

SYNTACTIC CONTROL OF SPEECH TIMING:
A DEVELOPMENTAL STUDY

Michiko Mochizuki-Sudo and Kumiko Tanno-Sato*

Abstract

The purpose of this study was to investigate syntactic influences on speech timing from a developmental point of view. Our experiment consisted of two sessions: syntactic test and recording. Ambiguous sentences were selected as linguistic materials.

The results of the experiment indicated that the boundaries of grammatical categories coincided with speech boundaries. The ability to detect the structure of ambiguous sentences was related to the motor control of speech timing. Also, the subjects with a developing syntactic ability showed an intermediate stage of timing-control ability.

Introduction

A number of studies have been made on speech timing in English and have shown that a variety of factors influence the duration of speech segments and pauses (Lehiste, 1972, 1980; Oller, 1973; Harris & Umeda, 1974; Umeda, 1975; Klatt, 1975). Among the factors observed in these studies, there are influences of phonetic environments, stress-timed rhythm and segment positions in words. In addition to these extra-grammatical factors, some of the empirical studies have found that speech is syntactically controlled. For example, segments in phrase-final position are longer than they would be in other positions. Also, pre-boundary lengthening is observed. Segments in major categories - such as noun, verb, adjective and adverb - are longer than those in minor categories, such as determiner and conjunction.

What these syntactic influences on speech suggest is that a speaker utilizes his or her syntactic knowledge in speech motor processing. In other words, the acoustic properties of speech can be used to determine whether the speaker can properly handle the the structure of sentences. Cooper & Cooper (1980) made the first extensive examination of the relation between sentence structure and speech timing in English. However, they only used adult subjects. In the present study, we investigated the syntactic influences on speech timing from a developmental point of view. Among syntactic structures, ambiguous sentences were selected as the linguistic materials of this study for the following two reasons: First, phonetic environments that might otherwise cause durational differences can be controlled in the case of ambiguous sentences; second, the ability to detect ambiguities manifests the degree of developing linguistic competence.

* Tamagawa University

Most of the previous studies on linguistic ambiguity deal with various types: phonological, lexical, surface structural and deep structural. In this study, we limit ourselves to surface structural ambiguities.

Hypothesis

We assume that the ability to detect the structures of ambiguous sentences is related to the motor control of timing. Our hypothesis is that once a child learns these syntactic structures, he can control the speech timing. Conversely, if he fails in grasping the structures, he will also fail in the timing control. It follows that there is no one who can correctly control the timing without the syntactic ability. Our concern was also to test another possibility, namely, that a child could fail in motor control in spite of his having acquired the syntactic structures. Our hypothesis is summarized in Table 1.

Table 1. Our hypothesis for syntactic and motor-control ability

Syntax		
Motor-control	Yes	No
Yes	○	×
No	?	○

Experiment

1. Linguistic material

Two ambiguous sentences were used in this experiment.

1. The boy chased the dog with a stick.
2. Ann talked to the boy by the red telephone.

The ambiguities in these two sentences can be captured by assigning the following structures, respectively:

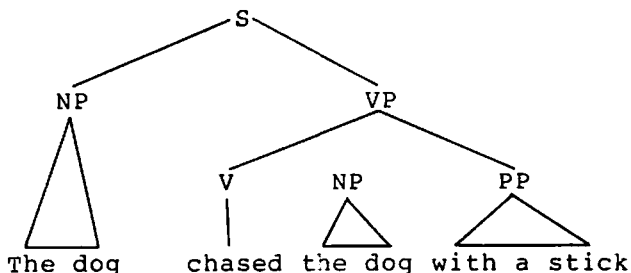
- 3.(a) The boy chased NP[the dog]pp[with a stick.]
- (b) The boy chased NP[the dog with a stick.]
- 4.(a)¹Ann talked to NP[the boy]pp[by the red telephone.]
- (b) Ann talked to NP[the boy by the red telephone.]

¹ In this structure, two readings can arise.

- i) Ann used the red telephone.
- ii) Talkings took place next to the red phone.

