INDUCING SUBVOCALIZATION IN PRESCHOOL CHILDREN

A Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Raymond N. Sampson

May, 1973

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ABSTRACT

Electromyographic (EMG) recordings were taken from 48 four and five year old children during a recall task in which they saw pictures whose names contained or did not contain labial phonemes. When the children were encouraged to rehearse, subvocalization occurred during both picture presentation and during a subsequent rehearsal period. Subvocalization induced during the rehearsal period aided stimuli recall. Older female Ss, and higher I.Q. Ss were found to recall more pictures than younger Ss, male Ss, and lower I.Q. Ss, respectively. The relevance of these findings to the mediational-deficiency hypothesis and production-deficiency hypothesis was discussed. The mediational-deficiency hypothesis states that when a child makes the proper verbalizations at the proper times, he is less able than an older child to use them as mediators of overt behavior. The production-deficiency hypothesis contends that a younger child does not spontaneously produce the verbal mediators at the appropriate time in the task. Direct observation studies of rehearsal were also discussed in light of their relevance to the findings. Variables affecting neurological maturation and possible ways to facilitate neural functioning ("thought?") were suggested.

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CHAPTER I

PROBLEM

Locke (1970) defined subvocalization as "the articulatory aspects of language related behavior which are covert but measureable". His description was used to define the process investigated in the present research.

When four or five year old children are shown pictures for a short period and are then asked to remember what they have seen, subsequent testing reveals that their recall of the pictures is less than that expected of older children and adults. Older children and adults seem better able to utilize their subvocalization ability for the purpose of remembering what they have seen (McGuigan, 1970; Flavell, et al, 1966; Daehler, et al, 1969; Conrad, 1971; Locke & Fehr, 1970a&b; Reese, 1962; Hagen & Kingsley, 1968; Potts, 1968; Flavell, 1963, p. 158; Kenney, Cannizzo, & Flavell, 1967; Moely, Olson, Halwes, & Flavell, 1969).

A number of possibilities could account for the failure of very young children to match the recall performance of others. Possibley the four or five year old does not view the stimuli to be as meaningful as do older and more experienced children. If the stimuli to be recalled are not very meaningful to the very young child then his attention span or effort to recall may be truncated. Another possibility may be that the very young child does not rehearse at the appropriate times. Perhaps he subvocally rehearses but not at the times most conducive to recall.

An experimenter can take steps to increase the probability that the stimulus he presents to a very young preschool child is meaningful or interesting, but even when this is done, preschoolers do not perform or remember very well. The children silently rehearse (subvocalize) while they are viewing a picture to be recalled but they cease rehearsing when the picture is removed from view (Locke & Fehr, 1970a&b). Older children and adults seem to do just the opposite. They tend to rehearse in the absence of a stimulus to be recalled and not while the stimulus is being viewed (McGuigan, 1970; Flavell, et al, 1966; Daehler, et al, 1969; Conrad, 1971).

Developmentalists, such as Piaget, would say that the preschooler does not think logically. He is in an early developmental period called the preoperational representation period. Longstreth (1968, p. 144) stated that the preoperational nature of the preschool child is defined by the following: "The child does not perform a given mental operation" (rehearsing in the presence of a stimulus) "as part of a system of other related operations" (rehearsing in the absence of a stimulus) "but rather as an isolated event that has no bearing on other possible operations."

Longstreth (1968, p. 157) stated that Piaget did not ask what caused the four or five year old to behave as he did, nor did he ask if the processes could be speeded up or slowed down by certain experiences, nor did he experiment to find out. The present investigation sought to determine if the developmental process of subvocalizing at the appropriate times could be speeded up or otherwise changed to enhance the learning rates of the Ss.

As was noted earlier, a body of evidence exists which suggests that subvocal rehearsal may aid recall in adults and older children (McGuigan, 1970; Flavell, et al, 1966; Daehler, et al, 1969; Conrad, 1971). Very young children do not rehearse subvocally or out loud in an interval of delay between presentation and recall (Locke & Fehr, 1970a&b; Daehler, et al, 1969; McGuigan 1970; Conrad, 1971; Reese, 1962; Hagen & Kingsley, 1968; Potts, 1968; Flavell, et al, 1966; Flavell, 1963, p. 158; Kenney, Cannizzo, & Flavell, 1967; Moely, Olson, Halwes & Flavell, 1969). The present investigation addressed itself to a question that has never been investigated. Can a four and five year old child be induced or taught to subvocally rehearse during an interval of delay between presentation and recall? If so, will such rehearsal aid his recall? Inducing subvocalization, if it could be done, was assumed to be desirable in that the time required for a very young child to learn or retrain the maximum number of stimulus items would be shortened. Implied in this assumption was the assumption that a four or five year old child induced or taught to subvocally rehearse at the appropriate times, would like the older child and adult, recall more task items than a child who does not subvocally rehearse.

A related assumption was that a child subvocalizes only task relevant material. When asked to subvocally rehearse and recall the word "cat", for example, a child would subvocally rehearse "cat" and when queried, would overtly respond with "cat". He would not covertly rehearse the word "dog" and respond with the word "cat". This assumption was made because when a child rehearses subvocally, the response is silent. One cannot hear another subvocalizing (Locke, 1970). The investigator had to assume that experimental subjects would rehearse subvocally only what they were told to subvocally rehearse and not other material.

Other evidence suggested that the central nervous system development of older children was more advanced than that of younger children (Tanner, 1970). Older children would assumedly recall more task items than younger children if indeed the central nervous system is involved in learning or memory.

Another related assumption was that girls would recall more task items than boys. Evidence indicated that girls at any point in their development were closer to their final mature status than boys (Tanner, 1970).

Since the attempt to induce subvocalization involved only one session per child another assumption was in order. Children of greater intelligence were assumed able to recall more task items than children of lesser intelligence. Brighter children were thought to learn more quickly than their counterparts.

Two possible techniques for detecting, measuring, and recording subvocalization were available. One was electromyograph recording of the lower lip muscle movement of each S and the other was kymograph recordings which recorded only pressure changes in the vocal tract. The more accurate technique appeared to be electromyography (EMG). EMG lower lip recordings provided a moment by moment printed record of all muscle potentials, which are nerve fiber positive electrical charges that accompany the slight muscle contractions involved in subvocalization. The EMG printed paper records also displayed the frequency, amplitude, duration and overall configuration of those potentials (Locke & Fehr, 1970b.). Provided with the printed paper records of the muscle activity of each S, the investigator was able to compare the amplitudes or extent of muscle contraction during rehearsal of labial items (words containing either /b/, /p/, /m/, /f/, /v/, /w/, /hw/, or rounded vowels), which were articulated by the lips of each S and nonlabial items (other words) which did not involve lip movement.

The decision to use EMG recordings provided a test for the final assumption. When measuring a muscle involved in lip movement the extent of the muscle activity (amplitude) for labial items involving lip muscle activity would be greater than for nonlabial items which did not involve lip muscle activities during periods of presentation (stimulus present) and delay (stimulus absent) (Locke & Fehr, 1970a&b). Labial items required lip muscle activity when they were rehearsed whereas nonlabial items did not. This procedure aided in inferentially determining whether Ss cover oral behavior was task related rehearsal. If occurring subvocalization was not rehearsal, such as would occur under instances of random subvocalizaing of labial and nonlabial words, then it was supposed that no significant amplitude difference would be found between labial and nonlabial items.

