TEMPORAL CONTROL IN SPEECH OF CHILDREN AND ADULTS

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ABSTRACT

Speech utterances of children and adults are compared with respect to phonologically short and long vowels, voiced and voiceless plosives, and the interaction between vowel duration and following consonant. It appears that four-year-old children and, to a lesser extent six-year-old children have not yet mastered the temporal control of these vocalic and consonantal segments. Results are interpreted in terms of a developing timing mechanism.

1. INTRODUCTION

From a segmental and suprasegmental point of view, acoustic-phonetic research of young children's speech utterances contributes to a better understanding of the development of speech motor control such as phonetic timing [1]. Phonetic timing concerns start and duration of phonetic intervals such as vowel duration, syllable duration, etc. [4]. One of the most appropriate instruments to investigate the timing mechanism in speech, as well as to study the development of this mechanism, are durational analyses of the utterances and their segmental constituents. Different linguistic factors will affect the duration of single phonetic intervals; concerning phonological features that serve to distinguish words (e.g. the short-long opposition in vowels, voicing and also contrastive stress) length is one of the main characteristics and influences duration of phonetic intervals.

Concerning developmental research, several studies have shown that children have a slower speaking rate and that segmental durations are longer and more variable than those of adults [7]. These temporal parameters approach the adult norm with increase in age [1], [5]. Most studies make use of an *imitation* procedure with nonsense words or a sentence repetition task. This in order to compare in a direct way young children's data to adult data and to control for the set of utterances across ages.

However, the phonological features of the child's speech utterances will be reflected by durational values that are appropriate to his/her own developing mechanism [1]. Therefore, we chose to make use of *spontaneous* but controlled speech utterances instead of imitative speech. In this paper we want to emphasize two aspects that relate the linguistic parameters of 'vowel length' and 'voicing' in Dutch to the phonetic-acoustic cues 'duration of the vowel' and 'duration of the closure'. As will be evident, short and long vowels differentiate in short vs. long duration while voiced and voiceless plosives are characterized by short vs. long closure duration [4].

Firstly, two basic questions can be formulated as follows: 1) how do young children handle durational values of short vowels as opposed to long vowels and 2) how do they handle differences in closure duration of intervocalic voiced and voiceless plosives?

Secondly, the contextual effect of lengthening of the vowel preceding a voiced consonant (short closure) and shortening of the vowel preceding a voiceless consonant (long closure) will be examined in the utterances of children and adults. This phenomenon, which is known as temporal compensation [4] is not inherent to the phonological system of Dutch but is considered to be an articulatory coordination. One of the claims to be made is that the temporal coordination between V and C is only mastered gradually by young children.

2. METHOD

2.1. Subjects

Four different age groups participated in the experiment: four-, six- and twelve-year-olds, plus adults. So far, only results of the two youngest age groups and adults are available and will be presented here. Each group consisted of six subjects, equally divided over male and female speakers. All of them were monolingual speakers of Dutch and none of them was judged to have any hearing loss or speech disorder. All subjects lived in the same area of the South-East of the Netherlands.

2.2. Material

Data are presented that refer to a set of 28 meaningful words. They are all two-syllabic (C)V$CV(C) words with lexical stress upon the first syllable ($=syllable boundary). The intervocalic consonant was either a voiced plosive, that is /b/ or /d/, or a voiceless plosive, that is /p/ or /t/, e.g. the words 'kabel' (cable) vs. 'stapel' (pile). In approximately half of the words the vowel preceding the intervocalic consonant was a phonologically short vowel /ɑ/, /ɔ/, /ɛ/, or /ɪ/, otherwise it was a long vowel /a/, /o/, or /e/. Experimental research with young children imposes several constraints upon the selection of meaningful words to be used: No exact minimal pairs could be found, 11 words with intervocalic voiceless plosives and 17 words with intervocalic voiced plosives were selected (among which optimally matched pairs), the initial consonants were not always identical and we had to make choices of one-morphemic as well as two-morphemic words. To avoid an imitation procedure all the words were elicitated by picture cards.

2.3. Procedure

The elicitation procedure was based upon pictures drawn on separate cards. In all age groups we chose for the same procedure and all subjects pronounced the same set of words. The words were elicitated by questions or sentences that had to be completed only by the word itself. This task would account for a spontaneous but controlled speech production without imitation whatsoever.

2.4. Recordings

Recordings of the four-year-old children were made at home with a Tandberg recorder and a microphone Sennheiser MD21HN. The six- and twelve-year-old hildren and the adults were recorded in a laboratory setting with a Revox A77 recorder and an electrolaryngograph to registrate the exact timing of the vocal pulsing. All subjects were recorded twice and both recordings were used for analysis. Even four- and six-year-old children pronounced 'correctly' 90% of both voiced and voiceless plosives; i.e. during segmentation both visual and auditory information indicated that neither substitution of voiced by voiceless plosives had taken place (and vice versa), nor any deletion of intervocalic plosives.

2.5. Measurements

The synchronous audio- and electro-larynx signals were stored digitally on a microVAX II computer and the speech editing system provided visual and auditory information for segmentation. To be consistent in measurements we always concentrated upon the oscillographic signal using the traces of laryngeal activity for verification. In this paper we report on the following measures:

- vowel duration preceding intervocalic voiced and voiceless plosives
- closure duration and burst duration of the intervocalic plosives
- word duration

We do not want to dwell upon the criteria used for segmentation; they can be found in [2] and are in accordance with most criteria used in literature.

3. RESULTS

3.1. Vowel duration

Mean durations of the separate vowels, as well as mean durations of short vowels pooled and long vowels pooled, are presented in Table I. As can be deduced from the data, vowel durations between the age groups differ considerably.

