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AUTHOR McNeil, David
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ABSTRACT

A study of the speech process was conducted. The process is described as one closely linked to the one involved in the problem of the serial order in behavior. It is pointed out that in the speech of young children the grammatical relations that are properties of elementary underlying sentences appear in the grammatical meanings. Six examples of child speech patterns are given. By the end of the second year, children come to express grammatical relations through word combinations. A methodological assumption is made that the duration of speech can be taken to be a function of the duration of underlying schemata. The hypothesis is suggested that the basic encoding process in speech is one that produces underlying elementary sentences. It was found that there is clearly a difference in the amount of time allotted to actual word combinations and to successive holophrastic utterances. A counter hypothesis is also suggested, i.e., that successive holophrastic utterances show variation in order and cover a longer span of time because they are not included within a single intonation contour. A different form of evidence that underlying sentence structure plays a central role in regulating the duration of speech is taken from the temporal organization of imitation. It is speculated that the brain processes for constructing underlying sentences have evolved in such a manner as to produce new foci of attention at this natural rate. In this sense speech can be said to be the bridge between conscious awareness and largely unconscious cognitive operations, such as identification, classification, and storage. (CK)

Sentences as Biological Processes*

David McNeill

University of Chicago

As one produces or listens to speech, there must be processes in the brain that correspond to and underlie the speech. It is a truism that there is continuous and general activity within the nervous system, activity that now and then rises to the surface as speech. But I will make the further assumption that there are also more particular brain processes that correspond specifically and exactly to particular utterances. Utterances that are heard, according to this view, trigger a certain series of processes in the brain that would not otherwise occur, while utterances that are spoken are the result of processes that lead up to each utterance and not to some other.

The process I have in mind is closely linked to the one involved in the problem of the serial order in behavior as Lashley (1951) discussed it in a celebrated paper of that same name. Lashley said, for example, that "... syntax is not inherent in the words employed or in the idea expressed. It is a generalized [cerebral] pattern imposed on the specific acts as they occur" (p.119); and, "This is the essential problem of serial order; the existence of generalized schemata of action which determine the sequence of specific acts, acts which in themselves or in their associations seem to have no temporal valence" (p.122). The most obvious example of wuch sequences, as Lashley pointed out, is speech. The brain

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processes that are specifically associated with utterances have the effect of imposing a particular temporal valence, order, on speech by determining the order of events at some point in the brain, where the production (or reception) of speech is directed.

Early child speech. A striking fact about the speech of young children is that the grammatical (or semantic) relations that are properties of elementary underlying sentences appear in the earliest organized utterances. From the outset, children's patterned speech is completely dominated by these basic relations. The child behaves as if he were obeying the general principle,

$$\text{grammatical relations} \Rightarrow \text{combinations of words,}$$

and demanding of each grammatical relation that it uniquely determine a certain word combination (the converse cannot hold for two-and three-word combinations, i.e., each word combination does not uniquely determine a grammatical relation).

Virtually every child, regardless of the language to which he is exposed, uses word order to distinguish grammatical meanings (Slobin, 1970). A familiar example is Adam, one of the pseudonymic children observed by Brown and his colleagues (Brown and Bellugi, 1964). Adam had 3 grammatical classes: nouns, verbs, and a generalized class of modifiers (sometimes called "pivots). Of the $(3)^2=9$ and the $(3)^3=27$ possible two-and three-word combinations of these classes, Adam used in fact 4 two-word combinations and 8 three-word combinations. The 4 and 8 combinations that Adam used were all and only the ones that fit the above principle in that each combination directly expressed a grammatical relation and no combination that could not have expressed a grammatical relation was used (more details contained in McNeill, 1966). More recently Bloom (1970) has very thoroughly established that children's earliest word patterns obey the general principle given above. Bloom's observations were made at an earlier stage of development than Brown's and included notes on the contextual situation of the child's speech as well as a record of the child's speech itself. Such notes on the contextual situation are crucial for interpretation. Bloom was able to show that virtually every utterance at even the earliest stages expresses one or more coherent semantic relation. At least the following six can be found in examples she reports:

1. Modification. E.g., black hair said of a doll's hair

2. Direct object of verb. E.g., Kathryn want a raisin

3. Location E.g., foots flower when looking at a picture of a flower on a bare foot

4. Possession. E.g., Kathryn sock said of the child's (Kathryn) sock

5. Indirect object of verb. E.g., Kathryn ə bear said as Kathryn gives a raisin to her toy bear

6. Subject of sentence. E.g., Jocelyn said of a friend who had bruised her cheek.

This set of six relations is not an exhaustive list of the grammatical relations possible within elementary underlying sentences, but it includes all the major relations, and they occur in the earliest patterned speech of children.

These same relations emerge as expressional possibilities gradually during the period of one word utterances, before the advent of patterned speech. Smith (1970) in a study of this penomenon found evidence in the contextual circumstances of holophrastic speech that single words would begin to be used in each of these relations only after a certain stage of development had been reached. Before that point, there was no evidence of the relation. The order in which the relations emerged during the holophrastic period corresponds more or less to the order in which they are listed above, and the six relations appear for the first time together only at the conclusion of the holophrastic period. There is in other words a continuity between the one-word and multi-word stages of development in the linguistic relations children use. What happens toward the end of the second year, then, is not that children begin to express the grammatical relations of simple underlying sentences, but that children come to impose the general principle mentioned previously: they begin to express grammatical relations through word combinations.