In summary, the present investigation provided a test for the following hypotheses:

(1.) The amplitude of the EMG signal will be greater for labials than nonlabials during the stimulus presentation and the stimulus absent, or delay periods.

The orbicularis oris muscle was found to be active in lip movement (Locke & Fehr, 1970a&b); consequently the orbicularis oris muscle was assumed to be more active for labial items which are articulated by the lips than for nonlabial items. This provided a way to infer whether Ss covert oral behavior was task related rehearsal. If occurring subvocalization was not actual rehearsal then it would be presumed that no significant difference would be found between labial and nonlabial items.

(2.) Recall performance is positively correlated with I.Q.

The attempt to induce subvocalization involved only one session per child and the Ss had to remember the names of as many pictures as possible. Brighter children were hypothesized to recall more than less intelligent children, because brighter children simply learn more quickly.

(3.) Older subjects will recall more than younger subjects.

The physiology and general neural development of children increases with age (Tanner, 1970). The older the individual, the more mature his neurological structures. Tanner (1970), stated that after age 4 years:

> there is a continuous increase in the number and size of dendrites in all layers of the cortex, and in the number and complexity both of the exogenous fibers from lower in the brain, and in the association within and between cortical areas.

The ability of the child to perform was presumed to be directly affected by such growth.

(4.) Girls will recall more than boys.

Girls are always closer to their final mature status than boys (Tanner, 1970). This suggests that the mental functioning of girls may be more advanced than the mental functioning of same age boys. Tanner asserts that:

> The stages of mental functioning described by Piaget and others have many of the characteristics of developing brain or body structures and the emergence of one stage after another is very likely dependent on (i.e., limited by) progressive maturation and organization of the cortex.

(5.) Subvocalizers will recall more than those not subvocalizing.

A body of evidence exists suggesting that rehearsers remember more than nonrehearsers (McGuigan, 1970; Flavell, et al, 1966; Daehler, et al, 1969; Conrad, 1971). Subvocal rehearsal should be followed by a consequent better performance than those not subvocally rehearsing.

CHAPTER II

REVIEW OF THE LITERATURE

A Period of Introspection

After observing covert oral behavior during silent reading, Bain, as reported in Pintner (1913) concluded that "a suppressed articulation is in fact the material of our recollection". Egger, according to Pintner (1913), concluded that he subvocally spoke and Ballet, as reported in Pintner (1913), concluded that he could hear himself subvocalizing.

The German psychologist, Stricker, as cited by Pintner (1913), reported his introspections and those of one-hundred others. Ninety-nine reported having experienced what they considered to be subvocal speech during thinking. Stricker concluded that articulatory activity accompanied his every thought of every sound.

> Ideas of words consist of nothing else than the consciousness of the excitation of those motor nerves that are connected with the articulatory muscles. Ideas of words are motor ideas (Pintner, 1913).

Support for the notions of Stricker came from some other investigators. As late as 1947, the great Russian investigator Sechenov stated:

> It even seems to me that I never think directly in words, but always in muscular sensations which accompany my thought in speech form. In any case, I do not sing to myself only with sounds. I always sing with the muscles; then the recollection of sounds appears (p.142).

Paulhan, according to Pintner (1913), objected insisting that he could maintain an image of a vowel while simultaneously articulating yet another vowel. He also believed that he could think of a vowel sound without a corresponding motor movement in the muscles of his vocal tract. Paulhan and Stricker were both partially correct. Their notions appeared to be situation specific.

Wyczoikowska, reporting as early as 1913 his belief that covert oral behavior accompanied listening to speech, constructed the following motor theory of speech perception:

> Only when the stimulus coming from the voice of person A incites mechanically the same coordinate movements of the organ of speech of person B is the latter able to understand the word that is spoken to him until it is repeated by his own organ of speech (although in a more simple way)(Locke, 1970).

The Empirical Era

Empirical investigations considered subvocalization to be only a part of the total process of "dumb speech", "inner speech", "silent speech", and "covert oral behavior" (Locke, 1970; Vygotsky, 1962, p.p. 130-131; McGuigan, 1970; Sechenov, 1947, p. 532). Vygotsky, (1962, p.p. 130-131) for example, was critical of the concept of inner speech as merely the retention of acoustic, optic, motor, and synthetic images of words. He repudiated the behaviorist concept of internal speech as simply a soundless form of external speech ("speech minus sound"). According to Vygotsky (1969, p. 534), internal speech was a unique psychological phenomenon. Internal speech was "the living process of the birth of the thought in the word" and as such reflected a complex interrelationship of thinking and speech. Thought was rebuilt and modified and "is not expressed but is achieved in a word". Sechenov (1947, p. 532) asserted, on the other hand, that as the child mastered speech he developed the ability to hold back his movements associated with visual, auditory, and tactile impressions, and began to express his thoughts in words. Inhibition was then extended to the external expression of words as well; "then only dumb speech remains which is accompanied by soundless movements of the muscles of the tongue in the mouth cavity". McGuigan (1970), conversely, noted that the speech musculature may be activated for reasons other than the production of language, preferred the "more neutral term covert oral behavior. . . in place of terms like silent speech". Subvocalization was defined by Locke (1970), simply as the articulatory aspects of language related behavior which was covert but measureable. The present research addressed itself only to subvocalization and not to the broader issue of "dumb speech", "inner speech", "silent speech", or "covert oral behavior".

Very few investigators inquired into the role of subvocalization in the child and even fewer investigators used the extremely powerful tool of EMG recording (Conrad, 1971). McGuigan, Keller and Stanton (1964) reported an EMG study using children and one using college subjects. The studies revealed that the mean amplitude of chin EMG was significantly greater during silent reading periods than during rest periods for both subject groups.

McGuigan and Bailey (1969) reported another EMG child study. Children (mean age = 10) were selected showing pronounced subvocalization during silent reading from the subjects used by McGuigan, Keller, and Stanton (1964). The subjects were retested after 2 and 3 years. During the original test the investigators found that the subjects exhibited a significant amount of subvocalization as measured by lip and chin EMG during silent reading. On the second and third tests the mean amplitude of subvocalization decreased from the original. The authors concluded that subvocalization "naturally" decreased in amplitude with age but, nevertheless, persisted at a significantly high level in the adult.

No experiment to date has been conducted attempting to induce subvocalization in young children. One study, however, conducted by Keeney, et al, (1967) did attempt to induce "whispering" in six and seven year old children in which the children were urged to rehearse "out loud". The method used to distinguish between the "rehearser", or whisperer, and "nonrehearser" or nonwhisperer was direct observation. Each S rehearsed, that is whispered, with a toy plastic space helmet over his head. Fitted to the helmet was a movable visor covered with translucent tape. When the space helmet visor was down E sat in front of S and watched for any lip or mouth movements and recorded any he could "read" or believed were verbal rehearsal.

