?

Two possible functions of heightened covert oral behavior during the performance of a language task have been stated: (1) such responses are detrimental to a person in that they interfere with his language proficiency; (2) the heightened covert oral behavior is beneficial in that it facilitates the reception, decoding and/or processing of ~~incoming~~ language stimuli. The former is the classical position and, with regard to subvocalization during silent reading, has been stated in such ways as: "..any observable form of vocalization -- such as silent lip movement...retards the rate of silent reading (which) has been common professional knowledge since the early scientific studies of reading."[18] Lepley, it will be recalled, interpreted his findings in this manner. With regard to the present study the issue is: did Group P exhibit a poorer quality of handwriting than Group E because their relatively greater amplitude of covert oral behavior interfered with writing proficiency? Or do poor writers find writing sufficiently more exacting that they need to exaggerate their level of covert oral behavior in order to more adequately perform? The fact that Ss in general tend to increase their level of oral responding during the performance of language tasks argues that such responses are beneficial. If they are beneficial, then it would follow that the more difficult the task the greater the need to exaggerate covert oral responses. If this hypothesis is tenable, it should be possible to manipulate experimental conditions and observe systematic variation of the amplitude of covert oral behavior. Several experiments have been successfully conducted with this as their purpose. For example, Edfeldt showed that amplitude of silent speech increases as the difficulty of the prose being read is systematically increased. Edfeldt's interpretation is that silent speech occurs in all individuals and that it is likely that "...silent speech actually constitutes an aid toward better reading comprehension..."[19] A similar result is reported by Sokolov though in this translation he provides data for but a single case; the conclusion is that amplitude of lip EMG increases as S moves from writing familiar material to unfamiliar (and more difficult) material.[20] One further example is provided by the work of McGuigan and Rodier.[21] These experimenters demonstrated that amplitude of covert oral behavior increased when several kinds of auditory stimulation were introduced into the silent reading situation. Their interpretation was that the increased amplitude of covert oral behavior faci. tated silent reading.

In short, these findings indicate that covert oral behavior is beneficial in the performance of language tasks; it remains to more precisely determine the role of this class of behavior in the reception, decoding and/or processing of language stimuli.

Previous research has shown that breathing rate increases significantly during silent reading.[22] We have noted here that this measure increased significantly during both the oval and writing periods, and that the increase was significantly greater while writing than while drawing ovals. To attempt to understand these results, we may tentatively assume that the increase in breathing rate while drawing ovals is an index of the increase in general level of arousal required for the performance of this type of task. Noting that respiration is intimately involved in the production of speech, we may hypothesize that the faster breathing rate during the word, relative to the oval, period occurred because Ss were making covert language responses. That is, if the Ss were in fact engaged in "silent speech" during writing, then increased respiratory activity would be required for the production of such silent speech.

Summary

Three experiments were conducted in which Ss wrote words or engaged in comparable non-language (control) tasks. It was found that covert oral behavior and breathing rate were significantly greater during the language task, but this was not the case for covert non-oral behavior. Furthermore, amplitude of covert oral behavior varied inversely with the quality of handwriting. The interpretation is that covert oral behavior is beneficial in the performance of language tasks.

Footnotes

* Received for publication . 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.

1 Thanks to Douglas Gresham, Susan Guthrie, Marty Muller, Norman Ostrov, and Ronald Savukas for their help in collecting and analyzing data.

2 A. W. Edfeldt, Silent Speech and Silent Reading, 1960, 153; F. J. McGuigan, Barbara Keller, and Eleanor Stanton, Covert language responses during silent reading, J. Educ. Psychol., 55, 1964, 339-343; F. J. McGuigan and William I. Rodier, III, Effects of auditory stimulation on covert oral behavior during silent reading, J. exp. Psychol., 76, 1968, 649-655.

3 A. A. Smith, R. B. Malmo, and C. Shagass, An electromyographic study of listening and talking, Canad. J. Psychol., 8, 1954, 219-227; H. Wallerstein, An electromyographic study of attentive listening, Canad. J. Psychol., 8, 1954, 228-238.

4 L. A. Novikova, Electrophysiological investigations of speech, in N. O'Connor (ed.), Recent Soviet Psychology, 1961, 210-226.

5 E. Jacobson, Electrophysiology of mental activities, this JOURNAL, 44, 1932, 677-694.

6 Edfeldt, op. cit., 153.

7 W. M. Lepley, this JOURNAL, 65, 1952, 597-599.

8 Lepley, op. cit., 599.

9 F. J. McGuigan, Thinking: Studies of Covert Language Processes, 1966, 293.

10 Lepley, op. cit., 597-599.

11 J. F. Davis, Manual of Surface Electromyography, WADC Technical Report 59-184, Wright Air Development Center, Ohio, December 1959.

[12] This design was used in the first experiment to explore the relative effects of drawing ovals before and after writing words by the same Ss. Essentially the same results were obtained regardless of whether ovals preceded or followed the word period. For brevity, only data for the second oval period will be reported.

[13] McGuigan and Rodier, op. cit., 649-655.

[14] These groups were formed on the following basis. Two Ss from Group E and two from Group P said that they subvocalized during cursive writing; four Ss from Group E and two from Group P said that they did not. The remainder classified themselves as "doubtful." Consequently, four additional Ss who said that they subvocalized and two who said that they did not were randomly selected from the larger group of 90 Ss in order to form the two additional groups of eight Ss each who said that they did or did not subvocalize.

[15] This ratio is a simplified statement of that reported by D. T. Lykken, R. Rose, B. Luther, and M. Maley, Correcting psychophysiological measures for individual differences in range, Psychol. Bull., 66, 1966, 481-484.

[16] Lykken, Rose, Luther, and Maley, op. cit., 481-484.

[17] The problem of selecting a non-language task that is comparable to the writing of words as far as bodily arousal, movements, etc. are concerned is a difficult one. As will be seen, the fact that tongue EMG was significantly higher while writing words than while drawing ovals suggests that the heightened covert oral behavior served a language function in that it was involved in the reception and processing of language stimuli. Nevertheless, it could be argued that the relatively heightened tongue EMG occurred, for example, merely because writing words requires more variations in the direction of hand movements than does the drawing of ovals. The question is, what other non-language task might be more similar

to writing words, but is not so novel as to produce considerable covert behavior merely because it requires more effort or attention than does the copying of familiar words? To further study this problem, a third, control, experiment was conducted using six Ss randomly selected from Psychology classes. The same procedures as reported above were used, except that the Ss wrote words, drew ovals or drew clefs in counter-balanced order. Unfortunately, the Ss were not as sufficiently adept at drawing clefs as they were at other tasks, so that drawing clefs is probably too demanding to serve as a suitable control task. Nevertheless, even though the ns were too small to allow us to run meaningful tests of significance, the results are in line with those of Experiments I and II, i.e., the mean ratio for tongue EMG while writing words was .737, while for drawing clefs and ovals it was .603 and .564, respectively. These findings, taken with the fact that the difference in tongue EMG between writing words and drawing ovals was higher for Group P than for Group E, strengthen the interpretation that the covert oral behavior served a language function.

[18] E. A. Betts, Foundations of Reading Instruction, 1950, 450.

[19] Edfeldt, op. cit., 154.

[20] A. N. Sokolov, Speech-motor affer ntation and the problem of brain mechanisms of thought, Soviet Psychol., 6, 1967, 10.

[21] McGuigan and Rodier, op. cit., 649-655.

[22] McGuigan, Keller and Stanton, op. cit., 339-343; McGuigan and Rodier, op. cit., 649-655.

Covert Response Patterns During the Processing of Language Stimuli[1]

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Our efforts to identify the events that occur within a person as he silently receives language stimuli have resulted in the specification of a few reliable phenomena, but the sparsity of our knowledge is indicated by the highly speculative hypotheses about processes of information input, decoding, storage, retrieval, and the like. Typically, the central nervous system carries the burden for the processing of language stimuli, though feedback loops between receptors, effectors and the brain are also usually implicated (e.g., Hebb, 1949; Lashley, 1951). Our speculations about the intimate interrelations among receptor, effector and brain events as a function of language input are gradually being modified and more empirically based as improvements are made in our research techniques and designs. The goal is to specify temporal relationships among the numerous events that occur during language processing and to identify the function of each event.

One phenomenon that has been reliably demonstrated is heightened covert oral behavior when Ss receive and process language stimuli (prose) during silent reading (e.g., Faaborg-Andersen and Edfeldt, 1958; Edfeldt, 1960; McGuigan, Keller and Stanton, 1964; McGuigan and Rodier, 1968). However, the general design used in these studies was to compare amplitude of covert oral behavior during a resting (baseline) condition with amplitude when Ss engaged in the single task of silent reading. We have, therefore, little knowledge, gained under controlled conditions, about comparable changes when Ss engage in other tasks. Consequently, we do not know whether the covert oral response is a function of language input, or whether it occurs regardless of the nature of S's task. The purpose of this investigation was to study relative changes in covert behavior under controlled conditions where only the type of task was varied. More particularly, an effort was made to compare amplitudes and patterns of responses during silent reading with behavior during memorization, listening to auditory prose, to music and to nothing. The specification of response patterns as a function of type of stimulus input and task should enhance our understanding of the function of covert behavior and, eventually, identify its role in the complex sequence of events that occur during the processing of language stimuli.

Experiment I

Subjects. Seventy-five undergraduate female psychology students were randomly assigned to five groups. The number of Ss available for each dependent variable measure is specified in Table 1; attrition was due to frequent failure of the integrator and because the arm measure was not added until late in the experiment.

Procedure. The S was first assured that she was not going to suffer any discomfort, and surface electrodes were placed on the chin and preferred forearm, following Davis (1959).[3] Instructions were given that the experiment involved thinking and listening and close attention should be paid so that any information presented could be later recalled. Each S first relaxed for a 1 min. rest period, during which time baseline measures were recorded; then S silently engaged for 5 min. in one of the following activities, depending on her group: (1) reading a portion of Poe's The Black Cat; (2) memorizing a portion of that story; (3) listening to a portion of the story presented by means of a tape recorder; (4) listening to a selection of music from Vivaldi on tape; or (5) listening to a blank tape with instructions to pay attention in case she heard anything.

Apparatus. The laboratory was unshielded and consisted of two adjacent sound-deadened rooms, one for S and one for observation and recording. The electrodes led into two Tektronix 122 amplifiers and a current amplifier, all placed in series to provide X 10,000 amplification. Chin electromyograms (EMG) were integrated on line every second by means of an integrator modeled after that reported by Jacobson (1940). The integrated chin signals and direct arm EMG were recorded on a Visicorder.

Quantification of the Data. Response values in the intervals 10 sec. prior to, following the start of and at the end of the activity periods were discarded. For chin EMG the heights of the integrated traces were measured in cm. and a mean value was obtained for each S during rest and the activity period. For arm EMG, the height of the largest spike within each 5 sec. period was measured, and a mean maximum amplitude was computed for each S during rest and the activity period. (For further details of the apparatus and quantification procedures for Experiments I and II, see McGuigan and Rodier, 1968).

Results[4]

The mean value of the integrated chin response during rest was subtracted from the mean value during the activity period of each S, and similarly for the arm response. Group means of these differences were then computed and

Insert Table 1 about here

entered in Table 1. We can note that chin EMG increased from rest to activity for all conditions and that the increase is greater when Ss read, memorized or listened to the story than when they listened to music or to nothing. However, none of these means differ significantly from zero, (α = .05 throughout). The mean increase from resting for arm EMG is greater for the memorization and reading conditions than for the other three conditions, though none of the means for this measure approach significance. Duncan's Range Tests indicated

Table 1

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

Response		Condition				
		Reading	Memorize	Listen Story	Listen Music	Listen Nothing
Integrated Chin EMG	$\bar{X}$	.31	.23	.44	.08	.11
	n	8	7	7	6	8
Maximum Amplitude Arm EMG	$\bar{X}$	.18	.48	.03	.02	-.04
	n	6	4	4	6	4

that there were no significant differences between means for either the chin or the arm responses.

The relatively high chin responses for the three conditions that involved language stimuli was sufficiently encouraging to invite follow-up research, particularly in view of the possibility that the failure of the statistical tests to indicate significant differences may have been due to the small *ns* available.

Experiment II

__Subjects__. Forty *Ss* from the same population as for Experiment I were 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.

__Procedure__. The same procedures and apparatus as previously specified were used except that tongue and preferred forearm EMG were recorded on coordinated audio tape recorders, and 2-min. rest periods preceded each activity period.

__Quantification of the Data__. The analog EMG signals from magnetic tape entered a root-mean-square (RMS) voltmeter, which gave out a direct current 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 digital voltmeter that read the amplitude of the RMS signal instantaneously every 5 sec. The resulting sampled (RMS) amplitudes were printed out on a digital recorder. Values in the intervals 10 sec. before, after the start of and at the end of each activity period were discarded. Mean values were computed for each *S* for 1 min. of rest prior to activity and during the 5 min. of each activity period.

Results

The mean amplitude of tongue EMG during each rest period was subtracted from the mean amplitude during the corresponding consequent activity period for each S, and similarly for arm EMG. For example, an S's mean tongue amplitude during the rest period preceding reading was subtracted from her mean tongue amplitude during reading. Group means of these differences were computed and entered into Table 2. Sandler's A test (cf McGuigan, 1968) indicates that tongue EMG significantly increased for the memorization,

Insert Table 2 about here

reading and nothing conditions.[5] To study the relative increases, paired t-tests were conducted between all possible pairs of means. It was found that the memorization condition led to a significantly higher amplitude of tongue response than did all other conditions, (memorization vs. listening to the story, $t = 3.11$; memorization vs. music, $t = 4.18$; memorization vs. reading, $t = 2.62$; memorization vs. nothing, $t = 3.28$). No other pairs differed significantly.

Arm EMG significantly increased only for the memorization and reading conditions. Tests between pairs indicate that all conditions led to a significantly greater increase in the arm EMG than did the change for the music condition (music vs. listening 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. listening to story, $t = 2.94$). No other pairs differed significantly.

The results of Experiment II are generally consistent with those of Experiment I in that amplitude of covert oral and non-oral behavior was high during memorization and reading relative to the other three conditions. It

Table 2

Mean Covert Response Changes in μv for Five Conditions (Experiment II)

Response		Condition				
		Reading	Memorize	Listen Story	Listen Music	Listen Nothing
Sampled	$\bar{X}$	3.23	6.89	1.85	.69	1.84
Tongue EMG	A	.106*	.062*	.405	2.447	.194*
Sampled	$\bar{X}$	2.23	5.09	.56	-1.39	1.19
Arm EMG	A	.155*	.129*	1.142	.267	.302

* $p < .05$

therefore seemed advisable to conduct an additional experiment in which more extensive and sensitive measurements could be made.

Experiment III

Subjects. Twenty-five Ss from the same population as before were presented all five conditions using a repeated treatments design as in Experiment II.

Procedure. The same procedures as previously specified were used, except that chin, tongue and preferred forearm EMG, electroencephologrars (EEG) from the right motor area (C-4), and pneumograms were recorded on an eight-track data tape recorder.

Apparatus. High permeability steel with a magnetic liner surrounded the S and apparatus rooms to effectively shield extraneous radio frequency and low frequency signals. The amplifiers were the same as before, but amplification was X 100,000.

Quantification of the Data. The analog EMG and EEG signals from tape entered an RMS voltmeter, as before; the resulting signals were fed to a voltage-to-frequency converter which yielded a signal that varied between 0 and 10,000 counts/sec. The signal from the converter entered an electronic counter which counted the frequency for each 10-sec. period, and converted it to a binary-coded decimal signal that was printed out on a digital recorder; this value is a mean integrated RMS voltage and provides the amplitude of each measure for each 10-sec. interval of the experiment. Mean values during each rest and each activity period were computed for each S, as in Experiment II. Pneumograms were quantified by determining respirations per min. during the resting sessions and during the experimental periods for each S.

Results

The mean value for each measure during each rest period was subtracted from the mean value during each corresponding consequent activity period for each S, as in Experiment II. Group means were then computed and entered in Table 3. It can be observed that both measures of covert oral behavior (tongue and chin EMG) significantly increased from resting during

Insert Table 3 about here

reading and memorization, but not during the other three conditions. The results of A tests between all possible pairs of means indicated that memorization led to a significantly higher amplitude of chin EMG than did listening to the story (A = .172) to music (A = .146) and to nothing (A = .158); the mean increase during reading was significantly higher than during music (A = .190) and nothing (A = .255). No other differences for chin EMG were significant. The mean increase for tongue EMG was significantly higher during memorization than while listening to the story (A = .174); to music (A = .118), and to nothing (A = .094); the mean tongue EMG increase was also significantly higher during reading than during music (A = .194) and nothing (A = .179). No other pairs of means differed significantly.

The measure of covert non-oral behavior (preferred forearm EMG) increased significantly from rest during reading, memorization and listening to the story. The increase during memorization was significantly higher than during all other conditions (vs. listening to story, A = .153; vs. reading, A = .149, vs. music, A = .137; vs. nothing, A = .139). The means during reading and listening to the story were significantly higher than during the music condition (A = .226 and .252 respectively). No other pairs differed significantly.

Respiration rate significantly increased during reading, memorization, listening to the story, and listening to music. The increases during memorization, reading and listening to the story were all significantly higher than

Table 3

Mean Covert Response Changes for Five Conditions.

EMG Measures are Integrated (μv). (Experiment III)

Response		Condition				
		Reading	Memorize	Listen Story	Listen Music	Listen Nothing
Chin EMG	$\bar{X}$	6.92	8.65	.86	.66	.14
	A	.202*	.099*	4.362	7.650	88.848
Tongue EMG	$\bar{X}$	9.67	18.45	6.65	- .76	- .87
	A	.199*	.110*	.395	61.72	5.74
Arm EMG	$\bar{X}$	4.08	10.46	1.23	- .31	.63
	A	.263*	.137*	.209*	4.561	.975
Respiration Rate (per min.)	$\bar{X}$	2.33	2.98	2.25	1.34	.55
	A	.082*	.064*	.060*	.093*	.425

*$p < .05$

while listening to music or to nothing: (memorization vs. music, $\underline{A}$ = .130; memorization vs. nothing $\underline{A}$ = .099; reading vs. music, $\underline{A}$ = .252; reading vs. nothing, $\underline{A}$ = .142; listening to story vs. music, $\underline{A}$ = .251; listening to story vs. nothing, $\underline{A}$ = .095). No other pairs of means differed significantly.

Due to technical difficulties, useable EEG records were obtained from only nine Ss. Even so, an analysis of these data indicated that mean integrated EEG (C-4) significantly decreased from the condition of resting to that of listening to nothing ($\bar{X}$ = -1.23 μv, $\underline{A}$ = .239). No other EEG changes approached significance.

Discussion

The response patterns during the several conditions may be briefly summarized as follows. First, the finding that silent reading resulted in heightened covert oral (tongue and chin EMG) and one measure of non-oral (preferred forearm EMG) behavior, and in increased breathing rate confirms previous findings cited above. The design used in the present investigation, furthermore, allows us to assert that increased covert oral behavior and increased breathing rate during reading do not occur merely because Ss change from a condition of relaxation to one of silent activity, regardless of the nature of that activity, i.e., both measures of covert oral behavior and breathing rate increased significantly more during reading than during attentive listening to nothing and to music.

To further interpret the above findings, we may note that comparison of behavior during reading with that while listening to music and to nothing also involves a comparison of the use of visual vs. auditory modalities. However, covert oral behavior and breathing rate were not significantly greater than the auditory condition in which language stimuli were presented (viz., listening to the story). It would, therefore, appear that the relatively increased covert oral behavior during silent reading was not due to (1) a mere change in alertness or (2) a comparison of visual vs. auditory modalities, or (3) processing of stimuli, regardless of the nature of those stimuli. Rather relatively heightened covert oral behavior and breathing rate appear to be associated with the processing of language stimuli that occurs during silent reading.

The same general pattern of behavior occurred during memorization as for reading, except that covert behavior was of a relatively greater amplitude during memorization, e.g., covert oral behavior during reading was not significantly greater than while listening to the story, but it was significantly higher during memorization than while listening to the story. The interpretation of this finding may be facilitated by observing that in reading S merely samples the prose. But in memorization S processes and reprocesses every word, an activity that may more extensively involve the speech musculature.

Amplitude of covert oral behavior while listening to the story tended to increase, but in no case was the mean for this condition significantly different from zero. A similar tendency was previously reported (McGuigan and Rodier, 1968). It is possible that covert oral activity does increase during attentive listening to prose, but our results still are not sufficiently positive to allow that conclusion. Perhaps differences in experimental procedure are responsible for this contrast in results with those of others, e.g., Smith, Malmo and Shagass (1954) reported a significant increase in chin EMG during listening, but they reduced the volume control at intervals so that S had to make an effort to hear the prose.

The general pattern of results for the conditions in which Ss listened to nothing and to music is negative, and there were no significant differences between these two conditions. The limited finding of a significant decrease in EEG during the nothing condition is in accord with the finding of Lindsley (1952) that EEG amplitude decreases from relaxed wakefulness to alert attentiveness.

The common response patterns for arm EMG and breathing rate during the three conditions in which language stimuli were presented deserve special attention. That is, when Ss read, memorized or listened to the story arm EMG and breathing rate significantly increased, and the increases for these three conditions were significantly greater than for the conditions of listening to nothing and to music. It is possible that, because the respiratory mechanism is intimately involved in the production of speech, increased rate occurred because Ss were making covert language responses. That is, if the Ss were in fact engaged in "subvocal speech" when reading, memorizing and listening to prose, increased respiratory activity would be required for the production of such "silent speech." The relatively high arm EMG during the three conditions that involved language may be due to the fact that it was preferred forearm EMG that was recorded. It is possible that, because the preferred arm is used in writing, language stimuli (regardless of modality or type of language task) evoke heightened activity in that region. This interpretation is supported by the findings of Davis (1939), for this investigator reported that during "mental arithmetic," covert activity was greatest in the right arm, followed in turn by the left arm and then in the leg. Davis states that Ss spontaneously reported that "... they had a strong tendency to write during multiplication..." (p. 458) and suggests that "... we are dealing with a right arm task..." (p. 459).

The type of design used in this investigation has yielded some clues as to the patterns of covert behavior during the silent processing of language stimuli. It is suggested that covert oral behavior, preferred forearm activity and increased breathing rate are associated with the performance of language tasks. Requirements for an enlargement of our understanding of the functions of the various bodily events are that we more extensively sample from the non-oral regions and that we continue to systematically vary type of stimulus input and task.

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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]Thanks to Douglas Gresham, William Rodier III, and Ronald Suiter, for their contributions to this research.

[3]Pneumograms were also recorded in Experiments I and II and chin EMG in Experiment II, but these data will not be presented because of their questionable value.

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

[5]Tongue EMG also significantly increased while the *S*s listened to the blank tape. However, this finding was not confirmed in Experiment III and thus is not considered to be reliable (see Table 3).