Speech duration. What happens at the end of the second year to cause children to adopt this new principle? I will suggest that it is the emergence of a biological process which yields, for the first time, structures in the brain that correspond to the structure of underlying elementary sentences. These structures are the schemata discussed by Lashley. Lashley was concerned to show that the cerebral schemata of serial order imposes a temporal valence when there is none intrinsically. He was concerned, that is, only with the order of events in time. It is possible to go a step further by considering the possibility that such schemata also impose a temporal value, that is, a duration for events. In this case, order and duration are linked. The emergence of a regulation of temporal order implies a regulation of duration.

My methodological assumption is that we can take the duration of speech to be a (not necessarily one-to-one) function of the duration of underlying schemata. Making this assumption, we can examine speech rates for what they tell us about the duration of underlying brain processes. Some kind of correlation between the duration of internal processes (such as the operation of a cerebral schemata) and external ones (the duration of speech) seems inevitable. The correlation is probably low, however, since many factors other than the operation of internal schemata influence speech duration. Hence, we must combine large numbers of observations to isolate the contribution of a single factor such as the duration of the internal schemata for sentences. Table 1 is an artificial and somewhat idealized example that illustrates the main findings we have obtained from studying speech durations in older children and adults. Actual observations, described below, confirm this idealized example in all major respects. The upper half of Table 1 shows a single utterance - John didn't

Table 1 here

tell Mary - and the number of linguistic units of various kinds it contains (syllables, morphemes, words, phrases, underlying sentences). Also shown is the average duration in this utterance of each of these linguistic units. Average duration is computed simply by dividing the duration of the whole utterance (1.90sec) by the number of units it contains of the appropriate kind (6 syllables, 5 morphemes, etc.). The lower half of Table 1 shows the same grammatical structure when it is part of a larger utterance - John didn't tell Mary to examine the book - and shows again the number of linguistic units of each kind as well as the average duration in this new utterance of each. The crucial point of the example is that the average duration of all linguistic units except underlying sentences - morphemes, words, and surface phrases - becomes shorter as the utterance becomes longer. The average duration of underlying elementary sentences, on the other hand, is the same regardless of length. The addition of underlying elementary sentences adds equal increments of time. The addition of other linguistic units adds unequal (in fact, smaller) increments of time.

The reason for this is a pause of 1.0sec between the

	Time	Number	Mean Duration
	1.90sec		
Utterance	(John did--n't tell Mar--y)	1	1.90sec/utterance
Syllables	( ) ( )( ) ( ) ( )( )	6	0.32sec/syllable
Morphemes	( ) ( )( ) ( ) ( )	5	0.38sec/morpheme
Words	( ) ( ) ( ) ( )	4	0.47sec/word
Phrases	( ) ( ) ( )	3	0.64sec/phrase
Sentences	( )	1	1.90sec/sentence

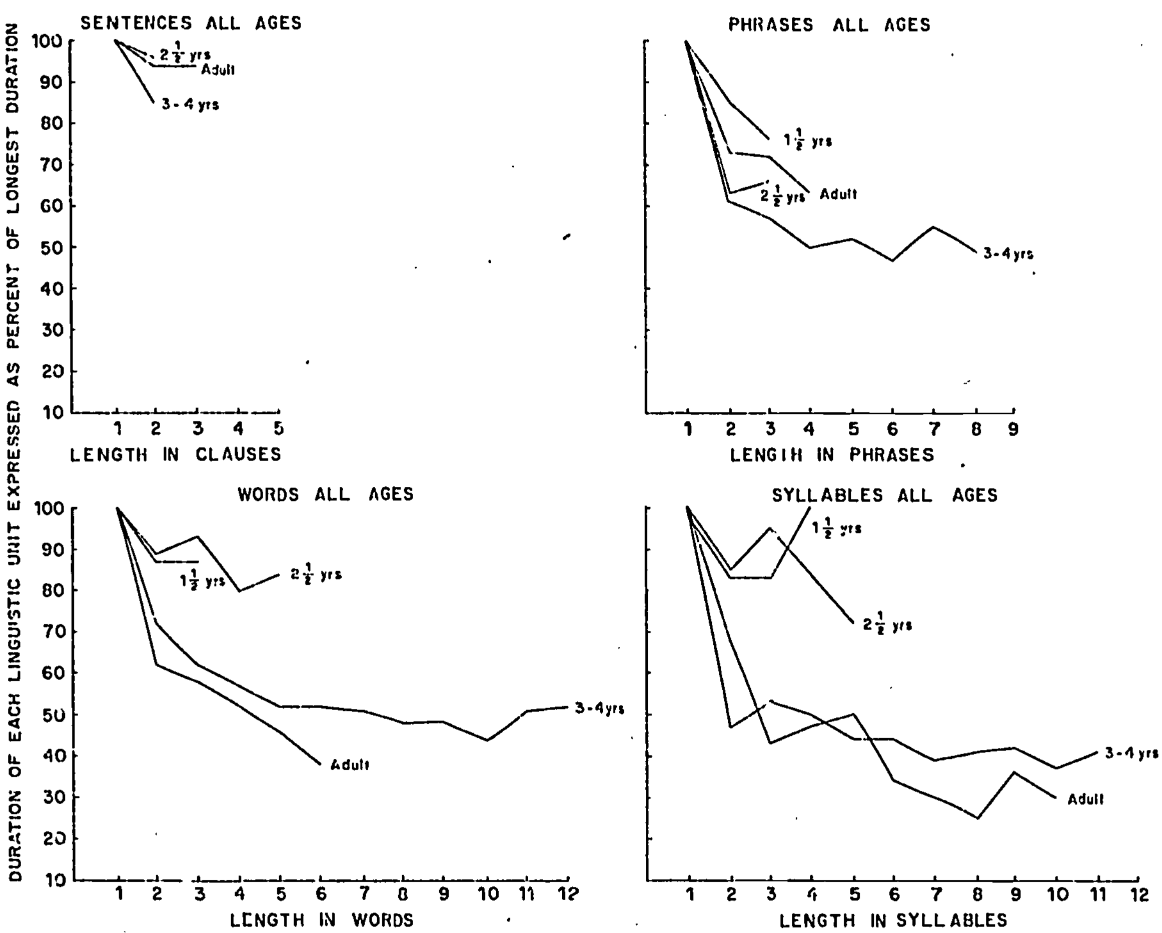
	Time			Number	Mean Duration
	1.40sec	1.00	1.40		
Utterance	(John did--n't tell Mar--y		to ex--am--ine the book)	1	3.80sec/utterance
Syllables	( ) ( )( ) ( ) ( )( )		( ) ( )( )( ) ( ) ( )	12	0.23sec/syllable
Morphemes	( ) ( )( ) ( ) ( )		( ) ( ) ( ) ( )	9	0.31sec/morpheme
Words	( ) ( ) ( ) (		( ) ( ) ( ) ( )	8	0.35sec/word
Surface Phrases	( ) ( ) ( )		( ) ( ) ( )	6	0.47sec/phrase
Underlying Sentences	(( )		)	2	1.90sec/sentence