In this paper, however, we were not concerned with the ii)reading. Thus, at least two readings arise in each sentence because the prepositional phrase beginning with "with" or "by" can modify either the verb phrase or the noun phrase dominated by the verb phrase, as shown in Fig. 1 and Fig. 2.

(a)



(b)

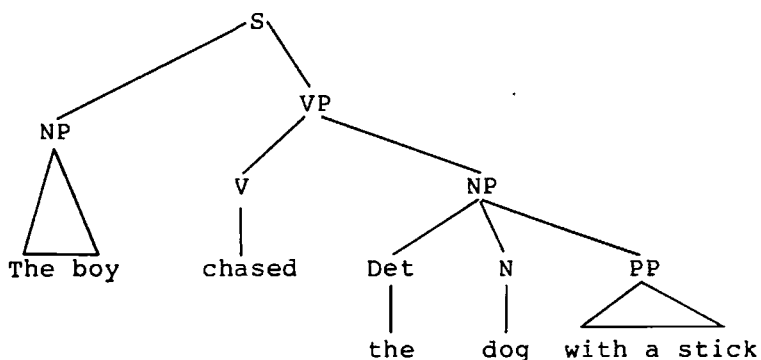
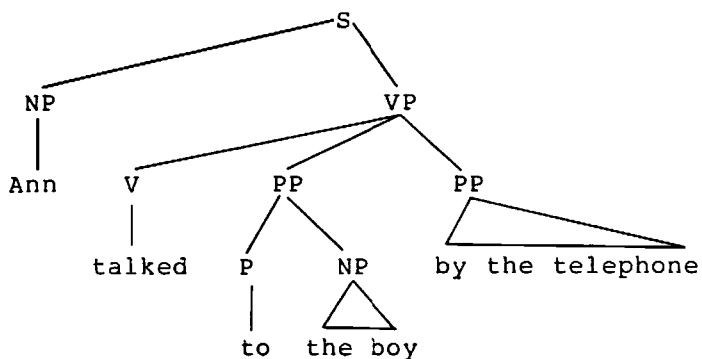


Fig. 1

Fig. 1 shows two structural representations of sentence 1. Fig. 1 (a) represents the 3 (a) reading, while Fig. 1 (b) represents the 3 (b) reading. When the prepositional phrase "with a stick" modifies the verb phrase as in 3 (a), the meaning of the sentence can be paraphrased by 5 (a). On the other hand, when the phrase modifies the 5 noun phrase, the meaning of the sentence can be paraphrased by 5 (b).

- 5. (a) The boy had a stick.
- (b) The dog had a stick.

(a)



(b)

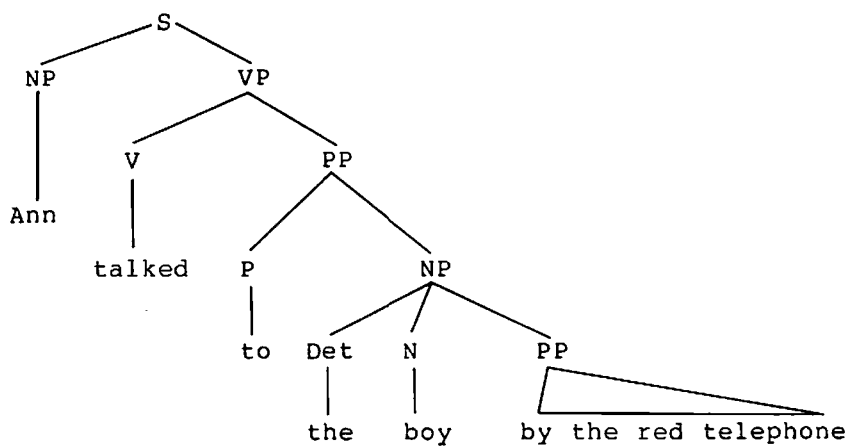


Fig. 2

Fig. 2 shows two structural representations of sentence 2. Fig. 2 (a) represents the 4 (a) reading, while Fig. 2 represents the 4 (b) reading. When the prepositional phrase "by the red telephone" modifies the verb phrase as in 4 (a), the meaning of the sentence can be paraphrased by 6 (a). On the other hand, when the phrase modifies the noun phrase, the meaning of the sentence can be paraphrased by 6 (b).