The Effect of Increased Reading Rate on Covert Oral Behavior [1,2]

Educators have traditionally held that "subvocalization" during silent reading is detrimental to reading proficiency, e.g., Betts (1950) has stated that "...any observable form of vocalization--such as silent lip movement... retards the rate of silent reading (which) has been common professional knowledge since the early scientific studies of reading" (p. 450). One implication of this position is that the reduction of subvocalization should result in increased reading proficiency. Efforts have been made to test this hypothesis by reducing amplitude of covert oral behavior through operant techniques (e.g., McGuigan, 1966). Another implication is that increases in one's reading rate should reduce the amplitude of covert oral behavior during reading.

The classical view of the function of covert oral behavior has, however, more recently been challenged. Edfeldt (1960), for example, holds that silent speech (as measured by electromyograms from the speech musculature) occurs in all individuals and it is likely that "...silent speech actually constitutes an aid toward better reading comprehension" (p. 154). McGuigan and Rodier (1968) also concluded that covert oral behavior during silent reading is beneficial. The hypothesis that covert oral behavior facilitates the reading process thus leads to a prediction contrary to that of the classical position, viz., that an increase in reading rate should <u>not</u> reduce the amplitude of a person's covert oral responses; it is even possible that increases in reading rate would result in increased amplitude of covert oral behavior. It was the purpose of this experiment to decide between the classical and the more contemporary interpretations of the function of covert oral behavior during reading. Consequently reading rate of <u>S</u>s was increased and the effect on the amplitude of their covert oral behavior was studied.

Method

Subjects. Undergraduate female students at Hollins College volunteered to take a "Speed Reading" course, and were randomly assigned to one of three groups: 22 to the Experimental Group, 11 to Control Group #1 and 11 to Control Group #2. Attrition in Groups E, C_1 and C_2 was five, five, and four Ss respectively.

Procedure. All Ss were first administered Form A of the Nelson-Denny Reading Test (1960). Members of Groups E and C_1 then individually rested, read silently, and rested again in the laboratory while the following measures were taken: electromyograms (EMG) from the tongue, lips, throat, and leg; electroencephalograms (EEG) from the occipital lobes; electrooculograms (EOG) from the external canthi; and pneumograms. Group E (two sections of 11 Ss each) was then given a reading rate improvement course using the Science Research Associate's (SRA) accelerator. The Ss read daily from their own books. The accelerator setting was individually determined on the basis of a timed rate and comprehension test using SRA IVa Blue Booklets. Individual scheduling problems limited the number of sessions to a minimum of 12 for some Ss and to a maximum of 17 for others.

At the end of the reading course all Ss from the three groups were given Form B of the Nelson-Denny Reading Test and were individually tested in the laboratory with the same electrode placements as for the first laboratory reading session.

Results and Discussion

Table 1 shows that Group E increased their reading rate on the Nelson-Denny Reading Test by 149 words per minute, that their rate while the psychophysiological measures were being taken increased by 145 words per minute, and that both increases were significantly different from zero (t = 5.58 and

Table 1

Mean Reading Rate Changes (Words Per Minute) and Comprehension Scores

	Group											
	Experimental (n=17)				Control #1 (n=6)				Control #2 (n=7)			
	Nelson-Denny		Laboratory		Nelson-Denny		Laboratory		Nelson-Denny		Laboratory	
	Rate (WPM)	Comprehension (%)	Rate (WPM)	Comprehension (%)	Rate (WPM)	Comprehension (%)	Rate (WPM)	Comprehension (%)	Rate (WPM)	Comprehension (%)	Rate (WPM)	Comprehension (%)
Before Course	332	87	361	62	397	82	419	63	294	85	-	-
After Course	481	85	506	66	412	84	344	65	315	86	277	67
Change	149*		145*		15		-75		21			

* $p < .05$

$\underline{t}$ = 3.51 respectively). The rate changes for Groups $\underline{C_1}$ and $\underline{C_2}$ were minor and not significant. The mean increase in reading rate for Group $\underline{E}$ was significantly greater than the change for Group $\underline{C_1}$ on both the Nelson-Denny ($\underline{t}$ = 2.97) and in the laboratory ($\underline{t}$ = 2.60). Similarly, the increase for Group $\underline{E}$ was significantly greater than the change on the Nelson-Denny for Group $\underline{C_2}$ ($\underline{t}$ = 3.46). Changes on the Nelson-Denny were not significantly different for the two control groups. Comprehension scores universally remained quite stable. It can, thus, be concluded that the experimental Ss did in fact increase their reading rate, leading to the question of whether or not there was a change in their covert oral behavior.

The psychophysiological data were recorded on a multi-channel tape recorder and converted to mean integrated amplitudes for each 10 sec. period of relaxation and reading using the digitizing apparatus previously reported (McGuigan & Rodier, 1968). Table 2 presents the resulting mean values for the EMG, EEG and respiration measures during the resting and reading periods. It can be observed that, in general, all groups increased the amplitude of their covert oral behavior (lip, throat and tongue EMG) during reading relative to the prereading rest periods; the only notable exception is for throat EMG for the control groups, indicating that this electrode placement is insensitive relative to those for lip and tongue activity. The increase in covert oral behavior for Group $\underline{E}$ is generally significantly greater than zero. A sample of non-oral behavior (leg EMG), on the other hand, showed little change when Ss went from rest to the reading condition, suggesting that the behavioral changes during reading were localized in the speech musculature. Mean integrated EEG significantly decreased from a resting to a reading condition. Respiration rate increased during reading relative to rest, the increases being significantly different from zero for Group $\underline{E}$. All of these results

Table 2

Mean Response Values (μv) Before and After the Reading Improvement Course

		Before Course					After Course				
Measure	Group	Rest	Read	Rest	Difference	t	Rest	Read	Rest	Difference	t
Tongue EMG	E	2.7	2.8	2.5	.1	.19	2.2	2.4	1.9	.2*	2.92
	C_1	1.7	2.2	2.4	.5*	2.77	1.6	1.6	1.1	0	.00
	C_2						2.0	2.2	1.7	.2	.66
Lip EMG	E	1.7	2.5	1.9	.8*	2.87	1.7	2.3	1.8	.6*	4.93
	C_1	1.2	1.9	1.7	.7	2.56	1.7	2.7	2.2	1.0*	4.81
	C_2						2.9	3.2	2.9	.3	1.01
Throat EMG	E	1.2	1.3	1.2	.1	.64	1.1	1.2	1.0	.1	1.38
	C_1	1.0	1.0	1.0	0	1.00	1.2	1.2	1.1	0	1.00
	C_2						1.2	1.2	1.2	0*	3.87
Leg EMG	E	1.0	1.0	1.0	0	.10	1.1	1.0	1.0	-.1	.70
	C_1	.7	.7	.7	0	.00	1.1	1.0	1.0	-.1	.54
	C_2						1.1	1.0	.9	-.1*	3.36
Frontal EEG	E	6.0	4.3	6.0	-2.2*	6.20	6.0	4.5	6.0	-1.5*	3.61
	C_1	5.2	4.0	5.3	-1.2	.74	4.8	3.6	4.8	-1.2*	2.50
	C_2						5.6	4.6	6.2	-1.0	1.04
Respirations Per Minute	E	15.9	18.1	16.8	2.2*	2.63	16.1	17.8	15.3	1.7*	3.02
	C_1	18.2	19.7	16.5	1.5	1.92	16.5	19.9	17.2	3.4	2.99
	C_2						16.5	17.8	15.7	1.3	1.54

* $p < .05$

confirm previous findings from our laboratory. The general response pattern that thus emerges as Ss change from rest to silent reading is that covert oral behavior and respiration rate increase, that mean electrical activity of the brain decreases, and that these changes are independent of covert non-oral behavior. These findings are consonant with the interpretation that heightened covert oral behavior during silent reading is serving a language function.

To study changes from before to after the reading course, the mean differences of the values in the difference columns of Table 2 were entered into Table 3. For example, tongue EMG of Group E increased from rest to reading by .1 μv before the reading improvement course, by .2 μv after the reading course, yielding a net increase of .1 μv. The increase in amplitude of this measure of covert oral behavior was significant ($p < .05$). The corresponding change for Control Group #1 was -.5 μv, a relatively large decrease perhaps due to habituation. The increase for Group E was thus large relative to that for Group C_1 and the difference between these two groups would have been significant beyond the .06 level ($t = 2.03$). None of the other measures significantly changed, nor was there a significant difference between groups. Considering only the change from rest to reading for the laboratory session after the reading improvement course, the two control groups did not differ significantly on any of the measures. These results thus fail to indicate that increasing reading rate leads to a reduction in amplitude of covert oral behavior; rather, the suggestion is that amplitude of tongue EMG actually increases as a result of increasing reading proficiency; to firmly establish this conclusion, based as it is on the "borderline significance" stated above of $p < .06$, requires a replication of this experiment (which is currently underway).

Specifiable and unique eye movements occur when one's eyes reach the end of a line of type. These particular responses were automatically counted by

Table 3

Mean Response Changes (μv) from Before to After the Reading Improvement Course

Group	Tongue EMG	Lip EMG	Throat EMG	Leg EMG	Frontal EEG	Respirations Per Minute
E	.1	- .2	0	- .1	- .7	- .4
C_1	- .5	.3	0	- .1	0	1.8
t	2.03	1.08	.20	.14	.06	1.38

feeding the electrooculograms into an amplitude sensing device and thence to an electronic counter. Table 4 presents the mean number of these responses for the three groups. A number of data were lost because polarity was unintentionally reversed by reversing the eye electrodes for some Ss from the first to the second testing. Nevertheless it can be seen that Group E significantly decreased the number of these particular eye movements ($t = 3.23$); Control Group #1 increased the number of such movements, but the increase was not significant ($t = 1.95$). Furthermore, the change for Group E was significantly different than for Group C_1 ($t = 3.76$). Considering only the values for the second test, Control Group #1 made significantly more movements than did Group E ($t = 3.52$). The facts that all three groups had essentially the same number of these movement responses on their first test and that Group E decreased the number of them during the second test indicates that this change was produced by the reading improvement course. Essentially all of the experimental Ss did decrease the number of these eye movements, the greatest decrease for an S being 57. This finding is in accord with results cited by Tinker (1965, pp. 108-109). It may be that the experimental Ss sometimes read two lines of prose simultaneously and in this way increased their rates.

Conclusion

Previous findings were confirmed in that heightened covert oral behavior was recorded during silent reading, that this increase was accompanied by increased respiration rate and decreased EEG, and that these changes were independent of covert non-oral behavior. Furthermore, increasing reading rate did not result in decreased covert oral activity; rather, it appeared to produce increases in the most sensitive oral measure (tongue EMG). Perhaps a greater increase in reading rate than occurred here would make this behavioral effect more pronounced. The reading improvement course also resulted in a

Table 4

Number of Eye Movements Normally Made at the

End of Lines of Prose During Laboratory Test

Group	n	Before Course	After Course	Difference
$\underline{E}$	12	172.7	151.5	-21.2*
$\underline{C}_1$	5	171.2	212.6	41.4
$\underline{C}_2$	7	-	171.6	-
Number of Lines Read		171	177	

* $\underline{p} < .05$

decrease in the kind of eye movements that occur when one reaches the end of a line of prose, suggesting that Ss learned to sometimes read more than one line simultaneously. The results are consonant with the hypothesis that covert oral behavior is beneficial, rather than detrimental, to the performance of language tasks such as silent reading.

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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. Thanks to Douglas T. Gresham for his valuable help in many ways.

Patterns of Covert Processes Evoked by Different Classes of Language Stimuli

Evoked electroencephalographic patterns have been found to systematically vary with a number of stimulus characteristics. "Meaningfulness" of stimuli (cf. Uttal, 1964), discriminability of stimuli (Haider, Spong, and Lindsley, 1964) and informational value of stimuli (Chapman, 1964) are a few examples of stimulus variables that have produced different central compound evoked potentials (CEPs). The purpose of this study was to extend the previous CEP findings in the area of meaningful stimuli. More particularly, the effort was to compare patterns of CEPs evoked by words with control stimuli of white noise. Furthermore, CEP pattern as a function of image evoking power of the words was studied, i.e., two extremely high imagery words and two extremely low imagery words were selected from the list standardized by Paivio, Madigan, and Yuille, 1968). Finally, since most previous studies neglected other bodily activities during the recording of CEPs, the simultaneous recording of a variety of other covert processes might shed light on the internal processing of information contained in the language stimuli. The following is a brief report of pilot work.

Method

Subject. The S was a female volunteer student of Hollins College.

Apparatus. The S was seated in a comfortable chair in a sound deadened room which was well shielded from extraneous electronic signals. Potentials were picked up with silver-silver chloride disk surface electrodes, transmitted to a second shielded (control) room, and were amplified and recorded on a Sanborn seven-channel data tape recorder as reported elsewhere (McGuigan & Rodier, 1968). Signals were averaged using a Digital Equipment Corporation PDP 8/I computer and AX08 analog-to-digital converter. This system permitted triggering on the auditory stimulus and averaging signals prior to the trigger (a negative delay). The stimuli were presented via a small portable dc tape recorder.

Procedure. The words used were all in the Thorndike-Lorge (1944) AA category for frequency of occurrence in general usage (i.e., they occurred more than 100 times per million words). The high and low imagery words were separated by a mean of 2.3 standard deviations on Paivio et al.'s imagery scale, and were approximately equated for length. Each stimulus word and white noise was presented 32 times in a random order, with the limitation that the same word was never presented twice consecutively. The following responses were measured: 1) tongue EMG, 2) lip EMG, 3) neck EMG, 4) nonpreferred arm EMG, 5) horizontal EOG, 6) EEG from the parietal area, and 7) EEG from the occipital area.

On reporting to the laboratory, the S was taken to the experimental room and assured that she was not going to experience pain or discomfort. She was instructed to listen to the words as they were played and to keep overt movements to a minimum as far as possible. She was then given effective instructions to relax following which the tape recorded stimuli were presented without interruption.

Results

The data were analyzed by averaging 2 sec. signal sweeps from the various sites beginning 75 msec. before the word onset. Averages were obtained for presentations of all stimuli together (160 sweeps) and each individual stimulus (32 sweeps) was also averaged separately.

The traces of averages for the EOG from all 160 stimuli (Fig. 1) suggest that a noticeable response occurs about 100 msec. after the stimulus presentation. However, of the EOG traces to the individual stimuli only the word "mind" shows a response (Fig. 2), indicating that this stimulus is responsible for the deflection in Figure 1. The implication is that there is an EOG response to the word "mind" that does not occur to the other stimuli, although it is apparent that this evidence is extremely

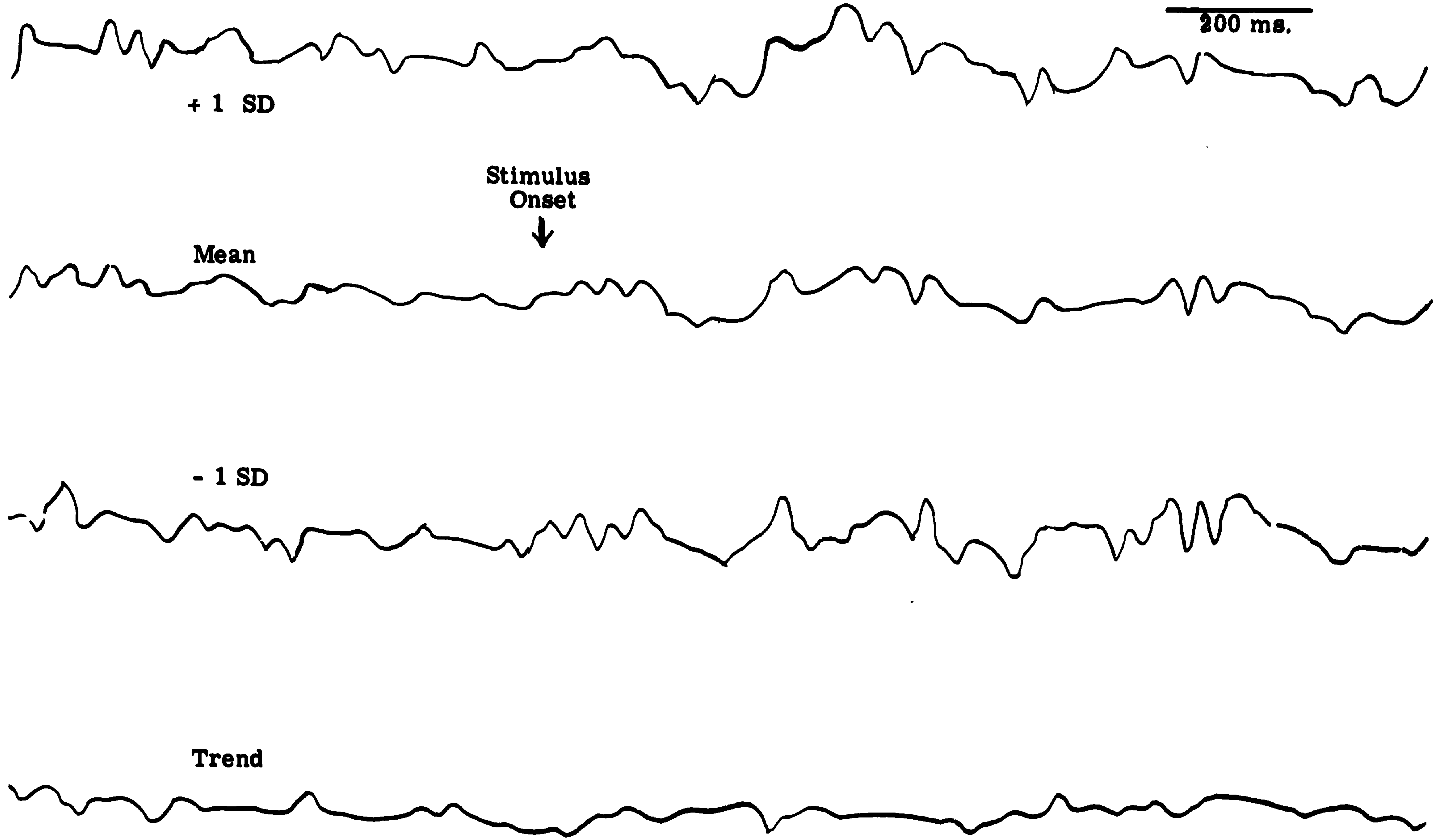

Fig. 1. Averaged EOG to all 160 stimulus presentations. Data points for ± 1 Standard Deviation from the averaged (mean) curve are shown. Trend line (bottom) suggests that responses did not change as a function of number of trials.

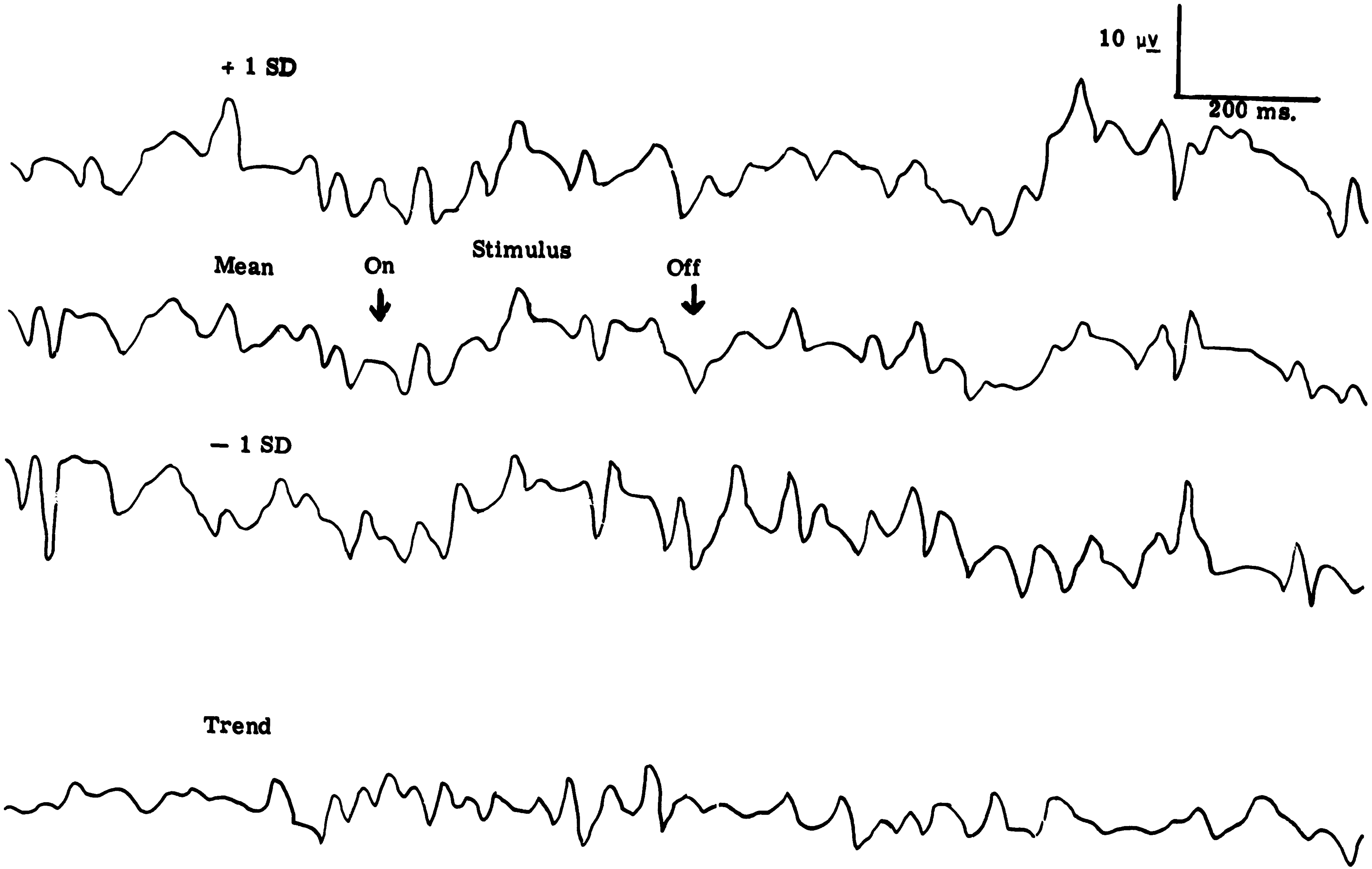

Fig. 2. Averaged EOG to 32 presentations of "mind."

tentative. Similar findings occur for the EEG traces. Of these, the clearest result is that from the parietal area (Fig. 3). There is an obvious deflection in the line following the stimulus onset by about 50 msec; similar deflections occur in the traces for the high imagery words of "girl" (Fig. 4) and "car" (Fig. 5), and to a lesser extent to the word "mind" (Fig. 6). There was no noticeable response to the noise or the word "fact."