The investigators could not hear the S but maintained that they observed Ss oral activity through the translucent tape without ever being detected. In spite of these precautions the investigators may have been detected by the Ss and may have labeled some children "nonrehearsers" who were indeed "rehearsers" (Hansen & Lehmann, 1895 & Locke & Fehr, 1970a.) Using their direct observation method, they may have missed some subvocalizers who were indeed rehearsing but not whispering "out loud". The direct observation method, furthermore, precluded the possibility of distinguishing between task-related lip movement and lip movement unrelated to the task. The possibility existed that all lip movement of their subjects had nothing to do with rehearsal, either out loud, or subvocally.

In 1895, Hansen & Lehmann (Edfeldt, 1960) placed adult subjects in a room with especially good acoustics, and asked them to think of a number or word. The subjects almost always produced unconscious whispering which could be heard by an observer. The observer and subject could not, however, report lip movements. This provided the first empirical evidence suggesting that even whispering, much less subvocalization, could not always be detectable by direct observation. Other empirical evidence supporting the fallibility of direct observation soon followed. Wyczoikowska (1913), Reed (1916), Thorson (1925), Barlow (1928), and Rounds & Poffenberger (1931) conducted experiments in which covert larygeal activity was mechanically amplified and recorded. Subvocalization was found to accompany or was associated in some way with both thinking and silent reading. Their work revealed that "speech-like" movements which were inaudible and invisible to the observer were not only confirmed but specifiable in terms of the frequency, amplitude, duration, and overall configuration of their instrumentally recorded tracings. Electromyography appeared to be more valuable than other methods used in the study of subvocalization.

Evidence revealing the weaknesses of the direct observation method came from other sources. Locke and Fehr (1970a) took EMG and sound recordings from 12 four and five year old males and females during a recall task in which they saw pictures whose names contained either labial or nonlabial phonemes. The children covertly articulated the names of the pictures during presentation but not during a period provided for recall, providing further evidence which suggested that very young children did not rehearse at the appropriate times. The authors criticizing the studies of Keenery, et al, (1967) and Daehler, et al (1969), stated that they observed subvocal activity which could not be seen or heard by direct observation having EMG tracings almost as great in amplitude as patterns yielded by visible, audible speech.

There seemed to be some practical reasons why investigators did not seem eager to use four and five year old children as subjects in formal experiments. Piaget himself admitted that it was the lease investigated period in the entire developmental transition, somewhere between preoperational thought and the beginning construction of concrete operations (6-7 years) (1963, p. 150). If the child had not yet developed beyond the preoperational period, then it was considered only a slightly misleading generalization to say that he had:

> "no stable, enduring, and internally consistent cognitive organization, no system-in-equilibrium, with which to order, relate, and make coherent the world around him. His cognitive life, like his affective life, tends to be an unstable, discontinuous moment-to-moment one" (Flavell, 1963, p. 158).

Piaget once stated, interestingly enough, that the thought of the preoperational child was midway between that of the socialized adult and the completely autistic and egocentric thought of the Freudian unconscious (Flavell, 1963, p. 156).

If the child was beyond the preoperational stage, he became noticeably more testable in formal experiment. He was able to address himself to a problem and to apply his intelligence toward the solution of the problem, rather than assimilating it into some egocentric play schema (Flavell, 1963, p. 162).

Why four or five year old children did not rehearse during periods provided for recall was not clear. One theory, the mediational-deficiency hypothesis, stated that given that a child made the proper verbalizations at the proper times he remained less able than the older child to use them as mediators of overt behavior (Reese, 1962, Hagen & Kingsley, 1968; Potts, 1968).

The production-deficiency hypothesis, another theory, contended that the younger child did not spontaneously produce the verbal mediators at the appropriate time in the task. The production deficient child was assumed able to understand and produce relevant words appropriately in some contexts. His deficiency was assumed to be in his failure to produce them in particular task situations (Flavell, Beach & Chinsky, 1966).

The validity of either theory has yet to be determined. Suffice it to say that four and five year olds do not spontaneously rehearse during periods provided for recall (Locke, 1970; Reese, 1962; Conrad, 1971). Rehearsal, "out loud", however, may yield higher recall scores, (Flavell, Beach & Chinsky, 1966; Daehler, Horowitz, Wynns, & Flavell, 1969; Conrad, R., 1971). The importance of learning more about the subvocal prerecall articulatory activity of the child seemed obvious.

Physiology in Electromyography

Electromyograms record muscle potentials accompanying muscle contraction. Such potentials are related to neural commands exciting the muscle, so inferences can be made regarding motor commands. The motor units within a muscle are known as muscle spindles. They are receptors for "muscle sense" (kinesthesis) and a working knowledge of their functioning will help in understanding some of the strengths and weaknesses of electromyography.

Muscle spindles are stretch receptors which can be excited by stimulation of their motor fibers. Each spindle signals mechanical events by means of two different outputs (afferent fibers) which are controlled by two different inputs (efferent fibers) (Matthews, 1964).

The spindle is several millimeters long and contains two to twelve intrafusal muscle fibers the diameter of which varies from six to twenty eight microns. The center portion of the spindle is eighty to two hundred microns wide, due to the presence of fluid in that area surrounding the intrafusal fibers (Matthews, 1964).

The interior of each spindle contains two afferent endings (primary and secondary) and two motor endings known as the gamma efferents (fusimotor fibers). The responses of the afferent endings to mechanical stimuli have been found to differ. The differences, furthermore, originate inside the spindle rather than in transmission of the stimulus, though the electrical discharge rate for the secondary endings does not exceed that reached during a maintained stretch. Conversely, primary endings undergoing the same process, discharge at very rapid rates during the stretch phase. The primary endings immediately stop discharging at the beginning of muscle release or relaxation while the secondary endings do not cease firing until the muscle has been released almost entirely (Matthews, 1964). Primary endings signal both the instanteous length and velocity at which the muscle is being stretched. The secondary endings signal the instantaneous length (Bridgeman & Eldred, 1967, p. 236; Matthews, 1964).

Extrafusal muscle fibers (outside the spindle) are supplied by another type of fusimotor fiber called alpha motor fibers. Alpha motor fibers produce a contraction and excite a spindle ending. The speed of contraction, as well as its strength, seems to vary directly with the size of the alpha motor fiber. Some of the smaller alpha fibers, in addition to their extrafusal effect, also appeared to have an apparently specific excitatory effect on the afferent discharge of some spindle primary endings (Matthews, 1964). Indirectly alpha motor fibers supply, as do gamma motor fibers, intrafusal fibers. The alpha motor fiber effect is not confined to extrafusal fibers.

Stimulation of a single motor fiber whether large or small can excite more than one sensory ending. Multiple sensory ending excitation should be expected since individual intrafusal fibers were supplied by more than one motor fiber and one motor fiber sometimes supplied more than one spindle (Matthews, 1964).

