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ABSTRACT

Partial replication of the Luria and Tikhomirov experiments in the verbal regulation of behavior has led to results and conclusions contradictory to those of the Russian researchers. Subjects for these experiments included mentally handicapped children and adults. The results of four sets of experiments are presented. In general, the basic findings of Luria and Tikhomirov with respect to regulation by the rhythmic aspect of speech were replicated, constituting a clear confirmation of that aspect of Luria's hypothesis. However, results did not generally confirm predictions derived from that portion of Luria's hypothesis which relates to the regulatory function of speech in its meaningful aspect. Reasons are suggested to account for these differences. (Author)

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THE ROLE OF SPEECH IN THE REGULATION OF BEHAVIOR

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The Role of Speech in the Regulation of Behavior[1, 2]

Jean A. Rondal[3]

About twelve years ago, Luria and collaborators published the results of their research in the development of the verbal regulation of behavior. The term verbal regulation refers to the ability to conform one's behavior to a preliminary instruction or plan. According to Luria, an elementary form of verbally regulated behavior is achieved by about age one year and a half when the child becomes able to respond to simple orders and soon after to immediate inhibits of commands. At this age, however, the child is still unable to respond properly to more complicated instruction like "when you see the light, press the rubber bulb" which requires that he first refrain from pressing before the light appears, then press the bulb when the light does appear, and lastly stop pressing until the next light appears.

In handling such situations, the child may take advantage of self-vocalizations accompanying performance of the motor task. The verbal accompaniment must re-present in some sense the preliminary instruction. The nature of the relationship between such preliminary instruction and verbal accompaniment changes as a function of age (and probably as a function of the motor task

although this aspect has not so far been analysed). These age changes have constituted the main focus of the Soviet research on this topic. For children younger than three years, any combination of motor and verbal responses is difficult and of no regulatory value. With children in a second stage, between 3 and 4 years, a clear regulation of motor reactions is obtained when a verbal accompaniment, regardless of the meaning of the word employed, corresponds rhythmically to the motor task[4] (if, for example, the child is required to say "go" while pressing the bulb once, or "go, go" while pressing the bulb twice). But as soon as the rhythmic correspondence between verbal and motor responses is removed, the child is no longer able to perform the motor task correctly (if, for example, he is to say "two" when asked to press the bulb twice for each light).

For children in a third stage, by 5 years of age, the meaning of the verbal accompaniment begins to predominate over its rhythmic aspect so that if the two aspects, meaningful and rhythmic, come into conflict (as in the preceding example) the meaningful aspect predominates, mediating correct motor performance. Subsequent development consists of an increasing influence of speech in its meaningful aspect but no longer in the form of external speech but rather in the form of inner speech, functionally related to the preliminary instruction. The functional unity of preliminary instructions (which mature subjects can give to themselves) and consequent inner speech supply the structure within which conscious and voluntary movement henceforth takes place.

Luria's thesis was widely accepted in the early sixties and his experiments were quickly integrated into the literature involving the mediational deficiency notion. However, when the first western replications occured in the late sixties, they led to rather contradictory results and conclusions compared to those of Luria (cf., Wozniak, 1972, for a review).

A peculiar situation follows from this discrepancy. While it is hardly possible to find any text in developmental psychology which does not mention Luria's thesis and findings, the experimental demonstration or at least replication still remains to be done.

The ground thus seemed prepared for a new and thorough investigation of Luria's hypothesis. This investigation was the goal of the work presented below.

In a first set of experiments with children from 3 to 7, we tried to replicate the experiments of Luria and Tikhomirov as related in Luria (1961). Experimental sets II and III were devised to answer some of the questions asked by the first set of experiments. Finally, in a fourth set of experiments, some motor tasks were presented to a small group of adults and they were asked to report on their possible inner verbalizations during the tasks. In addition, in a final study electromyographic measurement of covert lip movements was made during the performance of the motor tasks. As the methodology varied from one set of experiments to the other, we will present methods, results and partial conclusions set by set, before collecting the main data in a general conclusion. Finally, the implication of this trend of

research for the education of handicapped (specially mentally retarded) children will be presented.

Experimental Set I (experiments 1 to 5)

METHOD

Subjects: Sixty-four children from 3 to 7 years, described as developmentally normal, were divided into 8 groups of 8 subjects each, with each group containing only children whose ages fell within a 6 month span (e.g., 3-3 1/2, 3 1/2 - 4, 4 - 4 1/2, etc.).

Apparatus: The subjects sat on a chair and were presented with visual stimuli (i.e., colored lights). The interval between lights varied randomly between 4 and 6 sec. while stimulus duration varied randomly between 1 and 2 sec. The motor response consisted in squeezing a rubber bulb. This response was recorded by means of a polygraph. Verbal responses were recorded on a tape recorder.

Experimental model: Each of the first 5 experiments to be reported consisted of the following four successive tasks (except where otherwise indicated):

Task A: Motor response only (M.R.)

Task B: Verbal response only (V.R.)

Task C: M.R. and V.R.

Task D: Task A repeated

Approximately 20 stimuli were presented in each of the four tasks. While the four tasks were performed in the same experimental session, about 10 days separated one experiment from the other for each child.

Experiments: The first five experiments are defined by different instructional conditions. These are as follows:

Experiment 1: Subjects were asked to press the rubber bulb once for each stimulus. The verbal response (in task B and C) is "press." For information we shall give the instructions for each task in this experiment. Task A: otor response (M.R.) only (Instruction: "I want you to press the bulb once for each light, but not press when the light is not on."). Task B: Verbal response (V.R.) only (Instruction: "I want you to say "press" each time the light is on."). The bulb is removed during the performance of task B. If not good enough, the V.R. will be practice. Task C: Verbal response and Motor response (Instruction: "This time, I want you to do two things. You will say "press" and at the same time press the bulb once for each light." Then the instruction is repeated in a reverse order. "Remember I want you to do two things, you will press the bulb once and at the same time say "press" for each light."). Task D: Repetition of Task A.