The EEG from the occipital area (Fig. 7) shows an obvious deflection in the averaged trace for all 160 stimuli. Fig. 8 suggests an individual reaction to "car," Fig. 9 a lesser one to "mind," and Fig. 10 a rather noticeable reaction to white noise.

Relatively little in the way of clear-cut responses appeared for the various electromyograms. Such negative results may not mean, however, that there is no muscular activity in response to the various stimuli. Rather, it may be that the extremely rapid muscular responses (compared to the relatively slow brain and eye reactions) are not susceptible to averaging by the techniques used here. More particularly, it may be that the sampling time used by the computer (set for the EEGs) missed the more rapid muscular activity. Nevertheless an occasional muscular response was of interest, e.g., Figure 11 suggests tongue activity, particularly as indicated by the +1 standard deviation curve. Similarly, Figure 12 shows an unusual "quietening" effect of the stimulus "mind," an effect that had incidentally been noted in earlier pilot work, suggesting that perhaps the response was not in fact time-locked to the stimulus. Figure 13 shows a peculiar, and delayed, response in the non-preferred arm to all 160 stimuli, again as indicated by the variability measure. The major component of this response appears in the averaged response to "mind" (Fig. 14).

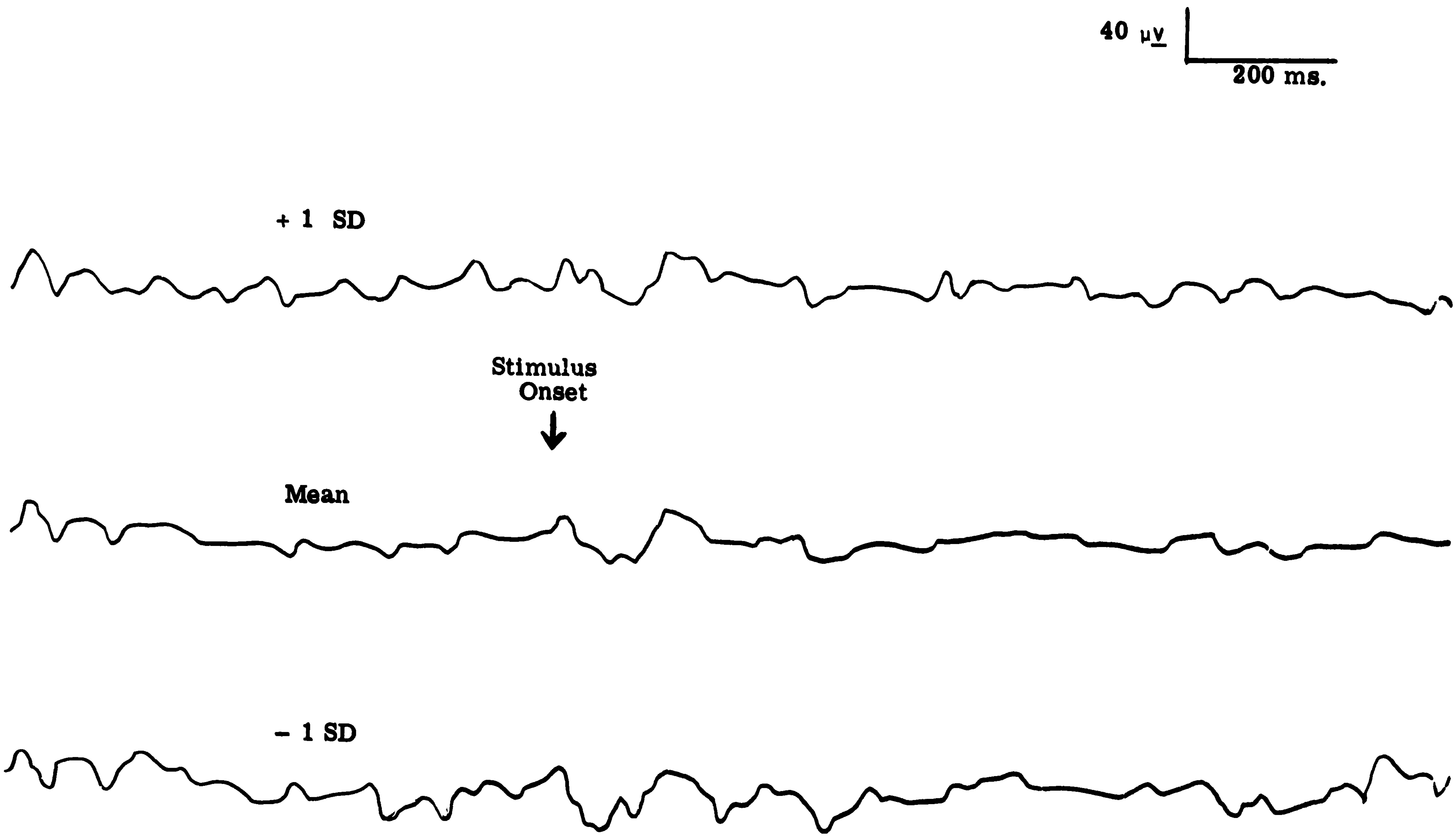

Fig. 3. Averaged parietal EEG to all 160 stimulus presentations.

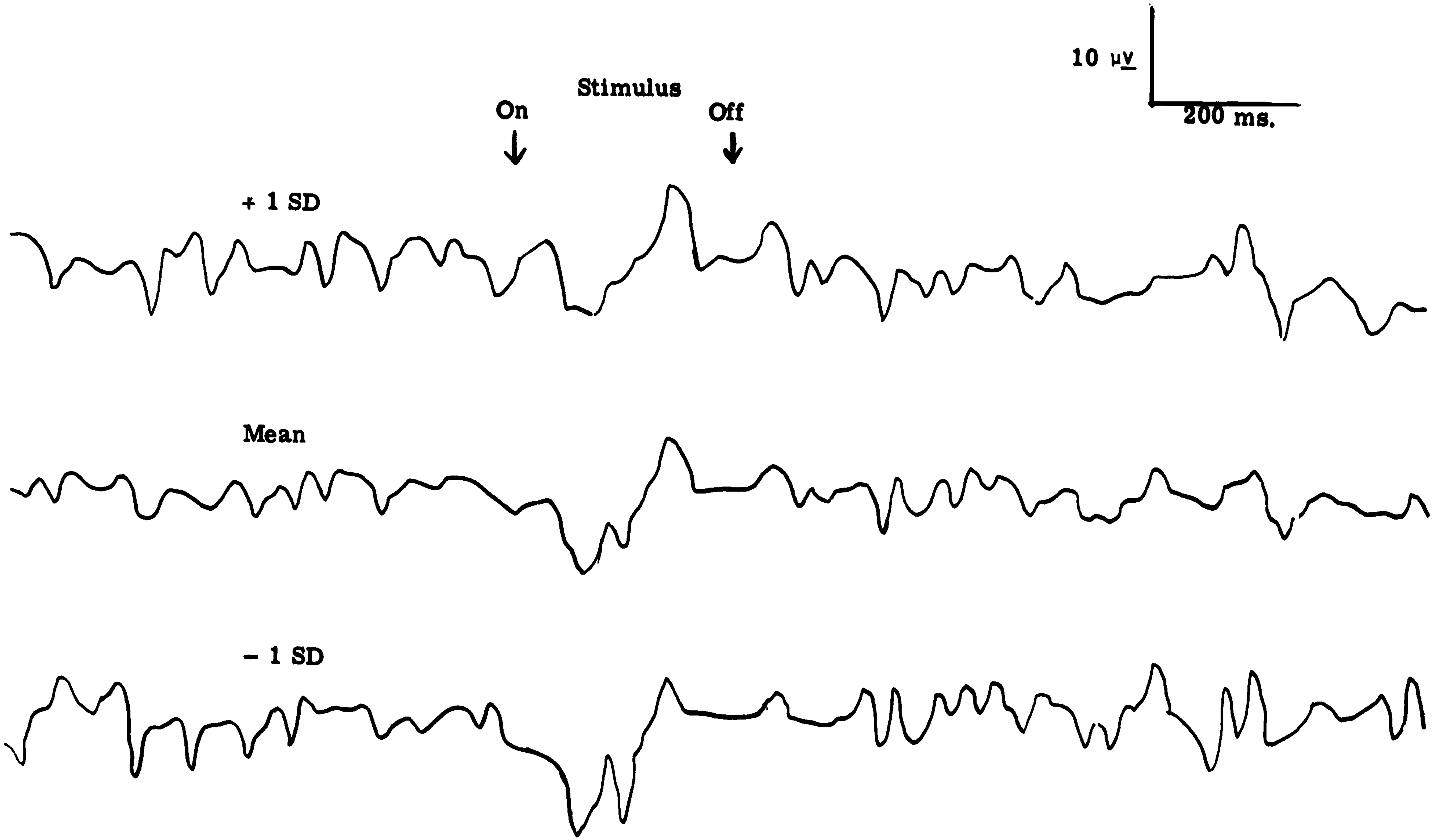

Fig. 4. Averaged EEG (parietal) to 32 presentations of "girl."

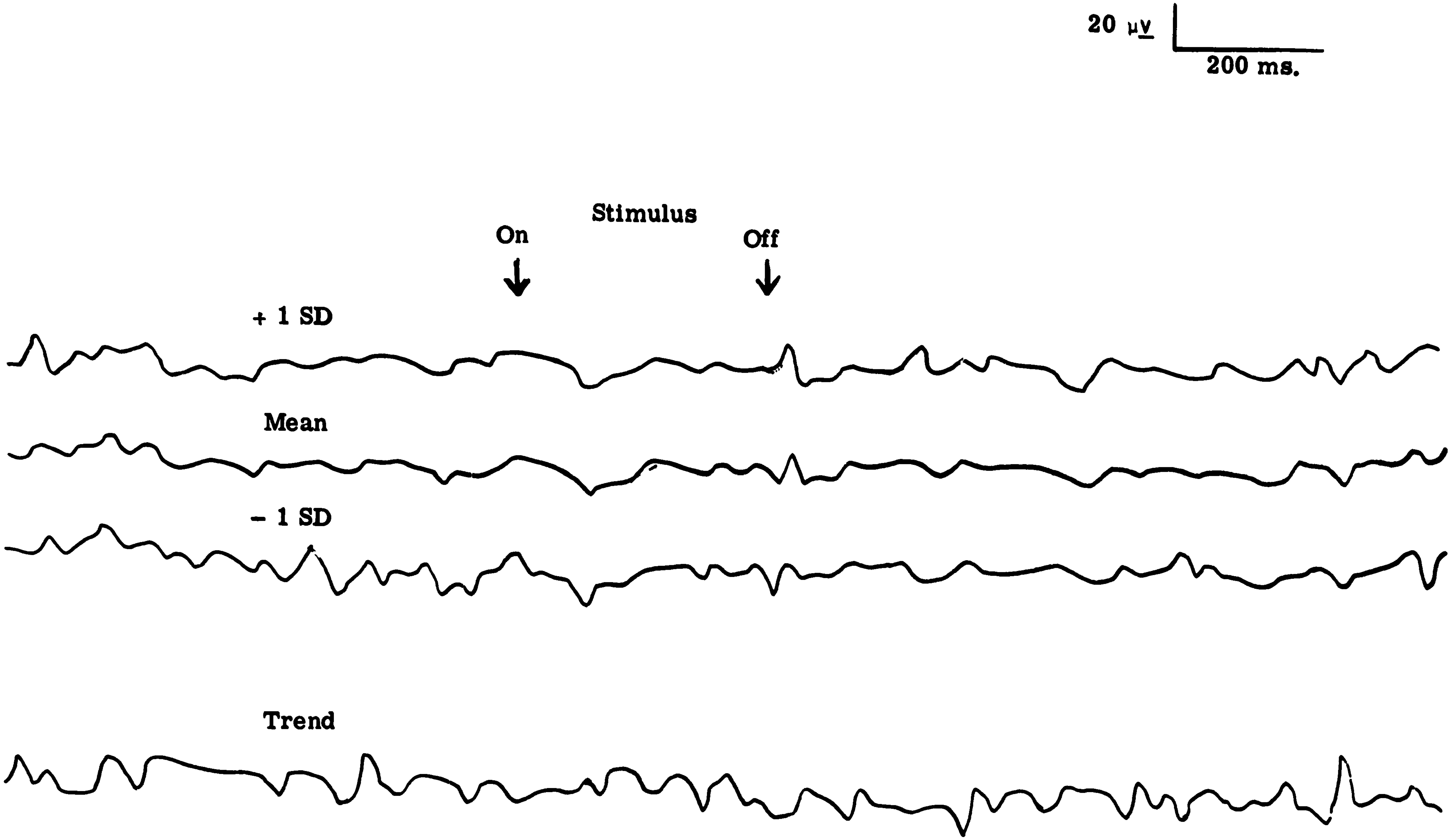

Fig. 5. Averaged EEG (parietal) to 32 presentations of "car."

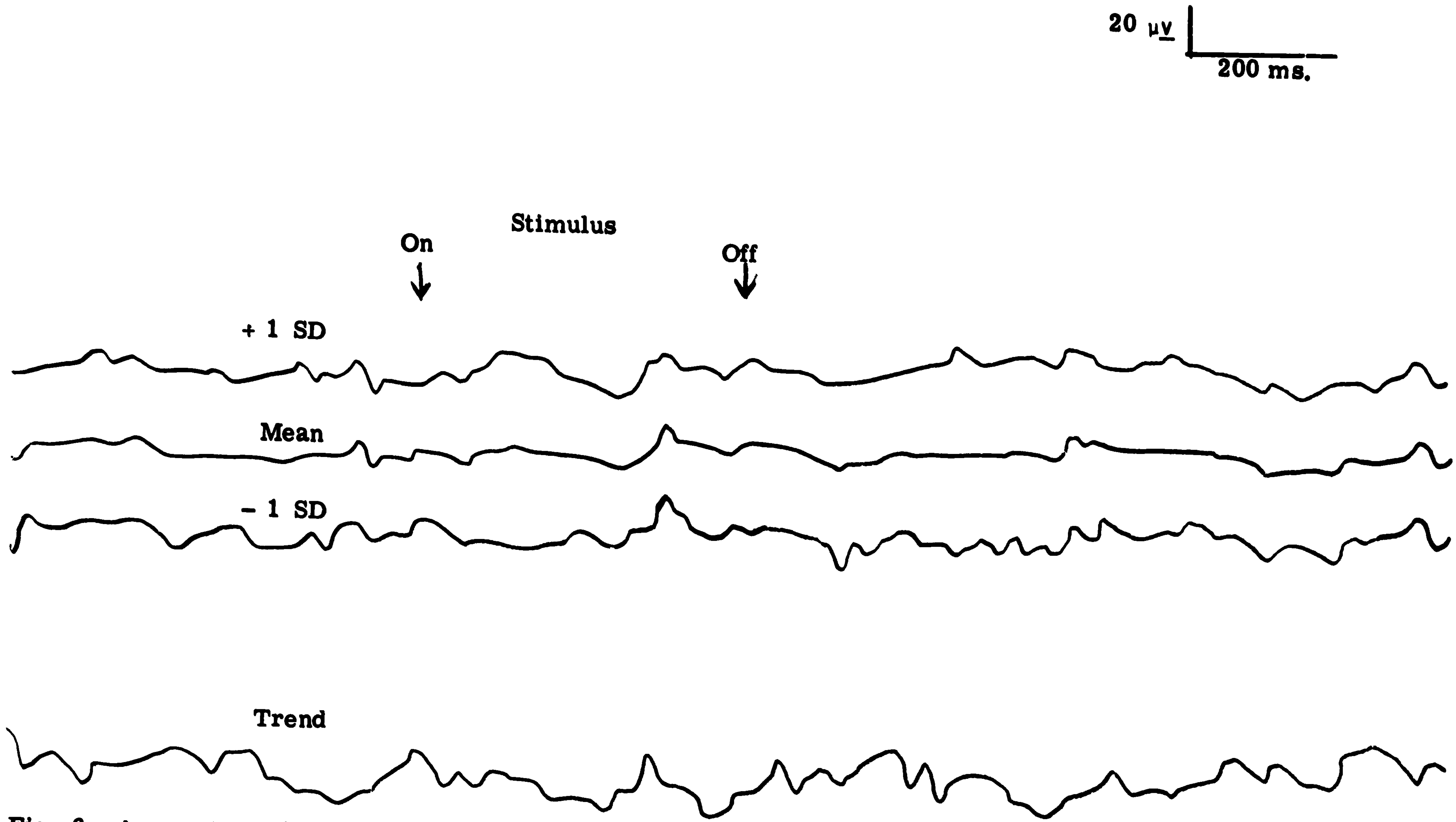

Fig. 6. Averaged EEG (parietal) to 32 presentations of "mind."

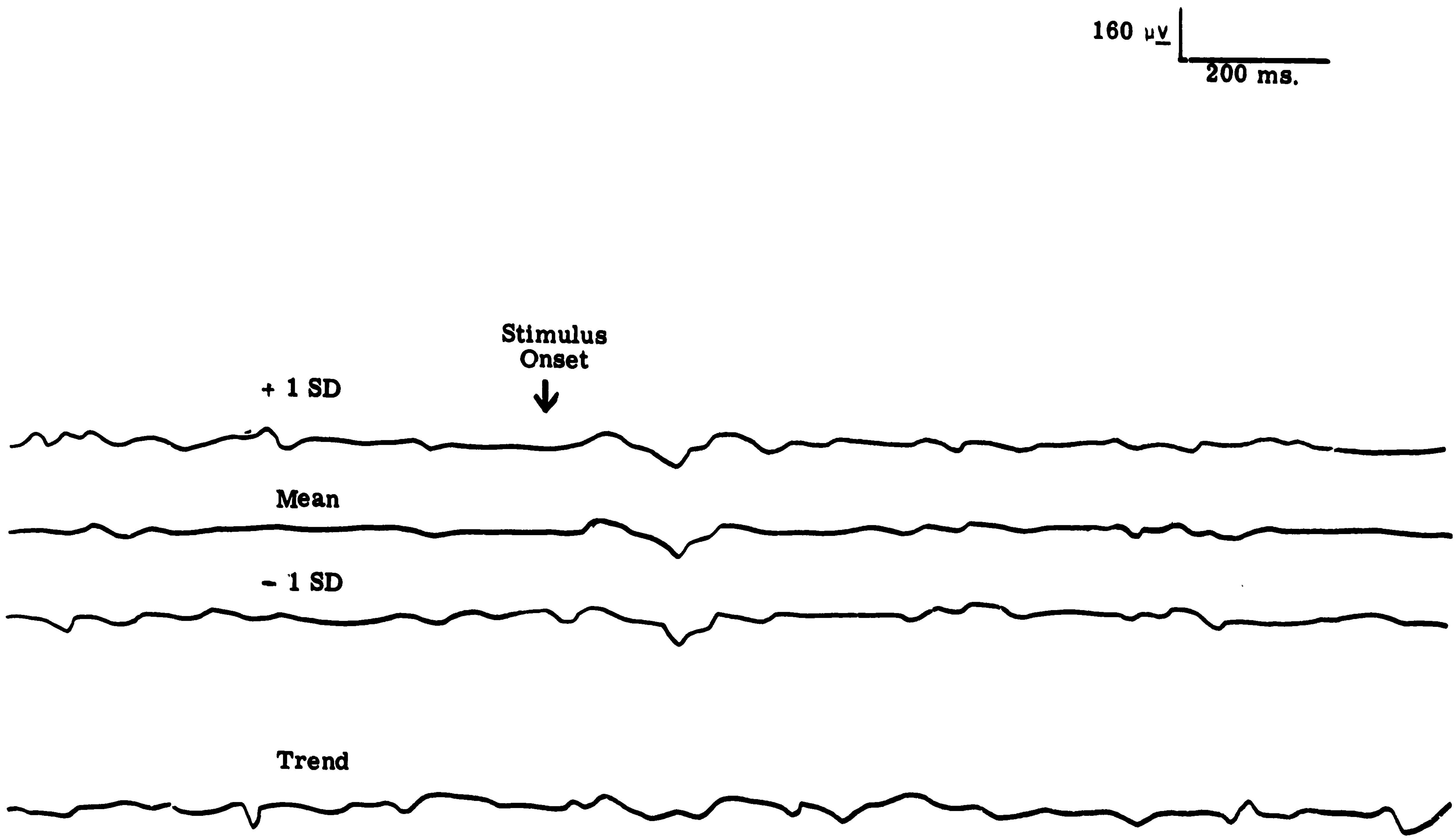

Fig. 7. Averaged occipital EEG to all 160 stimulus presentations.

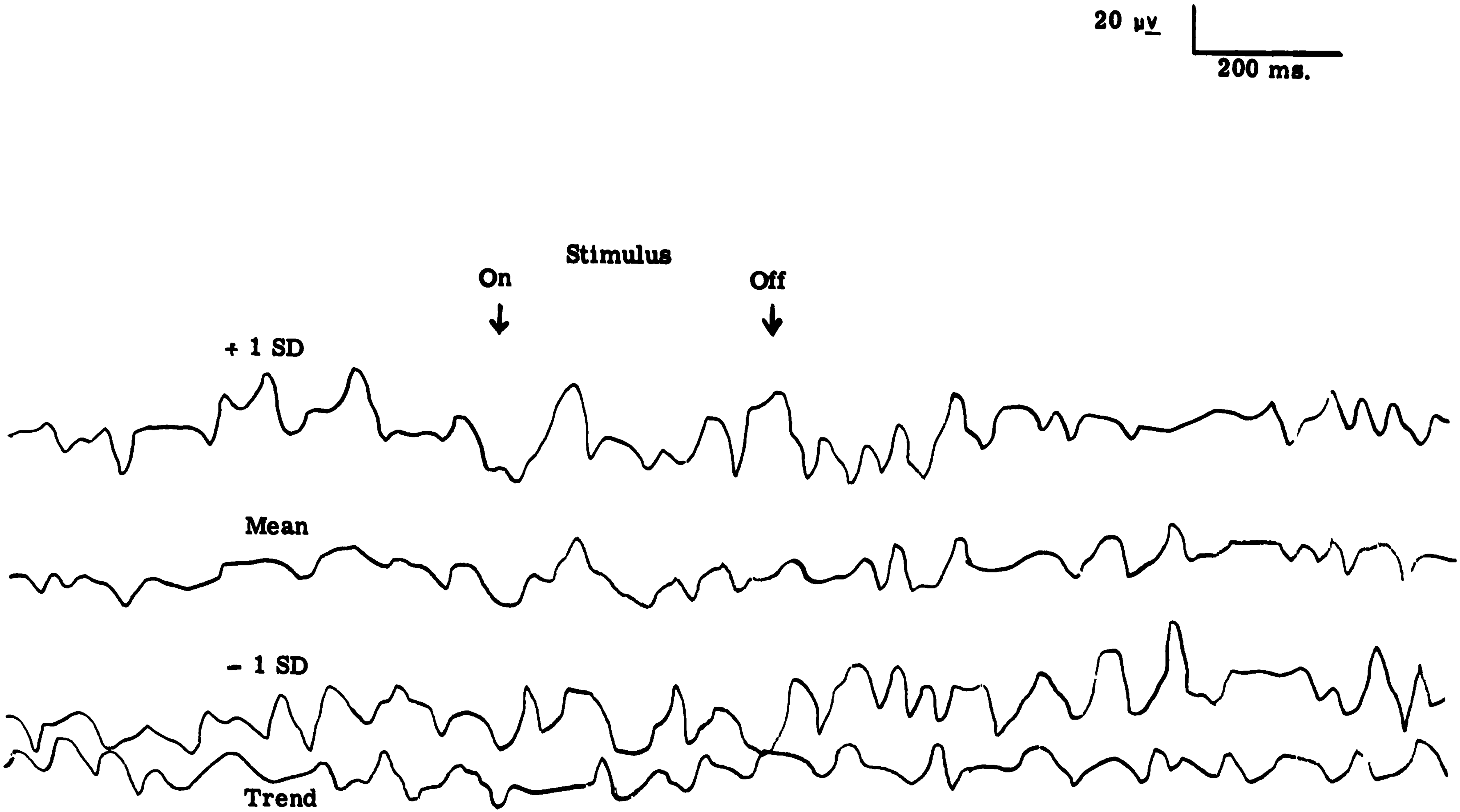

Fig. 8. Averaged EEG (occipital) for 32 presentations of "car."