two clauses. Goldman-Eisler (1968) found that in fluent (reading) speech most pauses fall at grammatical boundaries, and in particular at boundaries between clauses. In the example of Table 1, the effect of the pause at the clause boundary is to equalize the duration of the underlying elementary sentences in the utterance with more than one elementary sentence, while simultaneously permitting the duration of the other linguistic units to shrink. Since most pauses are at clause boundaries (in fluent speech), most utterances occupy equal increments of time with equal increments in the number of underlying elementary sentences, but less time with increments of other units.

The hypothesis to be suggested, then, is that the basic encoding process in speech, the schema of order, is one that produces underlying elementary sentences. Pauses will occur at clause boundaries when the utterance of syllables, words, or surface phrases has run faster than the production of underlying elementary sentences; pauses thus give time for the process of encoding underlying elementary sentences to catch up. The function of such pauses is to permit speech to proceed smoothly at the underlying level, even at the cost of interruptions at the surface level.

Fig. 1 here

Temporal Compression of speech. Figure 1 shows the average duration of syllables, words, surface phrases, and under-



SENTENCES ALL AGES
PHRASES ALL AGES
WORDS ALL AGES
SYLLABLES ALL AGES
DURATION OF EACH LINGUISTIC UNIT EXPRESSED AS PERCENT OF LONGEST DURATION
LENGTH IN CLAUSES
LENGTH IN PHRASES
LENGTH IN WORDS
LENGTH IN SYLLABLES
2½ yrs
Adult
3-4 yrs
1½ yrs

lying elementary sentences in samples of the spontaneous speech of speakers of widely different ages. The age range is approximately from 18 months to 30 years. (In order to compare linguistic units of different absolute durations, all durations have been normalized to the percentage scale, by expressing the average duration of a particular unit as a percent of the longest duration of that unit. The minimum sample size is 700 utterances.)

As can be seen in Fig. 1, there is little change in unit duration with length when the unit is the underlying elementary sentence ("clauses" in Fig. 1). That is, the ideal situation illustrated in Table 1 holds fairly closely also for these samples of spontaneous speech. The average duration of other units is compressed, however, especially in the speech of older speakers. The average duration of syllables in adult speech, for example, is compressed to almost 30% of its maximum duration (which occurs with monosyllables). It is impossible to say at present whether this compression comes from an acceleration of output or from a general adjustment of syllable and word duration that affects the duration of all syllables and words at a given length in the same way. Young children show the same constancy at the level of underlying structure as older children and adults do. If underlying structure is "available" to children at the beginning of patterned speech, which much evidence suggests, this constancy is predictable, given the argument that underlying structures come from the operation of brain processes that are necessary for the organization of serial behavior. According to this argument, even the youngest children, if they use word sequences to express grammatical or semantic relations, will follow the time constraints that older children and adults follow.

Figure 1 shows relative durations, each linguistic unit providing its own baseline. When absolute durations are considered it becomes clear that children resemble adults not only in consuming equal increments of time with each underlying sentence, but also in consuming the <u>same</u> amount of time. Whereas the average duration of syllables, words, and surface phrases becomes shorter with development (adults talking much more rapidly and older children talking somewhat more rapidly than younger children), the amount of time taken to construct underlying elementary sentences does not change. It is on the average 1.0 to 2.0 seconds regardless of the age of the speaker. At the abstract level of sentence structure, the rate of speech is a relatively fixed quantity. One infers that the brain processes responsible for the organization of speech into grammatical forms, once available, operate with much the same speed for all speakers at any level of development. In contrast, the duration of syllables in the speech of two-year olds is double the syllable duration in adult speech (0.4 sec for little children compared to 0.2 sec for adults after compression).