6. (a) Ann used the red telephone.
- (b) The boy was close to the red telephone.

2. Subjects

We tested 13 American subjects of six age groups, ranging from 8-year-old children to adults. There were one to three subjects, male and female, in each group.

3. Procedure

We tested each subject individually. The experiment consisted of two sessions. One was a syntactic test to determine whether the subject comprehended the two readings of each test sentence. The other was a recording session for the purpose of acoustic measurements.

3.1 Session A-Syntactic Test

We tested each subject individually. At the beginning, the subjects were told that this was not a test and that we were interested in how they understood sentences and how they produced them.

(A) Practice Session: The subjects were first shown an ambiguous picture, and then explained how a single picture could be seen in two different ways. The picture we used in this experiment is shown in Appendix 1. The subject was then given sentence 7 that involved the lexical ambiguity of "bad" whose meaning could be either a wooden stick used for hitting a ball or a flying mouse-like animal.

7. The little boy saw a bat in the park.

Using these two examples, we could give the subjects an idea about "a single picture or sentence that can be seen in two different ways." We used a lexically ambiguous sentence as practice material, since some previous studies have shown that the ability to detect lexical ambiguity appears earlier than the ability to detect syntactic ambiguity (Shultz & Pilon 1973; MacKay, 1966; MacKay & Bever, 1967).

(B) Test Session: Immediately after the Practice Session, we conducted the Test Session. This session consisted of three kinds of questions.

First, the subjects were shown sentence 1 and were asked to read it aloud twice. Next, one of the experimenters asked the following question to determine whether the subjects could recognize the two readings of the sentence.

8. Can you read this sentence in two different ways as you did before?

If the subjects could successfully explain the two readings at this point, the rest of the procedure in the Test Session was skipped.

Second, for those who could not respond correctly, we asked question 9

9. Who had a stick?

This question helped some of the subjects capture the two readings which they could not get in the first stage. Also, we could find out which interpretation the rest of the subjects captured. All of them selected "the boy" as the answer to question 9. If the subject recognized the ambiguity at this second stage, the following procedure was skipped.

Third, the subjects who selected "the boy" as the answer to question were shown sentence 10 which is unambiguous because "seeing the dog with a stick" is odd due to semantic constraints.

10. The boy saw the dog with a stick.

Then, they were asked "Who had a stick?" Immediately after asking this question, we rechecked whether they could disambiguate sentence 1.

Similarly, we devised three stages to check their ability to detect the ambiguity of sentence 2. First, we asked them question 8. Then, for those who could not explain the two readings, we asked question 11.

11. Where was the boy?

The subjects who interpreted the red telephone as an instrument to communicate with answered as in 12, while those who interpreted the red telephone as a place where the boy stood gave an answer as in 13.

12. On the other side of the red telephone.

13. The boy was close to the red telephone.

Third, for those who gave an answer like 12, we showed sentence 14 which is unambiguous due to semantic constraints and then asked, "Where was the boy?"

14. Ann talked to the boy by the door.

Immediately after asking this question, we rechecked whether they could disambiguate sentence 2.

3.2 Session B-Recording

The reading text consisted of eight repetitions of each linguistic material in a pseudo-random order (each sentence type had two different readings, which made a total of thirty-two sentences in the text). Each sentence appeared with one of the different meanings following in parentheses as shown in Appendix 2.

The subjects were instructed to read each sentence first to themselves and then to read it aloud at a comfortable speaking rate. At the same time, they were told to think of the meaning of the sentence during their production. In the case of children, the two different meanings of each sentence typed in the text were explained again before the recording. In the case of mispronunciations, or any awkward pauses, the subjects were instructed to repeat the sentence from the beginning. Before the actual recording, they were provided a short period of practice during which they were familiarized with the task and the sentence materials. The recording was made in an anechoic room at the University of Tokyo or in a sound-proofed room at Tamagawa University. The utterances were recorded by means of a microphone (SONY ECM-54; SONY ECM-65) and a tape recorder (TEAC T-3600; SONY 9000 F2).