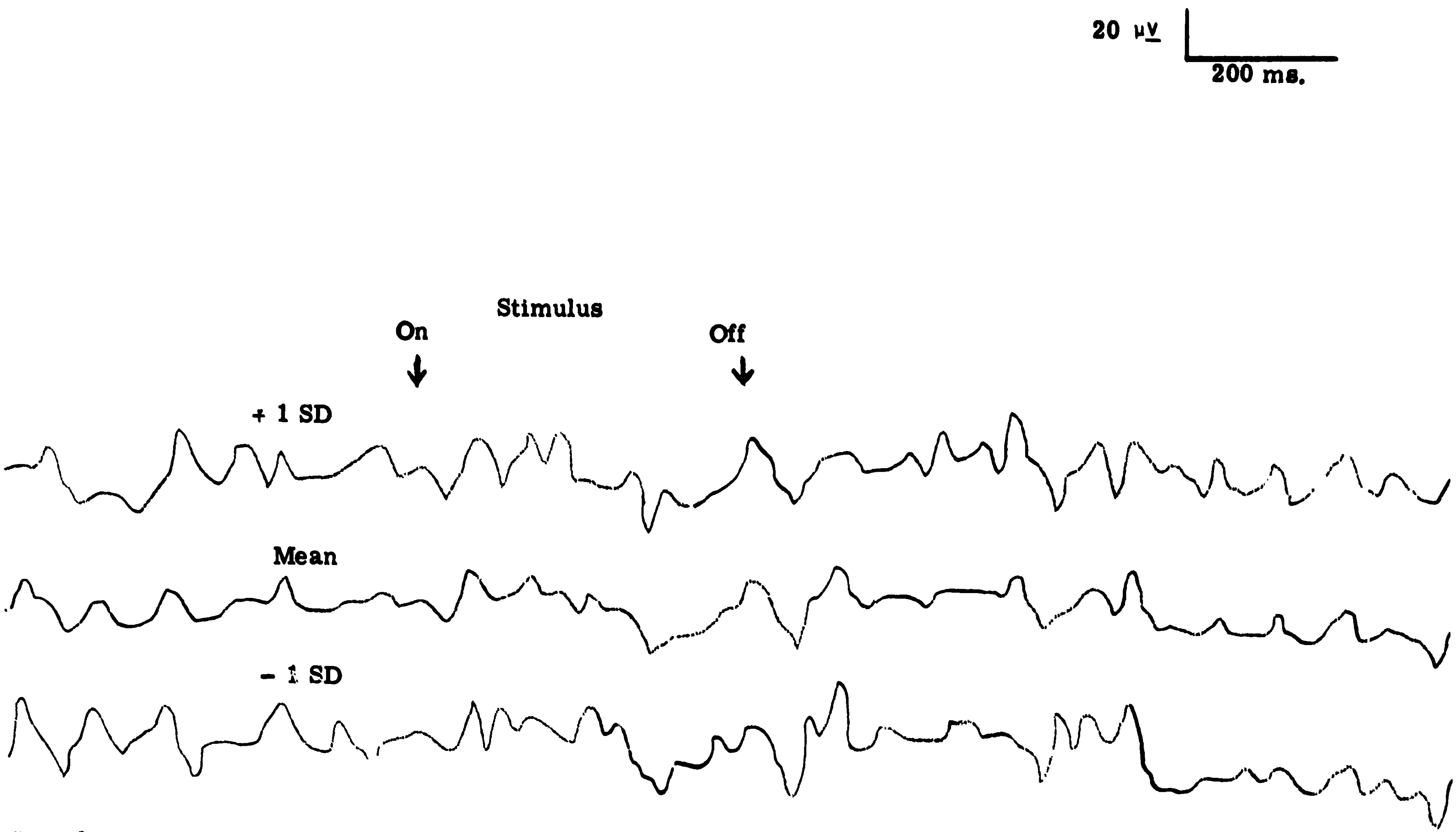

Fig. 9. Averaged EEG (occipital) for 32 presentations of "mind."

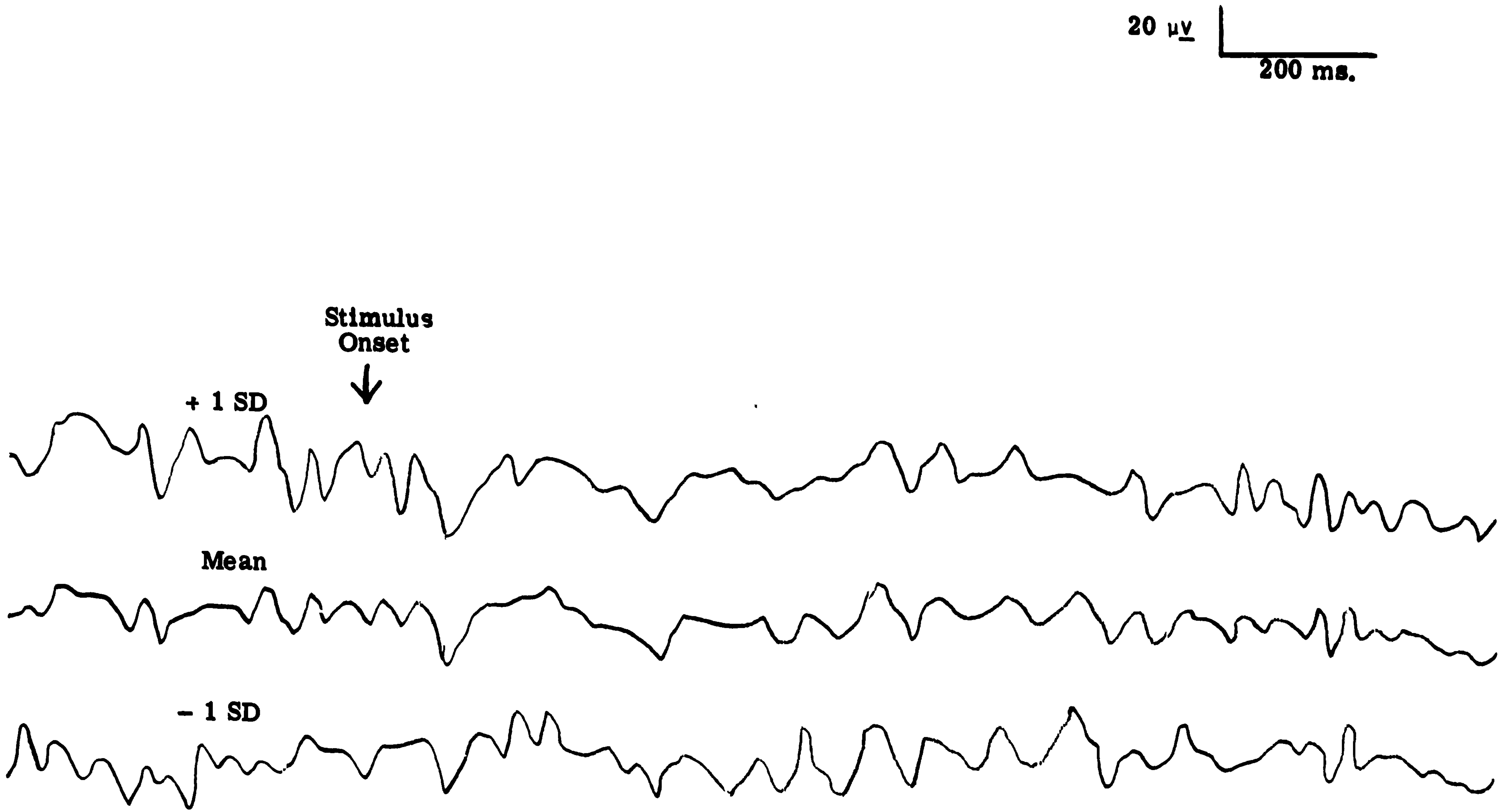

Fig. 10. Averaged EEG (occipital for 32 presentations of "white noise."

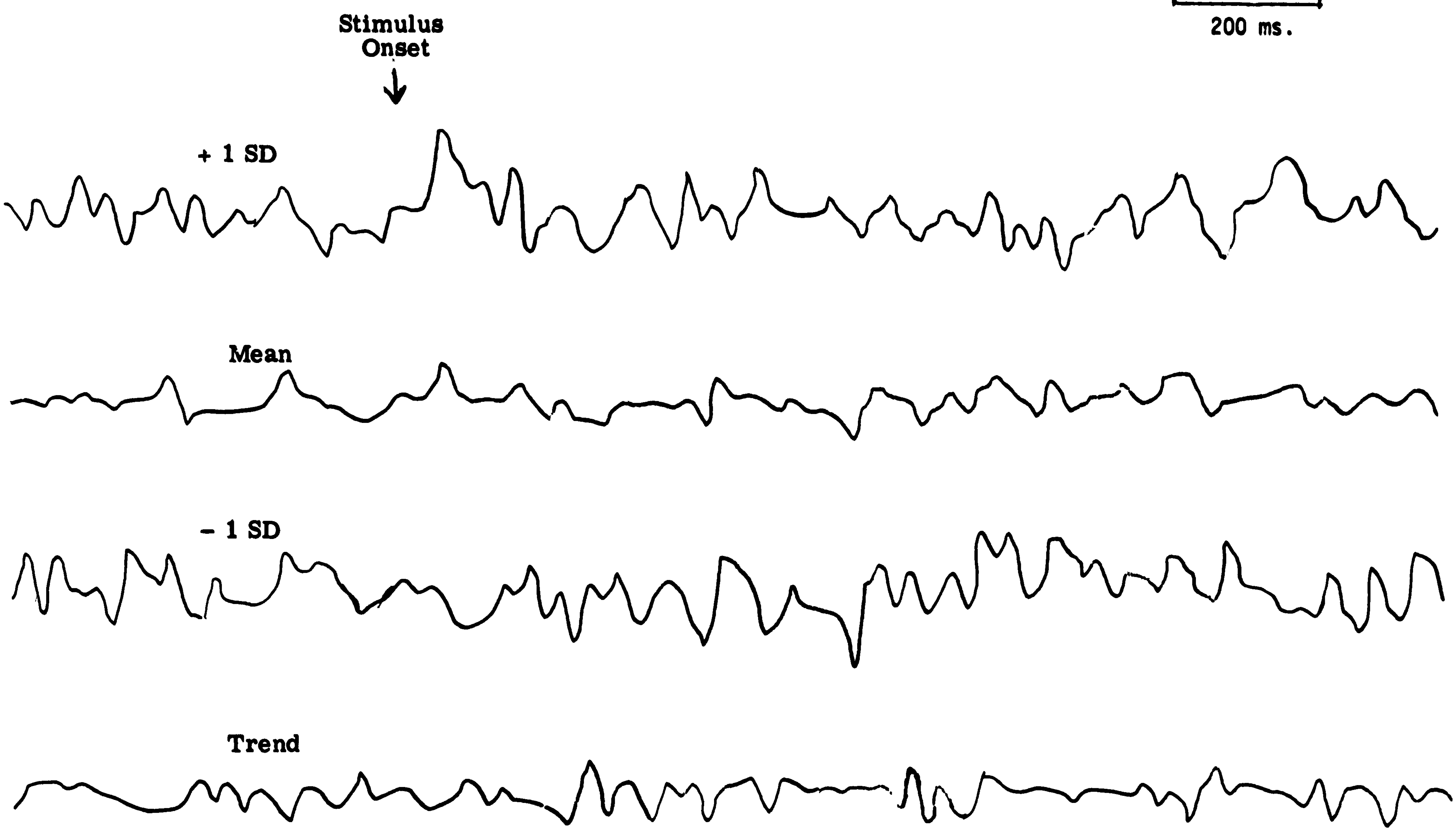

Fig. 11. Averaged tongue EMG to all 160 stimulus presentations.

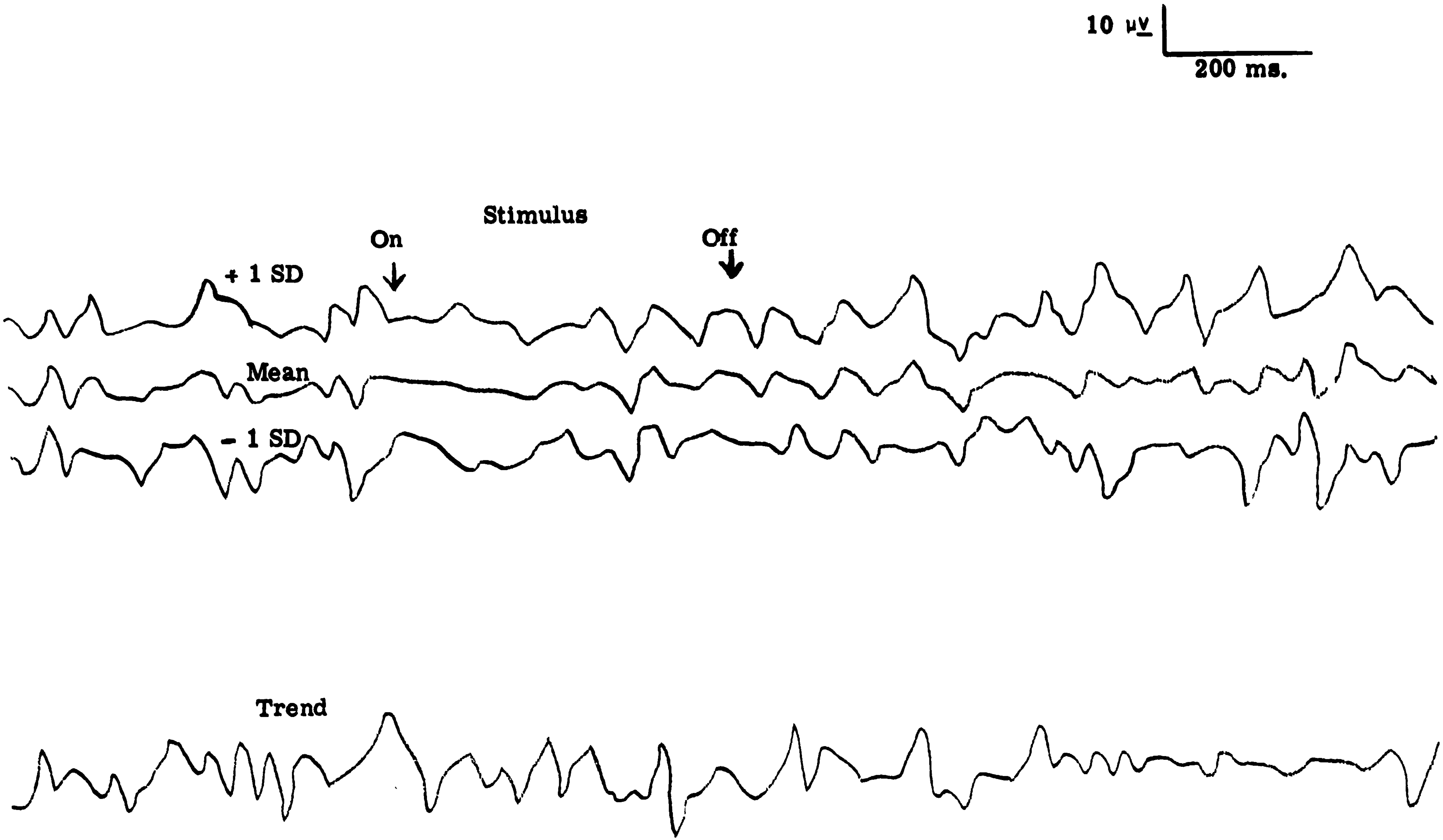

Fig. 12. Averaged tongue EMG to 32 presentations of "mind."

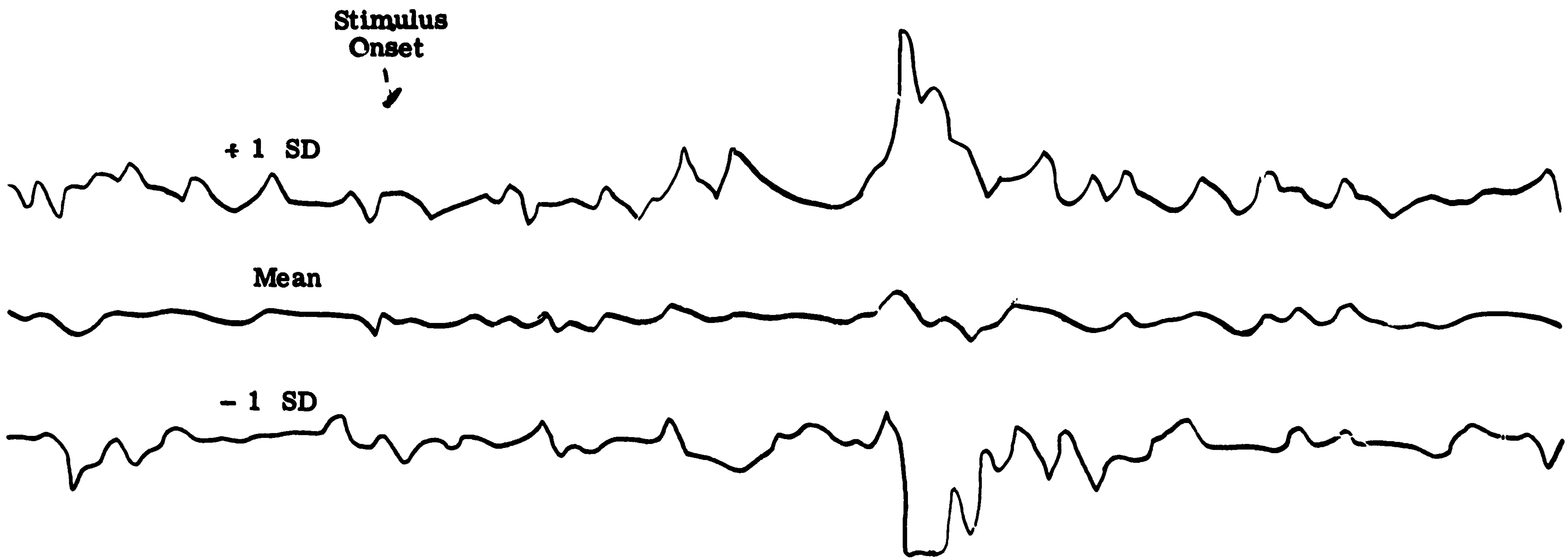

Fig. 13. Averaged non-preferred arm EMG to all 160 stimulus presentations.

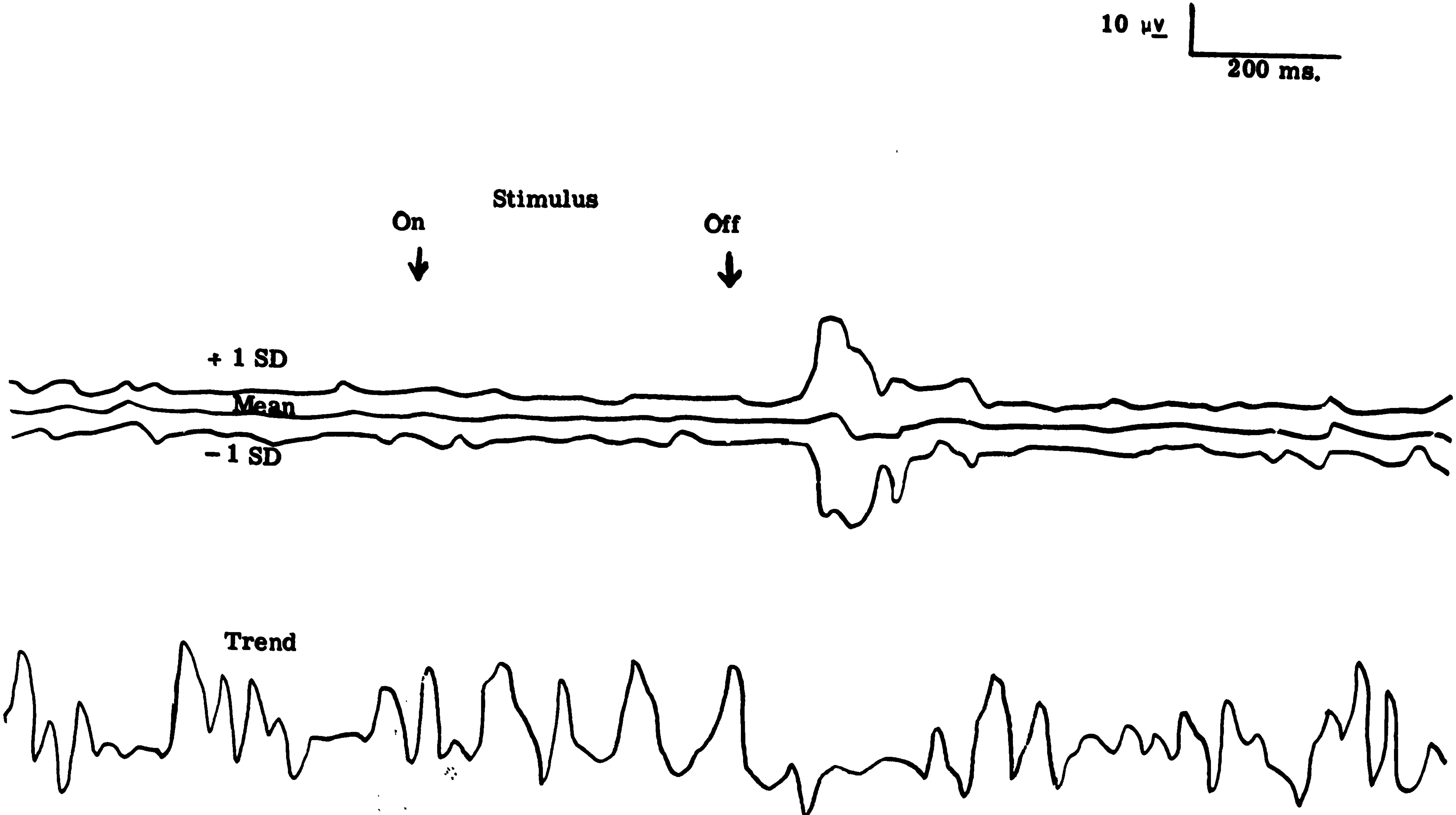

Fig. 14. Averaged non-preferred arm EMG to 32 presentations of "mind."