Experiment 2: Subjects were asked to press the bulb twice for each light. The verbal response (in task B and C) is "press, press."

Experiment 3: Subjects were asked to press the bulb once for each red light (positive stimulus) and to refrain from pressing for each white light (negative stimulus). The different lights were presented at random. No task B was presented in this experiment.

Experiment 4: The motor response was identical to that in experiment 2, but the verbal response (in tasks B and C) was different. It consisted of the word "two." No task D was performed in this experiment.

Experiment 5: The motor responses were identical to those of experiment 3 (one press of the bulb for each positive stimulus, and no pressing for each negative stimulus). The verbal response for the postive stimulus was also the same ("press") but the verbal response for the negative stimulus was different, consisting of the word "no." No task D was performed in this experiment.

RESULTS

Results are expressed in average percentages of errors in motor performance by age and task. The statistical significance of the observed differences was assessed according to the Wilcoxon Matched Pairs test. Occasionally, where interesting differences were obtained, the data are broken down by the type of error committed.

Experiment 1: (See Table 1 & 2)

In task C, the significant decrease in errors obtained in children between 3.6 and 4 appears to be due mainly to a decrease in extra bulb presses, i.e., in perseverative squeezing. Furthermore, these perseverative responses reappear in task D when the child ceases to accompany his motor response with a vocal response. The effect of V.R. on M.R. is, therefore, generally one of facilitation when there is an opportunity for facilitation (i.e., between 3 and 4, but the single press task is already relatively too simple for children older than 4.6.

Table 1

Average Percentages of Total Errors by Age and Task

Ages	3-3.6	3.6-4	4-4.6	4.6-5	5-5.6	5.6-6	6-6.6	6.6-7
Tasks								
A	38	32	22	12	6	2	2	2
C	32	18	14	11	3	2	2	2
D	40	34	14	11	6	2	2	2
$.01 < P \leq .05$	-	A-C C-D	-	-	-	-	-	-

N.B. Task B is performed with an average of 20% or fewer errors from age 3 on.

Table 2

Average Percentages of Different Types of Errors

Between Ages 3 and 4.6 Years

Ages		3-3.6	3.6-4	4-4.6
Tasks	Error types			
A	O	16	12	10
	ER	22	20	12
C	O	14	10	10
	ER	18	8	4
	VO	19	9	9
D	O	17	12	10
	ER	23	22	4

Key: O = omission ER = extra bulb press VO = omission of V.R.

Experiment 2: (See Table 3 & 4)

A facilitative effect of V. R. on motor performance is generally observed. It reaches statistical significance in age groups 3.6 - 4 and 4 - 4.6. The errors analysis suggests that this effect is mainly achieved through a reduction of extra responses while omissions remain unaffected by V. R. A similar effect but less marked is also observed in group 4.6 - 5. For group 3 - 3.6, however, the situation is different. From task A to task C, the percentage of omissions decreases markedly, but an increase in extra responses suggests that the young child is induced by the concommitant verbalization to press the bulb more than once and often cannot then stop responding after two presses.

Experiment 3: (See Table 5 & 6)

The verbal pattern could not regularly be obtained from 5 of the 8 children in the first age group. Therefore results in task C for this group have been omitted in this table. In the older age groups, the introduction of the verbal response appears to improve the motor performance, but this reaches significance only for the 3.6 - 4 year old group.

Experiment 4: (See Table 7 & 8)

Task B was performed with an error average of 25% between 3 - 3.6 years, and error averages of 20% or fewer from age 3.6 on.

It appears that the monosyllabic verbal accompaniment exerts a negative influence on the double press task, particularly between 3 and 5 years. It results in an increase in the percentage of single presses of the bulb despite the instruction given to press twice before

Table 3

Average Percentages of Total Errors

Ages	3-3.6	3.6-4	4-4.6	4.6-5	5-5.6	5.6-6	6-6.6	6.6-7
Tasks								
A	73	69	49	38	13	11	6	6
C	58	32	28	25	15	11	3	6
D	71	72	45	30	11	12	5	5
$.01 < P \leq .05$	-	A-C C-D	A-C C-D	-	-	-	-	-

N.B. Task B was performed with averages of 15% of errors or fewer from age 3 on.

Table 4

Average Percentages of Different Types of Errors Between 3 and 5 Years

Tasks	Ages / Error types	3-3.6	3.6-4	4-4.6	4.6-5
A	OM	21	12	8	9
	PM	35	19	9	9
	ER	17	38	32	20
C	OM	15	10	10	5
	PM	15	14	8	9
	ER	28	8	10	11
	VO	16	7	7	6
D	OM	24	20	12	7
	PM	23	17	8	10
	ER	23	35	25	13

Key: OM: omission of M.R. (i.e., no press of the bulb); PM: partial omission of M.R. (i.e., one press of the bulb); ER: extra bulb press; VO: complete omission of V.R. (in task C only)

Table 5

Average Percentages of Total Errors Before the Positive Stimulus

Ages	3-3.6	3.6-4	4-4.6	4.6-5	5-5.6	5.6-6	6-6.6	6.6-7
Tasks								
A	51	39	25	18	9	7	7	5
C		19	17	12	5	5	5	4
$.01 < P \leq .05$	-	A-C	-	-	-	-	-	-

N.B. Task B was performed with averages of 90% of errors or fewer from age 3.6 on.

Table 6

Average Percentages of Total Errors Before the Negative Stimulus

Ages	3-3.6	3.6-4	4-4.6	4.6-5	5-5.6	5.6-6	6-6.6	6.6-7
Tasks								
A	39	36	22	18	19	10	5	8
C		17	12	10	11	10	5	5
$.01 < P \leq .05$	-	A-C	-	-	-	-	-	-

Table 7

Average Percentages of Total Errors

Ages	3-3.6	3.6-4	4-4.6	4.6-5	5-5.6	5.6-6	6-6.6	6.6-7
Tasks								
A	65	61	41	30	11	10	6	6
C	69	65	44	34	20	18	6	5
C_2	58	32	28	25	15	11	3	6
$.01 < P \leq .05$	-	$C-C_2$	$C-C_2$	-	-	-	-	-

N.B. 1)C_2 lists the results from task C of experiment 2 for purpose of comparison. Because those data came from separate experiments, no statistical comparison between A and C_2 has been made.