Gamma motoneurons are excited earlier or at a lower threshold than alpha motoneurons in excitatory (reactive) reflexes (Matthews, 1964). Matthews, (1964) also stated that the discharge of gamma motoneurons may precede that of alpha motoneurons and concluded that higher parts of the nervous system (recticular formation, motor cortex, pyramidal tract, basal ganglia, thalmus, cerebellum, etc.) can control the gamma motoneurons. Higher centers of the nervous system can also exert separate control over the gamma motoneurons of different muscles and over both kinds of fusimotor motoneurons (Matthews, 1964). Central nervous system control is necessary for numerous reasons, one being Matthews' (1964) finding that intrafusal fibers possess plastic properties so that they do not return to their initial length or tension after contraction.

Clearly the chief function of the muscle spindle is to play a part in the subconscious (subawareness) nervous system control of muscular contraction, during both movement and steady contraction. The primary endings responding to both the length of the muscle and the velocity at which it is being stretched behave in just the manner required to give stability to a muscle servo-mechanism. The velocity response of the primary endings enables them to predict the length of the muscle after the delay time of the reflex, thereby insuring that the response will be appropriate to the time when the reflex was initiated (Matthews, 1964). The response of primary endings, furthermore, can be varied by the fusimotor fibers. Possibly this could provide a way for the central nervous system to adjust the damping of the stretch reflex, suiting the particular movement being undertaken.

The problems encountered when attempting to record, measure, and interpret the activities of such a dynamic, labile system can be appreciated. The likelihood that an investigator will find (or know when he finds) subjects whose neural development is identical seems diminutive. Individual differences when found could be accounted for, at least in part, by differences in the dynamic phase of the muscle and nervous system of each subject.

Gay and Harris (1971, p. 246) stated the following:

> Electromyography is not a very simple or routine laboratory technique. Because of their overlapping locations, various muscles of the speech mechanism cannot be accurately mapped. Even with reliable locations, procedures for electrode implantation are not always straightforward.

Electrodes placed over a deep muscle will pick up considerably less electrical activity than when over a muscle closely located under the skin (Davis, 1959, p. 9). Narrowly spaced electrodes (bipolar electrodes) yield lower potentials than do widely spaced ones. Wider electrode spacing permits information from deeper layers to become measureable (Davis, 1959, p. 21). Physical movement, moreover, causes the muscles to slide upon one another in various ways and to a considerable extent the skin slides over the muscle layer. An accurate placement one minute may thus be quite inaccurate the next minute depending upon the size of the muscle and the direction of muscle movement (Davis, 1959, p. 29). The aforementioned problems were remedied in the present experiment by placing narrowly spaced electrodes over a large muscle (orbicularis oris) located just beneath the skin surface. The electrode placements were checked regularly to insure that they remained appropriately placed.

CHAPTER III

METHOD

Subjects

The present research required the use of a fully equipped laboratory available for full time use. Texas Children's Hospital provided such a setting and was selected as the testing site.

Problems of obtaining an adequate sample and transporting the subjects to the testing area also arose. Several preschools in the Houston area, willing to ask their students to serve as a subject pool for the experiment, were located. The parents of each child who participated in the experiment provided transportation to and from Texas Children's Hospital.

Once the preschools consented to have their children serve as a subject pool, lists of prospective subjects were obtained. Teachers were instructed to recommend only right-handed Caucasians, between the ages of four and five having no noticeable hyperactivity or auditory, visual or speech problems. The selection requirements served to provide a more homogenous group differing primarily in only those variables of concern to the experiment, that is, age, sex, and I.Q. Letters were sent to the parents of each prospective subject asking for permission to use their children in the experiment. Each letter also contained a complete explanation of how the study was to be conducted and advisement of the necessity for the parents to provide transportation to the hospital laboratory. They were further advised that those willing to participate would receive a summary of the research results following the experiment.

After obtaining parental approval, the Stanford-Binet Intelligence Test was administered to each child in order to obtain a global measure of school-related intellectual functioning. Intelligence test administration also provided an opportunity for the children and investigator to become familiar with each other prior to the experiment. While administering the Stanford-Binet, the investigator was able to detect those not meeting the limitations of the proposed subject pool, that is, Caucasian and right-handed, with no noticeable hyperactivity, auditory, speech or visual problems. Another screening method was thus provided.

The subjects came from several preschools in the Houston area. Originally, 38 females and 31 males were selected; of these 12 were randomly chosen for a pilot study which preceded the present investigation. The pilot study served to orient the investigator to the laboratory equipment and proper electrode placement procedures. Those children used in the pilot study were not used in the actual experiment.

Nineteen males and twenty-nine females took part in the actual experiment. Nine children refused to participate. The ages ranged from 4-0 to 5-10 (mean age: 5-1) for those participating.

Stimuli

The stimuli were 24 pictures on 9"-11" cards, meeting the following criteria:

(1.) 12 of the picture labels, when spoken, were monosyllabic labials always having a labial phoneme in initial position;

(2.) 12 of the pictures labels, when spoken, were nonlabials (i.e. had no /b/, /p/, /m/, /f/, /v/, /w/, /hw/, or rounded vowels);

(3.) Stimulus pictures could be labeled unambigously by four and five year olds or if alternate labels were likely it was assumed that they could not violate the phonetic class to which the item belonged (e.g., pig/piggy; both contain a labial phoneme).

The pictures were arranged in four ensembles by three pictures representing labial phonemes and four ensembles of three pictures representing nonlabial phonemes. The stimuli presented were listed in Table I.

Procedure

The investigator met the child and parent when they arrived at Texas Children's Hospital. Each parent was required to sign a release form and was instructed to wait for their child in the hospital lobby. No child was accompanied by the parent into the laboratory.

Once in the laboratory, each child was shown all the

TABLE I

Labials and Nonlabials In Order of Presentation

Ensemble No.	Stimuli
1 (Labial)	Bowl Bird Bear
2 (Nonlabial)	Hat Duck Church
3 (Labial)	Bee Boy Fish
4 (Nonlabial)	Dog Deer Chair
5 (Labial)	Ball Boat Bed
6 (Nonlabial)	Cat Ear Eye
7 (Labial)	Pig Mouse Man
8 (Nonlabial)	Doll Girl Tree

equipment. He received a complete description of how and what the equipment recorded. The electrodes were described as "little microphones that listen to show how hard you think". The polygraph (Model 7; Model 7P511 preamplifiers and integrators) recording pen tracing movement, and Oscilloscope were said to "record how hard you can think". The experiment was described as a "thinking game", and each child was told that if he agreed to participate he would receive a present immediately following the experiment.

After obtaining Ss' consent, he was seated in a chair and electrodes were placed on him in the following locations:

(1.) Beckman electrodes, 1mm in diameter, were placed on the lower lip over the orbicularis oris a muscle involved in the articulation of labial phonemes (Cooper, 1965; Locke & Fehr, 1970b.); chin tip 2 cm above and below chin-tip identation which detects labial activity of the orbicularis oris (Cooper, 1965; Locke & Fehr, 1970a.; McGuigan, Keller & Stanton, 1964). Electrodes were also placed on the temporalis muscle adjacent to and just above the left eye which during pilot testing was found to detect yawning, eye blink, lip-licking, and teeth biting (Davis, 1959).