Figure 1 shows that speakers at all stages of development tend to consume a standard increment of time with each additional underlying elementary sentence. It is equally clear from Fig. 1 that the youngest speakers also show little compression of surface elements, but that those surface elements which are most abstract (surface phrases) show compression to adult levels at an earlier point in development (two-and-one-half years) than do elements which are less abstract (words and syllables). The order of development thus corresponds exactly to the order in which aspects of sentence structure develop in children's language. Full surface phrase markers always emerge as grammatical possibilities before phrases include all the requisite morphemes (and hence syllables) (Brown and Bellugi, 1964). Children's sentences generally include, for example, subject, predicate, location, adverbial, and other kinds of phrases, but they often omit prepositions, articles, auxiliaries, and other small elements which add to the word and syllable count but not to the phrase count. As surface structure becomes more elaborate, then, the rate at which it is produced also increases. There is not a corresponding change in the duration of underlying structure. This correlation between knowledge of grammatical structure and linguistic performance is completely understandable with the argument that that children and adults attempt to hold constant the amount of time spent constructing underlying elementary sentences. Then, more elaborate surface expressions of underlying elementary sentences will impose a temporal compression of surface elements. Children will resemble adults in regard to duration solely to the extent that they resemble adults in regard to the number of elements of surface structure that are included within the time span of an elementary sentence; and, in fact, children first match this number with phrases and last (among the elements tallied in Fig. 1) with words and syllables.

Successive holophrastic utterances. I mentioned before certain evidence for the claim that children in the holophrastic period encode grammatical and semantic relations, and proposed as a hypothesis that children leave the holophrastic period when they develop the cerebral capacity to construct underlying elementary sentences. These new brain processes make possible the serial organization of surface utterances, i.e., sequences of words that express grammatical and semantic relations, and thus usher in the development of surface structure. One would not expect from this argument that holophrastic utterances should show any of the temporal characteristics of grammatical patterns. These temporal characteristics ought not to appear even when children produce, as they sometimes do, two or more holophrastic utterances in succession that would be grammatically related if they were part of a single pattern. An example from Smith (1970) is mommy... shoe, said by a child who wished to have his mother put his shoe on. Smith observed of such sequences that unlike true sentence patterns, which are yet to come, there is variable word order in successive holophrastic utterances, there is not a single intonation contour, and the amount of time occupied by the successive words is between 2 and 4 sec. That is, successive holophrastic utterances lack both the grammatical property of a fixed word order and the temporal property of requiring 2 sec or less for completion that are characteristic of grammatical sequences. Lacking both of these traits, there is also no basis for a phonological pattern to be extended over the pair of words.

Smith's examples come from the speech of one child. Table 2 shows the duration (onset to offset) of 13 successive holophrastic utterances taken from the speech of four other children who have been studied by Rodgon (personal communication). Successive holophrastic utterances have intonation contours that typically are the same over the two words ($\acute{1}\ \acute{2}$, $\grave{1}\ \grave{2}$, or $\bar{1}\ \bar{2}$), whereas word combinations have a different contour over each word, the whole making a unified pattern (typically $\acute{1}\ \grave{2}$, but also $\bar{1}\ \hat{2}$). For comparison, 12 actual word combinations have also been timed from the speech of the children in Rodgon's study (the subjects were in transition from holophrastic to patterned speech).

Table 2 here

There is clearly a difference in the amount of time allotted to actual word combinations and to successive holophrastic utterances. We find a range of values for the latter that is essentially the same as reported by Smith. The patterned utterances, on the other hand, take somewhat less time than the ones summarized in Fig. 1. Rodgon's subjects were younger than the children included in Fig. 1, which may account for the dis-

TABLE 2

TWO WORD HOLOPHRASTIC AND GRAMMATICAL SEQUENCES

HOLOPHRASTIC	TIME (SEC)	GRAMMATICAL	TIME (SEC)
oh-put matches	3.15	This-is nice	1.35
doggie bye bye	3.90	my shoe	1.05
open purse	3.75	go baby	1.20
doggie woof-woof	2.05	don't doll	1.50
dah awgaw	3.40	book down	0.75
book baby	4.50	open bok	0.90
awgaw bip	1.95	bye da	0.75
duh awgaw	1.65	bye buk	0.90
unguyah buk	4.20	bye bye cow	1.20
bye ligh	3.30	go bye bye	1.20
igh allah	3.00	bai daddy	1.50
bai daddy	1.95	ma mommy	1.05
bai bai daddy	3.30		
AVERAGE DURATION	3.09	AVERAGE DURATION	1.11

crepancy, but they were also part of an experimental regime in which an attempt was made to induce word combinations in the child's speech.

With either interpretation, however, the fact remains that there is a very large discrepancy in duration between semantically related holophrastic utterances and grammatically expressed combinations. Some hypothesis is necessary to account for this difference. The hypothesis that a cerebral mechanism becomes available at the end of the holophrastic period, through which underlying elementary sentences are constructed, is one such account. Successive holophrastic and patterned utterances have a fundamentally different origin in a child's speech according to this view, a difference which is reflected in the temporal, ordinal, and phonological properties of what is said.