2)Task B was performed with an error average of 25% between 3 - 3.6 years, and error averages of 20% or fewer from age 3.6 on.

Table 8

Average Percentages of Different Types of Errors Between 3 and 5 Years

Tasks	Ages / Error types	3-3.6	3.6-4	4-4.6	4.6-5
A	OM	17	9	7	8
	PM	30	21	10	9
	ER	18	31	24	13
C	OM	14	8	7	7
	PM	40	38	15	15
	ER	15	19	22	12
	VO	15	8	5	2

Key: See experiment 2

each light. This is an effect of the impulsive aspect of the verbal accompaniment. This effect appears well marked between 3 and 4 years.

Experiment 5:

The performance for positive stimuli was not very different from that of experiment 1 and we shall report only the results for negative stimuli. (See Table 9)

As in experiment 3, the verbal pattern cannot be obtained regularly from the majority of children between 3 and 3.6. In the older groups the verbal response appears to improve motor performance for negative stimuli (i.e., decreasing incorrect squeezes), although not significantly. This result between 3.6 and 4.6 contradicts the findings of Tikhomirov in a similar experiment where the children were required to verbalize the Russian equivalent of "I don't press" before the negative stimulus (and "press" before the positive stimulus). Tikhomirov observed from 3 to 4 years, and in silent condition, an average of 42 percent of bulb presses before the negative stimulus versus 72 percent with the verbal accompaniment. These results were used by Luria to hypothesize that up to 4 or 4.6 a verbal accompaniment cannot help inhibiting a motor response. Using a different V. R. ("no") here, we do not reproduce the Tikhomirov effect. Perhaps a V.R. like "no" functions as a self-inhibitor earlier in the life of the child than the more syntactically complicated "I don't press." However, when comparing task C in experiments 3 and 5 (particularly between 3.6 and 5 years) one observes a slight superiority of task C, experiment 3, i.e., when no V. R. is produced while M. R. has to be inhibited. This difference, although not significant, is in accordance

Table 9

Average Percentages of Errors Before the Negative Stimulus

Ages	3-3.6	3.6-4	4-4.6	4.6-5	5-5.6	5.6-6	6-6.6	6.6-7
Tasks								
A		37	21	22	17	4	8	6
C		29	22	11	6	6	6	6
C_3		17	12	10	11	10	5	5
$.01 < P \leq .05$		-	-	-	-	-	-	-

N.B. 1) C_3 lists the results from task C of experiment 3 for purposes of comparison. Again, because those data came from separate experiments, no statistical comparison between A and C_3 has been made.

2) Task B was performed with error averages of 20% or fewer from age 3.6 on.

with the conclusion drawn by Luria from Tikhomirov's experiment.

Conclusions From Experimental Set I

1. For children between 3 to 3.6 years of age, the simple V.R. was available in about 75% of the trials in experiments 1, 2, 4 and not available in the majority of cases in experiments 3 and 5 where a discriminate verbal response was called for. The percentage of omissions of verbal responses in task C in experiments 1, 2, 4 also suggests a certain rivalry between V.R. and M.R. at this stage, heading to the regular suppression of some V.R.s, some M.R.s, or both. The presence of a V.R. leads to a slight improvement of motor performance in experiments 1 and 2. However, it is important to ask why the V.R.s do not lead here to a stronger improvement of the M.R.s? At least two alternative explanations can be considered: (1) the young child may be limited in his motor abilities (i.e., not be able to perform in a better way on the motor task whether the experimental condition be silent or with verbal accompaniment, simply because the developmental level of his motor neurodynamics does not allow him to do very much better); or (2) his own verbalizations may still be deficient in regulating his ongoing motor behavior. Experimental Set II using a nonverbal feedback device in the same motor tasks should allow us to clarify the alternative.

2. For children between 3.6 and 5 years of age, the characteristic findings reported by Luria, except in experiment 5 with the V. R. "no," have generally been replicated. An interpretation of this sole difference from the Luria - Tikhomirov findings has been proposed.

3. For children older than 5 years, the proposed motor tasks included in experiments 1-5 appear to be generally too simple. In particular, the motor tasks in experiments 3 and 5 did not supply the expected basis on which to test the transfer of the regulatory power of speech from a rhythmic to a meaningful aspect. In order to test this transfer hypothesis, more complicated motor tasks, presenting a challenge to children between 5 and 8 years of age, were devised. Results from these tasks will be reported shortly in discussing the third set of experiments (experiments 9 to 13).

Experimental Set II (experiments 6 to 8)

METHOD

Subjects: The same 24 children from 3 to 4.6 who participated in experimental Set I took part in this second set of experiments.

Apparatus: The same as in experimental Set I, except that a reinforcement-distribution device (RDD) was added. The RDD consisted of a mechanical dog sitting on the top of the light box. When manually activated by the experimenter the dog started barking and shaking its head for about one and a half seconds.

Experimental model: About 20 stimuli were presented in each of tasks A, B and C.

Task A: Silent performance of the motor task. The RDD is not employed and is not visible to the child.

Task B: Silent performance of the motor task, but the RDD is now employed and every correct response is reinforced.

Task C: Silent performance as in task A, but the RDD, although

visible, no longer functions (the child is told that he should be able to do the task by himself).

Experiments: Experiments 6, 7 and 8 are defined by different instructional conditions. These are as follows:

Experiment 6: Subjects were asked to press the bulb once for each light. The motor response is thus similar to that in experiment 1.

Experiment 7: Subjects were asked to press the bulb twice for each light. The motor response was thus similar to that in experiments 2 and 4.

Experiment 8: Subjects were asked to press the bulb once for each positive stimulus and to refrain from pressing for each negative stimulus. The motor response was thus similar to that in experiments 3 and 5.

