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ABSTRACT

Two experiments related to the development of verbal self-control in children were conducted. In the first experiment, 36 adults and 36 four year olds were administered a vocal alone, a motor alone, and a combined-reaction-time task. In the second experiment, 54 kindergarten subjects and 60 fifth-grade subjects were each administered a double motor (a motor response followed by a second motor response), a double vocal ("Go," "Go"), and a combined vocal-motor reaction-time task. The results indicated that when two overt responses are combined, the initial response is somewhat inhibited, but that there is nothing unique about the vocal response in this process: the latency of the initial response was the same whether it was followed by a vocalization or by a second motor response. Further, by the age of four, there was no difference between the ability to combine two motor responses and the ability to combine a motor response and a vocal response. (Author/AA)

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Technical Report No. 362

THE MOTOR COMPONENT OF SPEECH IN THE VERBAL REGULATION OF BEHAVIOR

by

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Report from the Project on
Children's Learning and Development

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ABSTRACT

This paper reviews the Soviet theory of the development of verbal self-control in children. Three stages (impellent, supplementary speech, internal semantic connections) are described, and the role of the vocal, or speech, component (as contrasted with the verbal, or semantic,) is discussed as one of at least four types of supplementary speech training in the verbal regulation of behavior.

Two experiments are reported, utilizing nursery school, kindergarten, fifth grade, and college aged subjects. In the first experiment, 72 Ss (36 adults and 36 four-year-olds) were administered a Vocal Alone, a Motor Alone, and a Combined (vocal and motor) reaction time task. The results replicated Soviet experiments, in that Motor Alone was significantly faster than Motor Combined, but the difference between Vocal Alone and Vocal Combined was not statistically significant. The second experiment involved 54 kindergarten and 60 fifth grade subjects. Each child was administered a double motor (a motor response followed by a second motor response), a double vocal ("Go," "Go") and a Combined vocal-motor reaction time task. While the motor response always preceded the vocal response, it made no difference in the response latency of the initial response whether it was followed by a vocalization or a second motor response.

These results suggest that when two overt responses are combined, the latency to the initial response is increased (i.e., the initial response is somewhat inhibited), but that there is nothing unique about the vocal response in this process. Further, it appears that by the age of four there is no developmental difference between the ability to combine two motor responses and the ability to combine a motor and vocal response.

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I

INTRODUCTION

Soviet investigators of the "verbal control of behavior" have been concerned with the developmental process by which verbal instructions influence the child's motor behavior in situations where conflicting nonverbal stimuli are present. When such control is established, "voluntary" or conscious behavior is said to be the result. In the now-classic Soviet bulb-squeezing experiments, a child is instructed to squeeze a rubber response bulb once when he sees a signal light flash. The bulb is connected to a potentiometric recorder, and the "stability" of the child's responses is indexed by the latency and amount of recorder pen movement. From such experiments three distinct stages in the development of voluntary movements have been identified. During the impellent period (approximately two years of age) the child can be impelled to squeeze the bulb, but the action cannot be inhibited once initiated. The conflict here is between the verbal instructions and the excitation produced by the hand-squeeze; the excitation dominates, and unstable performance results. Only during the transitional supplementary speech period (three to four years of age) can such unstable performance be eliminated, and then only with the aid of various types of auxiliary verbal activity. Finally, with the establishment of internal semantic connections, the verbal regulation of behavior is complete, and the five year old child is able to verbally plan and silently perform the required action in a consistent way.

English-speaking researchers first became interested in the verbal control of behavior through the translated reports of Soviet neuropsychologist A. R. Luria (1958, 1959, 1960, 1961). By far most of this interest focused on the supplementary speech period, and only on one type of auxiliary verbal activity: combining the child's vocalizations with the hand squeeze. Such speech was reported to be self-regulatory. The motor aspect of the vocalizations is more developed than the motor response of the hand, so the hand squeeze action is more stable with the vocalization than without it. Luria emphasized the motor component in the vocalization rather than its semantic aspect during the supplementary speech period, since even the vocalization of nonsense syllables had a stabilizing effect on the hand squeeze.