(2.) Using the 10-20 System, (Jasper, 1958), an agreed upon international standard for electrode placements, Grass electrodes were placed on O_z to X_2 and

$T_{3.5}$ to X_1, which provided measures of EEG temporal lobe and visual area activity for another experiment.

(3.) A Grass electrode, for ground, was clipped to the left ear lobe.

(4.) One dummy monopolar Grass electrode was placed on the left forearm to divert Ss attention from the speech mechanism.

While one investigator applied the electrodes an associate presented the stimuli to S asking him to identify them. When it was determined that S could correctly label each picture he was asked to accompany E into the 6' X 7' X 7' electrically shielded room.

When in the electrically shielded room, S was comfortably seated in a dental chair approximately 3 feet from E who was seated at a small table having an event marker system and artifact button hidden from Ss view. The S was then instructed as follows:

> I am going to show you some pictures, 3 at a time, and what I want you to do is try and remember what pictures I show you. I'll tell you how I want you to do it. Look at the pictures and tell yourself what they are - over and over and over again, and keep telling yourself what they are - until I point to you. And when I point to you, you tell me what they were, because I can't see them. Okay? Say them to yourself, now - don't whisper them or say them out loud. Okay?

Prior to the presentation of every set of 3 pictures each child was told that he was to be shown 3 more pictures. He was told to remember the pictures by telling himself what they were -

to himself, not out loud - until E pointed to him. All Ss conformed to this procedure immediately.

Recording speed for the Grass Polygraph alternated between 50 mm and 100 mm per second. The research associate monitored the equipment while the investigator sat directly in front of the S to insure adherence to the proper experimental procedures. An artifact button was pressed whenever E detected S movement considered not to be language related (e.g., lip smacking, teeth grinding, yawning, body movement, etc.). When artifacts were detected an electrical signal (+.8 volts) was recorded on the Grass polygraph paper (mean delay time was 1.5 seconds). An event marker system was also used to record both presentation (+.3 volts) and delay (-.3 volts) periods onto the paper records. One could thus clearly determine the location and duration of artifacts and presentation and delay periods when analyzing the polygraph paper records.

The exposure time of each picture was 4 seconds following the procedure used by Locke and Fehr (1970a.) with an interim interval of approximately 2 seconds. Each series of three pictures, the presentation period, was followed by a 15 second delay period which was provided for rehearsal. A timer connected to the event marker system was electrically activated by a delay switch registering the beginning of the delay period. When the timer recorded 15 seconds it automatically turned off all the monitoring equipment. Immediately after the timer deactivated the monitoring equipment E pointed to S who then orally recalled the three pictures.

The paper records were analyzed by the following standard procedure: from EMG tracings the magnitude (in microvolts) of the single greatest pen deflection occurring within each Ss' presentation and delay period was assessed for both labial and nonlabial items (Locke & Fehr, 1970a.). Oral recall tracings were not recorded because the primary purpose of the equipment was to study prerecall subvocalization or the articulatory aspects of language related behavior which are covert but measureable in young children.

Pilot testing and previous research (Davis, 1959; Locke & Fehr, 1970a.; Cooper, 1965; McGuigan, Keller & Stanton, 1964) suggested that there were some conditions to be met before the single greatest pen deflection was considered to be an indicator of subvocalization. If the single greatest pen deflection on the orbicularis oris was found to occur during periods of heightened muscle activity on the temporalis and $T_{3.5}$ placements, then the orbicularis oris pen deflection was not considered to be an indication of subvocalization. Recall that heightened muscle activity on the temporalis EMG placement and the $T_{3.5}$ EEG placement was found to occur during some periods of swallowing, yawning, lip-licking, teeth gritting, smiling and frowning. The $T_{3.5}$ and temporalis placements thus served as controls (Davis, 1959). Chin muscle magnitude, conversely, served as an indicator of subvocalization (Locke &

Fehr, 1970a.; Cooper, 1965; Davis, 1959; McGuigan, Keller, Stanton, 1964; McGuigan & Bailey, 1969). Another safety precaution was thus provided increasing the likelihood of assessing only those pen deflections occurring during periods of subvocalization. Instances of subvocalization accompanying heightened muscle activity of the temporalis and $T_{3.5}$ placements undoubtedly occurred; however, in such cases it was impossible to distinguish between how much muscle amplitude was due to subvocalization and how much to artifacts. Screening out some subvocalization periods, it was thought, was better than running the risk of assessing what may have been only artifacts.

Means based on the maximum orbicularis oris peaks from the tracings of each S were analyzed to determine whether Ss' peripheral-oral activity was actually subvocalization. Four means were thus obtained, based on the following:

(1.) four tracing measurements for each S during labial presentation periods;

(2.) four during labial delay periods;

(3.) four during nonlabial presentation periods; and

(4.) four during nonlabial delay periods.

An analysis of tracing means was undertaken using a t test of correlated means. McNemar (1969, p.p. 113-114), stated that when we have two means based on the same individuals, the test of significance of the differences must make allowance for the fact that the two sets of scores are not random with respect to each other. A t test of correlated means was in order.

A multiple linear regression analysis was used to determine the effects of age, sex, and I.Q. on performance. The technique is a general approach of which analysis of variance is a special case. The primary uses for this multiple correlation technique are: it yields the most favorable weighting for combining a series of variables used in predicting a criterion and provides an indication of the accuracy of subsequent predictions. Regression analysis also allows one to analyze variation into component parts (McNemar, 1969, p.p. 206-207).

Guilford (1965, p.p. 314-315) asserted that the curvature in regression is often found to be so slight that no one knows whether there is merely a chance deviation from linearity. A test for linearity was therefore used to determine whether the regression was linear.

CHAPTER IV

RESULTS

Results of the analysis of variables investigated in this study were presented in the following manner:

A. Hypothesis 1: The amplitude of the EMG will be great er for labials than nonlabials during the stimulus presentation and the stimulus absent or delay periods

B. Hypothesis 2: Recall performance is positively correlated with I.Q.

C. Hypothesis 3: Older Ss will recall more than younger Ss.

D. Hypothesis 4: Girls will recall more than boys.

E. Hypothesis 5: Subvocalizers will recall more than those not subvocalizing.

F. Summary

In order to determine if hypothesis one was supported th grand sum of all measured tracing magnitudes, or the total height of the pen tracings as measured in millimeters, was computed. Calculations were also made of the grand mean of th tracing magnitudes and the standard error of the mean differences. There was a marked disparity in labial-nonlabial magnitudes for both the presentation and delay periods. The labial-nonlabial magnitudes for the presentation period was

was significant beyond the .0005 level of confidence and strongly suggested that S activity was task related subvocal rehearsal. In other words Ss seemed to be subvocally rehearsing in the presence of the stimulus. The delay period providing for rehearsal in the absence of the stimulus also showed a significant labial-nonlabial disparity beyond the .0005 level of significance. As indicated in Table 2, rehearsal appeared to be a common S activity when the stimulus was present and when it was absent. There were 48 Ss participating in both the labial-nonlabial presentation periods and the labial-nonlabial delay periods. The peak amplitudes occurring during all four periods were summed for every subject, making a total of 192 observations. The sum and mean of the amplitudes observed during the labial presentation periods were 4182 and 21.78 millimeters, respectively. This was almost identical to the 4173 millimeter sum and 21.73 millimeter mean observed during the labial-delay periods. The summed total of the amplitudes and their means observed during nonlabial presentation and delay periods were much lower. Amplitude sums for the nonlabial presentation periods and nonlabial delay periods were only 3057 millimeters and 3252 millimeters. The mean amplitude for the nonlabial presentations was only 15.92 millimeters while the mean amplitude for the nonlabial delay period was only 16.93 millimeters. The standard error of the mean difference or the estimate of the amount that the obtained means could be expected to differ from