No verbal response was elicited in any of these experiments. The respective effects of the verbal accompaniment and the nonverbal feedback (RDD) on motor performance were evaluated by comparing tasks C and B respectively in experiments 1 and 6, 2 and 7, and 3 and 8.

RESULTS

Experiment 6: (See Table 10)

From 3 to 3.6 the nonverbal control of M.R. proves to be more powerful than the verbal control of M.R. (compare task B in this experiment with task C in experiment 1). This effect can not be attributed to the simple repetition of the motor performance, nor to the training which occurred from the time of experiment 1,

Table 10

Average Percentages of Total Error

By Age and By Task

Ages	3-3.6	3.6-4	4-4.6
Tasks			
A	31	11	5
B	12	8	6
C	28	10	6
A_1	38	32	22
$.01 < P \leq .05$	A-B	$A-A_1$	-

NB. A_1 lists the results from task C of experiment 1 for purposes of comparison. Again no statistical comparison between A_1 and B and C has been made.

as is indicated by a comparison of performance in A to A_1. After 3.6 years, however, a strong decrease in motor errors has occurred between task A in experiment 1, and task A in this experiment, while differences between the silent condition and nonverbal feedback condition are small or nonexistant.

Experiment 7: (See Table 11 & 12)

Three points are of importance here:

1. For the group of children between 3 and 3.6, the non verbal control leads to a clear and significant increase in correct motor performance. Such an improvement was not attainable, in experiment 4, with a verbal accompaniment.

2. For children between 3.6 and 4.6, the nonverbal control of M.R. leads also to a significant improvement of motor performance; but, in experiment 2, the same type of improvement was already possible through verbal accompaniment. Children of this age, then, seem to be able to take advantage of either a verbal or a nonverbal means of control of their motor performance.

3. For children from 3 to 3.6, the analysis of errors indicates that in comparison to older children, errors of partial omission (PM) are most frequent (the same result was obtained in experiment 2). Furthermore, the introduction of nonverbal feedback leads to a diminution of partial omissions, but perseverations (ER) remain at the same level. After 3.6, on the other hand, it is perseverative responses which decrease more as a function of the introduction of nonverbal feedback. It thus seems that progress towards a correct double press response passes from a first period (3 - 3.6)

Table 11

Average Percentage of Total Errors

Ages	3-3.6	3.6-4	4-4.6
Tasks			
A	60	52	32
B	31	25	12
C	50	36	20
A_4	65	61	41
$.01 < P \leq .05$	A-B	A-B	A-B

N.B. A_4 lists the results from task A in experiment 4. Again, no statistical comparison has been made between A_4 and B and C.

Table 12

Average Percentage of Different Types of Errors

Ages		3-3.6	3.6-4	4-4.6
Tasks	Error types			
A	OM	12	8	8
	PM	27	18	8
	ER	21	26	16
B	OM	5	5	4
	PM	6	6	3
	ER	20	14	5
C	OM	12	6	5
	PM	14	10	7
	ER	24	20	8

Key: See experiment 2

in which the child simplifies the response by giving only a single squeeze to a period of perseverative responses (3.6 - 4.6), and then finally to a period of correct responses.

Experiment 8:

Results for positive stimuli are not very different from those in experiment 6. Therefore, we shall only report results for the negative stimulus. (See Table 13)

Between 3 and 3.6 years, the verbal pattern was not correctly obtained for most children, as in experiment 3. The nonverbal pattern proves to be efficient here and leads to a significant improvement of motor performance before negative (and positive) stimuli. After 3.6 years of age the levels of performance reached within the nonverbal feedback condition or within the verbal accompaniment condition (experiment 3) are close together.

Conclusions From Experimental Set II

It seems clear that once provided with an external and nonverbal means of control, our subjects between 3 and 3.6 years are reasonably able to improve the level of their motor performance. The results from experimental set I must indeed be interpreted in terms of an insufficient capability of those children to take advantage of self-verbalization in the kind of motor tasks which were presented. After 3.6 years, children seemed capable of taking advantage of either a verbal or a nonverbal means of controlling their motor performance.

Table 13

Average Percentage of Errors Before

Negative Stimuli

Ages	3-3.6	3.6-4	4-4.6
Tasks			
A	44	32	20
B	20	9	5
C	30	18	10
$.01 < P \leq .05$	A-B	A-B	-

Experimental Set III (experiments 9 to 13)

METHOD

Subjects: 48 children from 5 to 8 years were divided into 8 groups of 8 subjects, with each group containing only children whose ages fell within a 6 month span (e.g., 5-5 1/2, 5 1/2-6, 6-6 1/2, etc.). Most of the children between 5 and 7 years old had participated in experimental set I before.

Apparatus: The same as in experimental set I.

Experimental model: As in experimental set I with two exceptions: 1) there were sometimes additional tasks (E, F, G...) the content of which is defined separately in the different experiments; and 2) more stimuli (between 30 and 40) were employed in each task.

RESULTS

Experiment 9:

The experiment consisted of the following tasks:

Task A: Subjects were asked to make a (relatively) long press of the bulb for the long light (1 sec. of duration) and a (relatively) short press for the short light (flash). The two stimuli occurred in a random order. The interval between lights varied randomly between 1 and 8 seconds.

Task B: Subjects were asked to say "long" for the long light and "short" for the short one.

Task C: Subjects were asked to give the appropriate verbal and motor responses for each light.

Task D: The same as Task A. (See Table 14 & 15)

In this experiment, the V.R. which accompanied the M.R. in task C could only regulate the M.R. by means of its meaningful aspect. Before 6 years, the stimulus discrimination according to the proposed durations is difficult or impossible for most children. Therefore we have not included these results in the tables. However, as is obvious from the table, the V.R. does not lead to any change in average correct percentages of M.R. Rather, motor performance seems to improve slowly from task A to task D presumably as a consequence of the repetition of the task. From an analysis of errors it appears that the great majority of errors are errors in duration of the press (omissions and extra responses are relatively rare). Also, the percentages of omissions of V.R. in task C was under 10%.