It is important to stress that combining vocalization with the hand squeeze is only one of at least four types of supplementary speech training[1]

[1] In addition to vocalization training, other experiments have been reported (Luria, 1958) in which the instructions are segmented and carefully given to the child, continuous reinforcement is administered, or sanctioning afferentiation is used (i.e., the light goes off immediately after the child's motor response).

and that Luria's treatment of the phenomenon was more theoretical and less detailed than the actual laboratory experiments. This situation has caused non-Soviet researchers considerable difficulty in their attempts at direct replication, especially since they seemed more interested in interpreting the phenomenon within existing mediational (e.g., Kendler & Kendler, 1961; Miller, Shelton, & Flavell, 1970) and operant conditioning (Meichenbaum & Goodman, 1969) approaches, rather than understanding it in its own right. The finding which completely thwarts mediational or operant conditioning explanations of the stabilizing effects of vocalization on the hand squeeze response is that the vocalization appears to follow the hand squeeze rather than precede it. This fact is basic to an understanding of the regulatory effect of vocalization.

To date, Wozniak (1972) has offered the only defense of Luria's account of the verbal control of behavior, and a general understanding of the relationship between vocal and manual responses, with emphasis on a developmental perspective, is still quite incomplete. The purpose of this paper is to explore this relationship by way of an original technical report from Luria's laboratory, and to present some data from one of our recent experiments.

The original experiments on the vocal aspects of the verbal control of behavior were conducted by Homskaya and Tikhomirov during the 1950's. For the purposes of this discussion, we shall stay within what Wozniak (1972) has referred to as the "simple initiation-inhibition" paradigm, in which the child is instructed to squeeze a response bulb only once each time a stimulus light flashes. It is well known from Luria's reports that the young child (1-1/2 to 4 years of age) cannot perform this task in a stable fashion, but tends to emit responses between signals (errors), and squeeze too much or too many times in response (perseveration) to the stimuli. What is not well known, however, is the crucial role of the verbal instructions in the production of voluntary responses as opposed to conditioned responses.

It would be quite easy to condition a child in this paradigm to mindlessly emit the appropriate responses over trials as a function of appropriate reinforcement. The verbal control of behavior, however, implies that the experimenter's verbal instructions set up a unique series of cognitive events which lead to a voluntary response. Language allows such behavior to be more easily established, more easily reversed, and less dependent upon the immediate stimulus environment. Our point here is not to deny the existence of conditioning, but rather to distinguish it from voluntary behavior.

Tikhomirov (1958) pointed out that the word, like any complex stimulus can create auxiliary excitation centers in the cortex which then lead to an auxiliary motor impulse. In contrast to other types of stimuli, however, language also creates a series of selective connections, or internal semantic responses, which influence motor responses. The nervous processes of the 1-1/2 to 4 year old child are thought to be "diffuse," tend to "irradiate" easily, and have poor "mobility" in the Pavlovian sense. What is more, the young child cannot use language to stabilize his behavior during this stage of development. Consequently, when asked to "squeeze once when the light comes on," the child does not emit stable motor responses, and does not spontaneously employ language as an aid to successful performance. It is important to point out here that Soviet researchers assume that the child completely understands the experimenter's instruction, and that unstable responses are a function of the child's lack of voluntary self-control.

The child's own speech may be introduced as a self-regulating aid between the ages of three and four by having the child say "go" while squeezing the response bulb. As Tikhomirov (1958) had concluded:

> In this way movements accompanied by speech are slowed down and become as it were less impulsive. This speech based regulation permits many children to increase the general tone of inhibition and to master the tendency toward extraneous motor impulsive reactions.

As we have previously suggested, the vocalization is slower than the manual response, but it in some way influences the initiation of the manual response which precedes it. This inhibitory effect, as described by Tikhomirov, is measured by the increase in latency to the manual response, but it is unclear whether there is an equal increase in latency to the vocalization when the two responses are combined. Such an increase would suggest that when two responses are combined, it takes a greater amount of time to execute both responses. If, however, the second response takes no longer in the combined condition than when done alone, some sort of coordination between the two responses must be occurring.