There is, however, a counterhypothesis. One might maintain the opposite of what is being suggested here: that successive holophrastic utterances show variation in order and cover a longer span of time because they are not included within a single intonation contour. While it is not completely clear how this theory explains variability in word order, there is a more important reason why the counterargument cannot be sustained. Sentence-like intonation contours develop over babbling sequences very early in the holophrastic period - long before successive holophrastic utterances appear. These contours extend over stretches of babbled speech sufficiently long to cover two-word combinations, should any exist. Moreover, the same children in Rogdon's study who produced successive holophrastic utterances without temporal regulation also produced patterned combinations of words with temporal regulation. Why do children not integrate succissive holophrastic utterances under a single intonation contour when such contours are already in use and have been used for several months? The answer must be that there is no underlying schema for organizing a sequence of words in the case of successive holophrastic utterances. For this reason, the successive words are not under temporal control and there is no basis for imposing a single intonation contour on them.

Evidence from imitation. A different form of evidence that underlying sentence structure plays a central role in regulating the duration of speech can be taken from the temporal organization of imitation. We performed an experiment with 4-and 5-year-old children in which an adult deliberately varied the rate of presentation of model sentences over a wide range, the purpose being to see whether children could copy the rate of the adult's delivery. The model sentences covered a number of different syntactic forms, many of them with more than one underlying elementary sentence, and the adult's speech rate varied from about three times faster to three times slower than normal.

The children were told to say what the adult said, but they were not specifically told to imitate his rate of delivery. Nonetheless, we find that children imitate variations in rate closely. Expressing the adult variation in rate as a deviation, plus or minus, from the adult's own average ("normal") sentence duration, and the child's variation as a similar deviation from the child's own average sentence duration, the direction of the child's deviation agreed with the adult's direction on 90% of the trials. On virtually all occasions, then, when the adult sped up or slowed down, the child did the same. The magnitude of the child's adjustment of his speech rate, however, was typically less than the variation in the adult model, a discrepancy that suggests that the child's new speech rate was a true change in the speed of sentence processing, and not merely a metronomic following of some adult tempo. The direction and degree of change were separately registered. In contrast to the level of accuracy of 90% with direction of change, the magnitude of the children's adjustment agreed with the adults to within only 30%, on the average. When speech was faster than normal the children came within 9 percentage points of matching the adult, but when it was slower they came within only 45 points of the adult. The "success" in the case of fast speech almost certainly is the adult's, not the children's, since the adult was unable to shrink sentence duration to the same relative degree that he could expand them.

This much, however, does not establish that underlying sentences are the controlling unit in imitation. We have measured sentence duration, but the child may have been changing, say, word duration. To show that sentence dura-

TABLE 3

IMITATION OF SLOW MOVING DEEP STRUCTURES

ADULT MODEL		CHILD IMITATION	
DURATION RELATIVE TO AVERAGE		DURATION RELATIVE TO AVERAGE	
SYLLABLES	SENTENCES	SYLLABLES	SENTENCES
—	—	—	—
—	+	+	+
+	+	+	+

tion was the decisive factor, the adult changed duration in two ways. One was merely to utter the entire sentence faster or slower, in which case all durations (syllables, morphemes, words, surface phrases, underlying elementary sentences) shrink or expand together. As already noted; children imitate the direction of such changes accurately. The second method was to speed the output of words within phrases, but to introduce pauses between phrases. In this case, the duration of all superficial linguistic segments is reduced, while the duration of elementary underlying sentences is normal or expanded. We find that children imitate the duration of the underlying sentence in such cases. At the same time, they make the duration of surface elements (which had been shorter than average in the model) longer than average. In other words, the children respond exclusively to the time taken to construct the underlying structure, and this duration in turn determines the time allotted to the surface elements in the imitation. Table 3 shows in part the results of this phase of the experiment (syllable and sentence data only). Only changes in direction are considered, as it is the only direction of change that children accurately imitate. The finding, very clearly,

Table 3 here

is that the duration of surface elements is anchored to the duration of underlying elementary sentences, which in turn, is imitated from the adult model.