Experiment 10:

The experiment consisted of the following tasks:

Task A: Subjects were asked to press the bulb once for each long light (1 sec. of duration) and to press twice for each short light (flash). As a rule, when there were two different stimuli they occurred in a random order. The interval between lights varied randomly between 1 and 4 seconds.

Task B: Subjects were asked to say "one" for the long light and "two" for the short one.

Task C: Subjects were asked to give the appropriate verbal and motor responses for each light.

Table 14

Average Percentage of Errors Before the Short Stimulus

Ages	6-6.6	6.6-7	7-7.6	7.6-8
Tasks				
A	21	22	18	21
C	20	24	17	17
D	23	31	24	19
$.01 < P \leq .05$	-	-	-	-

N.B. Task B was performed with averages of 10% or fewer of errors from age 5.6 on.

Table 15

Average Percentage of Errors Before the Long Stimulus

Ages	6-6.6	6.6-7	7-7.6	7.6-8
Tasks				
A	80	61	41	42
C	77	52	40	36
D	69	54	38	29
$.01 < P \leq .05$	-	-	-	-

N.B. Task B was performed with averages of 10% or fewer of errors from age 5.6 on.

Task D: The same as Task A.

Task E: Subjects were asked to say "yes" for each light.

Task F: Subjects were asked to press the bulb once for the long light and to press twice for the short one, but to say "yes" for each light. (See Table 16 & 17)

For reasons previously indicated, this experiment was not performed with children younger than 6 years of age. Between 6 and 7, the experiment demonstrated the facilitative effect of V.R. "yes" before the long stimulus. Between 7 and 8, a similar effect was obtained with V.R. "one" before the same stimulus. These two effects are to be attributed to the impulsive aspect of the verbal accompaniment. A statistically significant but isolated effect of V.R. "two" (i.e., an effect of the meaning of V.R.) is demonstrated between 7 and 8 before the short stimulus. But in this case we cannot exclude the alternative explanation that the effect is a function of the repetition of the tasks, since the level of performance reached in task C was maintained in Task D. The analysis of errors indicated that the most common error pattern was an inversion of the required M.R., i.e., the production of a simple press before the short stimulus and the production of a double press before the long stimulus. In any respect, the introduction of the verbal accompaniment in task C seems not to lead to a marked breakdown in this error pattern.

Experiment 11:

The experiment consisted of the following tasks:

Table 16

Average Percentage of Errors Before the Short Stimulus

Ages	6-6.6	6.6-7	7-7.6	7.6-8
Tasks				
A	55	52	35	39
C	54	53	30	18
D	44	38	26	19
F	66	45	36	30
$.01 < P \leq .05$	-	-	-	A-C A-D

N.B. Tasks B and E were performed with 25% or fewer of errors after age 6 on.

Table 17

Average Percentage of Errors Before the Long Stimulus

Ages	6-6.6	6.6-7	7-7.6	7.6-8
Tasks				
A	36	32	42	32
C	30	35	13	12
D	42	31	27	13
F	17	17	16	15
$.01 < P \leq .05$	A-F	-	A-D	A-C
	D-F	-	A-F	
$P \leq .01$			A-C	

N.B. Tasks B and E were performed with 25% or fewer of errors after age 6 on.

Task A: Subjects were asked to make a strong press of the bulb for the red light and a light press of the bulb for the white light. The interval between stimuli varied between 1 and 8 seconds.

Task B: Subjects were asked to say "strong" for the red light and "light" for the white one. Both verbal responses were to be pronounced in a natural way (i.e., without accent of intensity on "strong").

Task C: Subjects were asked to make the appropriate verbal and motor responses for each light.

Task D: The same as Task A.

Task E: Subjects were asked to say "strong" (with accent of intensity) for the red light and "light" (in a soft voice) for the white light.

Task F: Subjects were asked to say "strong" (with accent of intensity) and to make a strong press of the bulb for the red light and to say "light" (in a soft voice) and to make a light press of the bulb for the white light. (See Table 18 & 19)
(N.B. As a rule in every task where verbal responses and motor responses are to be combined, the instruction is repeated a second time in a reverse order as to the requirement of verbal and motor responses.)

A differentiation in magnitude of motor response is difficult to achieve for children younger than 7 years. Several stages can

Table 18

Average Percentage of Errors Before the Red Stimulus

Ages	5. 6-6	6-6. 6	6. 6-7	7-7. 6	7. 6-8
Tasks					
A	75	58	54	14	20
C	81	54	44	18	25
D	80	48	47	28	13
F	60	23	22	14	19
.01 < P $\leq$ .05	-	A-F	A-F	-	-
		C-F	C-F		
		D-F	D-F		

N.B. Tasks B and E were performed with averages of 10% of errors or fewer from age 5 on.

Table 19

Average Percentage of Errors Before the White Stimulus

Ages	5.6-6	6-6.6	6.6-7	7-7.6	7.6-8
Tasks					
A	53	40	57	12	19
C	48	44	45	18	18
D	52	47	41	20	24
F	31	22	15	10	11
.01 < P < .05	A-F D-F	-	C-F D-F	-	-
P ≤ .01			A-F		

N.B. Tasks B and E were performed with averages of 10% of errors or fewer from age 5 on.

be observed in the progressive mastery of the required motor differentiation. First, a complete nondifferentiation is characteristic of most children between 5 and 5.6. At this stage, the motor responses have approximately the same magnitude regardless of which stimulus is presented. At an intermediate stage characteristic of children from 5.6 to 7 there is a period of unsteady differentiation. The differentiation remains good provided that a large difference in magnitude is maintained before strong and light presses. This differentiation, however, is rather costly in terms of the energy necessary to sustain it: this makes it difficult to maintain over a long period of time and therefore is unsteady. Finally at about 7 - 7.6, the differentiation begins to stabilize. Strong and light presses become close together in magnitude, hinting of more flexible and adapted motor neurodynamics. What about the introduction of verbal responses into the motor task in this experiment? As can be seen from the tables above, the addition of a meaningful verbal response in task C does not lead to a marked improvement in motor performance. On the other hand, as soon as the verbal accompaniment (in task F) corresponds rhythmically to the motor responses, a marked and often significant improvement in motor performance is obtained wherever it can be obtained, i.e., between 5.6 and 7 years. Lastly, it does not seem that the mere repetition of the motor task is in itself a sufficient explanation for the marked effect demonstrated.