Conclusion

It seems likely that internal information processing involves responses in a variety of bodily locations, and that the characteristics of the responses vary as a function of such stimulus parameters as meaningfulness (words) vs. meaningless stimuli (white noise), or class of language stimulus (high vs. low image evoking words). The results of this pilot study indicate the feasibility of eventually ascertaining patterns of covert processes as a function of such classes of stimulus input.

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Covert Behavior as a Direct Measure of Mediating Responses

The limited power of single unit S-R laws to explain complex behavior has led to the postulation of an increasing number and variety of hypothetical constructs. Hull's (1952) r_G, Kender and Kendler's (1969) mediational response, Osgood's (1953) mediating reaction, Schoenfeld and Cumming's (1963) perceptual response, and Underwood's (1965) implicit associative response are a few examples. Independent of this development, psychophysiology has recently experienced an exponential growth (Ax, 1964). To a large extent, the goals pursued in the development of hypothetical constructs and in the measurement of psychophysiological variables have been similar. That is, the purposes of these hypothetical constructs and of the direct recording of electromyograms, electroencephalograms, galvanic skin responses and so forth have both been to specify what is happening between the S and the R. Consequently, by relating the hypothetical constructs of the theoretician with the directly measured empirical events of the psychophysiologist's laboratory progress in both areas should be enhanced. It was, therefore, the purpose of this study to attempt to obtain a direct measurement of the mediating response.

In order to enhance the likelihood of success, a paradigm was used in which we could focus our attention on one particular bodily region, viz., the speech mechanism. More particularly, we hoped to find evidence of mediation in the form of increased electromyograms in the speech apparatus, relative to amplitude of covert oral behavior under two control conditions: 1) where the mediator was not likely to be oral; and 2) where there was no mediator at all.

Method

Subjects. Six male and six female children, ages 11 to 13 years were randomly assigned to three groups, with an equal number of each gender in each group.

Apparatus. Electrodes were placed on the tongue, left and right forearms and calf of the right leg for electromyograms (EMGs), at the external canthus of each eye for electrooculograms (EOGs), and electroencephalograms (EEGs) were recorded from the motor area of the dominant hemisphere (C-4). Signals from each placement were led from the S room to the apparatus room for amplification (X 100,000) by two Tektronix 122 Amplifiers and one channel of a Honeywell galvanometer amplifier placed in series, and for recording on a Sanborn seven-channel data tape recorder. Stimulus material was presented from the apparatus room through a window by means of a shielded 35 mm. slide projector controlled by an external timer. The S and apparatus rooms were effectively shielded by high permeability steel and a magnetic liner built into the walls, ceilings and floors.

Procedure. The Ss were introduced to the laboratory with assurances that they would not feel anything from the electrodes, the electrodes were attached and they were then given relaxation instructions. There were four critical phases for each group (Table 1). During Phase I four nonsense symbols (adapted from Tracy Kendler, Personal Communication, 1967) were exposed five times each while the Ss merely observed them. During Phase II the Verbal Mediation Group learned to orally respond "one" or "two" to each of the symbols (as indicated), the Mediation Control Group learned to press a button with their left or right foot to each stimulus presentation, and the No-Mediation Group learned to press a button with their left or right hands. All Ss were told "right" or "wrong" after each response and practice continued until each S made five consecutive correct responses. The interstimulus interval for all phases varied about a mean of 10 sec. (± 2 sec.) and the stimuli were presented in a random order. During Phase III all Ss responded to Nonsense Symbol #1 by pressing

Table 1

Paradigm for Verbal Mediation With Two Control Conditions

["R" indicates the Response made to each Nonsense Symbol (NS)]

Phase #	Verbal Mediation	Mediation Control	No-Mediation
I	Four nonsense symbols visually presented to all groups.		
II	NS #1 - R "One"	NS #1 - R (Left Foot)	NS #1 - R (Left Hand)
	NS #2 - R "Two"	NS #2 - R (Right Foot)	NS #2 - R (Right Hand)
	NS #3 - R "One"	NS #3 - R (Left Foot)	NS #3 - R (Left Hand)
	NS #4 - R "Two"	NS #4 - R (Right Foot)	NS #4 - R (Right Hand)
III	NS #1 - R (Left Hand)	NS #1 - R (Left Hand)	NS #1 - R (Left Hand)
	NS #2 - R (Right Hand)	NS #2 - R (Right Hand)	NS #2 - R (Right Hand)
IV	NS #1 - R (Left Hand)	NS #1 - R (Left Hand)	NS #1 - R (Left Hand)
	NS #2 - R (Right Hand)	NS #2 - R (Right Hand)	NS #2 - R (Right Hand)
	NS #3 - R (Left Hand)?	NS #3 - R (Left Hand)?	NS #3 - R (Left Hand)
	NS #4 - R (Right Hand)?	NS #4 - R (Right Hand)?	NS #4 - R (Right Hand)

a button with the left hand and to Nonsense Symbol #2 with the right hand, under the same conditions as for Phase II. Phase IV (the test phase for mediation) was continuous with Phase III; all four stimuli were randomly presented five times each but the Ss were not told when they were "right" or "wrong". Finally a check showed that the Ss had retained the responses learned in Phase II.

Quantification. The signals during Phases I and IV were recorded on tape and converted to mean integrated response amplitudes using the method reported by McGuigan and Rodier (1968). The integrating system was activated by a triggering signal that coincided with the onset of the visual stimulus presentations so that the first second of each stimulus presentation was accurately specified for the response quantification. Briefly, this digitizing procedure was to feed the signals into an RMS voltmeter which emitted a dc level signal that could vary between 0 and -1 v. The resulting dc signal then entered a voltage-to-frequency converter which emitted pulses that were proportional (in frequency) to response amplitude. These pulses were counted by an electronic counter for the one-second interval, printed out by a digital recorder and converted to voltage at the S.

Theoretical Predictions

The expectation from verbal mediation theory is that the following chains were established during Phases II and III in the Verbal Mediation Group:

N S #1-----$r_{\text{"one"}}$-----s----- Press Left

N S #2-----$r_{\text{"two"}}$-----s-----$R_{\text{Press Right}}$

Since the covert oral responses of "one" and "two" had also been established to Nonsense Symbols #3 and #4 as a result of training in Phase II, and since $r_{\text{"one"}}$ and $r_{\text{"two"}}$ had become antecedents for the overt responses to NS #1 and

NS #2 of pressing left and right respectively (in Phase III), when $r_{\text{"one"}}$ and $r_{\text{"two"}}$ were evoked by Nonsense Symbols #3 and #4 in Phase IV they should produce the overt pressing responses to these stimuli too, i.e.,

NS #3-----$r_{\text{"one"}}$-----s-----$R_{\text{Press Left}}$

NS #4-----$r_{\text{"two"}}$-----s-----$R_{\text{Press Right}}$

Consequently, the expected covert oral responses of "one" and "two" to Nonsense Symbols #3 and #4 respectively in the test phase should be recordable as heightened covert oral behavior. Furthermore, these covert oral responses should occur very rapidly after the onset of the test stimuli; hence the selection of the first one-second interval of the presentation of Nonsense Symbols #3 and #4 for quantifying responses. Neither of the two control groups, obviously, should show heightened covert oral behavior to Nonsense Symbols #3 and #4 since only limb (non-oral) responses were made to these stimuli during training.

Results and Discussion

The mean integrated response amplitude (μv) for each measure was quantified for the first second of each stimulus presentation for Nonsense Symbols #3 and #4 (the test stimuli for mediation). A mean value (pooling the results for the two stimuli) was then computed for each S for Phase I (Initial Phase) and for Phase IV (Test Phase). Group means were then computed (Table 2). The Verbal Mediation Group had a mean tongue response amplitude of 8.3 μv during the initial phase, which increased to 13.9 μv during the test phase; this mean increase of 5.6 μv is significantly different from zero (t = 6.83). The mean increases of the tongue response for the two control groups of 1.4 μv and .9 μv were not significantly different from zero. Furthermore, the mean increase for the verbal mediation group was significantly greater than for the Mediation Control Group (t = 3.46), and for the No-Mediation Group (t = 3.51). The two control groups did not differ significantly on the tongue measure. There were no other significant differences between the Verbal Mediation Group and the two control groups. The fact that no response measure other than tongue EMG changed significantly from the initial to the test phase for the Verbal Mediation Group indicates that the heightened covert oral behavior during mediation was not merely an aspect of a state of general arousal -- rather, the suggestion is that the response change was localized in the oral region. These results thus indicate that Nonsense Symbols #3 and #4 evoked covert oral responses during the test for mediation in the Verbal Mediation Group, but not in the two control groups. These findings are in accord with the theoretical expectations specified above, viz., that the heightened covert oral behavior recorded for the verbal mediation group may actually have been a direct measure of mediating responses. While the effort was only to test for relatively heightened covert oral behavior during mediation, future research could conceivably be designed to distinguish between different mediators, e.g., to identify different patterns of covert oral behavior that may correspond to "subvocal" responses of "one" vs. "two".

The purpose of the Mediation Control Group was to provide control data on the locus of the oral mediating response in Ss who mediate but with non-oral mechanisms. Consequently it is conceivable that evidence for the mediating response for this group could be found in the left arm when Nonsense Symbol #3 was presented and in the right arm for Nonsense Symbol #4. Table 2 indicates that the arm responses were in fact relatively high for this group -- left arm EMG significantly increased to both test stimuli and the increase was significantly greater for the Mediation Control Group than for the Non-Mediation Group (t = 2.76). Neither arm EMG significantly increased for

Table 2

Mean Response Amplitudes to Test Stimuli (μv) for Initial Level and Test Condition

		Group							
	Verbal Mediation			Mediation Control			No Mediation		
Measure	Initial	Test	Difference	Initial	Test	Difference	Initial	Test	Difference
Tongue	8.3	13.9	+ 5.6*	9.8	11.1	+ 1.4	8.7	9.6	+ 1.0
EEG	14.2	14.0	- .2	13.6	14.8	+ 1 2	13.7	13.1	- .6
Eye	7.1	7.4	+ .3	6.5	7.6	+ 1.2*	6.3	6.2	- .1
Right Leg	2.9	3.1	+ .2	2.4	2.2	- .2	3.4	3.2	- .2
Left Arm NS #3	6.8	7.2	+ .4	2.6	6.0	+ 3.3*	9.4	5.9	- 3.5
Left Arm NS #4	6.8	8.0	+ 1.2	2.1	7.9	+ 5.8*	8.4	5.5	- 2.9
Right Arm NS #3	13.0	12.1	- .8	2.1	5.2	+ 3.1	6.3	7.8	+ 1.5
Right Arm NS #4	11.5	13.8	+ 2.3	2.0	5.2	+ 3.2	6.6	6.5	- .1

* $p < .05$

either of the other groups. The relatively large activity in the arms is, thus, suggestive for this group and it is possible that bilateral transfer makes it difficult to differentially isolate covert mediators of "right" and "left".

The only other significant response change from the initial to the test phase was for eye activity in the Mediation Control Group, and no other differences between groups were significant.

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Footnotes

1. Work on this article was supported, in part, 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.

The Effects of Manipulating Covert Oral Behavior During Silent Reading -- A Report of Continuing Exploratory Research

Two opposing views of the function of covert oral behavior during silent reading have been specified in several of the other sections of this report. Briefly, the traditional view has been that "subvocalization" retards reading proficiency. This classical notion has more recently been challenged by the position that heightened covert oral behavior occurs in everyone during silent reading, and that it is beneficial in processing the language stimuli that constitute the prose being read. One effort to decide between these two opposing positions has been to actually reduce the amplitude of covert oral behavior during silent reading and to observe its effects on reading proficiency (McGuigan, 1967). This attempt was based on the assumption that operant procedures would be effective, viz., that the presentation of a slightly noxious stimulus following a relatively large amplitude of covert behavior should act as a punisher, and that the withdrawal of the stimulus when the behavior decreased in amplitude should act as a negative reinforcer. While this strategy seems straightforward enough a number of serious control problems have been encountered (cf. McGuigan, 1967). In the present paper we will present additional data relevant to the problem, offer some tentative conclusions, and elaborate on some of the difficulties encountered.

Method

Subjects. Approximately 50 individuals have been studied in a preliminary fashion in order to select Ss who emitted relatively large amplitudes of covert oral behavior during silent reading and who would cooperate by participating in repeated sessions in the laboratory. All Ss received $ .50 or $1.00 compensation for each session. The results for 5 Ss will be reported.

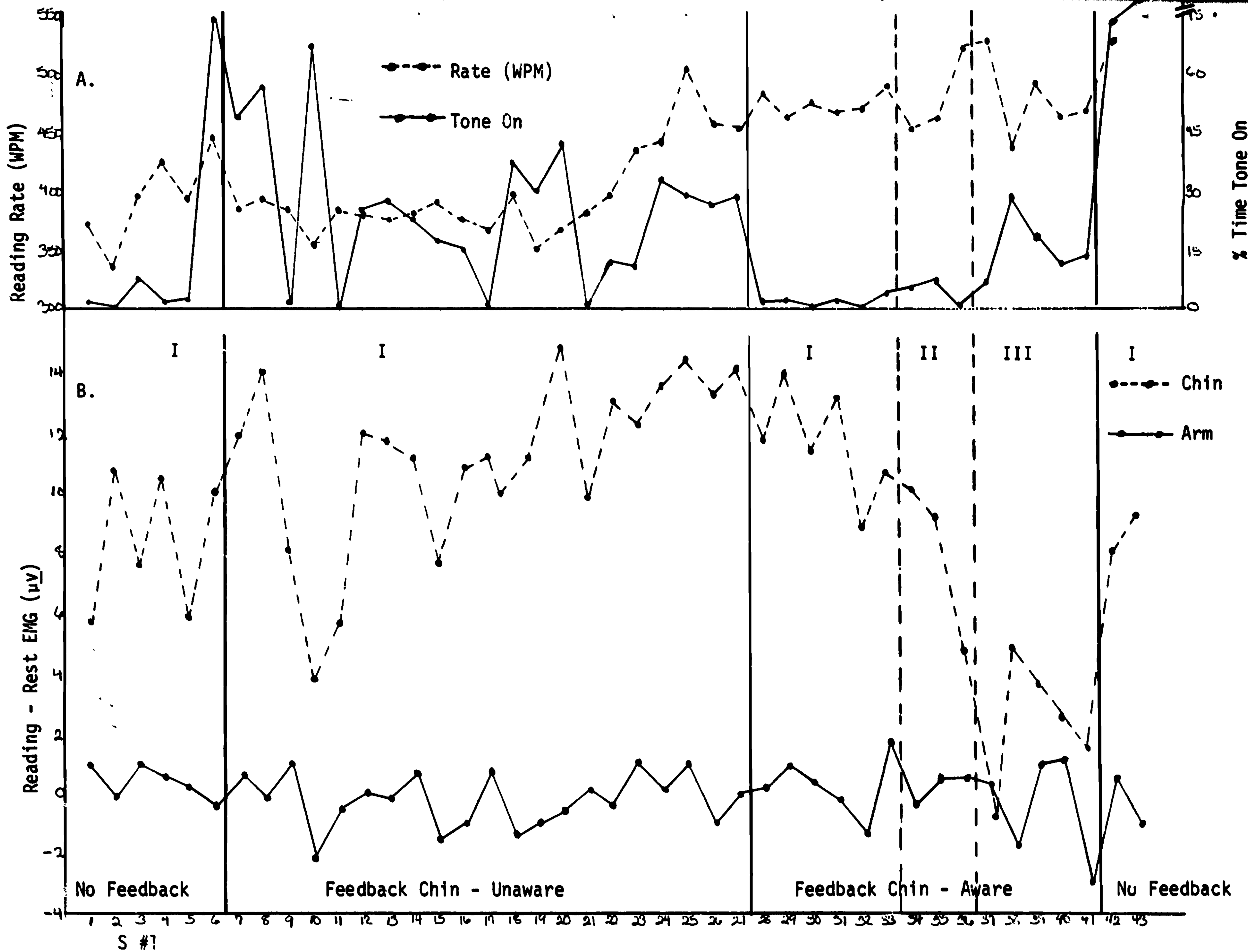
<u>Method</u>. Each <u>S</u> was first introduced to the laboratory with assurances that he would in no way be harmed and the various sensors were attached (as specified for each <u>S</u> in the Results section). The <u>S</u> then rested following rather extensive relaxation instructions following which he silently read a passage appropriate for his educational level. As will be seen, each <u>S</u> read for several sessions (see Results section) without feedback in an effort to study the effects of adapting to the laboratory situation and to establish a baseline level. Feedback was then introduced in the manner previously reported (McGuigan, 1967), i.e., signals from the speech mechanism (e.g., chin EMG) entered a meter relay that was set in accordance with the results from the baseline sessions. Hence a slightly noxious tone would commence when <u>S</u>'s response exceeded the amplitude set by the high hand of the meter relay (which value was determined by allowing the relay to be activated about 50% of the time on the session preceding the first feedback session). The second (lower) hand of the relay was set so that a reduction of the response amplitude would terminate the tone (the negative reinforcer). Specific values of the meter relay settings will be specified for each <u>S</u> under the Results section. The equipment, laboratory quantification procedures, etc. are specified in the other sections of this report.

Results

Mean amplitude of the various signals during the pre-reading rest session were computed, and subtracted from the mean value during reading for each session. The results are plotted in the following figures. In Figure 1 B (lower figure) we can note the increase in amplitude of chin EMG for <u>S</u> #1 (a female college student) during each of the first six sessions in which an attempt was made to establish a stable baseline

Fig. 1. A. Reading Rate in the Laboratory for the 43 Sessions. Percent time tone was on during feedback is also indicated, as is the percent time that it <u>would</u> have been on before and after the feedback sessions.

B. Amplitude of Chin and Arm EMG for Each Session. Meter settings for Sessions 1 - 33 (indicated by "I") were 40.0 for "Tone On" and 32.5 for "Tone Off;" they were lowered to 32.5 and 25.0 for Sessions 34 - 36 ("II") and to 17.5 and 10.0 for Sessions 37 - 41. For the final two sessions the settings were returned to 40.0 and 32.5 ("I").



A.
Rate (WPM)
Tone On
Reading Rate (WPM)
% Time Tone On
B.
Chin
Arm
Reading - Rest EMG (μv)
I
II
III
No Feedback
Feedback Chin - Unaware
Feedback Chin - Aware
S #1

(the No Feedback condition). The variability of this measure ranges from approximately 6 μv to 11 μv throughout these initial sessions.

On Trials 7 - 27 S received feedback (tone on) when her chin EMG amplitude exceeded that of the upper hand of the meter relay set at 40.0 and feedback was terminated when chin amplitude fell below the lower hand set at 32.5 (arbitrary units); the portions of Figure 1 in which these settings were used is indicated by the Roman numeral "I." The S was not told why the tone was coming on and, as indicated by inquiries at the end of each session, she was never able to verbalize the response-contingency relationship (though she developed a number of hypotheses such as that we were studying the effects of interfering noises on the reading process). As can be observed, these 20 sessions of feedback without awareness of the source failed to reduce her chin amplitude. Starting with Session 28 she was informed that she was controlling the tone (to her considerable amazement), that she could therefore terminate it, but she was not told how she controlled its onset and offset. It can be observed that amplitude of chin EMG, while generally increasing prior to Session #28, generally decreased through Session #33. For Sessions #34, #35, and #36 the meter relay settings ("II") were lowered to 32.5 and 25.0, thereby requiring a smaller amplitude of chin EMG before S could terminate the tone. Under meter condition II we can note a rather dramatic reduction in amplitude of chin EMG. For Sessions 37 - 41, the meter relay settings were lowered still further to 17.5 and 10.0 ("III"), and we can notice that amplitude of Chim EMG hovered noticeably lower than the level for the baseline period, and for essentially all of the previous sessions too, for that matter. The amplitude markedly increased again, however, when S was told that the tone would no longer function (Sessions #42 and #43).

Observation of non-preferred arm EMG (Fig. 1B) shows no systematic change throughout the sessions; the fact that it failed to increase during reading (i.e., the curve hovers around zero) indicates that behavioral changes in the speech musculature during silent reading were not merely an aspect of a heightened state of general arousal.

In Figure 1 A (top) we can note that the percentage of time during the reading session that the tone was on (or would have been on during the non-feedback sessions) is rather well correlated with amplitude of chin EMG; especially is this apparent during Sessions 28 - 41 when feedback was effective in reducing amplitude of chin EMG.

Figure 1 A also shows reading rate for each session. The S's instructions were to merely read in a normal manner; she was never told to attempt to increase or decrease her rate. The reading material, being articles from the Scientific American, was approximately of the same difficulty level at each session, though its interest value no doubt varied (even though each article was selected by S). Reading rate was relatively low during Sessions #1 and #2, perhaps due to normal adaptation to the laboratory, electrodes, and the like. For Sessions #3, #4, #5, and #6 rate somewhat increased; if introduction of feedback had any effect at all it was to reduce reading rate; this measure then appears to be quite stable until about Session #23. During the several sessions following #23 under the Feedback-Unaware condition apparently there is an increase in reading rate which seems to be accompanied by an increase in chin EMG (Figure 1 B, sessions following about #22). Conversations with S indicated that she learned to ignore the tone when it came on (since she thought she was powerless to prevent it), thus leading to an increase in her reading rate after Session #23. But it may be important to emphasize that the increased reading rate following Session #23 was accompanied by increased chin EMG.

Once S was informed that she controlled the tone, amplitude of chin EMG was "shaped" downward considerably (sessions indicated by "I," "II," and "III" under the "Aware" condition), though reading rate was not substantially affected by the reduction (Sessions 28 - 41); it can be seen that S came to almost totally eliminate the tone during these sessions. As she verbalized it, she just read in a very relaxed state -- the focus was not on her speech musculature for, in fact, she did not know the specific source of feedback control.

These results are thus not consistent with the traditional point of view, viz., that the noticeable increase in reading rate following Session #22 was accompanied by increased chin EMG, and that the sizeable reduction in chin EMG was not accompanied by a noticeable increase in reading rate.