The only study in the United States directly pertaining to Tikhomirov's research was reported by Birch (1971). Using children ranging from 3-1/2 to 6-1/2 years of age, Birch addressed the question of whether manual and vocal reaction time to a visual stimulus would be affected by how the Ss were required to make their responses--either separately or in combination. More specifically, in the "vocal alone" condition, Ss were instructed "as soon as you see the light, say the color"; in the "manual alone" condition, "as soon as you see the light, take your finger off the red button and touch the plate"; and in the "combined" condition, "this time you have to do two things to turn off the light: say the color and touch the plate." One half of the Ss were tested with the Vocal-Manual-Combined order of conditions while the other half were tested with the Manual-Vocal-Combined order.

Birch found that the manual start times (latency of removing the finger from the start button) were faster when the S performed the manual response separately than when required to perform a manual and vocal response in combination. Vocal response times were also faster in the separate than in the combined condition. Furthermore, in the combined condition, manual start and target times were much faster for Ss who received the Vocal-Manual-Combined condition sequence than the Manual-Vocal-Combined sequence. However, it is difficult to draw conclusions from Birch's results, since the combined condition was always administered after either the vocal alone or manual alone conditions. This lack of complete counterbalancing of experimental conditions makes the comparison of either separate condition (manual or vocal) with the combined condition meaningless.

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In our initial experiment, then, our chief concern was whether there is a similar increase in the latency of vocal and manual responses when comparing the separate to the combined condition, and whether this relation was the same for adults as for children. Secondly, we were interested in determining if vocal and manual response latencies were related to the order of presentation of the experimental conditions when they were completely counterbalanced.

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II

EXPERIMENT I

METHOD

Subjects

A total of 36 children (mean age 55 months with a range of 49 to 65 months) from a semirural Wisconsin community preschool and 36 University of Wisconsin undergraduate students participated in the study.

Apparatus

A wooden partition 30 inches in height separated E from S visually. Located within the S's side of the partition was a panel (approximately [illegible] inches from the S's face) upon which were mounted a stimulus light (frosted glass stimulus light two inches in diameter) and a microphone. A telegraph key was mounted at the base of this panel. The duration of the stimulus light flash was approximately .5 second. The microphone (connected to a Lafayette voice-activated relay) and the telegraph key activated Lafayette multi-choice reaction times which were calibrated to 1/100 second. The stimulus light and reaction timers were simultaneously initiated by a switch activated by a 1-5 second variable delay mechanism controlled by E.

Procedure

Each S was seen individually, the adults in a laboratory on campus, and the children in a mobile laboratory parked near the preschool. All Ss received identical instructions: during the Vocal Alone (V) condition, each S was to say "go" as fast as possible when the light was illuminated; during the Manual Alone (M) condition, the S was to press the telegraph key as fast as possible; and during the Manual-Vocal-Combined (MVC) condition, the S was to emit the vocal ("go") and manual (press) responses as rapidly as possible (the order of occurrence of these responses was not emphasized by E). The response stimulus foreperiod was varied from 1 to 5 seconds (as unsystematically as possible) with E's verbalization of "ready" serving as the foreperiod stimulus. Each S was tested under all three conditions.

The sequence of conditions was counterbalanced with six Ss being randomly assigned to each of the following condition orders: M-V-MVC, M-MVC-V, V-M-MVC, V-MVC-M, MVC-M-V, and MVC-V-M. Two practice trials for adults, four practice trials for children, and ten test trials were administered for each of the three conditions. The dependent measure was vocal and manual response latency to the stimulus light under the experimental conditions.

RESULTS

Median manual and vocal reaction times were computed for each S.[2] An initial Response Modality (4) x Trial Blocks (2) x Condition Order (6) mixed analysis of variance was performed separately for the children's and adults' data. This analysis revealed no Trial Block (trials 1-5 versus 6-10) main effect or interactions, and the data were collapsed across this factor.