Experiment 12:

The experiment consisted of the following tasks:

Task A: Subjects were asked to press the bulb three times for the single light (i.e., flashing once) and to refrain from pressing for the double light (i.e., flashing twice). The interval between stimuli varied randomly between 1 and 8 seconds.

Task B: Subjects were asked to say "one, two, three" for the single light and not to say anything for the double light.

Task C: Subjects were asked to make the appropriate verbal and motor responses for each stimulus.

Task D: The same as Task A.

Task E: Subjects were asked to say "three" for the single light and to say "no" for the double one.

Task F: Subjects were asked to say "three" and to press the bulb three times for the single light and to say "no" and refrain from pressing for the double light.

Task G: Subjects were asked to say "three times" for the single light and "no" for the double one.

Task H: Subjects were asked to say "three times" and to press the bulb three times for the single light and to say "no" and refrain from pressing for the double light.

Task I: Subjects were asked to say "yes, yes" for each light.

Task J: Subjects were asked to press three times for the single light and to refrain from pressing for the double one, but to say "yes, yes" for each light. (See Table 20 & 21)

Four points are of some importance here:

1. For most children, the capability of completely inhibiting motor response when presented with a negative stimulus (double stim.) is well established by age 5 years. Thus, from 5.6 years the inhibition of motor response can successfully resist both a verbal and positive incitation (Task J).

2. The verbal accompaniment which corresponds rhythmically to the motor response (Task C) leads to a marked and often significant improvement in the motor performance to the single stimulus. In order to maximize the effect of such a V.R. it is necessary that each element of the V.R. be correctly matched with the M.R. This usually took one of three forms; 1) one two three

press press press

or 2) one two three

press press press or 3) one two three

press press press

however, as a rule this type of verbal motor correspondance was not achieved by the youngest children. This might help to account for the fact that the decrease in errors between tasks A and C was not nearly as marked for children between 5 and 5.6 as for older children.

Table 20

Average Percentage of Errors Before the Double Stimulus

Ages	5-5.6	5.6-6	6-6.6	6.6-7	7-7.6	7.6-8
Tasks						
A	5	12	12	6	7	4
C	7	3	4	6	12	2
D	10	4	4	7	8	5
F	8	10	6	4	5	8
H	13	5	10	1	1	1
J	28	8	5	8	4	2
$.01 < P \leq .05$	-	-	-	-	-	-

N.B. Tasks B, E, G and I were performed with averages of 10% of errors from age 5 on.

Table 21

Average Percentage of Errors Before the Single Stimulus

Ages	5-5.6	5.6-6	6-6.6	6.6-7	7-7.6	7.6-8
Tasks						
A	54	57	32	25	32	17
C	40	23	11	6	12	17
D	50	43	34	12	20	18
F	62	58	36	32	42	25
H	67	53	35	35	33	24
J	64	60	41	43	43	30
$.01 < P \leq .05$	C-H	A-C	A-C	C-F	A-C	-
	C-J	A-F	C-D	C-H	C-F	
		C-H	C-F	C-J	C-J	
		C-J	C-J	D-J	D-J	

N.B. Tasks B, E, G and I were performed with averages of 10% or fewer of errors from age 5 on.

In fact, for these youngest children, the V.R. correctly expressed was often accompanied by 2, 4 or even 5 presses of the bulb.

3. Verbal accompaniments which correspond semantically but not impulsively to the motor task (as in tasks F and H) not only did not improve motor performance at any age, but often led instead to an increase in percentage of errors. It is interesting to note, however, that in task F, the most frequent errors occurring to the single stimulus were not single but double pressures of the bulb. This indicates that the monosyllabic V.R. "three" did not function in a strictly rythmic manner (this would have led to a majority of errors involving a double press of the bulb); but rather that it was incapable of facilitating a triple press of the bulb. (The results here are therefore different from those observed in experiment 4, task C with the V.R. "two" employed with children from 3 to 5 years of age.)

4. Task J (before the single light) demonstrated that the verbal accompaniment "yes, yes" leads approximately to the same effects on M.R. as the V.R. "three" and "three times."

Experiment 13:

Subjects were asked to press the bulb once every three presentations of a light of the same color. Stimulus duration was 1 second, stimulus interval 1.5 seconds. Between 10 and 15 triplets (groups of three stimuli) were presented in each task. Tasks were

as follows:

Task A: M.R.

Task B: First light V.R. "no"

Second light V.R. "no"

Third light V.R. "yes"

Task C: M.R. + V.R.

Task D: Task A repeated

Task E: V.R. "yes" for every light

Task F: M.R. + V.R. (as in Task E) (See Table 22)

It seems reasonable to suppose that a correct performance of the motor task required here demands some kind of mental "counting" of the stimuli. The verbal accompaniment required of subjects in task F may disrupt this "counting" and lead to a consequent decrease in correct motor responses. One might also expect that the V.R. required in task C might even facilitate mental counting and this would then improve the motor performance. However, such an effect was not obtained. On the contrary, the V.R. in task C led to a slight increase in average percent of errors.

Conclusions From Experimental Set III

1. It would appear that the introduction of a verbal accompaniment which corresponds to the motor response only in terms of meaning and not in terms of rhythm fails, at least in the condition of these experiments, to regulate the motor performance.

Table 22

Average Percentage of Errors

Ages	5-5.6	5.6-6	6-6.6	6.6-7	7-7.6	7.6-8
Tasks						
A	44	38	17	12	12	8
C	53	39	21	10	11	9
D	45	34	12	8	16	13
F	58	54	30	21	10	18
$.01 < P \leq .05$	A-F	D-F	-	-	-	-

N.B. 1) Performance was measured for "triplets" of stimuli. A correct response implies that M.R. was inhibited twice and then produced at the appearance of the third of a "triplet" of stimuli.