During the last two sessions in which S was told that there would be no feedback, and in fact there was no feedback, chin EMG dramatically increased to approximately the baseline level of Sessions 1 - 6. At that time there also appears to be an increase in reading rate, once again hinting at a positive correlation between amplitude of covert oral behavior and reading rate. One possible consequence of this hypothesis is that, in this S, more rapid silent reading requires increased rapidity and/or number of oral muscle fiber contractions. There are other possibilities too, though, for instance that during the final no-feedback sessions S could stop concentrating on relaxing her entire body and thus concentrate more on what she was reading. This would not, however, explain why her reading rate was so much higher during the final no-feedback sessions than during the early sessions (e.g., 1 - 6).

Fig. 2. Changes in Respirations Per Minute (RPM) and in Tongue EMG. Missing data are indicated by dashed lines or lack of data points. Roman numerals indicate thresholds for feedback (See Fig. 1).

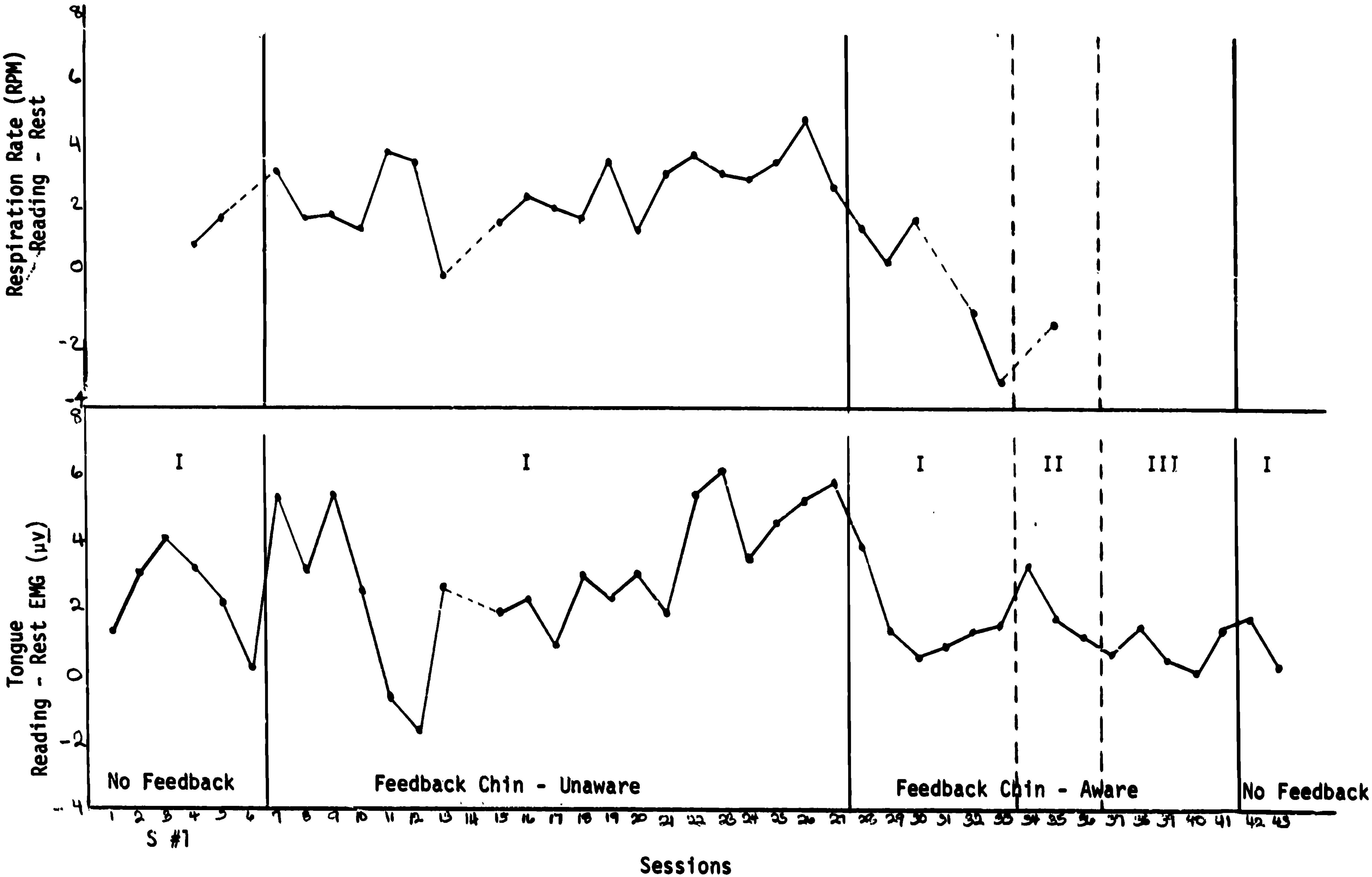

Respiration Rate (RPM)
Reading - Rest
8
6
4
2
0
-2
-4
Tongue
Reading - Rest EMG (µv)
8
6
4
2
0
-2
-4
I
I
I
II
III
I
No Feedback
Feedback Chin - Unaware
Feedback Chin - Aware
No Feedback
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
S #1
Sessions

Figure 2

In Figure 2 we can note changes in respiration rate and amplitude of tongue EMG as a function of sessions and conditions. Unfortunately a large number of data are missing for respiration, due to equipment malfunction, but it _is_ clear that respiration rate and tongue EMG noticeably decreased during the Feedback-Aware conditions (Sessions 28 - 41). During Sessions #42 and #43 tongue EMG continued at about the same level as for the preceding (Feedback) trials. It may be added that the mean amplitudes during Sessions #42 and #43 were more than 1 μv higher than during the preceding Feedback sessions, but these increases are obscured due to abnormally high resting levels.

The pre and post test results of administration of the Nelson-Denny Reading Test showed the following:

Results of Nelson-Denny Tests

	Pre test (Form A)	Post test (Form B)
	Raw Score	Raw Score
Vocabulary	75	73
Comprehension	66	66
Total	141	139
Reading Rate	426 WPM	615 + WPM

In addition, a second post test (readministration of Form A) was given several days after Form B and it was found that reading rate was 650 WPM. Hence, by day to day reading rate measures, and the independent measures of the objective reading test, it is clear that _S_ increased her reading rate from before to after the experiment. It is not clear exactly why this occurred, but it _is_ clear that the increase was not accompanied by a drop in amplitude of covert oral behavior, as the traditional educational theory of reading proficiency holds.

Fig. 3. Changes in Amplitude of Chin and Lip EMG During Silent Reading Relative to Pre-reading Rest Condition for S #2. Results are shown for the sessions when feedback from the lips was given to the subject and for preceding and following sessions when no feedback was given.

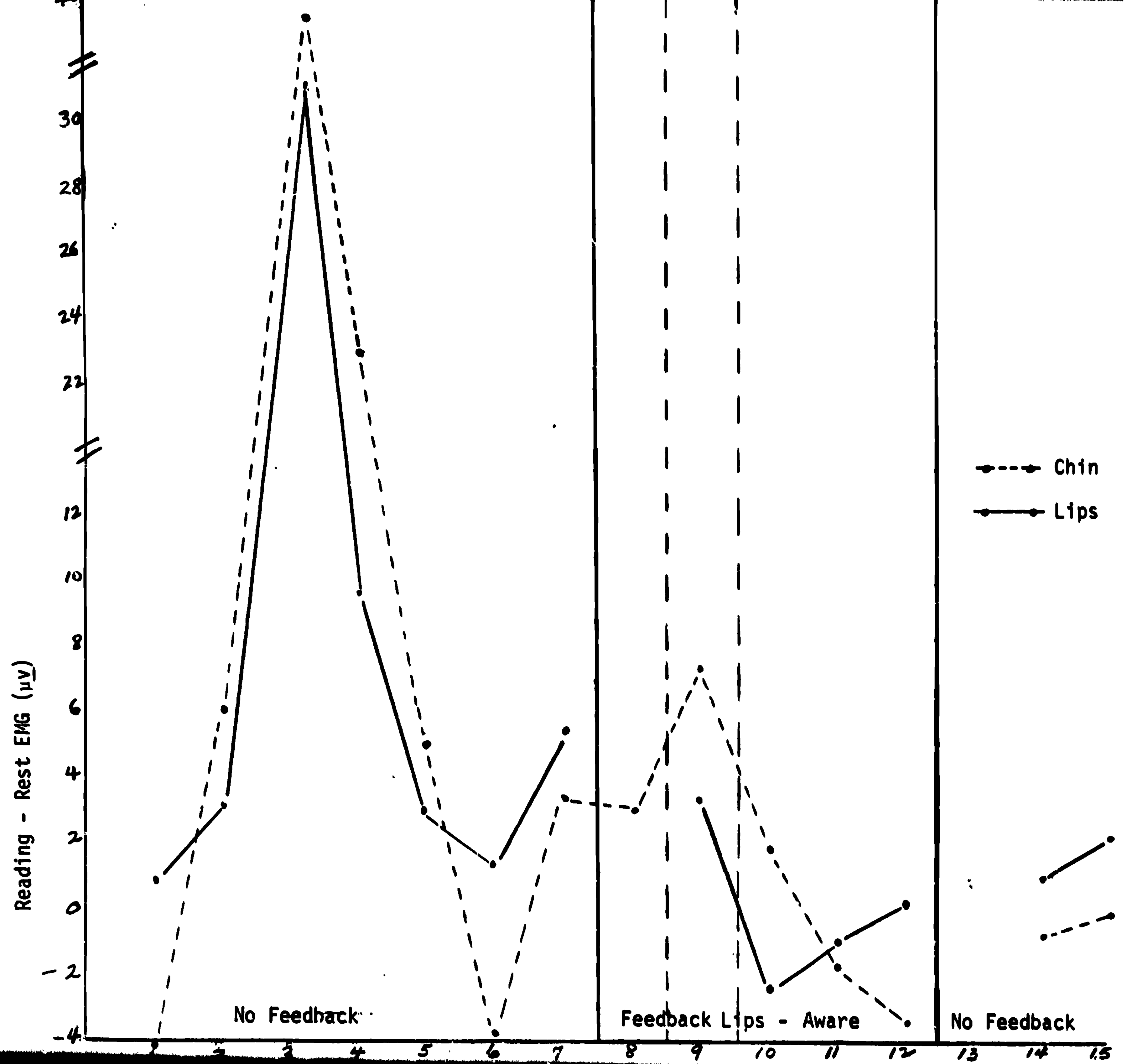
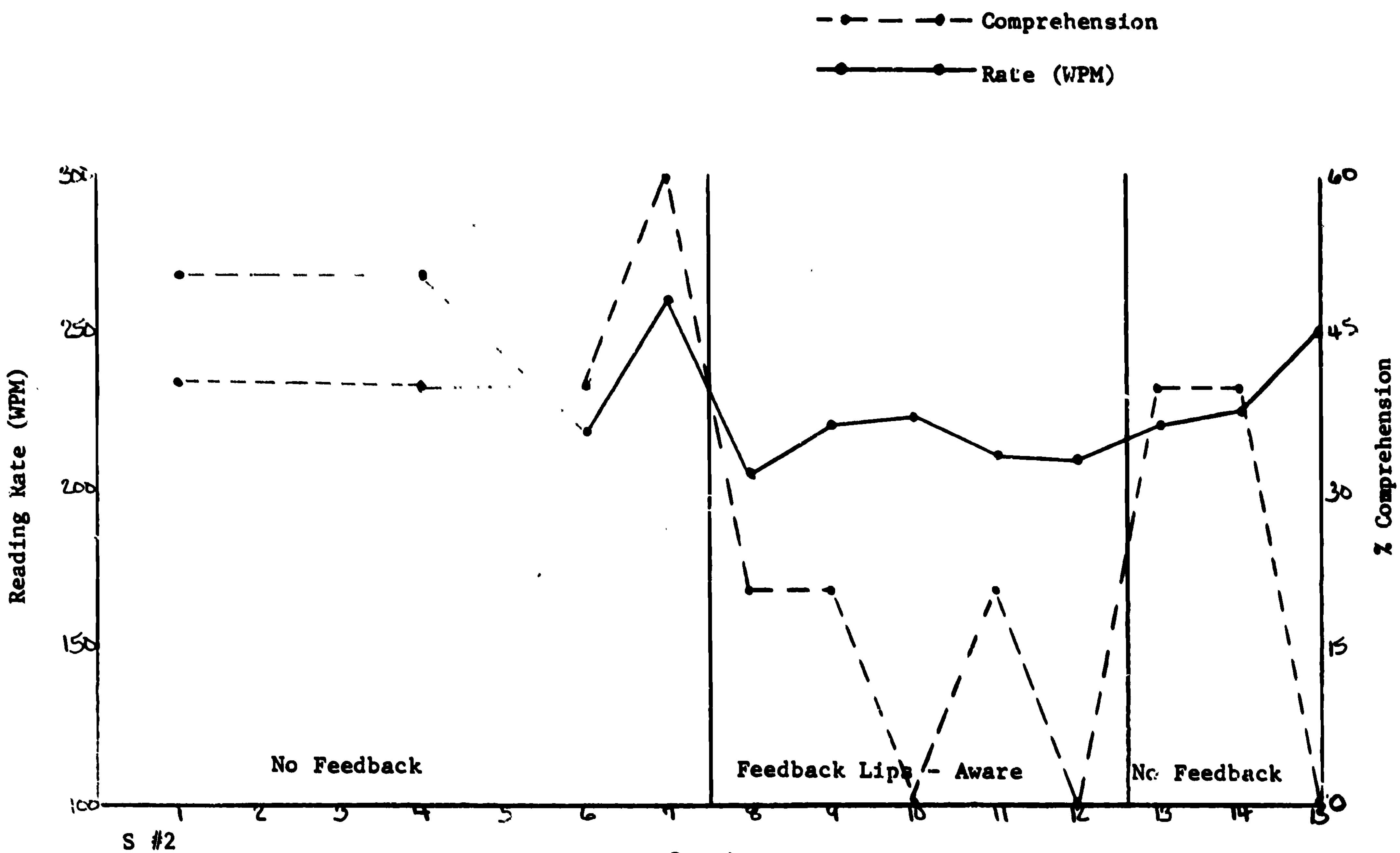

Chin
Lips
Reading - Rest EMG (μv)
No Feedback
Feedback Lips - Aware
No Feedback
30
28
26
24
22
12
10
8
6
4
2
0
-2
-4
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Fig. 4. Readings Rate and Comprehension Scores for Sessions.



Sessions

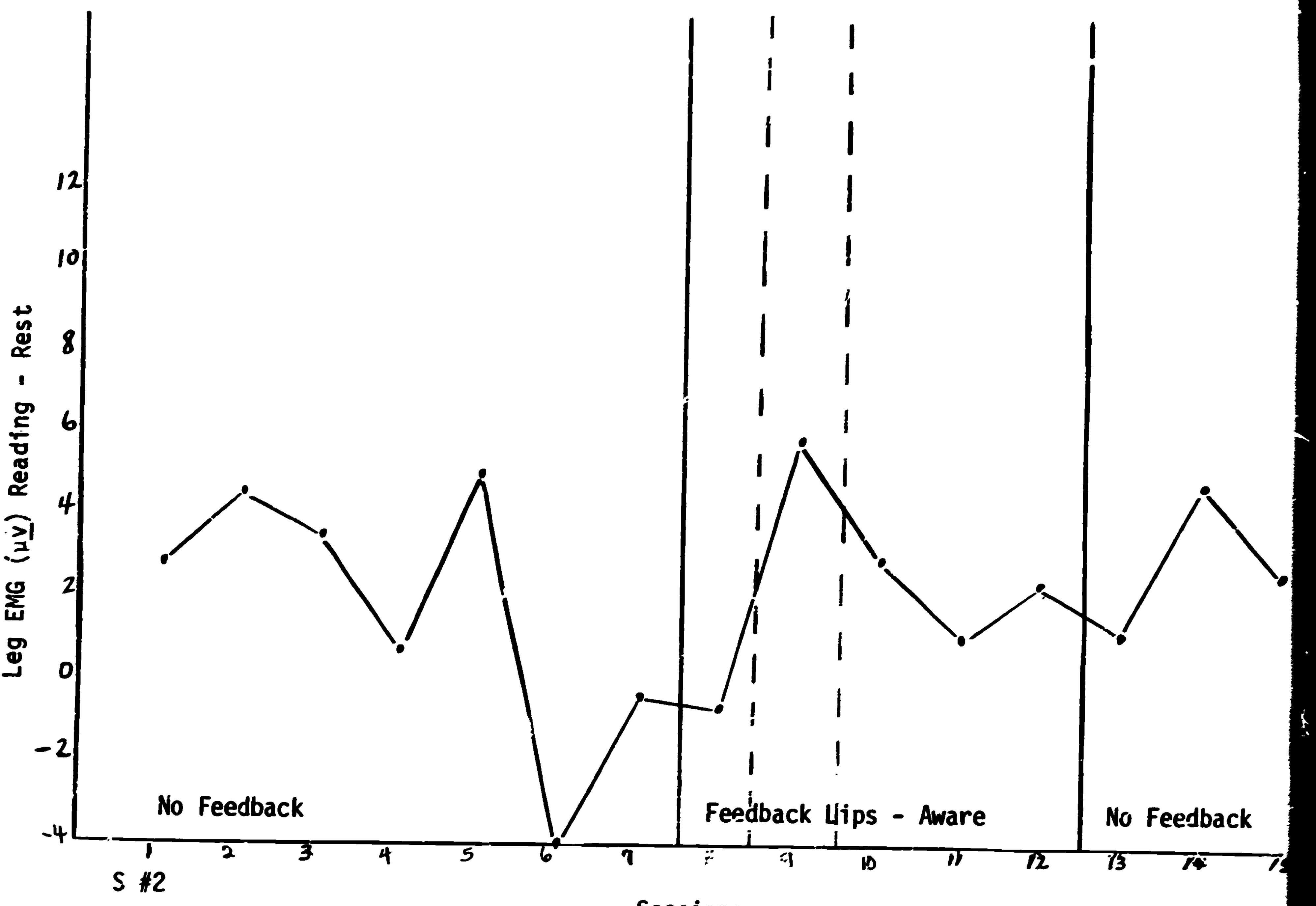
Figure 4

The results for S #2 (a female college student) are presented in Figures 3 - 6. Feedback was furnished from the lip EMG during Session #8 with the upper hand of the meter relay set at 20 and the lower at 14. The S was told that she would control the tone, that the purpose of the study was to see if she could improve her reading proficiency by reducing her lip movement, that the tone would be a signal to inform her that she was moving her lips too much, and that she should therefore keep the tone from coming on or terminate it as rapidly as possible when it did come on. The tone did not come on during Session #9 due to a malfunction; note the accompanying rise in chin amplitude. The meter hands for Sessions 10 - 12 were changed to 26 and 20. It can be seen that both chin and lip responses became sizeably reduced in amplitude during the feedback conditions, and that these measures both increased when feedback was removed during the final sessions.

Figure 4 shows the reading rate and comprehension scores during laboratory sessions. The S read college level selections from SRA Reading Laboratory IVa. It appears that reading rate decreased during the feedback trials, and increased again when feedback was removed. The reduced reading rate may have been because of the reduced amplitude of covert oral behavior, or because of some concern with or effects of the tone (concentration to keep it off that interfered with reading rate, concentrating on reducing muscular activity, etc.).

Figure 5 shows that leg EMG generally increased for S #2 during reading sessions, relative to resting. Several points of Figures 3 and 5 are possibly worth noting, viz., during Session #6 both chin and leg EMG markedly decrease, while both noticeably increase during Session #9. There is, thus, some resemblance in these curves, though they are at variance in other places.

Fig. 5. Change in Leg EMG During Reading Relative to Rest as Function of Session.



Leg EMG (μv) Reading - Rest
12
10
8
6
4
2
0
-2
-4
No Feedback
Feedback Lips - Aware
No Feedback
1
2
3
4
5
6
7
9
10
11
12
13
14
S #2
Sessions

Figure 5

Fig. 6. Changes in EEG from the Dominant Temporal Lobe and in Neck EMG During Reading Relative to Rest. Neither measure appears to systematically change as a function of condition or sessions.

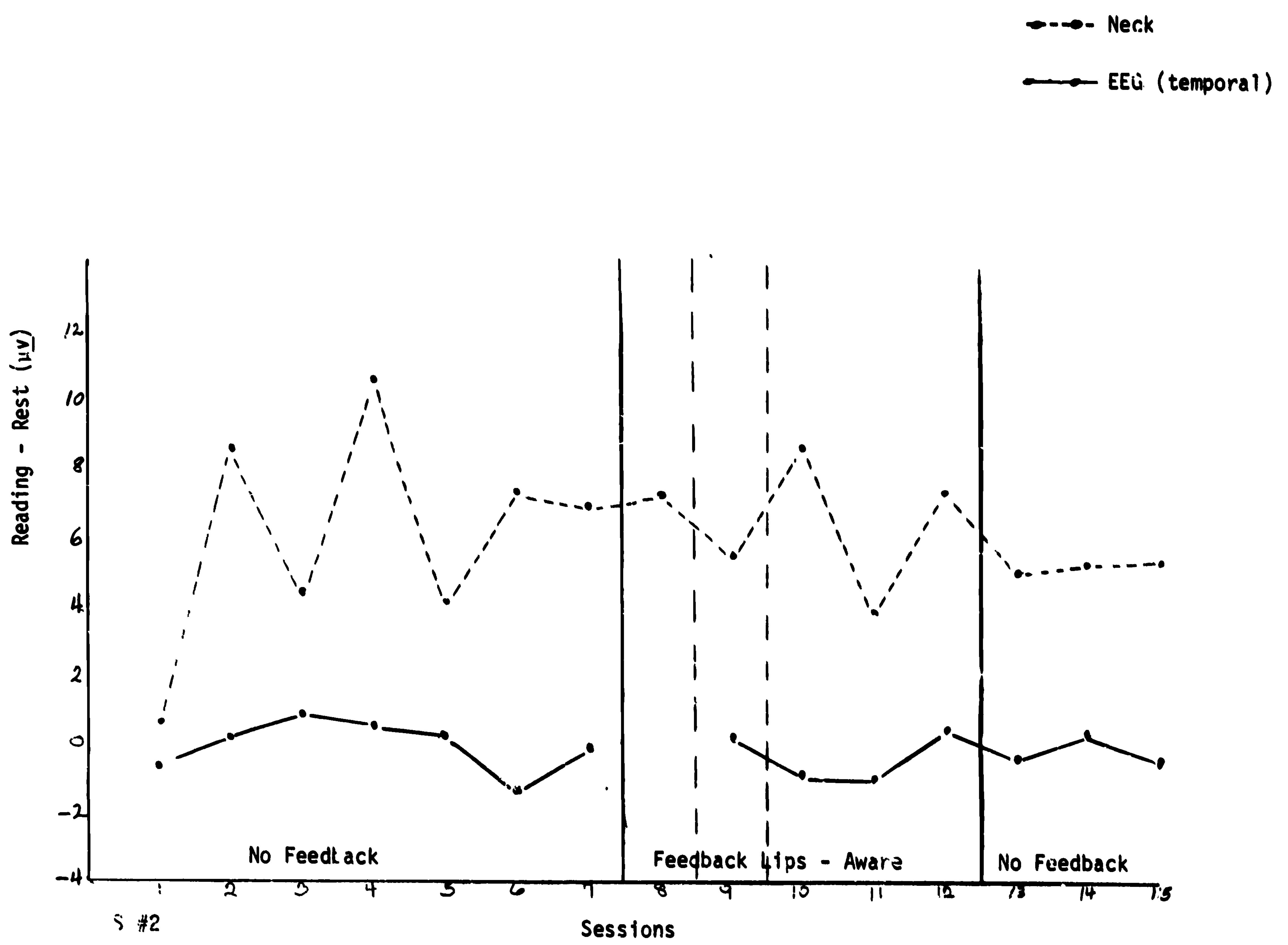

Neck
EEG (temporal)
Reading - Rest (µv)
12
10
8
6
4
2
0
-2
-4
No Feedback
Feedback Lips - Aware
No Feedback
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
S #2
Sessions

Figure 6

Differences between resting and reading conditions for neck and temporal EEG show little in the way of systematic change throughout sessions or as a function of feedback condition for S #2 (Figure 6).