Children

The analysis of variance revealed a Response Modality main effect ($F = 21.23$; df. = 3.90; $p < .01$). Tukey post hoc pair-wise comparisons were then performed (see Table 1). This analysis revealed that the mean median M reaction time (.448) was significantly ($p < .01$) faster than the manual response of MVC reaction time(.573). On the other hand, V reaction time (.623) was found not to be statistically different ($p = .05$) from vocal response reaction time (.655) in MVC. No other main effect or interaction was significant in the children's data.

Adult

The analysis of variance revealed a Response Modality main effect ($F = 144.41$; df. = 3.90; $p < .01$) (see Table 2). Tukey post hoc pair-wise comparisons were performed (see Table 3). This analysis revealed findings similar to those of the children. Mean median M latency (.233)

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[2] Investigators studying simple reaction time have noted that the distribution of reaction times tends to be non-normal and positively skewed (e.g., Hohle, 1967; McCormack & Wright, 1964; and Snodgrass, 1967). Inordinately long reaction times can be attributed to the S (especially children) being distracted by external events, and unrealistically rapid times are most likely the results of the S's anticipation of and responding prior to the onset of the reaction stimulus (Hohle, 1967). The mean of a distribution is more effected by extreme scores in a distribution than the median. "The occurrence of even a few very high or very low cases can seriously distort the impression of the distribution given by the mean, provided that one mistakenly interprets the mean as the typical value. If you are dealing with nonsymmetric distributions, and you want to communicate the typical value, you must report the median [Hays, 1963, p. 175]."

TABLE 1

CHILDREN'S MEAN MEDIAN RESPONSE TIMES (IN SECONDS)
FOR RESPONSE MODALITY BY CONDITION ORDER

(EXPERIMENT I)

Condition Order	Response Modality			
	M	V	MC	VC
M - V - MVC	.338	.511	.524	.577
M - MVC - V	.438	.668	.563	.671
V - M - MVC	.497	.732	.753	.794
V - MVC - M	.363	.533	.429	.539
MVC - M - V	.573	.718	.674	.735
MVC - V - M	.459	.578	.493	.614
Grand Mean	.448	.623	.573	.655

M = Manual Alone Condition

V = Vocal Alone Condition

MVC = Manual-Vocal-Combined Condition

MC = Manual Response in the Manual-Vocal-Combined Condition

VC = Vocal Response in the Manual-Vocal-Combined Condition

TABLE 2

ADULTS' MEAN MEDIAN RESPONSE TIMES (IN SECONDS)
FOR RESPONSE MODALITY BY CONDITION ORDER

(EXPERIMENT I)

Condition Order	Response Modality			
	M	V	MC	VC
M - V - MVC	.236	.335	.241	.331
M - MVC - V	.244	.313	.249	.324
V - M - MVC	.247	.373	.290	.375
V - MVC - M	.223	.351	.285	.349
MVC - M - V	.218	[illegible]8	.259	.343
MVC - V - M	.232	.333	.293	.368
Grand Mean	.233	.337	.269	.349

M = Manual Alone Condition

V = Vocal Alone Condition

MVC = Manual-Vocal-Combined Condition

MC = Manual Response in the Manual-Vocal-Combined Condition

VC = Vocal Response in the Manual-Vocal-Combined Condition

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TABLE 3

TUKEY PAIR-WISE COMPARISONS OF RESPONSE MODALITY FOR CHILDREN'S AND ADULTS' DATA

(EXPERIMENT I)

Comparison	Subjects	
	Children	Adults
M vs MC	**	**
M vs V	**	**
M vs VC	**	**
V vs VC		
V vs MC		
MC vs VC	*	**

* p < .05

** p < .01

M = Manual Alone Condition

V = Vocal Alone Condition

MC = Manual-Combined Condition

VC = Vocal-Combined Condition

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was significantly ($p < .01$) less than the manual response latency (.269) in MVC. However, V latency (.337) was not statistically different ($p = .05$) from the vocal response latency (.349) in MVC. No other main effect or interaction was found to be significant in the adult data.

