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EFFECTS OF INCREASED READING RATE ON COVERT PROCESSES *

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ABSTRACT. Three experiments, one with adults and two with children, were conducted to determine whether increasing reading rate affects covert oral behavior, and other covert processes. Previous findings were confirmed that during silent reading there is heightened covert oral behavior, increased respiration rate and decreased EEG amplitude, and there was essentially no change in leg EMG or pulse rate. Increased reading rate produced a decrease in end of line eye movements (indicating that the subjects learned to read more than one line at a time) and apparently increased amplitude of tongue EMG; the increased covert oral behavior as a result of increased reading rate was more apparent in adults than in children. Perhaps heightened covert oral behavior facilitates the reading process.

RESUMEN. Se realizaron tres experimentos, uno con adultos y dos con niños, para determinar si aumentando la tasa de lectura afecta la conducta verbal no-manifiesta, y otros procesos no-manifiestos. Fueron corroborados resultados previos que durante lectura silenciosa se encuentra elevada conducta verbal no-manifiesta, tasa de respiración subida y amplitud de EEG reducida, pero no se verificó ningún cambio en el EMG de la pierna ni en la tasa de pulsación. La tasa aumentada de lectura produjo una reducción en movimientos del ojo a fin de la línea (indicación de que los sujetos aprendieron a leer más de una línea a la vez) y evidentemente incrementó la amplitude del EMG de la lengua; la elevada conducta verbal no-manifiesta como resultado de la tasa aumentada de lectura fue más evidente en los adultos que en los niños. Tal vez la elevada conducta verbal no-manifiesta facilita la lectura.

The majority view of the function of "subvocalization" during silent reading has been that it 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). Wood's (1966) similar position is a more contemporary example. 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 feedback techniques (e.g., McGuigan, 1966). Another implication is that by increasing one's reading rate, amplitude of covert oral behavior during reading should decrease.

An alternative view of the function of covert oral behavior during silent reading is that the response is beneficial (cf., Schilling, 1929). Edfeldt (1960) 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 majority position, viz., that an increase in reading rate should *not* 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 obtain data relevant to the issue specified by the two above cited interpretations of the function of covert oral behavior during reading. For this, reading rate of students was increased and the effect on the amplitude of their covert behavior was studied.

While the issue as stated has implications for theories of thinking (cf., McGuigan, 1966) as well as technological implications for the teaching of reading, it is also important from the point of view of internal information processing. Why, for instance, do we achieve relatively uniform rates for reading, listening to speech, etc.? Is there some kind of psychological or physiological limit in linguistic processing? By studying muscular and neural events as a function of rate of linguistic input, we might find that our "standard" rates can be greatly increased, or that comprehension deteriorates once the body's built-in processing limit is reached.

METHOD

Subjects

For Experiment I, undergraduate female students at Hollins College volunteered to take a "Speed Reading" course and were randomly assigned to one of three groups: 17 subjects served in the Experimental Group, 6 in Control Group 1 and 7 in Control Group 2.

For Experiments II and III, male and female students from grades 8 through 12 in the Roanoke, Virginia public schools volunteered to serve as subjects and were randomly assigned to the Experimental Group and to Control Group 1. (Control Group 2 was dropped for Experiments II and III.) For Experiment II, 18 subjects were in the Experimental Group, and 12 in the Control Group. For Experiment III, 22 subjects were in the Experimental Group and 12 in the Control Group.

Procedure

All subjects were first administered one form of the Nelson-Denny Reading Test, 1960 edition. For Experiment I, members of Groups *E* and *C* No. 1 individually rested, read silently, and rested again in the laboratory while electromyograms (EMG) were recorded from the tongue, lips, throat, and leg. Additional signals recorded were bipolar electroencephalograms (EEG) from the occipital lobes, eye activity from the external canthi, and pneumograms.

Group *E* was then given a reading rate improvement course using the Science Research Associate's (SRA) accelerator and standard SRA procedures. The subjects read daily from light material of their own choosing. The accelerator setting was individually determined on the basis of a timed rate and comprehension test using SRA IVa Blue Booklets.

At the end of the reading course, all subjects from the three groups were given an alternative form 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. The EMG and EEG data were recorded on a multi-channel tape recorder, converted to mean integrated amplitudes for each 10-sec. period of relaxation and reading, digi-

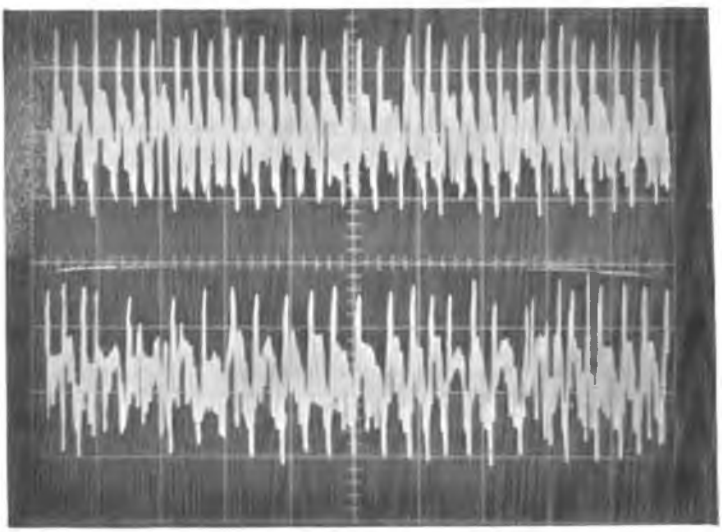

Figure 1. Sample Record of Eye Activity During Silent Reading for an Experimental Subject. Pre-test record is upper trace and post-test record is lower trace. The large spikes indicate movement of the eye from the end of a line of prose to the start of the next line. Each horizontal division is 4 sec.