In general, the results for S #2 do show that feedback reduced amplitude of covert oral behavior, but there is no consequent increase in reading rate -- in fact, the results suggest a reduction of reading rate.

An 11-year-old boy served as S #3, and he read fifth grade level selections in the laboratory from the SRA Reading Laboratory materials. Changes from rest to reading for chin, lip and leg EMG are shown in Figure 7 B. After seven sessions, feedback (tone) was triggered when chin amplitude exceeded 13 on the meter relay and terminated when amplitude fell below the low setting of 10. As usual, the settings on the meter relay were such as to produce the tone 50% of the reading time during the last No-Feedback session. Prior to Session #8 the S was told that some people move their lips when they read, and that if he moved his lips a tone would come on. The tone was sounded as an illustration. The S's task was to not move his lips, so as to prevent the tone from coming on; or if the tone was on that he was to make it go off by ceasing to move his lips. He was not, however, to stop reading when the tone sounded.

As with the preceding Ss, feedback was effective in reducing amplitude of chin EMG, and of lip EMG too (Sessions 8 - 11). Both oral measures increased during the ensuing No-Feedback condions (Sessions #12, #13), but little in the way of systematic change can be noted for leg EMG throughout the sessions. Manipulation of covert oral behavior had little effect, if any, on reading rate -- in fact, reading rate appears to be surprisingly

Fig. 7. A. Reading Rate and Comprehensions Scores for the 13 Sessions.

B. Two Measures of Covert Oral Behavior (Chin and Lip EMG) and One of Covert Non-oral Behavior (Leg EMG) as a Function of Condition. Feedback from the chin also reduced amplitude of lip EMG (Sessions 8 - 11).

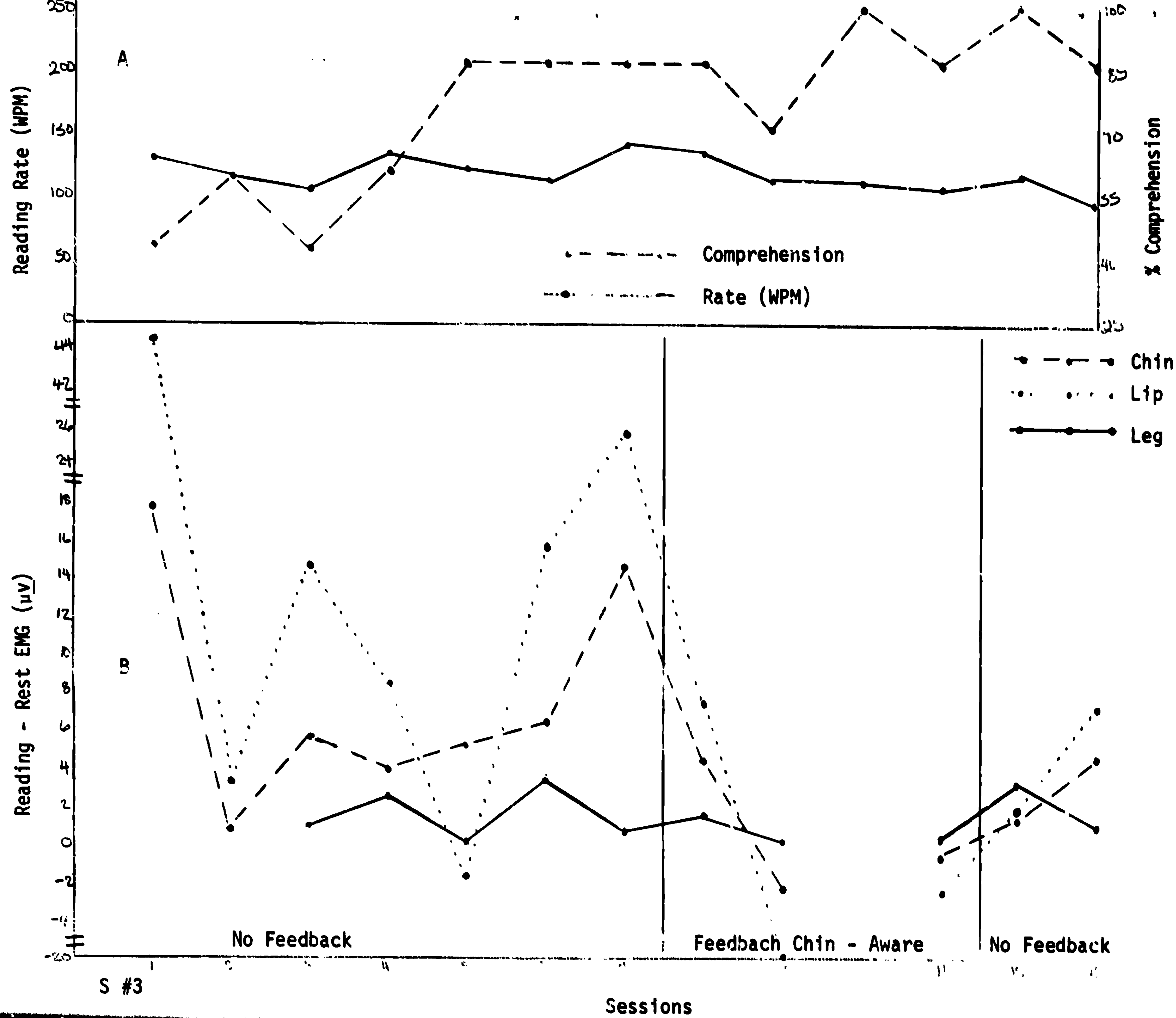

A
Reading Rate (WPM)
% Comprehension
Comprehension
Rate (WPM)
B
Reading - Rest EMG (μv)
Chin
Lip
Leg
No Feedback
Feedbach Chin - Aware
No Feedback
S #3
Sessions

Fig. 8. Changes in Integrated Temporal EEG, Eye Activity and Neck EMG During Reading Relative to Rest. Resting eye activity was abnormally high during Session 13, accounting for the large decrease.

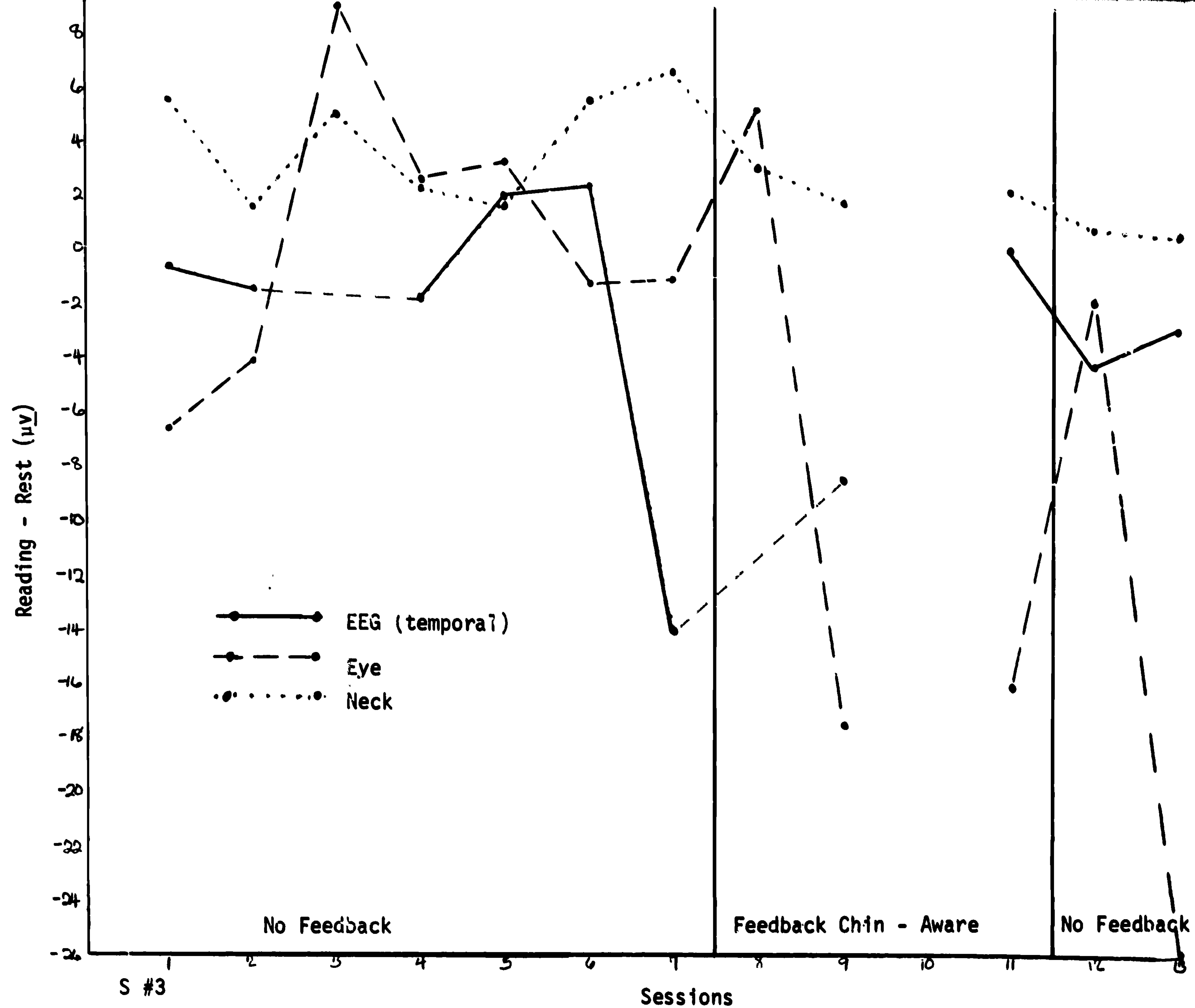

8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
Reading - Rest (μv)
EEG (temporal)
Eye
Neck
No Feedback
Feedback Chin - Aware
No Feedback
1
2
3
4
5
6
7
8
9
10
11
12
13
S #3
Sessions

Figure 8

constant throughout the sessions for this S, though there is an apparent increase in comprehension scores (Figure 7 A). Results for temporal EEG, integrated eye activity and neck EMG are presented in Figure 8. The general conclusion for this S is that decreased covert oral activity appears to have had no effect on reading proficiency.

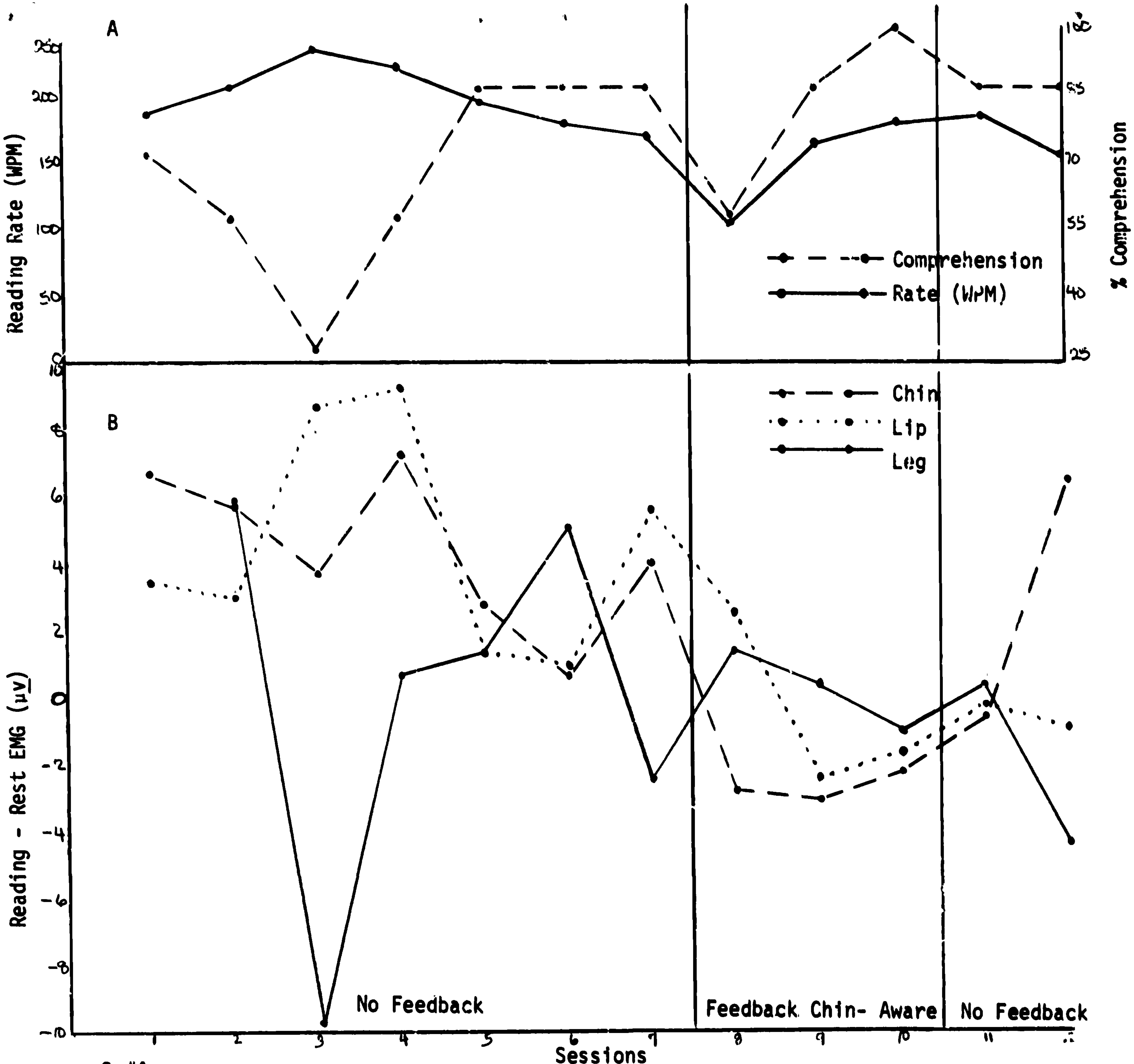
A 10-year-old boy served as S #4 who read SRA Reading Laboratory fifth grade materials in the laboratory. Feedback from the chin (meter settings of 18.5 and 21.0), lowered chin and lip EMG during Sessions #8, #9, and #10 (Figure 9 B). Removal of feedback increased chin EMG sharply (Sessions #11, and #12), and slightly increased lip EMG. Leg EMG was quite variable for this S; little needs to be said about this measure, except that there is no consistent increase from resting level during the reading sessions.

Figure 9 A shows that both measures of reading proficiency sharply decreased during the first feedback session, probably indicating interfering effects of concentrating on the feedback. The S soon adjusted, though, following which both curves increase. Throughout sessions there appears to be something of a resemblance between the curves for the rate and oral measures, viz., for sessions prior to #8 there is a decrease in reading rate and a general decrease in covert oral behavior. During Sessions #9, #10, and #11, both measures concomittantly increase. In any event, decreasing covert oral behavior did not increase reading rate.

Temporal EEG (Figure 10) decreased somewhat during the feedback sessions and remained low during the final two (No-Feedback) sessions. Neck EMG remained quite stable throughout, suggesting that the temporal EEG changes were just that, and not muscular artifacts.

Fig. 9. A. Reading Rate and Comprehension Measures for Sessions.

B. Changes in Chin, Lip and Leg EMG During Reading Relative to Rest as a Function of Condition and Sessions.


A
B
Reading Rate (WPM)
% Comprehension
Comprehension
Rate (WPM)
Chin
Lip
Leg
Reading - Rest EMG (μv)
No Feedback
Feedback Chin- Aware
No Feedback
Sessions

S #4

Figure 9

Fig. 10. Changes in Temporal EEG, Neck EMG and Eye Activity as a Function of Conditions and Sessions.

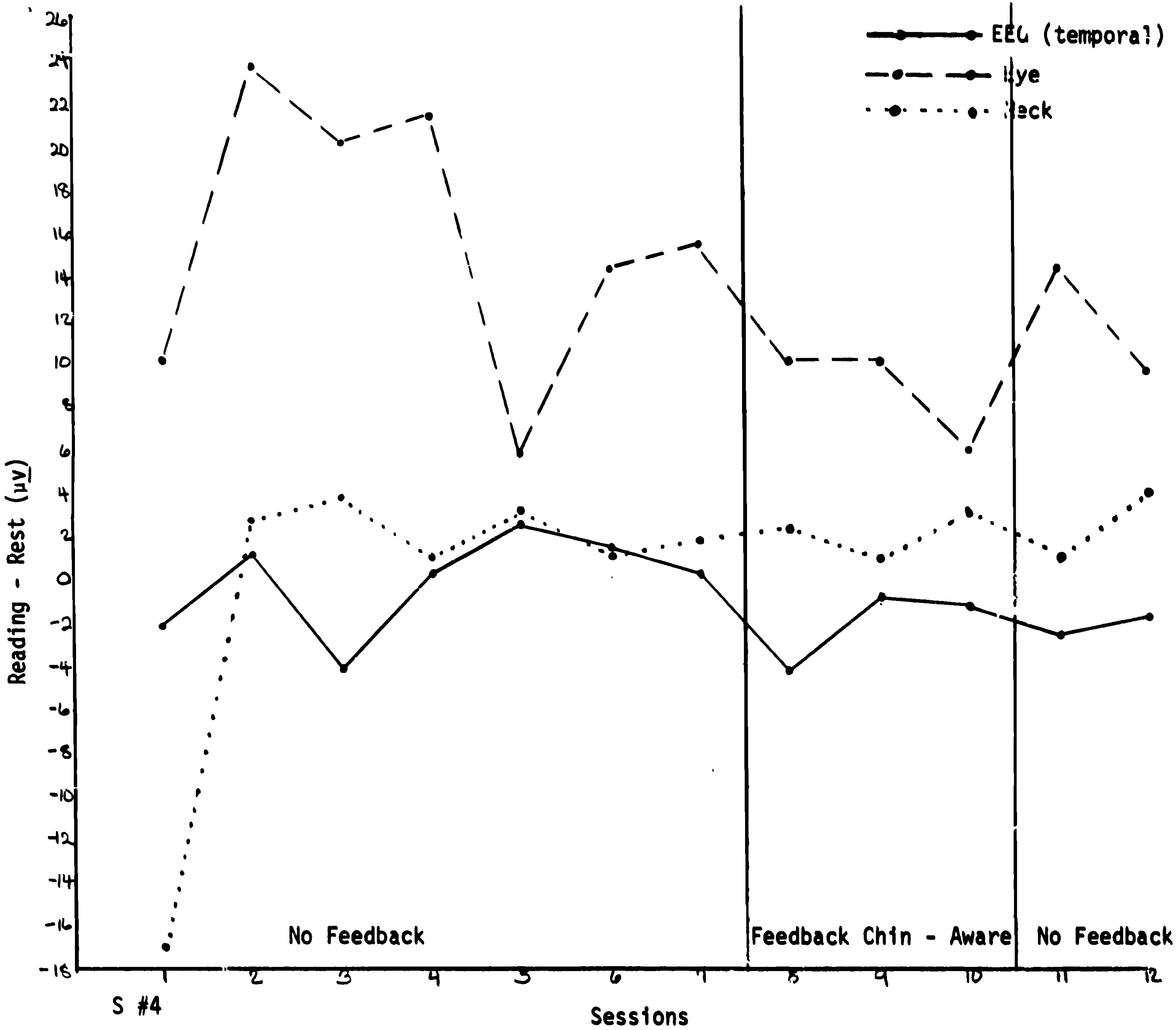

EEG (temporal)
Eye
Neck
Reading - Rest (μv)
No Feedback
Feedback Chin - Aware
No Feedback
S #4
Sessions

Figure 10

In short, with the exception of the first feedback session for S #4, reduction of covert oral behavior was not accompanied by an increase in reading rate.

The data for S #5 (a 15-year-old boy) are presented in Figures 11 - 14. The high hand of the meter relay was set at 35 and the low at 30 through Sessions 8 - 15, so that the tone was activated when chin amplitude exceeded 35 ("I"). The hands were changed for Session #16 to 25 and 20 ("II"), and to 16 and 11 ("III") for Sessions #17 and #18. The results are the only ones in the present study that fail to indicate that feedback reduces amplitude of covert oral behavior -- none of the three measures appear to noticeably change during the feedback sessions. Figure 12 suggests a slight increase in rate, but if this is the case, there also appears to be a drop in comprehension scores. Figure 13 indicates little or no systematic changes in eye and leg measures. The striking characteristic of Figure 14 is that temporal EEG increased during reading relative to rest. In no other subject has an integrated measure of EEG activity increased from a relaxation state. This finding is particularly interesting in view of the normal decrease in integrated activity from the occipital lobe. S #5 thus presents a puzzle in two respects: lack of effectiveness of the feedback on amplitude of covert oral behavior and the (differentially) heightened EEG activity from the temporal region. Further inquiry into the background of this S provided a possible cue, viz., that he had experienced "brain damage;" while he was now able to function normally, he remained rather slow in his school work. Perhaps his subvocalization was thus not modifiable as in normal Ss, and was required in order to support the requisite brain processes during reading.

Fig. 11. Change in Chin, Throat and Tongue EMG Throughout Sessions.