DISCUSSION

The finding that manual response latency was greater in the combined condition than in the separate condition is in agreement with Tikhomirov (1958). With regard to vocal response, no statistical difference was obtained in vocal latency between the separate and combined conditions. Furthermore, these results were consistent with adults and children as subjects. Finally, these findings, based upon complete counterbalancing of condition order, are in disagreement with Birch's (1971) results which indicated that both vocal and manual response latencies are greater in the combined than in the separate condition.

III

EXPERIMENT II

As indicated by the first study, the latency of a manual response increases when a vocal response is also emitted. There are two possible explanations for this finding. First of all, there may be something unique about speech (uniqueness of speech hypothesis) which results in an increase in manual response latency when both are emitted. Secondly, the longer manual response action time may simply be related to the fact that the task requires an additional response (number of responses hypothesis) and that the features of the response per se have little to do with the increase in manual response latency. In other words, the effects can be explained by the number of responses rather than the qualitative features associated with specific responses. The purpose of this study was to test these two hypotheses.

METHOD

Subjects

The subjects were 54 kindergarten (mean age = 5.2 years) and 60 fifth grade (mean age = 10.3 years) children attending two public elementary schools in Madison, Wisconsin.

Apparatus

The apparatus employed in this study was the same as in Experiment I except that two response keys were used instead of one

Procedure

Each child was tested individually in a mobile laboratory parked near the school. All children received identical instructions: during the Manual-Manual (MM) condition, each child was told to press (using the same hand throughout the experiment) both response keys consecutively as fast as possible when the light was illuminated; during the Manual-Vocal Combined (MVC) condition, to press one response key and to vocalize "go" as rapidly as possible (the order of these responses was not emphasized by E); and in the Vocal-Vocal (VV) condition, to vocalize "go" twice as rapidly as possible.

Each child was tested in all three experimental conditions. The sequence of conditions was counterbalanced by assigning Ss to each of the six possible condition orders. Each S received 4 practice trials followed by 10 test trials for each of the 3 experimental conditions. The dependent variable was the time taken to emit the first response under the various experimental conditions.

RESULTS

Median manual and vocal reaction times of the initial manual and vocal responses under the Manual-Manual condition and the Vocal-Vocal condition, as well as both responses in the Manual-Vocal-Combined condition, were computed for each S.[3] Tables 4 and 5 present all mean median reaction times partitioned on the basis of condition order and response modality. A 4 (Response Modality) x 6 (Condition Order) mixed analysis of variance was performed separately for the kindergarteners and fifth-graders.

Kindergarteners

The analysis of variance revealed a response modality main effect ($F = 2.67$; $df. = 3,144$; $p < .05$). Tukey post hoc pair-wise comparisons were then performed (see Table 6). The Tukey test indicated that the mean median MM (4.59) reaction time was not significantly different from the manual response of MVC (.446) reaction time. In addition, Vocal-Vocal (.543) latency was not statistically different from the vocal response of MVC (.563) latency. No other main effect or interaction was significant for the kindergarteners' data.

Fifth-graders

The analysis of variance also revealed a response modality main effect ($F = 86.76$; $df. = 3,162$; $p < .01$). A Tukey test was then performed (Table 3) and indicated that mean median MM response latency (.262) was not significantly different from the manual response of MVC (.251) latency. However, Vocal-Vocal response time (.382) was significantly slower ($p < .05$) than the vocal response of MVC (.356).

No other main effect or interaction was found to be significant.

DISCUSSION

The results indicate that the latency of a manual response is the same when a vocal or a second manual response is required, both for

[3] Data for one of the kindergarteners was lost, and in order to maintain equivalent cell frequencies, this S's scores were estimated based upon the average score of the remaining eight Ss in the condition order to which the S was assigned.