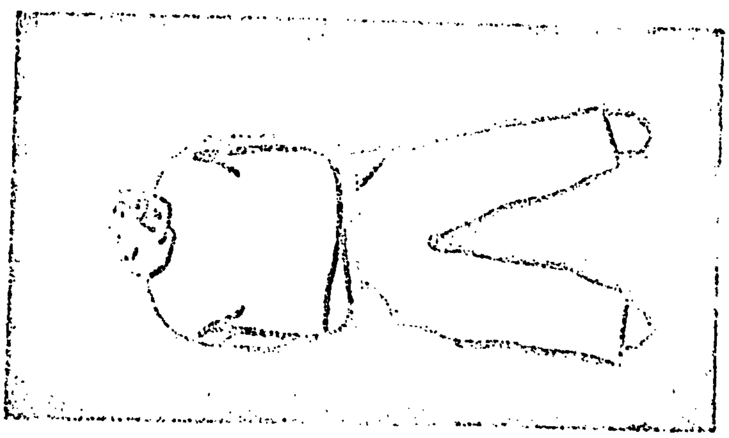
<u>The life span of underlying structure</u>. If there are brain processes that construct the structure of underlying elementary sentences, it should be possible to find some maximum duration over which these processes can be made to operate. Beyond this point, if for some reason a complete underlying structure has not been generated, the processes would begin to disintegrate, and the structure would be lost. When adults speak at slower and slower rates, they can tolerate an interword interval of about 4 sec without rehearsal (which increases the rate). The sentence the adult is trying to utter must be novel to him, not an imitation or memorized sentence, and the phenomenal effect is that the internal structure crumbles unless rehearsal is begun. We have estimated the maximum life span of underlying structure in the speech of children (who cannot be asked to report when rehearsal sets in) by the following method. We first show the child a picture of some scene - e.g., a fat boy jumping over a fence - and ask the child to describe it. We try to have him use a sentence close to a standard sentence that we have in mind for the picture - e.g., <u>The fat boy is jumping over the fence</u> - but since the exact form of the sentence is unimportant we do not insist on this. With suitable instruction it is possible to convey the idea to 4-year-olds that they are going to see the original picture in bits, a separate bit for each major part of the original picture, and that they should say the corresponding parts of the sentence as the bits of the picture are revealed. Thus, we first show the left-most picture of Fig. 2

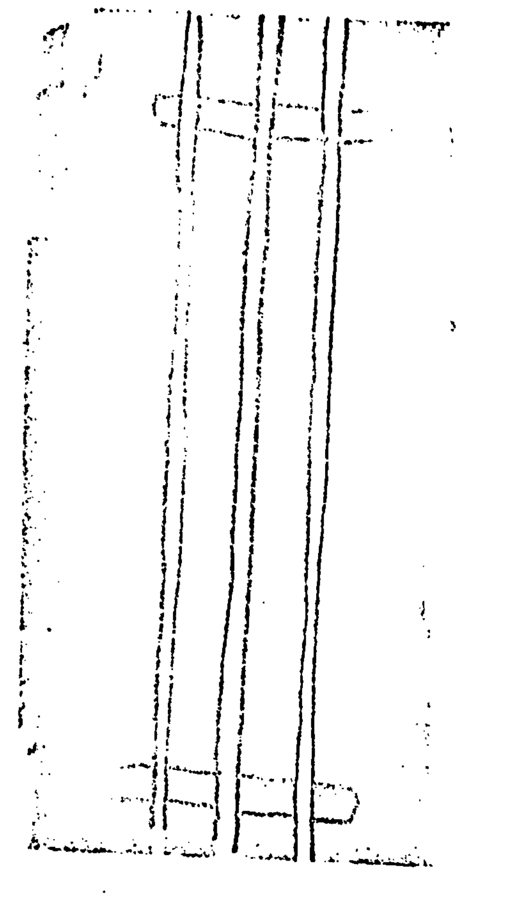
or 3, and then show, one by one, the pictures on the right. By controlling the rate of exposure of the right-hand pictures we control the child's rate of speech. At fairly high rates, say, a picture every 2 sec, children break the sentence into phrases in a manner typified by the following: a fat boy... jumps....over the fence (or...jumps over... ...the fence), in which sentence structure is preserved. We conclude that in these cases the child has successfully reconstructed the underlying structure in the amount of time we have given him. Since we exclude from consideration cases where anticipations occur, we eliminate sentences where the reconstruction obviously covered less time.