4. Measurements

Broad-band spectrograms were made from the tape recordings. Acoustic measurements were then obtained for the durations of the segments /d/, /a/, and /g/ of "dog" in sentence 1. The pause after /g/ was included in the duration of /g/. In case of sentence 2, the /b/ and /oi/ of "boy" and the pause after /i/ were measured. The durations of the plosives /d/ and /b/ included the closure interval and the burst of frication at release. The onset of the vowels was defined as the instant the first formant attained the steady state.

Results

Table 2 summarizes the results of the Syntactic Test.

As shown in Table 2, subjects 6-13 responded correctly in stage A to sentence 1, while subjects 1-5 fluctuated in their answers. As for sentence 2, subject 5 and 8-13 responded correctly in Stage A, while the rest of the subjects fluctuated in their answers. It should be mentioned that subjects 6 and 7 did not admit the ambiguities of sentence 2 as some adult British speakers do not.

Table 2. Results of the syntactic test

Stages	Sentence 1								Sentence 2									
	A		B			C			D	A		B				C		D
	Yes	No	Yes	No		Yes	No		No	Yes	No	Yes	No		Yes	No		No
				boy	dog		boy	dog					In-strument	Place		In-strument	Place	
I	1		x		x				x	x						x		x
	2		x	x						x						x		x
II	3		x		x				x	x							x	x
	4		x		x		x	x	x								x	x
III	5		x		x		x		x									
IV	6	x								x							x	x
	7	x								x							x	x
	8	x								x								
V	9	x								x								
	10	x								x								
VI	11	x								x								
	12	x								x								
	13	x								x								

The thirteen subjects were divided into six groups.

I : 8-year-old subjs.

II :10-year-old subjs.

III :12-year-old subj.

IV :14-year-old subjs.

V :16-year-old subjs.

VI :adult subjs.

The responses were divided into four groups.

A: Responses to question 8(responses in the first stage).

B: Responses to question 9 or 11 and the second check of the ambiguous sentence 1 or 2 (responses in the second stage). "Yes" indicates the subjects who could detect the ambiguity at this stage. The subcategories under B in sentence 1 "boy" and "dog", indicate which reading each subject chose. The subcategories under B in sentence 2 , "instrument" and "place", indicate the instrumental or locative reading of "by the red telephone".

C: Responses to the unambiguous sentence 10 or 14 and the third check of ambiguous sentence 1 or 2(responses in the third stage).

"Yes"indicates the subjects who could detect the ambiguity at this stage. The subcategories under C in sentences 1 and 2 are the same as those explained in B.

D: Responses that indicate a complete failure in detecting the ambiguity in any of the stages.

Table 3 shows the average durations of the key segments, /d/, /a/, /g/ and /dag/ and those of the whole sentence in sentence 1. Table 4 shows the average durations of the key segments, /b/, /oi/ and /boi/, the pause after /boi/ and those of the whole sentence in sentence 2.

Table 3. Average durations (msec) of word segments and sentence

Durations		/d/	/a/	/g/	/dog/	Duration of a Sentence
Subjects						
1	a	73	181	57	311	1899
	b	76	185	74	335	1926
2	a	122	324	129	575	3143
	b	126	291	154	571	3462
3	a	77	220	91	388	2102
	b	62	221	101	384	2130
4	a	117	301	73	491	2321
	b	114	279	76	469	2335
5	a	53	299	677	1029	3251
	b	74	303	594	971	3216
6	a	117	267	185	569	2136
	b	110	265	83	458	2033
7	a	89	225	152	466	1999
	b	91	227	79	397	1788
8	a	89	189	62	340	1708
	b	90	189	63	342	1648
9	a	70	210	71	351	1717
	b	67	211	54	332	1766
10	a	84	272	85	441	2089
	b	78	279	59	416	1983
11	a	88	198	99	385	1978
	b	92	195	95	382	2002
12	a	90	317	116	523	2262
	b	80	207	69	356	1930
13	a	86	198	81	365	1857
	b	72	199	64	335	1722

(a) and (b) indicate the "boy" and the "dog" readings, respectively.