TABLE 2

Peak EMG Amplitudes (uv) for Labial and Nonlabial Ensembles

	Presentation		Delay	
	Labial	Nonlabial	Labial	Nonlabial
N	48	48	48	48
Observations	192	192	192	192
Amplitude (mm)	4182	3057	4173	3252
Mean Amplitude	21.78	15.92	21.73	16.93
S_{MD}	.91		1.06	
t	6.44		4.53	
p	$<.0005$		$<.0005$	

the true means by chance was computed for presentation and delay periods. The standard error of the mean difference for the labial-nonlabial presentation periods was only .91 and 1.06 for the labial-nonlabial delay periods. The obtained means were thus expected to differ little from the true means. A t test of correlated means yielded a value of 6.44 for the labial-nonlabial item presentation periods and a value of 4.53 for the labial-nonlabial item delay periods. Both t values were statistically significant and reflected the marked amplitude disparity of labial versus nonlabial periods. The first hypothesis which stated that the amplitude of the EMG signal would be greater for labials than nonlabials during the stimulus presentation and the stimulus delay periods was supported because of the highly significant amplitude differences observed during labial-nonlabial presentation periods and labial-nonlabial delay or stimulus absent periods. Confirmation of the first hypothesis suggested that subvocalization was induced since 4 and 5 year olds do not rehearse spontaneously either out loud or subvocally in the absence of a stimulus (Reese, 1962; Hagen & Kingsley, 1968; Potts, 1968; Flavell, Beach & Chinsky, 1966; Locke & Fehr, 1970b.; Flavell, 1963, p. 158; Kenney, Cannizzo & Flavell, 1967; Moely, Olson, Halwes, & Flavell, 1969; Daehler, Horowitz, Wynns & Flavell, 1969; Conrad, 1971).

Since one of the Ss did not receive an I.Q. test the number of Ss selected for the regression analysis was only

47. The independent variables, I.Q., sex and age; and dependent variable, score (number of pictures remembered) were analyzed. The means, variances and ranges for independent and dependent variables were reported in Table 3. The average I.Q. for this sample was 130 and seriously restricted the generalizability of the results. Ss I.Q. scores ranged from the general population mean to four standard deviations above the general population mean and therefore were representative of only the top half of a normal distribution. The standard deviation for the samples was almost identical to the expected standard deviation of the population.

Eighteen males and twenty-nine females comprised the sample with an age range from 4-0 to 5-10 and a mean age of 5-1. The standard deviation was 5.35 months. Males were coded "0" for the anlaysis and females were coded "1" which yielded a mean of .61 and a standard deviation of .49.

The number of picture names recalled appeared to be quite varied for individual subjects. The scores for the Ss ranged from 8 to 24. The mean number of picture labels remembered was 18.31; the standard deviation was 4.19.

Table 4 reported the basic regression statistics for the independent variables. The multiple correlation coefficient which was the correlation between obtained and true scores was .6943. When squared the multiple correlation gave the coefficient of determination which represented the proportion of variances in the obtained scores determined by variance in the true scores.

TABLE 3

Measures of Central Tendency, Variation, and Range

for Dependent and Independent Variables.

Variable No.		Mean	S.D.	Variance	Minimum	Maximum
1	Intelligence Quotient	130.49	14.36	206.30	96.00	165.00
2	Sex (0 = M, 1 = F)	.61	.49	.24	.00	1.00
3	Age in Months	61.40	5.35	28.72	48.00	70.00
4	Items Correct	18.31	4.19	17.61	8.00	24.00

TABLE 4

BASIC REGRESSION STATISTICS

Variables:	I.Q., Sex, and Age
Standard Error of Estimate:	3.1239
Coefficient of Determination:	.4821
Multiple Correlation Coefficient:	.6943

The coefficient of determination and multiple correlation coefficients indicated that 48.21 percent of the variance in S's scores were accounted for by I.Q., sex and age. The standard error of estimate was only 3.1239 which gave the standard deviation of the difference between the actual scores and those which were estimated from the regression equation. The standard error of estimate could also be thought of as the standard deviation of the distribution of observed scores of the dependent variable around any given predicted score on the dependent variable. Regression analysis assumed homoscedasticity which meant that the standard error of estimate was equal for the distributions around all predicted scores.

The variables in the regression equation along with t values, partial F values and significance levels were summarized in Table 5. Hypothesis 2 predicted that recall performance for higher I.Q. Ss would be greater than for lower I.Q. Ss. Regression analysis supported hypothesis 2 and showed I.Q. to be significant beyond the .0001 level of confidence as a predictor of recall. Knowledge of S's I.Q. contributed more to an accurate prediction of S performance than did any other independent variable in the regression equation.

Hypothesis 3 predicted that older Ss would recall more than younger Ss was also supported by regression analysis. Although age did not contribute as much predictive power as I.Q. in the regression equation, age was found to be significant beyond the .01 level of confidence. Age was therefore

TABLE 5

Variables in the Equation

Variable	Standardized Error of Regression Coefficient	Standardized Regression Coefficient	Partial Correlation Coefficient	t Value with 43 df	Partial F with 1 & 43 df
I.Q.	.0326	.5440	.5970	*4.8829	*23.8429
Sex	.9644	.2812	.3550	**2.4907	** 6.2037
Age	.0889	.3014	.3750	**2.6540	** 7.0435

*p $<$ .0001

**p $<$ .01

a good predictor of S recall. The performance on the dependent variable by older Ss was greater than that of younger Ss despite the restriction in range of the ages of the children. If the age range had not been restricted then age would be expected to predict S performance to an even greater extent than it did in this study.

Sex also proved to be a significant variable in the regression equation. The sex difference in performance was significant beyond the .01 level of confidence although it predicted S performance on the dependent variable less well than the age variable. Hypothesis 4 was supported since girls recalled or remembered more of the pictures than did the boys. Sex was a good predictor of recall or performance. Unlike I.Q. and age, however, sex is a dichotomous variable. This condition tends to inflate the correlation coefficient thus somewhat reducing the predictive quality of the correlation coefficient.