TABLE 4

KINDERGARTENERS' MEAN MEDIAN RESPONSE TIMES (IN SECONDS)
FOR RESPONSE MODALITY BY CONDITION ORDER

(EXPERIMENT II)

Condition Order	Response Modality			
	MM	VV	MC	VC
MM - VV - MV	.427	.542	.393	.517
MM - MV - VV	.422	.559	.459	.553
VV - MM - MV	.537	.564	.572	.642
VV - MV - MM	.412	.477	.353	.507
MV - MM - VV	.418	.572	.407	.556
MV - VV - MM	.536	.547	.494	.602
Grand Mean	.459	.543	.446	.563

MM = Initial Manual Response in the Manual-Manual Condition

VV = Initial Vocal Response in the Vocal-Vocal Condition

MVC = Manual-Vocal-Combined Condition

MC = Manual Response in the Manual-Vocal-Combined Condition

VC = Vocal Response in the Manual-Vocal-Combined Condition

TABLE 5

FIFTH-GRADERS' MEAN MEDIAN RESPONSE TIMES (IN SECONDS) FOR RESPONSE MODALITY BY CONDITION ORDER

(EXPERIMENT II)

Condition Order	Response Modality			
	MM	VV	MC	VC
MM - VV - MVC	.224	.368	.222	.364
MM - MVC - VV	.267	.369	.244	.322
VV - MM - VMC	.295	.417	.270	.359
VV - MVC - MM	.273	.397	.293	.406
MVC - MM - VV	.285	.380	.262	.355
MVC - VV - MM	.229	.363	.216	.331
Grand Mean	.262	.382	.251	.356

MM = Initial Manual Response in the Manual-Manual Condition

VV = Initial Vocal Response in the Vocal-Vocal Condition

MVC = Manual-Vocal-Combined Condition

MC = Manual Response in the Manual-Vocal-Combined Condition

VC = Vocal Response in the Manual-Vocal-Combined Condition

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TABLE 6

TUKEY PAIR-WISE COMPARISONS OF RESPONSE MODALITY FOR KINDERGARTENERS' AND FIFTH-GRADERS' DATA

(EXPERIMENT II)

Comparison	Subjects	
	Kindergarteners	Fifth-Graders
MM vs MC		
MM vs VV	**	**
MM vs VC	*	**
VV vs VC		*
VV vs MC	**	**
MC vs VC	**	**

* p < .05

** p < .01

MM = Initial Manual Response in the Manual-Manual Condition

VV = Initial Vocal Response in the Vocal-Vocal Condition

MC = Manual Response in the Manual-Vocal-Combined Condition

VC = Vocal Response in the Manual-Vocal-Combined Condition

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kindergarten and fifth-grade children. The data do not support the notion that there is something unique about speech which affects manual response latency, but do appear to support the "number of responses" hypothesis. That is, the manual response reaction time may simply be related to the fact that the tasks in this experiment required an additional response. The features of the response (either vocal or manual) per se have little to do with the effect upon manual response latency.

This interpretation is not inconsistent with the Soviet position on the development of verbal self-control, since Luria (1961) has reported that requiring a child to squeeze a rubber response bulb and then put the hand on the knee are "two successive excitations [p. 60]," which inhibit the first response. However, this interpretation does minimize the significance of the vocal component of speech in the verbal control of behavior. The point to be emphasized is that the verbal instruction to emit an additional response (either vocal or manual) increases the strength of the inhibition of the initial response. Further, while we also observed this clash of two successive excitations in older children and adults, this additional inhibition is unnecessary for successful performance on the bulb-squeezing task.

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IV

CONCLUSION

In summary, the data from Experiments I and II suggest that requiring a S to emit a vocal and manual response to the presentation of a light will result in the manual response being emitted first, and the latency of the manual response will be greater than in the case where only a manual response is required to be emitted. The relationship between the manual and vocal response systems appears to be one of coordination of two responses, and there appears to be nothing unique about the speech system's effect on manual response latency since a comparable latency can be derived by requiring another manual response. It seems that the number and not the type of task responses influence the latency of the fastest response.

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