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ABSTRACT

The phonemic effects of word length, consonant-vowel structure, syllable structure, and meaning on word segmentation were investigated in two experiments with young children. The decentration hypothesis, which predicts that children who habitually direct their attention to word meaning would concentrate better at analyzing a spoken form without meaning (a pseudo-word) and would perform better on pseudo-words than on existing, structurally similar words, was tested. Results provide strong evidence that an onset-rime distinction is relevant for the process of segmentation, and word meaning seemed to have no influence, suggesting that the decentration hypothesis can be abandoned as an explanation for segmentation difficulties. It is concluded that effects of length and syllabic boundary can be explained by the disruptive effect of consonant clusters, which are not only difficult to segment by themselves but also adversely affect the processing of segments earlier in the word, and that a simple, strictly serial model for segmentation is not adequate. The results also indicate that an articulatory rather than phonological code is the object of segmentation. (MSE)

Phonemic Analysis: effects of word properties

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Introduction.

A central component in learning to read and write is to learn grapheme-phoneme correspondences and how to apply them. Learning to read involves translating letters and letterclusters in corresponding phonems blending them into a spoken word. Learning to write involves both determining the sequence of phonemes within a spoken word, and translating those into letters and letterclusters.

Of course, this applies only in so far as the learner uses a 'phonological' route, that is, by way of the constituent phonemes. The 'lexical' route is a possibility too; the unit of processing is not the letter or the phoneme in this case, but the word itself. This is the typical strategy for experienced readers. However, experienced readers use the phonological route too, for instance with infrequent words that have not yet their own access route. In the Dutch educational system, however, beginning readers learn to read by way of the phonological route, though it appears that beginning readers do use the lexical route too (Reitsma, 1983). In learning to write the start will be a phonological route too, followed later by a lexical route for many, but not all words (Frith, 1980; Simon, 1976).

In the development of learning to read and to write there are moments where it is crucial to have the fundamental understanding of the sound-structure of spoken words that is necessary for segmenting a spoken word into its consituent phonemes; a task that we will call phonemic analysis. To test this ability a subject is asked to produce in the right order the phonemes of a given, auditorily presented word (e.g., /pet/ into /p/ /e/ /t/)[3]. Formulated this way the task is very similar to those that are used in the first stages of learning to read and write. There have been developed a few other tests to tap 'phonemic awareness' (see below). Phonemic awareness as measured with such tasks, appears to be correlated rather strongly with reading ability (e.g., Liberman, Shankweiler, Fischer, & Carter, 1974; Rispens, 1974; Helfgott, 1976; Calfee, 1977; Bradley & Bryant, 1983, 1985; Fox & Routh, 1983; Beech & Harding, 1984; van Dongen, 1984) and writing ability (e.g., Bradley & Bryant, 1983, 1985; Fox & Routh, 1983; Perin, 1983; van Dongen, 1984).

A question then, is the following. Is the development of the ability to segment a (necessary) prerequisite for learning to read and write, or is it a consequence of learning these abilities, or are both these abilities themselves a consequence of the same cognitive development (Ehri, 1984)? Empirical research indicates that skills in phonemic segmentation primarily are caused by, and develop during, schooling in reading and spelling (see, for example, Cary, Algria, & Bertelson, 1978; Ehri, 1984; Perin, 1983; Tunmer & Nesdale, 1985). It seems therefore, that it is not a precondition that has to be fullfilled. On the other hand, it appears that actual performance in reading and writing is dependent upon skills in segmentation, and that performance can be improved by training in the skill of phonemic analysis.

This empirical relation between phonemic segmentation and reading and writing ability imparts practical relevance to the question why young children cannot perform phonemic segmentation and especially why some children have severe problems with this task, while their peers seem to have mastered this completely.

Generally the concept of 'metalingustic awareness' is introduced to explain why relatively late after having learned to speak and understand children come to the realization that a spoken word can be segmented into phonemes and master this skill. They do not yet posess "... the ability to reflect upon and manipulate the structural features of language, treating language itself as an object of thought, as opposed to simply using the language system, to comprehend and produce sentences" (Tunmer & Nesdale, 1984, p. 12). Both

[3] All our examples use Dutch materials. In Dutch there is a rather higher regularity and systematicity in grapheme-phoneme correspondence rules than in English.

speaking and listening, one genearlly is only aware of the final products of these activities. The transformation of one into the other, the mental processes involved, the stages revolved, all are inaccessible to perception, are 'transparent' (Cazden, 1976). Generally a speaker is not aware of the individual sentences, words, and phonemes that constitute an utterence, nor is a speaker aware of structural relation between the words and sentence constituents. These units and their relations only reach awareness as a consequence of intentionally directed attention. Phonemic awareness, i.e. realization that a spoken word can be segmented into phonemes and the skill in performing this act form, according to this view, an instance of metalinguistic awareness with phonemes as the objects of reflection.