2) The verbal stereotype in tasks B and E was correctly obtained from all children, from age 5 on.

2. On the other hand, the regulative value of the impulsive or rhythmic aspect of a verbal accompaniment has once again been demonstrated.

3. It remains to discuss a variable about which we have not said anything so far. What might have been the role of inner verbalization on the performance of at least some of the children in these tasks? Of our 48 subjects, 31 (65%) manifested external signs (e.g., lip movements) corresponding to possible inner verbalizations at least once during the tasks. Such manifestations were observed in children as young as 5 years. In most cases, they did not occur earlier in the procedure than task D. This suggests that they may have been induced by the external verbalizations in task C. Also, in most cases the content of these verbalizations, as far as we could tell, seemed to correspond to rhythmically rather than semantically appropriate verbal accompaniment of motor performance. This fact, then, indirectly supports point one above. Also, it is certainly possible that these inner verbalizations may have played a role in the lack of change in performance often observed between task C and D.

4. The failure to demonstrate a semantic regulatory effect for verbal accompaniment led us to ask ourselves whether this kind of effect may be found to exist at all under the experimental conditions which we have (and before us Luria and others) have been employing. This in turn led us, as reported in the next experimental set, to ask a group of adults to perform some similar but more complex motor tasks.

Experimental Set IV (experiments 14 to 15)

Adults were asked to perform silently three motor tasks at the end of which they were invited to verbally relate the content of their possible "mental accompaniment" during the performance. In a second experiment (15) another group of adults was proposed the same motor tasks while the modifications appearing in their labial electroactivity were recorded. The modifications are susceptible to adequately reflecting the inner verbal phenomena (Sokolov, 1972). Experiment 15 served as an objective control for the introspective reports collected in experiment 14. Different subjects were used in the two experiments in order to avoid the problem that, previously sensitized to their own inner dynamics during motor tasks, the subjects would have payed too much attention to their inner verbal phenomena in experiment 15.

Experiment 14:

METHOD

Subjects: Eight male and female adults between 24 and 35 years, all teachers.

Apparatus: The same as in the previous experiments.

Experimental model: Three tasks were presented successively and in the same order to each subject. All tasks were performed silently; between 30 and 40 stimuli were presented per task.

Task I: Subjects were asked to make one long press of the bulb followed immediately by a short press (i.e., long-short or L-S) for the short light (1/10 sec. of duration): and to make a

short press followed immediately by a long one for the long light (1 sec. of duration). The interval between the lights varied randomly between 1 and 6 seconds.

Task II: Subjects were asked to press the bulb three times for the white light and to press four times for the red light. The interval between lights varied randomly between 1 and 6 seconds.

Task III: Subjects were asked to make a light press of the bulb for the white light but to make a strong press for the red light. The interval between lights varied randomly between 1 and 4 seconds.

After completion of each task, subjects were asked: "Do you accompany yourself mentally during the performance of the motor task? If yes, how? Describe."

RESULTS

The information collected from interviewing the subjects seemed to point to an important participation of inner speech in motor performance. Table 23 summarizes these data as well as the individual percentage of errors made in the various tasks. (See Table 23)

The probability of covert verbalization appears to increase with the difficulty of the task, since task III which was described by all subjects as the easiest task, apparently elicited verbalization in the fewest subjects. Subjects who reported visual mental accompaniment (subject 1, task I and III; subject 8, task I), reported images which consisted in analogical representations of the task to be performed

Table 23

Mental Accompaniment and Percentage of Errors

in the Motor Tasks

Ss.	1	2	3	4	5	6	7	8	Average percentage of errors
Tasks									
I	x		+	+		+	+	x	
% of errors	13	38	42	52	20	51	19	15	31.13
II	+	+	+	+		+	+		
% of errors	12	20	30	21	22	33	33	22	24.13
III	x			+		+			
% of errors	3	9	16	14	5	7	16	4	9.25

Key: Subjects were numbered from 1 to 8, and tasks from 1 to 3.

x symbolizes a report of a mental accompaniment of the visual type and + a report of a mental accompaniment of the verbal type.

(e.g., a code --· or ·-- in task I or a large or a small pyramid in task III). Verbal accompaniments were reported to be of two types. Either they corresponded in meaning to the motor response ("long short" for a long press followed by a short one, "short long" for the reverse), or they corresponded rhythmically to the motor task ("one, two, three" for a triple press; "one, two, three, four" for a quadruple press). The former covert verbalization type was found exclusively in tasks I and II, while the latter dominated in task II, as if a meaningful but nonrhythmic verbal accompaniment was unable to supply a sufficient support in this task requiring a number of successive bulb presses. Table 23 also indicates the average percentage of errors in each task. These data support the classification of the tasks according to their relative difficulty, but do not (nor is it the case for the individual percentage of errors) bear any systematic relationship between the presence or absence of verbal or visual accompaniment and the quality of the motor performance. This leaves open the important issue as to whether internal verbal accompaniment is a mere auto-description by the subject of his ongoing nonverbal behavior or whether inner accompaniment facilitates accomplishment of the task.

Experiment 15:

(electromyographic exploration of inner verbal accompaniment during performance of the motor tasks)

METHOD

Subjects: Twenty subjects between 10 and 37 years of age (15 adults and 5 children between 10 and 13 years).

Apparatus: The subject held the bulb in his hand. Two superficial electrodes were fixed to the lip (orbicularies oris muscle), and two were fixed to the fore arm (epitrochleen muscles). The electrical activity of these muscles was measured by means of an electromyograph madelec Ms 6, and changes in muscle activity were polygraphically recorded (mingograph) at the same time as the stimuli and the manual presses of the response bulb.

Experimental model: The tasks were those of experiment 14, performed silently. After each task, subjects were again interviewed about any latent verbalization during performance.