Between the four- and six-year-old children no significant difference was found in overall vowel duration. Vowels of four- and six-year-olds were significantly longer than those of adults [$F(1,10)=36.20;p<.001$ and $F(1,10)=35.42;\ p<.001$]. Between four-year-olds and adults a 76% reduction of short vowels and a 47% reduction of long vowels was found; between six-year-olds and adults reductions of 52% and 36% respectively was found. The short-long opposition, which is an important phonological feature in Dutch, was clearly present in all age groups and the relative durational differences between short and long vowels was quite similar in the three age groups.

Table I. Mean durations in ms. of all vowels in the age groups. Below mean durations of short and long vowels are indicated as well as the ratio.

Short vowels	4	6	adults
/ɑ/	147	125	84
/ɔ/	146	120	81
/ɛ/	152	128	87
/ɪ/	140	119	79
Long vowels			
/a/	239	217	159
/o/	218	184	140
/e/	234	184	140
short	146	121	83
long	233	206	152
ratio	0.63	0.59	0.54

In Fig.1 we have indicated this short - long opposition across ages. We can see that both types of vowels shorten in the same amount with age.

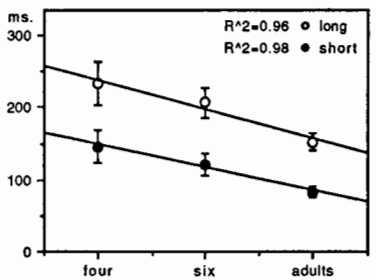

Fig.1 Reduction of short and long vowel duration across groups; regression lines predicting reduction of 'vowel duration' from 'age'.

Regression analysis of the variable 'vowel duration' upon 'age' shows that the proportion of variance of short and long vowel duration can be perfectly predicted from age ($R^2=.96$ and $R^2=.98$)

3.2. Closure duration

Closure duration of the intervocalic plosives /p,t/ and /b,d/ are compared in Fig.2. As a measure of contrast, the ratio voiced/voiceless closure duration was calculated. In par. 3.1 we have shown that the ratio short/long vowel duration *decreases* with age, i.e. the contrast increases with age. Contrary to this vocalic opposition, the contrast in consonantal closure for /b/ vs. /p/ *increases* with age form 0.58 to 0.66 to 0.72 and for /d/ vs. /t/ from 0.50 to 0.59 to 0.68.

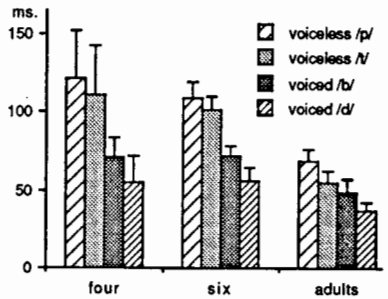

Fig.2. Mean closure durations in ms. for voiced and voiceless plosives in three age groups.

Overall closure duration and relative differences between voiced and voiceless closure durations show no significant differences in speech of four- and six-year old children. Analyses of closure durations between four-year-olds and adults as well as between six-year-olds and adults show significant differences at $p<.01$ or beyond, for both overall duration and relative differences between the voiced and voiceless plosives. Lengthening of the closure durations in speech of young children is certainly commensurate with their slower speaking rate. However, analyses of covariance, with word duration being the covariate and a measure of speaking rate, indicated that differences could not be attributed to speaking rate alone. Probably, some effects due to age and to developmental structure also had an influence.

3.3. Vowel duration as a function of the following consonant

The three age groups were compared in their use of vowel duration as a function of the following voiced and voiceless plosive. In Fig.3a, 3b, and 3c behaviour of short and long vowels is plotted for all subjects in the three age groups.

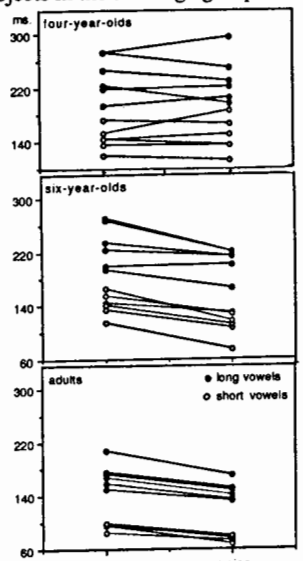

Fig.3a-c. Mean durations (in ms.) for vowels preceding voiced and voiceless consonants in the three age groups Each line represents vowel durations of one subject.

It will be clear that four-year-olds behave very differently from the older children and the adults [$F(1,10)=37.28;p<.001$ and $F(1,10)=36.20;p<.001$]; they do not make any distinction between vowel duration in a voiced or voiceless context. And, it is interesting to see that between the ages four and six a shortening of the vowel occurs only before voiceless consonants while vowel durations before voiced consonants remain the same.
Between six-year-olds and adults vowel duration reduces almost in the same amount whether preceding a voiced or a voiceless plosive. Analyses of covariance, with word duration being the covariate, indicated that differences in vowel duration preceding a voiceless plosive was not only determined by speaking rate but, again, by some effect due to developmental age.

4. DISCUSSION

Durational values of short and long vowels and voiced and voiceless closures in speech of three age groups were examined in relation to the phonological oppositions of 'vowel length' and 'voicing'. The children's relative temporal structure of short vs. long vowel seems to be acquired before the age of four while relative closure durations of voiced vs. voiceless plosives are still in a developmental stage by the age of six. And, contrary to studies using an imitation procedure [6], the spontaneous productions of children are different from those of adults: between the ages of four and six, timing of vowel and consonant in VC sequences becomes adult-like by restructuring vowel duration preceding voiceless consonants.

5. REFERENCES

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