The intercorrelations among recall scores, the dependent variable, and I.Q., age and sex were reported in Table 6. Almost no overlap occurred between the independent variables. None of the correlations were significant and all dependent variables were roughly independent. Boys and girls tended to be about equal in I.Q.. Girls tended to be a little older than the boys and the higher I.Q. Ss tended to be younger than the other Ss. The correlations between the independent variables and the dependent variables followed the same general

TABLE 6

Intercorrelations Among Recall Scores and I.Q., Sex and Age

Variable No.	I.Q. 1	Sex 2	Age 3	Score 4
I.Q. 1.	1.000			
Sex 2.	.079	1.000		
Age 3.	-.133	.209	1.000	
Score 4.	.526	.387	.288	1.000

order as did the correlations in Table 5, except for age and sex. In Table 6 sex correlated with the independent variable more than did age.

The analysis of variance testing linearity of prediction of recall by age, sex and I.Q. were reported in Table 7. The resulting F ratio was significant beyond the .0001 level of confidence. The F ratio suggested that the Eta coefficient was not larger than the multiple correlation and strongly suggested that the regression line was linear. Together all three variables, age, sex, and I.Q., were good predictors of performance or recall.

Analyzing the records in order to determine whether subvocal rehearsal enhanced recall proved difficult. The amplifier settings on the orbicularis oris channel for some Ss were adjusted so that a pen deflection measuring a standard 50 microvolt signal was greater than 1.5 mm. In such cases the physical restrictions of the recording pen movement precluded an accurate assessment of the magnitude of muscle activity as measured by the height of the pen deflection. When 50 microvolt signals resulted in pen deflections greater than 1.5 mm subvocal rehearsal or oribicularis oris activity, as measured by pen deflections, was truncated.

Only 31 Ss were tested under conditions where a pen deflection of 50 microvolts was equal to 1.5 mm. These Ss were used to determine if the amount of labial orbicular oris muscle acitivity during delay periods affected performance.

TABLE 7

ANALYSIS OF VARIANCE SUMMARY

Source of Variation:	Sum of Squares:	df:	Mean Square:
Linear Regression	390.5864	3	130.1955
Residuals from Regression	419.6263	43	9.7588
Corrected Total	810.2128	46	

F - Ratio = 13.34 with 3 and 43 df

Significance Level of F - Ratio = .0001

Table 8 listed the mean amplitudes for these Ss which were compared to S performance. The great range of mean amplitudes reflected the large differences in the amount of intersubject orbicularis oris muscle activity, the index of rehearsal. The resulting Pearson product moment correlation of .43 was tested using Fisher's r to z transformation and was found to be significant beyond the .01 level of confidence. Subvocalization was a good predictor of performance. When Ss subvocally rehearsed their performance or the number of pictures they recalled improved significantly, thus supporting hypothesis 5 which stated that subvocalizers would recall more than those not subvocalizing.

The range of individual differences such as I.Q. among Ss involved in the present experiment were much smaller (i.e. more homogenous) than would be expected among four and five year olds in the general population. Given a greater range of individual differences a Pearson product moment correlation greater than the one obtained would be expected (Anastasi, 1968, p. 92).

In summary, the experimental results supported all five hypotheses at or beyond the .01 level of confidence. Ss subvocally rehearsed during stimulus presentation and also during the interval of delay between stimulus presentation and recall. The extent or magnitude of subvocalization during the delay period significantly affected S recall of task items. In other words, greater subvocal activity during the delay period resulted in greater recall of stimulus items. Higher I.Q. Ss recalled more than lower I.Q. Ss, older Ss recalled more than younger Ss, and girls tended to recall more than boys.

TABLE 8

Labial Subvocalization As a Predictor of Performance

S	Mean Amplitude (Labial-Delay Period)	No. Correct
1.	9.25	14
2.	11.00	19
3.	11.00	24
4.	13.75	22
5.	9.25	14
6.	12.50	15
7.	14.50	22
8.	12.75	22
9.	3.50	20
10.	13.50	16
11.	4.75	23
12.	9.50	15
13.	11.50	13
14.	29.50	18
15.	6.50	8
16.	3.25	19
17.	14.50	22
18.	22.00	20
19.	3.50	9
20.	9.75	17
21.	23.75	24
22.	1.75	15
23.	10.25	22
24.	3.50	15
25.	11.75	22
26.	10.75	20
27.	11.75	21
28.	22.75	24
29.	10.30	20
30.	15.75	18
31.	12.50	22

$r_{xy}=.43$ $z=2.39$

$N=31$ $p<.01$

CHAPTER V

DISCUSSION

The primary findings of this investigation were that four and five year old children can subvocalize the names of familiar pictured objects during presentation and, when encouraged, also during a period provided for rehearsal. The results supported previous research (McGuigan, 1970; Flavell, 1966; Daehler, et al, 1969; Conrad, 1971) which suggested that rehearsal aids recall. Older Ss, females, and higher I.Q. Ss, furthermore, were found to recall significantly more stimuli than younger Ss, males and lower I.Q. Ss, respectively.

Earlier in this paper discussion was presented on the mediational and production deficiency hypotheses which have been offered as explanations for the apparent failure of very young children to behave verbally in tasks where adults and older children verbally mediate. This experiment lent support to a modified production deficiency hypothesis which contended that the younger child does not spontaneously produce verbal mediators at the appropriate time. A so called "production deficient" child, when encouraged, was found to be able to spontaneously produce verbal mediators at the appropriate time, thus aiding his recall. Evidence suggesting that such spontaneous rehearsal transfers to other tasks was not available. The point was however, there were times when a "production deficient" child was not "production deficient" since he could produce verbal mediators at the appropriate time and thus aid his recall.

The mediational deficiency hypothesis stated that given a child makes the properverbalizations at the proper times, he is less able than an older child to use them as mediators of overt behavior. The mediational deficiency hypothesis appears incorrect, in light of the experimental results. Young children may not rehearse at the proper time, but some can, and when they do they appear able to use the rehearsal as a mediator.

The Ss used in this experiment may no longer be rehearsing at the appropriate times and are as a consequence once again "production deficient". The fact that adults show greater labial tracings during rehearsal than during presentation and young children do not, suggests that only the adults are using speech to practice and store nonspeech stimuli (Locke & Fehr, 1970b.). All theories attempting to explain why very young children do not rehearse at the proper times have perhaps justifiable relied upon some supposed physiological or maturational deficiency. Tanner (1970, p. 123), for example, noted

> "that there is every reason to believe that the higher intellectual abilities appear only when maturation of certain structure or cell assemblies, widespread in location throughout the cortex, is complete. Dendrites, even millions of them, occupy little space, and very considerable increases in connectivity could occur within the limits of a

> total weight increase of a few percent. The stages of mental functioning described by Piaget and others have many of the characteristics of developing brain or body structures and the emergence of one stage after another is very likely dependent on (i.e., limited by) progressive maturation and organization of the cortex."

Why four and five year olds may not rehearse could also be due to other reasons. Perhaps, for example, such young children simply do not consider performing in a laboratory setting very important. An adult has undergone much educational training and has learned that he is expected to perform to the best of his ability. His esteem or sense of self-worth may be tied to his ability to perform well. He has learned, for example, that people treat "bad" performers differently than they treat "good" performers. An adult, or older child, may rehearse simply because he thinks he must do so. A very young child, in contrast, is somewhat more free to do as he chooses. He has not been trained to know the importance of performing as the adult or older child knows it. Perhaps a four or five year old child may decline to rehearse simply because the remembering is of little importance to him.