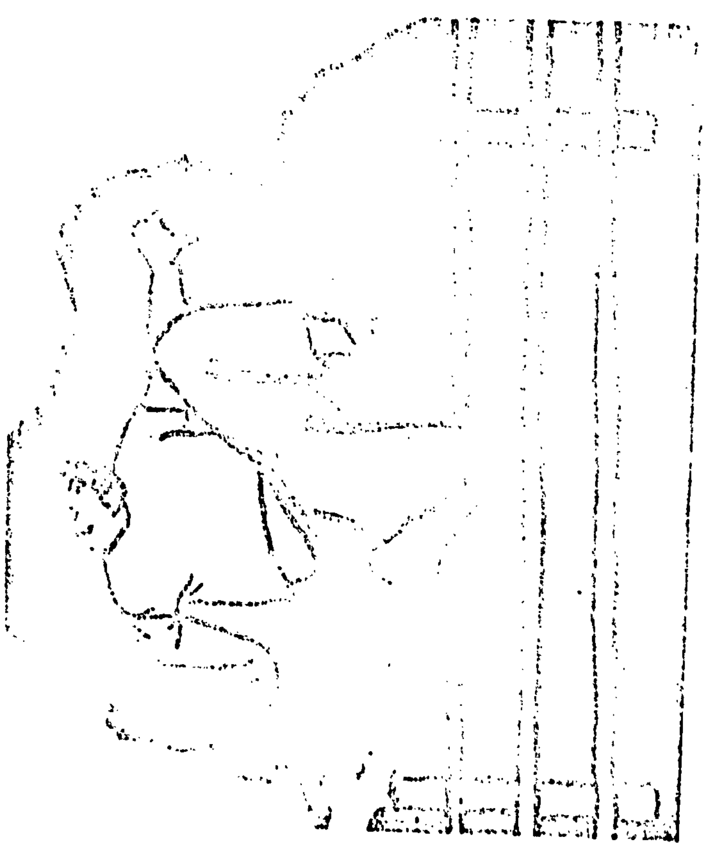
Fig. 2 here

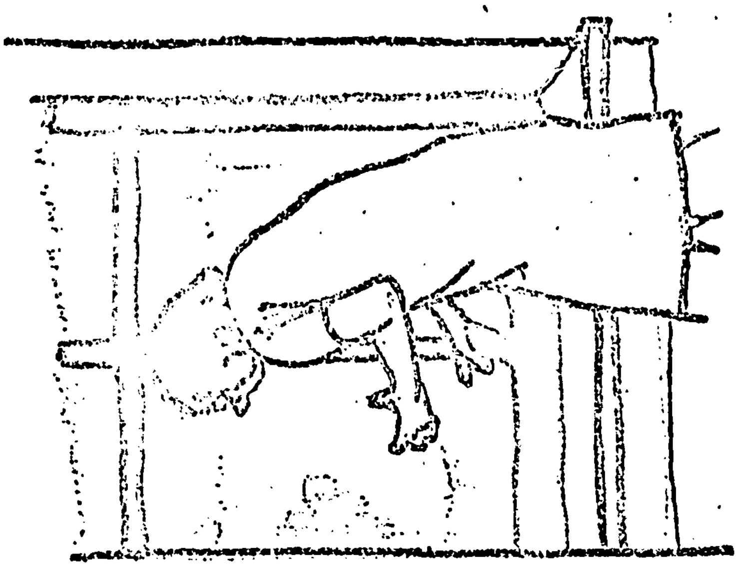
Fig. 3 here

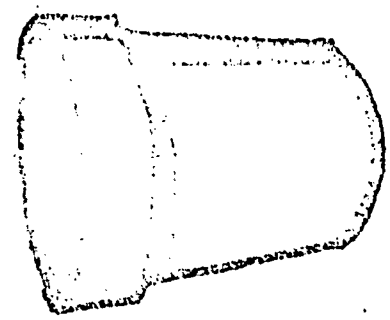
Reducing the exposure rate to one picture every 4 sec has no effect on the ability of children to maintain sentence structure. Children this age are able to rehearse (their lips can sometimes be seen to move) and so the exposure duration does not correspond to the effective sentence duration. However, children sometimes slow the rate of vocalization when the exposure rate is reduced, usually extending the vowels. As long as the child is actually vocalizing, his chances for rehearsing must be reduced. We find that if we measure the

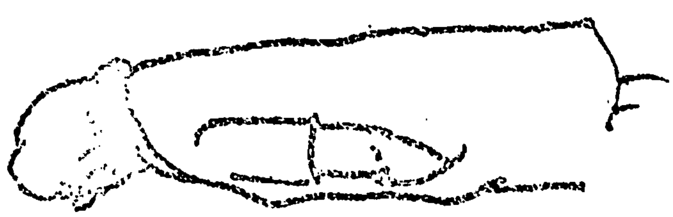


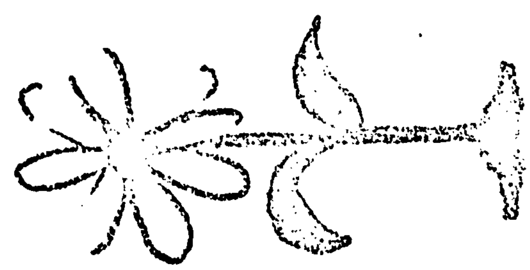


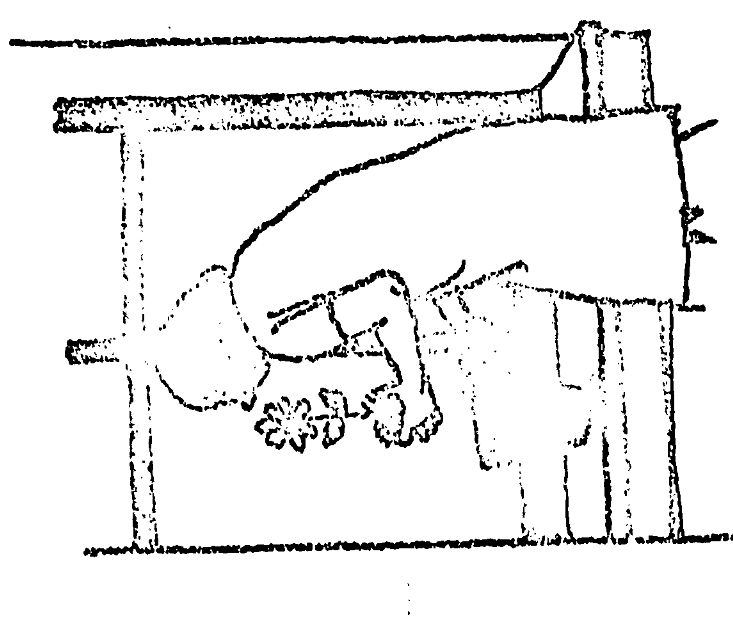












total amount of time spent in speech, there is a sharp discontinuity in the results. If this total amount of time is more than 3 sec, and the child has not yet completed the sentence he has been uttering, the structure of the sentence will collapse. There will be an abort in which the child either will begin over (The fat boy...is jumping...The fat boy is jumping...), or he will repeat the last phrase (The fat boy...is jumping....is jumping), or he will abandon the structure totally and utter single words (The fat boy...is jumping...fence) with or without the stock phrase There is ___, or he will insert words in a nongrammatical way (The fat boy....is jumping....fence over the fence), or he will fail with some combination of these. Thus, we estimate that the outer limit on the amount of time for the construction of underlying sentences is 3 sec for these children.