RESULTS

Table 24 summarizes the essential quantitative data. (See Table 24)

The first row presents the numbers of subjects who did not report any inner verbalizations, and for whom no noticeable modifications of the E.M.G. baseline were observed. The second row contains the numbers of subjects who reported a visual accompaniment. The third row presents the numbers of subjects who reported verbal accompaniments during the motor tasks but for whom no noticeable E.M.G. response was obtained; and row four contains the numbers of subjects who reported an inner verbal accompaniment and for whose modifications of the E.M.G. from

Table 24

Correspondences Between Latent Verbalization Reported By the Subjects and Electromyographic Response From the Orbicularis Oris Muscle

Number of subjects by tasks			Verbalizations	Observed modifications in E.M.G.
I	II	III		
3	7	12	-	-
2	1	2	-	-
4	2	0	+	-
11	10	6	+	+

baselines were observed. The content of the verbal and visual accompaniments did not vary according to the age of the subject and were not noticeably different from those reported during experiment 14. The correspondance between reported verbalization and E.M.G. response appeared to be good except for those subjects contained in table 24, row 3. The evidence from the subjects raises the question of whether inner verbalization can occur without noticeable peripheral manifestation, or perhaps whether peripheral manifestation does not, in some cases or with some subjects, occur in other articulatory muscle groups.[5] The fourth row of table 24 is of particular interest: the E.M.G. objectively confirmed the subjects' verbal reports. In most cases, it can be assumed that modification observed in the E.M.G. is not due to artifacts or facial synkinesis of arm and hand press and movements of the bulb. Indeed, most often in using muscles electroactivity appears at the lips before appearing at the arms. Once again, verbal accompaniment was meaningful in those tasks where short and long, and strong and light presses of the bulb were required, and most often of an impulsive type, when a number of repetitive simple presses were required. Besides providing an objective verification of the introspective reports, the E.M.G. technique allows a careful analysis of the temporal and spatial (magnitude) characteristics of inner verbal accompaniments.

We shall briefly summarize these data as follows:

1. Inner verbal accompaniment is far from being constant. It often tends to disappear before the end of the motor performance. Its magnitude and form may vary considerably from moment to moment on the same task and with the same subject.

2. In some cases, inner verbal accompaniment manifests itself only at the beginning of the motor performance. The subject seems to procecd to a verbal analysis of the task to be performed and then relies only on his sensory-motor system in the performance of the rest of the task. Verbal responses may further reappear from time to time, possibly in recall of the instructions if the subject for some reason becomes confused, or as comments after an error in motor performance, or if something unexpected happens.

3. In some cases, it is possible to distinguish between an increase in the labial electroactivity which remains for the whole or for a part of the task, from outbursts of action potentials occuring just before and during motor responses. Apparently, one is dealing with an increase in tonic muscle activity which testifies of the difficulty of the task for the subject. In this tonic activity, phasic discharges appear which one can correspond to the inner verbalizations.

Conclusions From Experimental Set IV

In a good number of cases, and particularly when tasks are of a sufficient level of difficulty, inner verbalization has been found to be clearly related to performance of motor tasks. This phenomenon, initially inferred from a subject's verbal reports, has also been objectively confirmed by electromyographic lip recording.

General Conclusion

Briefly summarized, we think that we are in position to support the hypothesis of the existence of a regulatory effect of speech in its impulsive or rhythmic aspect for subjects from about three years to adulthood. In this respect, the work presented here constitutes a confirmation of that previously reported by Luria and Tikhomirov. As to the possible regulatory function of speech in its meaningful aspect, however, where the correspondance between motor response and verbal response is independent of rhythm, we have not found within the limits of the verbal and motor tasks presented, our experimental settings and models, and the age ranges of our young subjects (i.e., up to 8 years), any clear experimental support for this hypothesis. As indicated by the data collected from experimental set IV, such verbal responses seem to occur spontaneously and internally in adults confronted with motor tasks of sufficient complexity. But, with those subjects, our experimental model has not allowed us to demonstrate more than a close correlation between motor performance and inner verbal accompaniment. That a causative

relationship exists between them remains to be proved. In conclusion, the important question concerning the existence of the meaningful verbal regulation of behavior in children remains to be answered. Are we to suppose that this function develops and becomes functional between 8 years and the adult age, which is considerably later than the ages proposed by Luria for this emergence in normal children; or are we to suppose that this rather late occurrence is more a function of the specific motor tasks which have been used in the present investigations than an index of the chronology of the development of the meaningful regulatory speech function itself? Hopefully, further research will allow us to clarify this issue.

The implications of this trend of research for the education of retarded children are numerous. We shall briefly discuss two of them. First, from a methodological point of view, the experimental situation employed in our investigation allows for the assessment of the child's ability to interprete verbal information and translate it into a chain of motor acts. The assessment of such cognitive and psychomotor skills is obviously of first importance for studies in retardation. Second, thanks to Luria, the attention of psychologists has been directed to the interesting properties of speech in the development of self-control. Modern discussions of mental retardation have focused on the limited ability of the retardate to lead an autonomous life through the organization of his own behavior. Lurian paradigms offer not only

an interesting way to explor certain basic aspects of these limitations more deeply, but also suggest several ways for compensating, at least partially, for deficiences in self-regulated behavior by teaching subjects to use speech in organizing their activity.

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Footnotes

1. The report translates and summarizes research performed at the State University of Liege, Belgium, 1972, which was partially supported by a grant from the National Board of Scientific Research (F.N.R.S.), Belgium. Dr. R. Wozniak's linguistic advice and suggestions in the preparation of the manuscript are gratefully acknowledged.

2. Parts of the original paper are published in the Journal de Psychologie normale et pathologique, 1973, 3, 307-324, and in the Revue de Psychologie et des Sciences de l' education, 1973, 8, 491-501.

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4. We will sometimes use the expressions: verbal response or accompaniment of a significant or meaningful type and verbal response or accompaniment of an impulsive or rhythmic type. By the former expression we mean a verbal accompaniment which can only assist the motor response by its meaning, while the latter refers to a verbal accompaniment which can only assist the motor response by its rhythm.

5. The specialized literature does not give a clear answer to this question (cf., Sokolov, 1972, for a detailed bibliography of those subjects).