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 *S*s 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 *S*s engaged in the *single* task of silent reading. We have, therefore, little knowledge, gained under controlled conditions, about comparable changes when *S*s engage in other tasks. Consequently, we do not know whether the covert oral response is a function of language input, or whether is 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 speci-

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fication 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 I; 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).

[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.

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 entered in Table 1. We can note that

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

chin EMG increased from rest to activity for all conditions and that the increase is greater when *S*s 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 (*Alpha* = .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 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 *n*s available.

EXPERIMENT II

Subjects. Forty *S*s from the same population as for Experiment I were presented the same five conditions (repeated treatments), sys-

[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.

tematically 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.

Qualification 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. preceding reading was subtracted from her mean tongue amplitude For example, an *S*'s mean tongue amplitude during the rest period 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 memoriza-

TABLE 2
Mean Covert Response Changes in m*v* 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	.108*	.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

* $p < .05$

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

EXPERIMENT III

Subjects. Twenty-five *S*s 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, electroencephalograms (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

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

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. Pneugrams 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 reading and memorization,

TABLE 3

Mean Covert Responses for Five Conditions. EMG Measures Are Integrated (m*v*). (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

* $p < .05$

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

Due to technical difficulties, usable EEG records were obtained from only nine *S*s. 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 *mu*v, 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 *S*s 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 *S*s 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 *S*s 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 *S*s were making covert language responses. That is, if the *S*s 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 *S*s 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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ABSTRACT

Three experiments were conducted in which *S*s silently read, memorized, listened to prose, to music or to nothing. The findings confirmed those previously reported that during silent reading *S*s significantly increase covert oral behavior (chin and tongue electromyograms, EMG), 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.

RESUMEN

Se llevaron a cabo tres experimentos en los cuales los sujetos deberían leer en silencio, memorizar, escuchar prosa, música o escuchar nada.

Los resultados confirmaron los mencionados anteriormente que durante un período de lectura en silencio, los sujetos aumentaron significativamente el comportamiento verbal "interno" (covert) (electromiagramas de quijada y de lengua, EMG), EMG de antebrazo preferido y el ritmo de respiración. Además, esos incrementos son significativamente mayores que aquéllos que ocurren durante el período cuando se escucha música o se escucha con cuidado sin oir nada. Un proceso similar de respuestas ocurre durante un período de memorización, aunque con más amplitud. Alteraciones en el EMG de antebrazo preferido y el ritmo de respiración son significativamente mayores durante las tres condiciones que involucran el lenguaje que para las condiciones que no incluyen lenguaje. Se llega a la conclusión que el comportamiento verbal "interno" más intenso, el aumento de respuestas de antebrazo preferido y el ritmo de respiración están asociados con el procesos de los estímulos linguísticos.

RESUMO

Realizaram-se três experimentos em que os Sujeitos leram, decoraram, escutaram prosa, música ou não escutaram nada. Os resultados confirmaram aquêles relatados anteriormente que durante um período de leitura (silenciosa), os Sujeitos aumentam significativamente comportamento verbal "interno" (*covert*) (electromiogramas do quiexo e da língua, EMG), EMG do antebraço preferido e passo

respiratório. Além disso, êstes aumentos são significativamente maiores que aquêles que ocorrem durante um periodo de escutar música ou de escutar atentamente sem ouvir nada. Um padrão de respostas semelhante ocorre durante um período de decorar alguma coisa, mas desta feita com maior amplitude. Alterações no EMG do antebraço preferido e passo respiratório são significativamente maiores durante as três condições que incluem linguagem relativamente àquelas que não a incluem. Conclui-se que comportamento verbal "interno" mais intenso, aumento de respostas do antebraço preferido e do passo respiratório estão associados com o processamento de estímulos linguísticos.