The similarity of this result to the adult limit of one word every 4 sec should not be taken too seriously, since the adult value was informally obtained. Nonetheless, the fact that children and adults consume similar amounts of time constructing underlying sentences in spontaneous speech implies that they are also limited to similar maximum amounts of time. (Experiments are being undertaken to measure this value for adults.) It may turn out that quite young children are able to sustain underlying structure for less time than adults and older children can. Such children to maintain an adequate margin between the maximum duration and the normal duration would normally have to produce underlying structures faster than adults do. There is a hint, in the very early patterned utterances included in Table 2, that little children do produce underlying structures in less time than older speakers do, which might reflect pressures arising from a lower maximum duration of brain proccesses when these processes are newly matured.

Table 4 here

Table 4 shows the breaking point at 3 sec in the experiment with 4-and 5-year-old children described above. The entries in this table are the average number of seconds that elapsed from the start of the child's speech until the event occurred noted in the left margin - i.e., the disruption of sentence structure (if any) and the end of the trial, when the child finished talking. Values are given separately, in the rows, for the total time speaking (excluding any pauses) and for the total time including pauses; and, in the columns, for sentences whose structure was preserved and for sentences whose structure was lost.

The hypothesis that best fits Table 4 is that the total amount of time spent in actual speech must remain within some critical limit, apparently around 3 sec. Any hypothesis about Table 4 requires that, when sentence structure is preserved, the time is not greater than when structure is not preserved. In the case of the hypothesis that the total time of actual speech is the critical factor, the prediction is in error only by 0.3 sec. The hypothesis that the critical factor is

TABLE 4

COLLAPSE OF SENTENCE STRUCTURE
(N=6, each subject counted once)

	SENTENCE STRUCTURE PRESERVED	SENTENCE STRUCTURE DISRUPTED
TOTAL TIME SPEAKING		
To Disruption	—	3.0 sec
To End of Trial	3.3 sec	4.9 sec
TOTAL TIME INCLUDING PAUSES		
To Disruption	—	7.3 sec
To End of Trial	8.5 sec	12.0 sec

the total interval, including pauses, over which sentence structure must be maintained is less accurate, being in error by 1.2 sec. As argued above, the success of the hypothesis that structure collapes when the speaking time exceeds some critical value can be understood as the result of rehearsal, which can go on unimpeded during pauses, but which presumably is blocked during actual speech. The total time spent actually speaking therefore is a more exact estimate of the time over which sentence structure can be maintained. And according to this estimate, the life span of the processes that produce underlying sentences is 3 sec.

The function of temporal regulation. Why is there a limit on the duration of the brain processes that produce underlying sentences? One could argue that what is shown by this temporal regulation is some characteristic rate for cognitive processing, in general. Mental activities probably take fairly stable amounts of time, and the flow of speech surely must be influenced by the flow of thought behind it. My argument, however, will be that the reverse of this is true. The temporal regulation of underlying structure functions to insulate speech from general cognitive processing. While cognitive processing perhaps takes stable amounts of time. The various processes that feed into speech take widely different amounts of time. The range of variation is at least 500:1. Given that the processing mechanism for speech must draw at varying times from processes that cover such an enormous temporal range, there is a great advantage to be gained in supplying the mechanism with its own, intrinsic time base.

Among the cognitive processes whose durations have been measured are: (1) Scanning visual arrays of letters, which can be done at a rate of 100 items per second (Sperling, 1971). (2) Encoding single visually presented letters, which takes about 500 msec per letter (Posner, 1971). (3) Negation in sentences which takes between 140 and 700 msec, depending on circumstances (Clark, in press). (4) Storage in long-term memory, which requires about 5,000 msec (Simon, 1969). Other processes have been timed, and no doubt still others could be put to the test of the clock. The point is that there is an enormous temporal range for cognitive operations that in one way or another play a role in the processing of speech. To take the extremes, the 10 msec scanning process discovered by Sperling would be involved whenever one is talking about visible events; the 5,000 msec storage process rediscovered by Simon is involved whenever one uses speech to mediate memory. There is, clearly, a function to be served by having the cerebral schemata for constructing grammatical sequences of words operate through a mechanism with a unique time base, separate from such cognitive operations. The separation in time implies a separation of mechanisms. The question of why the mechanism of speech operates with the speed it does (between 1 and 2 sec) can be understood by taking into account the process of attention. Each new underlying elementary sentence encodes further information into some sort of semantic form, and thus requires a shift of attention (assuming that semantically organized information is the focus of attention). Such attentional shifts in fact ordinarily occur every 1 or 2 sec (Triesman,). Thus, one can speculate, the brain processes for constructing underlying sentences have evolved in such a manner as to produce new foci of attention at this natural rate. In this sense speech can be said to be the bridge between conscious awareness and largely unconscious cognitive operations, such as identification, classification, and storage.