tized, and printed out. For further details of the laboratory and recording and quantification techniques, see McGuigan and Rodier (1968).

Pneumograms were quantified by counting number of respirations per minute during reading and rest. Eye activity was quantified as follows: when, during reading, subjects reached the end of a line of prose, a large spike occurs in their electrical records as they return their eyes to the left of the page to read the next line of prose (see Fig. 1). Th number of these spikes during reading was counted for each subject, and divided by the number of lines read. The ratio thus computed indicated mean number of "end of line" (EOL) eye movements, per line of prose read.

RESULTS AND DISCUSSION

Table 1 shows that the experimental subjects significantly increased their reading rate in all three experiments, as measured by the Nelson-Denny Reading Test, and in the laboratory while the psychophysiological measures were being taken. All mean differences were tested by *t* tests, with alpha .05. The reading rate changes for the control groups were minor and not significant. In all three experiments, the mean increase in

Table 1

Mean Reading Proficiency Changes

		Experiment 1			Experiment II			Experiment III		
Measure	Group	Pretest	Postest	Diff.	Pretest	Postest	Diff.	Pretest	Postest	Diff.
Nelson-Denny										
Rate (WPM)	E	332	481	149*	217	389	172*	250	470	220*
	C	397	412	15	229	230	1	203	231	28
% Comprehension	E	87	85	-2	71	68	-3	63	57	-6
	C	82	84	2	70	69	-1	57	61	4
Laboratory										
Rate (WPM)	E	361	506	145*	191	362	171*	261	480	219*
	C	419	344	-75	183	218	35	250	257	7
% Comprehension	E	62	66	4	72	75	3	64	58	-6
	C	63	65	2	74	75	1	64	63	-1
Eye Move-	E	1.008	.855	-.153*	1.002	.827	-.175*	.974	.802	-.172*
ments/line	C	1.000	1.200	.200	1.011	.992	-.019	.985	.984	-.001

$^*p < .05$

reading rate for the Experimental Group was significantly greater than the change for the corresponding Control Group on both the Nelson-Denny and in the laboratory. In Experiment I, the increase in reading rate on the Nelson-Denny for Group *E* was significantly greater than for Group *C* No. 2 (t 3.46; the mean pre-test and post-test rates for Group C No. 2 were 294 wpm and 315 wpm, with comprehensive scores of 85% and 86%). Changes on the Nelson-Denny were not significantly different for the two control groups. Comprehension scores generally remained rather stable for all groups.

In Table 1, it can also be seen that the experimental groups always significantly decreased the number of the EOL eye movements, and that the changes for the control groups were minor and non-significant. Furthermore, the changes in each experiment for the experimental groups were always significantly greater than for the control groups. In Experiment I, Control Group 1 made significantly more EOL movements on the second test than did Group *E* (t 3.52). The values for Control Group 2 on the pre-test and post-test were .970 and .970. The fact that all three groups had essentially the same number of these EOL eye responses on their first test, and that only Group *E* significantly decreased the number of them during the second test, indicates that this change was produced by the reading improvement course. To consider the reason for this decrease, we may examine a typical set of tracings for an experimental subject (Fig. 1). We may note that there was no noticeable reduction in amplitude from before to after the course. One suspicion is that the subjects, as a result of the special training, learned to process more than one line at a time. Informal conversations with several subjects confirmed this: When asked how their reading had changed, they volunteered that they now often read more than one line at a time. In short, these psychophysiological measures confirm that the reading course was effective in increasing reading rate. Further, this electrical technique, easy to use, probably provides a more objective method for measuring reading rate than the standard one by reading test. And certainly it is more sensitive, in that highly refined measurements are obtained with each return of the eyes to the next line of prose to be read.