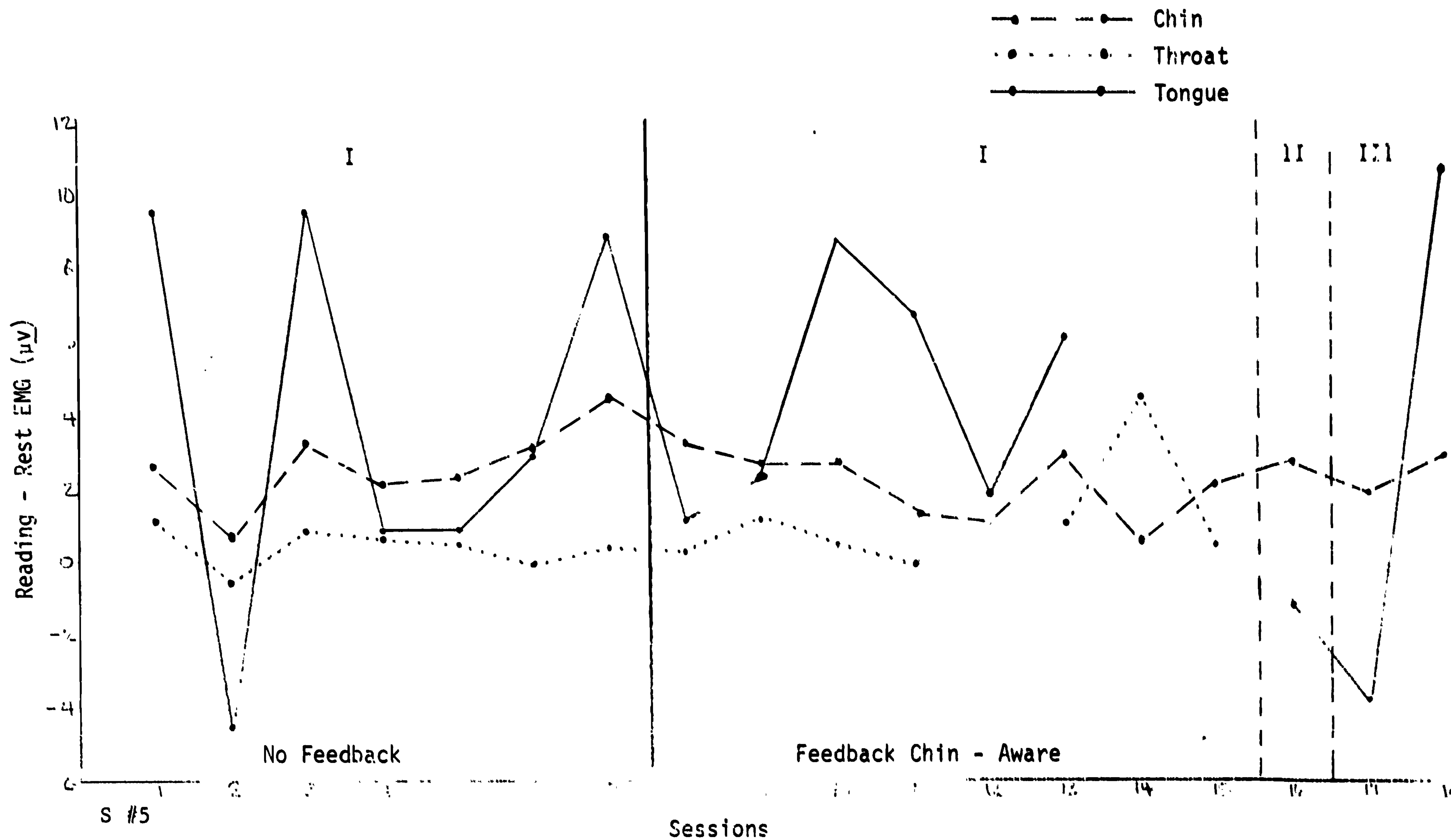

Chin
Throat
Tongue
12
10
8
4
2
0
-4
I
I
II
III
No Feedback
Feedback Chin - Aware
Reading - Rest EMG (μv)
S #5
Sessions

Figure 11

Fig. 12. Reading Rate and Comprehension Scores for Sessions.

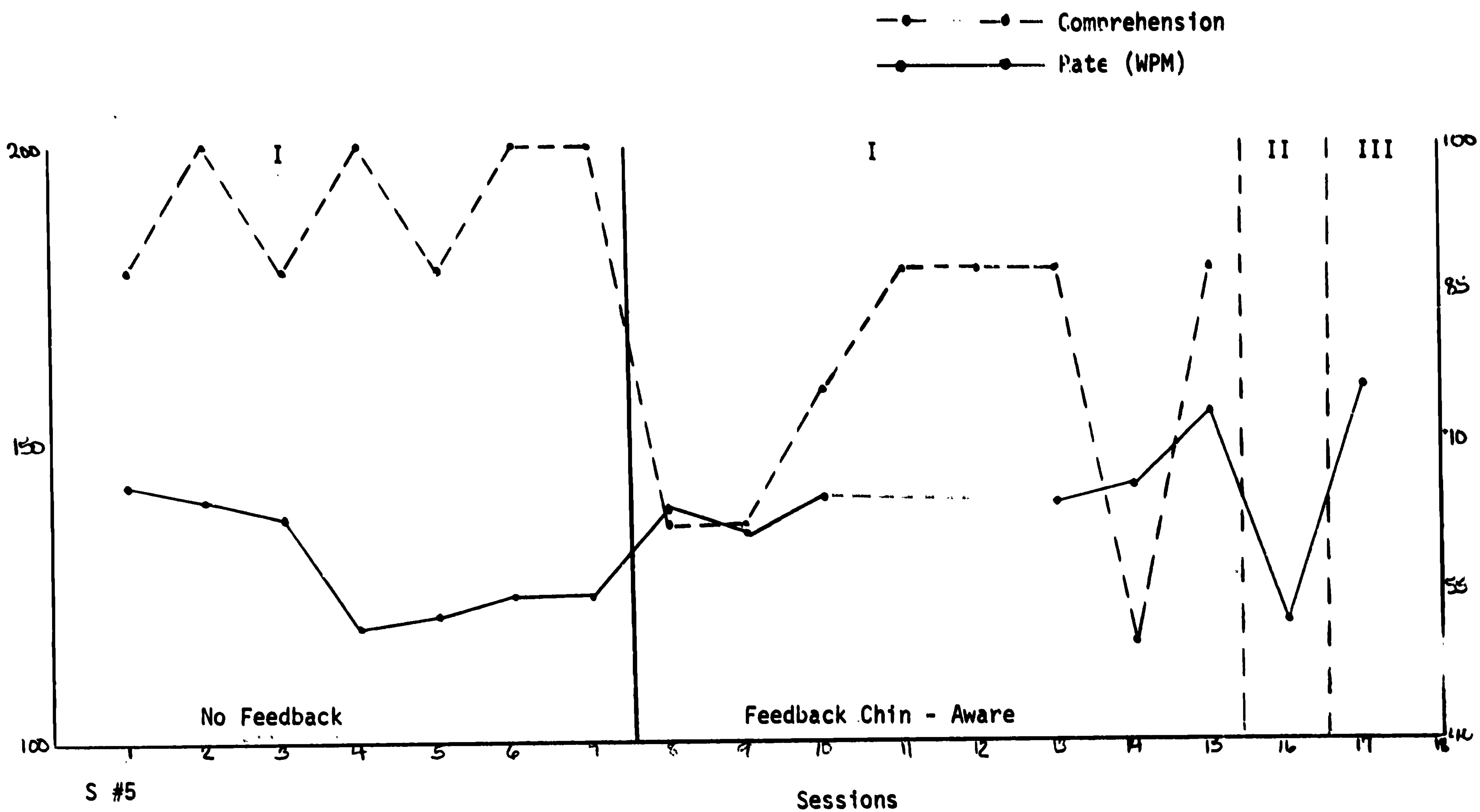
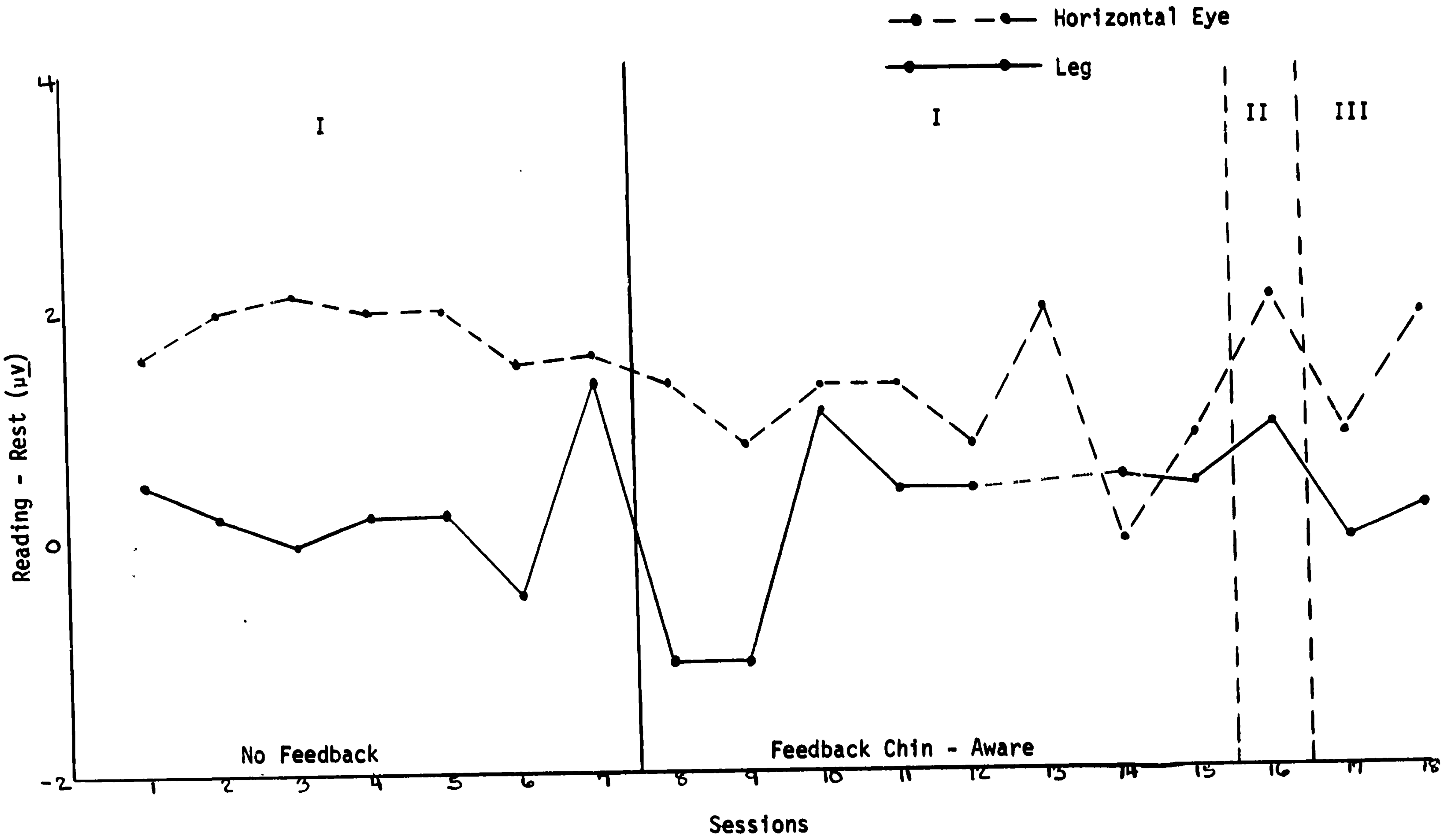

Comprehension
Rate (WPM)
200
150
100
I
I
II
III
100
85
70
55
40
No Feedback
Feedback Chin - Aware
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
S #5
Sessions

Figure 12

Fig. 13. Integrated Eye and Leg EMG as a Function of Sessions and Conditions.


Horizontal Eye
Leg
I
I
II
III
4
2
0
-2
Reading - Rest (µv)
No Feedback
Feedback Chin - Aware
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Sessions

S #5

Figure 13

Fig. 14. Temporal and Occipital EEG Changes Throughout the Sessions.

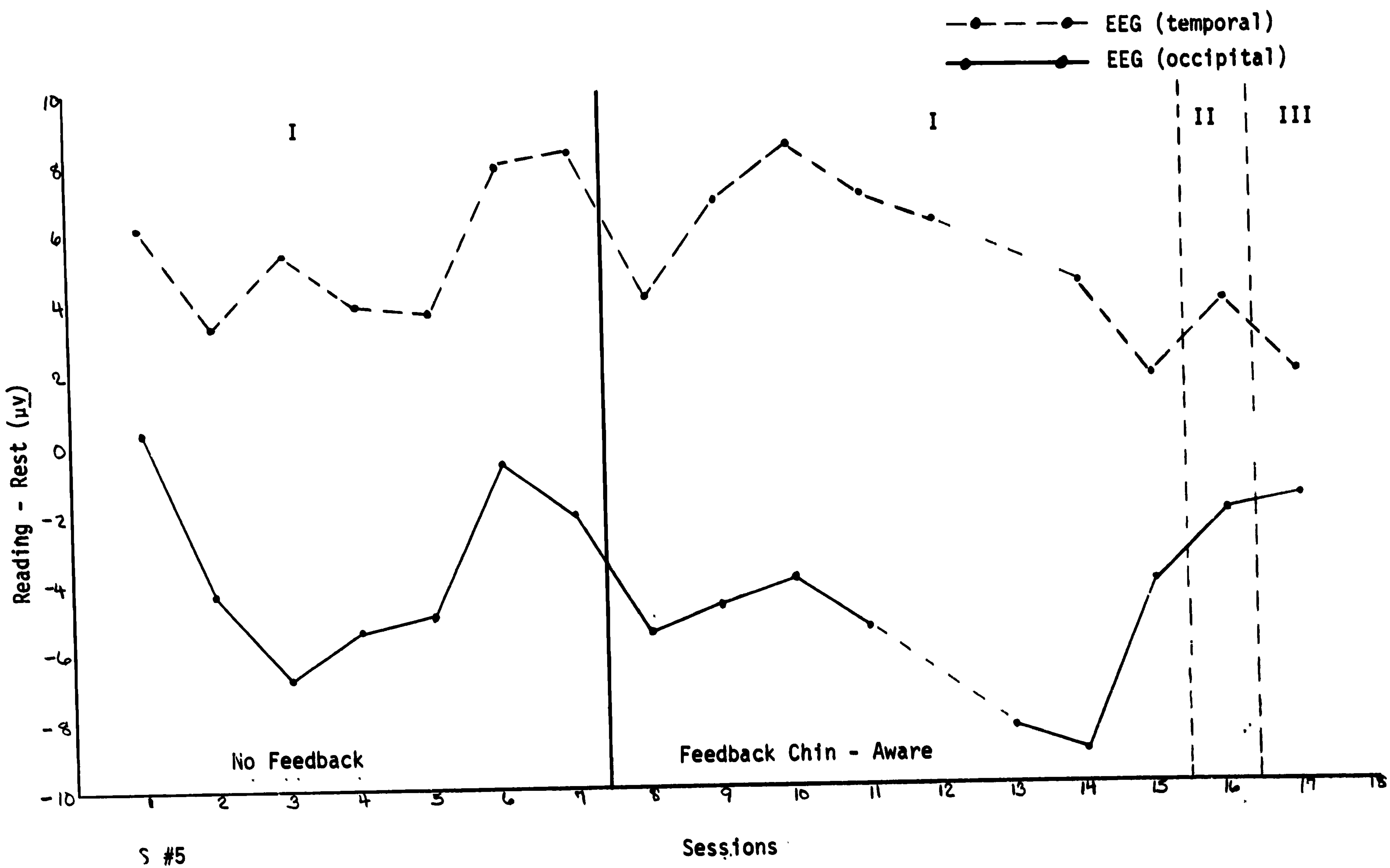

EEG (temporal)
EEG (occipital)
I
I
II
III
No Feedback
Feedback Chin - Aware
Reading - Rest (μv)
10
8
6
4
2
0
-2
-4
-6
-8
-10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
S #5
Sessions

Figure 14

The Effect of Remedial Reading on

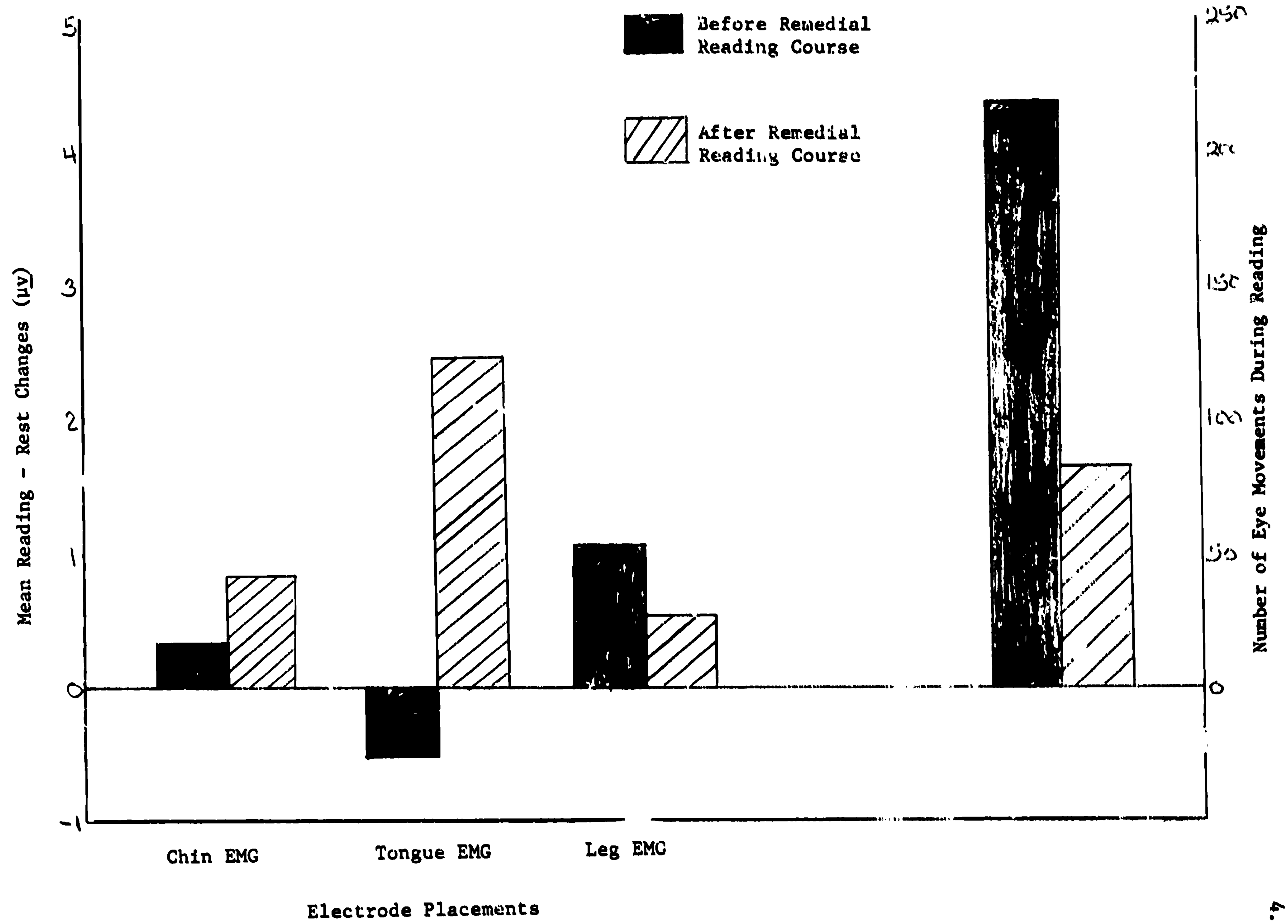
Covert Oral Behavior: One Case

This study concerns an 11-year-old girl who was experiencing reading difficulties; attendant emotional problems included a negative attitude towards school, requests to be excused from school on days when she had tests due to illness, ulcers, and so forth. She was in the fifth grade, having failed one year. Her school and classmates were relatively advanced. On the California Reading Test, Upper Primary for Grades 3 and L4 (Form W) she scored at grade 5.1 on Reading Vocabulary and at grade 6.0 on Reading Comprehension, for a Reading Grade Placement of 5.6. Psychophysiological measures (as discussed below) were taken during a silent reading session in the laboratory. She was then given about 30 individual remedial reading sessions using the Fernald method for a period of several months -- the meetings were irregular with lapses of weeks at times. This irregularity occurred because the psychologist wanted S to take the remedial instruction only when she wished and felt favorable towards it. At the conclusion of the remedial reading work she was retested on the California Reading Test, Elementary for Grades 4, 5, 6 (Form W). At this testing her reading vocabulary rose to 6.8 grade level, her reading comprehension to 7.8, and her Reading Grade Placement to 7.3. Her teacher, parents and the child herself reported noticeable improvement in her reading ability and in her attitude toward school work.

During the first laboratory session the S's reading rate on SRA Laboratory Material (fifth grade level) was 109 words per minute with a comprehension score of 80%. During the second laboratory session (after the remedial instruction) on comparable reading material her rate was 157 WPM with a comprehension score of 87%.

Each laboratory session consisted first of a relaxation period followed by a silent reading period. The results of the various covert process measurements are presented in Figure 1. The number of eye movements of the kind that occur when an S reaches the end of a line of prose were counted during the reading sessions. It can be seen (right vertical axis) that they dramatically decreased in frequency following the remedial instruction, corroborating the increased reading rate. Mean amplitude of the measures during rest were subtracted from respective mean amplitudes during reading and the results are plotted for the first and second sessions. It can be seen that chin EMG slightly increased from rest to silent reading prior to the remedial reading course (.3 μv) and that the increase was greater following the improvement in reading rate and comprehension (.8 μv). Tongue EMG increased much more dramatically; whereas amplitude of tongue EMG actually decreased during reading prior to the course (-.5 μv), it increased by 2.5 μv following the training. Leg EMG, however, was higher before than after the improvement in reading. It is apparent that the reading improvement was accompanied by increases in amplitude of covert oral behavior during silent reading, and that these responses were not merely an aspect of heightened bodily arousal, as shown by the reversal of the means for leg EMG. These results, tentative though they are being based on one S in a clinical setting, are consonant with the hypothesis that covert oral behavior is beneficial during reading. It may well be that the improvement in reading proficiency had as its basis an increase in amplitude of covert oral behavior.

Fig. 1. Response Changes from Rest to Silent Reading Before and After Remedial Reading Training. Covert oral behavior increased in amplitude after S developed greater reading proficiency, but covert non-oral behavior had the reverse change.


Before Remedial Reading Course
After Remedial Reading Course
Mean Reading - Rest Changes (μv)
5
4
3
2
1
0
-1
250
200
150
100
50
0
Number of Eye Movements During Reading
Chin EMG
Tongue EMG
Leg EMG
Electrode Placements