The body of evidence supporting a maturational deficiency, however, is simply too great to ignore. Tanner (1970, p. 122), asserts that after the age of four

> "there is a continuous increase in the number and size of dendrites in all layers of the cortex, and in the number and complexity both of exogenous fibers from lower in the brain and in the association within and between cortical areas."

This becomes of some importance when it is recalled that higher parts of the nervous system are directly linked to and control gamma motoneurons (Matthews, 1964). Insults, notably to the opercula, which is a part of the cerebrum bordering the lateral fissure and concealing the island of Reil, and post-frontal divisions of the left hemisphere, leads to the development of a state of the cerebral cortex in which the process of "memorizing" loses its highly automatized character and can be performed only with the aid of recitation in a loud, or soft voice (Luria, 1966, p.p. 338-357). Subvocalization (no sound), it was concluded, is of no benefit to those having either opercula or post frontal damage although their nervous system development may be at its zenith. The opercula and post-frontal divisions of the left hemisphere then seem to be keys allowing the communication of neural commands to reach the muscle spindles initiating subvocal rehearsal, rather than rehearsal in a loud or soft voice. Tanner (1970), accordingly, asserted that intercranial communication was premature in very young children consequently one would not expect them to perform as would a matured organism.

The findings of Luria (1966, p.p. 338-357) regarding the importance of the opercula and post-frontal divisions of the left hemisphere in subvocalization versus "whispering" or voicing of any kind should serve as a warning. Different cortical areas are involved when subjects rehearse via whispering out loud as opposed to rehearsing subvocally. The ability to subvocalize is quite a different thing from the ability to "whisper" or otherwise rehearse "out loud". Different areas of the brain are involved and, as a consequence, would seem to be of some importance when studying children having undeveloped nervous systems. The conclusions of Luria (1966, p.p. 358-357) further suggested that subvocal rehearsal cannot be studied by direct observation, particularly in light of research findings indicating that subvocalization can be inaudible and invisible to the observer (Wyzoikowska, 1913; Reed, 1916; Thorson, 1925; Barlow, 1928; Rounds & Poffenberger, 1931; Locke & Fehr, 1970a.&b.).

Piaget viewed the 4 and 5 year old to have "no stable . . . cognitive organization . . . with which to order, relate or make coherent the world around him" (Flavell, 1963, p. 158). The notions of Piaget would appear too apologetic for the subjects participating in the present experiment. When encouraged, the Ss in the present experiment were able to generalize from rehearsing in the presence of a stimulus to also rehearsing during the stimulus absent period, and, further, such rehearsal aided their recall. The present research results, in addition, make one wonder about the importance of sex and I.Q. in the developmental schema of Piaget. In other words, which is the more important: age, sex, or I.Q.? If age, then how much more important is it, and at what ages? The performance of the four and five year olds used in the present study was predicted by I.Q. to a much greater degree than by age.

What is I.Q.? A bright or high I.Q. child is often called "precocious" by observers attempting, albeit perhaps unknowingly, to explain via their use of the word "precocious" why the bright child is able to exhibit some behavior not manifested in the same age, less bright child. Could it be that the nervous system ("brain", "mind", "set of knowledge", etc.) of some four year olds is more developed than some five year olds because of some physiological difference such as hormonal changes or because of greater environmental stimulation.

Long term memory is dependent upon ribonucleic acid (RNA), since its synthesis is necessary for long-term maintenance of the vertebrate nervous system (Brigs & Kitto, 1962). The neuronal renewal process is continuous and its tissue growth is stimulated by RNA, which furnishes the templates for protein synthesis (Briggs & Kitto, 1962). Differentation and changes in neurons is modulated, among other things, by the following: Growth factors (Korner, 1965), which suggested that neuronal structures become more differentiated with age; hormones, such as adrenocorticotrophic (ACTH) hormone, which accelerates protein synthesis, activates transfer enzymes and nuclear RNA polymerase (Farese & Reddy, 1963); and electrical activity, which increase neuronal RNA-protein synthesis (Pevzner, 1966, p.p. 45-70), specifically to those functional systems or cortical areas known to be involved (Hyden, 1960, p.p. 215-223).

Differences in RNA between controls and trained animals were reported for an experiment in which rats were forced to reach for food with the front paw that was nonpreferred (Hyden & Egyhazi, 1964). From the cerebral hemispheres of five rats, ten single neurons were dissected out of the layer of large pyramidal cells in that area of the cortex known to be necessary for transfer of handedness under forced reaching conditions. The extracted RNA preparations were investigated. RNA from cortex contralateral to the trained paw occurred in greater quantities, per neuron, than in ipsilateral (same side) cortex; and with a different base composition of Adenine, Guanine, Cytosine and Uracil, which comprise the RNA structure (Ruckenstein & Simon, 1966). The control ipsilateral cortex had neuronal RNA in amounts and composition not distinguishable from that in either cortex of the untrained animals. Differentiation and growth of the specific cortical areas involved in a task seems to follow repeated task training. Repeatedly responding to a task, not simply age, seems to account for nervous system maturation.

Complete understanding of the mechanisms of memory underlying human behavior would profoundly advance scientific knowledge of the thought processes. One exciting theory of memory advanced by Hyden (1960) was disarminly simple: memory is incorporated into proteins synthesized by nerve cells, chemically altered by experience. Oversimplified, his theory stated that an experience, say the sight of a picture of a boy and the name, "boy"; and environment associated with it, such as a testing laboratory, set up nerve impulses that enter groups of neurons. These impulses affect the internal environment of the cell and their modulated frequencies jostle the backbone of very long nucleic acid molecules. This induces a change in RNA templates so that new protein molecules differing from any previously produced protein molecules, are synthesized. The new protein molecules are sensitive to the unique electrical patterns that modified the RNA of certain neurons. A repetition of the same electrical pattern, stimulated by mention of the testing laboratory, or the sight of a picture of a boy, is recognized by specific proteins and coded information is passed on to chains of experienced neurons. The child thus remembers the testing laboratory, the investigator, and the general circumstances in which he was asked to remember, via subvocal rehearsal, the picture of a boy.

The present investigation indicated that children can be induced to subvocally rehearse in the absence of a stimulus. Preschool children, however, normally behave nonverbally in recall tasks (Locke & Fehr, 1970b.; Daehler, et al, 1969; McGuigan, 1970; Conrad, 1971; Reese, 1962; Hagen, et al, 1968; Potts, 1968; Flavell, et al, 1966; Flavell, 1963, p. 158; Keeney, et al, 1967; Moely, et al, 1969). Perhaps after repeated spaced practice aimed at increasing their verbal behavior in recall tasks, preschool children can learn to automatically, or normally, subvocally rehearse in the absence of a stimulus. That is, it may not be necessary for them to follow the rigid age-related schedule advanced by some contemporary developmentalists.

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