Table 4. Average durations (msec) of word segments, pause and sentence

Durations		/b/	/oi/	/boi/	Pause	Duration of a Sentence
Subjects						
1	c	77	135	212	56	2025
	d	85	179	264	75	2300
2	c	146	339	485	119	3237
	d	152	309	461	116	3465
3	c	95	204	299	75	2521
	d	83	220	303	66	2448
4	c	121	299	420	70	2678
	d	128	305	433	76	2822
5	c	104	347	451	543	3604
	d	94	306	400	630	3642
6	c	112	314	426	222	2674
	d	118	315	433	192	2570
7	c	111	227	338	125	2182
	d	107	248	355	103	2174
8	c	103	201	304	78	2049
	d	100	185	285	75	1996
9	c	86	209	295	77	1968
	d	98	193	291	75	1945
10	c	101	277	278	169	2498
	d	101	275	376	103	2469
11	c	99	185	284	81	2240
	d	103	183	286	75	2222
12	c	123	373	496	224	2561
	d	115	290	405	250	2343
13	c	75	287	362	303	2618
	d	93	271	364	361	2649

(c) and (d) indicate the "instrumental" and the "locative" readings, respectively.

First, we conducted an F-test to examine the correlations between the durations of the key segments and those of the whole sentence in the two readings of each sentence, a and b in sentence 1 and c and d in sentence 2. Table 5 shows the durations of /a/ and /g/ in /dag/ are correlated with those of the whole sentence in the (a) reading, while in the (b) reading, the durations of /d/, /a/ and /g/ are correlated with those of the whole sentence.

Table 5. Correlations between the durations of key segments and the whole sentence (Sentence 1)

	(a) reading	(b) reading
R ²	0.799241	0.768759
Coeffs.	/a/ 5.4837 /g/ 1.41476	/d/ 10.2389 /a/ 3.80941 /g/ 2.21579
Const.	634.75	96.9528
F	19.9055	9.9735
F(p1,p2,α)	F ² ₁₀ (0.05)	F ³ ₉ (0.05)

Table 6 shows that the durations of /b/, /oi/ and the pause after /boi/ are correlated with those of the whole sentence in the (c) reading, while in the (d) reading, the durations of /oi/ and the pause are correlated with those of the whole sentence.

Table 6. Correlations between the durations of key segments and the whole sentence (Sentence 2)

	(c) reading	(d) reading
R ²	0.783198	0.617823
Coeff.	/b/ 12.6557 /oi/ -.139872 pause 2.60397	/oi/ 5.18471 pause 1.13092
Const.	817.639	1043.05
F	10.8375	8.08295
F(p1,p2,α)	F ³ ₉ (0.05)	F ² ₁₀ (0.05)

As we hypothesized, t-tests for matched pairs showed that the key word /dag/ and the segment /g/ were significantly longer in the (a) reading than the (b) for the subjects who detected the ambiguity of sentence 1 in stage A. In addition, the segment /d/ was longer in (a) than in (b) ($p < 0.20$), though the difference was not statistically significant. For the rest of the subjects who did not detect the ambiguity in Stage A, none of the key word segments of the key word were significantly longer in the (a) reading than in the (b) reading. Table 7 summarizes these results.

Table 7. Results of the t-tests for Sentence 1

	Subjects in Stage A				Subjects in Stages B, C, D			
	/d/	/a/	/g/	/dag/	/d/	/a/	/g/	/dag/
Σd	33	104	285	422	-10	46	28	64
n	8	8	8	8	5	5	5	5
\bar{d}	4.13	13.00	35.63	52.75	-2.00	9.20	5.60	12.80
Sd	6.24	39.31	35.98	59.29	13.04	17.20	44.03	30.15
to	1.869	0.935	2.801 *	2.516	-0.343	1.196	0.284	0.949

p<0.05

Subjects in stage A: Subjects 6-13

Subjects in stages B, C, D: Subjects 1-5

Table 8 summarizes the results of the t-tests for matched pairs in Sentence 2.