Means were computed for each subject for each psychophysiological measure during rest and during silent reading; rest values were then subtracted from reading values. Group means of these changes from resting to reading were then entered in Table 2 for both pre-test and post-test sessions. By examining the values for tongue and lip EMG as measures of

Table 2

Mean Response Changes From Rest to Silent Reading

As a Function of Condition

Response		Experiment I			Experiment II			Experiment III		
Measure	Group	Pretest	Postest	Diff.	Pretest	Postest	Diff.	Pretest	Postest	Diff.
Tongue EMG	E	0.0	.4	.4*	.6*	1.0*	.4	.3	.5	.2
	C	.5*	.1	-.4	1.4	1.1	-.3	.2	0.0	-.2
Lip EMG	E	.8*	.6*	-.2	.2	.4*	.2	.2	.3	.1
	C	.7	1.0*	.3	.5	1.0	.5	.2	0.0	-.2
Throat EMG	E	.1	.1	0.0	-.1	.0	.1	0.0	0.0	0.0
	C	0.0	0.0	0.0	-.3	.1	.4	0.0	0.0	0.0
Leg EMG	E	0.0	-.1	-.1	.2*	.1	-.1	.1	.0	-.1
	C	0.0	-.1	-.1	.1	-.4	-.5	-.2	.1	.3
Respiration	E	2.2*	1.7*		.3	1.4*		.5	-.9	
	C	1.5	3.4		2.1*	.5		-.3	-1.0	
		Occipital EEG			Occipital EEG			Pulse Rate/Min.		
	E	-2.2*	-1.5*		-1.5*	-1.7*		-.6	.8	1.4
	C	-1.2	-1.2*		-.9*	-1.8*		-2.8	-1.1	1.7

*$p < .05$

covert oral behavior, we can note that in 21 of 24 instances, these variables increased in amplitude during silent reading; in no case was there a decrease. These findings typically contrast with changes for leg EMG. In general, then, the results conform with previous findings that covert oral behavior increases during silent reading, and that the increase does not seem to be merely an aspect of heightened arousal.

Mean respiration rate increased during silent reading (with the one inexplicable exception during Experiment III), a finding reported many times (e.g., McGuigan & Rodier, 1968). Similarly, previous reports of a mean integrated EEG decrease during "mental activity" were confirmed. For Experiment III peripheral pulse rate (measured from the right index finger) was substituted for the EEG channel. It was found that only minor and non-significant changes occurred for this measure, again indicating that there was no heightened state of bodily arousal that could account for the increased covert oral behavior during silent reading.

To study changes from before to after the reading course, mean differences between pre-test and post-test values were entered in the "Difference" columns of Table 2. For example, in Expriment I, tongue EMG of Group *E* did not noticeably increase from rest to reading before the reading improvement course; after the reading course, however, the increase was .4 microvolts, yielding a net increase of .4 microvolts. That increase in amplitude of tongue EMG as a measure of covert oral behavior was significant (p less than .05). The corresponding change for Control Group 1 was −.4 microvolts. The increase of .4 microvolts for Group *E* was thus large relative to that for Group *C* No. 1 and the difference between these two groups would have been significant beyond the .06 level (t 2.03). 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 tongue EMG, or in fact on any of the measures. Similar results were obtained for Experiments II and III, i.e., in Experiment II, Group *E* increased the amplitude of its tongue EMG from before to after the reading course by .4 microvolts, while there was a decrease of −.3 microvolts in the control group; in Experiment III, the increase for the experimental group was .2 microvolts and the decrease for the control group was −.2 microvolts. However, the changes in tongue EMG were not significant for either group in Experiments II and III, nor were differences between groups significant. It may be that the significant increase in tongue EMG in Experiment I occurred because the subjects were adults and thus emitted relatively small tongue EMG during silent reading prior to the experiment. The children in Experiments II and III, on the other hand, had exaggerated tongue EMG (relative to that for adults) prior to the experiment. Hence, the course could produce a greater effect on the adults (who started from 0.0 microvolts amplitude during the pre-test, as can be seen in Table 2) than for the children (who had mean amplitudes of .6 microvolts and .3 microvolts in the pre-tests).

It has previously been reported that tongue EMG is probably the most sensitive measure of covert oral behavior (McGuigan & Rodier, 1968), a finding that perhaps explains why lip EMG, and especially throat EMG, were not particularly sensitive to the experimental treatment. In short, basing this conclusion primarily on the tongue EMG measures, there is some evidence that improvement in reading proficiency results in an increase in covert oral behavior. The main support for this conclusion is a consistent tongue EMG increase in three experiments for the reading improvement group, and a consistent tongue EMG decrease for the control groups. Regardless, however, it is clear that the reading improvement effected here did not result in a *decrease* in amplitude of covert oral behavior.

CONCLUSION

Previous findings of heightened covert oral behavior during silent reading were confirmed. The increased level of covert oral responding was generally accompanied by increased respiration rate and decreased EEG amplitude, and was independent of one measure of covert non-oral behavior. The reading improvement course was effective and resulted in a decrease in the kind of eye movements that occur when one reaches the end of a line of prose, suggesting that subjects learned to sometimes read more than one line simultaneously. Increasing reading rate seemed to increase amplitude of the most sensitive oral measure (tongue EMG), and the effect was more noticeable for adults; but in any event, improved rate did not result in decreased covert oral activity. Perhaps a greater increase in reading rate than occurred here would make this covert behavioral effect more pronounced, or disconfirm it. The results are thus at least somewhat consonant with the hypothesis that covert oral behavior is beneficial in the performance of language tasks such as silent reading; they also are rather clearly at variance with the position that covert oral behavior is detrimental to reading proficiency.

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FOOTNOTE

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