Table 8. Results of the t-tests for Sentence 2

	Subjects in Stage A				Subjects in Stages B, C, D			
	/b/	/oi/	/boi/	pause	/b/	/oi/	/boi/	pause
Σd	-13	176	163	-94	-11	-58	-69	39
n	7	7	7	7	6	6	6	6
\bar{d}	-1.86	25.14	23.29	-13.43	-1.83	-9.67	-11.5	6.5
Sd	10.27	28.64	35.30	49.58	8.06	24.53	24.53	17.98
to	-0.479	2.322	1.745	-0.717	-0.556	-0.966	-1.148	0.885

p<0.05

Subjects in Stage A: Subjects 5, 8-13

Subjects in Stages B, C, D: Subjects 1-4, 6, 7

The key word /boi/ was longer in (c) than in (d) (p<0.10) for the subjects who detected the ambiguity of sentence 2 in Stage A, and the key segment /oi/ was also longer in (c) than in (d) (p<0.20) for the same subjects. For the rest of the subjects, the differences in the durations of the key segments, key word or pause were not statistically significant.

Discussion

As we hypothesized, our results indicate that the ability to detect the structure of ambiguous sentences is related to the motor control of timing. In other words, once a child learns these syntactic structures, he can control the speech timing. Conversely, if he fails in grasping the structures, he will also fail in the timing control. The possibility that a child could fail in the motor control in spite of his having acquired the syntactic structures was also disconfirmed.

Specifically, the durations of the key word and/or the pause in (a) of sentence 1 or (c) of sentence 2 were longer than those in (b) of sentence 1 or (d) of sentence 2. That is to say, the boundaries of the grammatical categories coincided with the speech boundaries (cf. 1. Linguistic materials in Experiment).

Further, we looked at the data for each sentence in detail. As already mentioned in the results for sentence 1, the duration of /g/ in /dag/ was statistically significant. Since the duration of /g/ includes the pause after the key word, it follows that the pause was used to disambiguate the two readings. Also, the results suggest that the subjects who responded in Stages B and C of the Syntactic test show an intermediate stage of timing control ability. Especially, this tendency can be seen in the vowel of the key word /dag/, whose coefficient was the highest.

The results of sentence 2 suggest that the subjects who responded in Stage A seemed to manipulate the grammatical boundaries by the duration of the key segment /oi/ and/or the pause. It should be added that Subjs. 6 and 7 admitted only one reading of sentence 2, the locative reading. Though they were included in the subjects of Stage D, they manipulated the speech timing by using only the pause.

Acknowledgement

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Appendix 1. Ambiguous Picture



Appendix 2. Reading Text

1. The boy chased the dog with a stick.
(The boy had a stick.)
2. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
3. The boy chased the dog with a stick.
(The dog had a stick.)
4. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
5. The boy chased the dog with a stick.
(The dog had a stick.)
6. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
7. The boy chased the dog with a stick.
(The boy had a stick.)
8. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)

9. The boy chased the dog with a stick.
(The dog had a stick.)
10. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
11. The boy chased the dog with a stick.
(The boy had a stick.)
12. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
13. The boy chased the dog with a stick.
(The boy had a stick.)
14. The boy chased the dog with a stick.
(The dog had a stick.)
15. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
16. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
17. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
18. The boy chased the dog with a stick.
(The boy had a stick.)
19. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
20. The boy chased the dog with a stick.
(The dog had a stick.)
21. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
22. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
23. The boy chased the dog with a stick.
(The dog had a stick.)
24. The boy chased the dog with a stick.
(The boy had a stick.)
25. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
26. The boy chased the dog with a stick.
(The boy had a stick.)
27. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
28. The boy chased the dog with a stick.
(The dog had a stick.)
29. Ann talked to the boy by the red telephone.
(The boy was close to the red telephone.)
30. The boy chased the dog with a stick.
(The dog had a stick.)
31. Ann talked to the boy by the red telephone.
(Ann used the red telephone.)
32. The boy chased the dog with a stick.
(The boy had a stick.)