Metalinguistic awareness of linguistic properties does not come about at similar points of time as development in using these properties (van Kleeck, 1982) and reading- and writinginstruction (Donaldson, 1978). An essential cognitive prerequisite for the development of metalinguistic skills is the ability described by Piagetian notion of 'decentration' (see Van Leent, 1983; Lundberg, 1978; Valtin, 1984; Vellutino, 1979). Children in the pre-operative stage would tend to direct their attention to one single salliant aspect of an object of perception or reasoning, to the detriment of other aspects. The transition to the stage of concrete operations (7-11 yrs) would be characterized by the development of the ability of decentration, that is the ability to shift attention and the possibility to consider different aspects (Flavell, 1963).Previously the attention of the child would be directed to the meaning of a linguistic object as a salliant property; after having mastered decentration the child would be able to direct its attention to the form of the linguistic object and would thus acquire metalinguistic abilities. According to this decentration hypothesis, problems in phonemic segmentation would not arise because of properties of the task itself, but would arise in orientation of the attention.

The often reported bimodal distribution in the performance of metalinguistic tasks and the correlation between develópment of metalinguistic awareness and the ability to perform Piagetian conservation tasks (Hakes, Evans, & Tunmer, 1980) support this decentration hypothesis. Decentration and phonemic awareness cannot explain, however, why some children who have severe problems in mastering the skill of phonemic segmentation, nevertheless will be able to segment some words flawlessly. Van der Wissel (1984) has shown that children with extremely severe problems still perform way above the theoretically possible minimum score. They still could analyse some words perfectly and thus possessed the (metalinguistic) knowledge that a spoken word can be segmented into phonemes. Other causative factors play a role, which perhaps can also explain why some children develop metalinguistic awareness rather late. It is not known which factors actually make phonemic segmentation a difficult task. Much research has been done on the development of phonemic analysis and its relation with (problems in) learning to read. There has been remarkably less research, however, on the segmentation process itself and the influence of wordproperties on this process.

There are some results, however. Some authors report on the relative difficulty of different phoneme positions (Skjelford, 1976; Helfgott, 1976; Lewkowicz & Low, 1979; Williams, 1980; Stanovich, Cunningham & Cramer, 1984; Bradley & Bryant, 1985). The results are not clear-cut, though the initial phoneme of CVC's seems easier to segment than its final phoneme. Explanations offered, mention either certain auditory on articulatory properties (e.g., Helfgott, 1976) or certain taskspecific factors (e.g., Bradley & Bryant, 1985).

The relative difficulty of some phoneme categories has been reported too with some contradictory results. Continuants are more easily segmented than stops (Skjelford, 1976; Marsh & Mineo, 1977). Lewkowicz & Low (1978) and Stanovich et al. (1984), however, found no difference. Marcel (1980) reports a specific problem with the spelling of liquid and stopconsonants in clusters at the beginning of a word, and nasal and lateral consonants in clusters at the end of words. The errors made seem to reflect certain special phonological distinctions that these writers make.

The distinction between existing words and pseudowords has also been investigated to determine the influence of the visual word pattern. Perin (1983) obtained no differential effect but Tunmer and Nesdale (1985) report an advantage for existing words.

The studies mentioned here, and many others on phonemic awareness, employ a diversity of experimental tasks: counting the number of phonemes in a spoken word; pronouncing the word either without initial, or final phoneme; replacing a specified phoneme by another one; phoneme monitoring; rhyme monitoring, exchanging initial or final phoneme of two different words; pronouncing the sequence of phonemes of a given word. Though many of these tasks seem to have a 'common core' (Stanovich et al., 1984) it is probable that they will produce different results at some specific points. With respect to the relative difficulty of different phoneme positions, for instance, Skjelford (1976), Williams (1980), and Stanovich et al. (1984) indicate that the initial consonant in CVC's is easier to segment while, using a different task, Bradley & Bryant (1983, 1985) report an advantage for the final consonant of a CVC.

Following Liberman (1973), the 'tapping' task or modifications thereof, have often been used. In this task the subject should tap out the number of phonemes or syllables in a word, or indicate this number by producing a number of markers. This task is considered to be a more 'clean test' (Tunmer & Nesdale, 1985) than a task in which the phonemes have to be pronounced consecutively, since the phonemes that have to be pronounced are only very rough approximations of the phonemes within the spoken word. There are, however, a number of important questions which cannot be answered using the tapping task because it gives no information about the way segments are categorized by the subjects. Furthermore, it is questionable whether the relation between taps and phonemes is indeed of a less abstract nature, given also the problems which children have in counting synchronuously. Finally, a tapping task does not induce the necessity of labeling the segmented phoneme, so that the subject can more easily lose his place in the word to be segmented.

In the two experiments presented here the task for the subjects is to pronounce the phonemes of auditorily presented words. The reason for this is twofold. One reason is to use the same task in different experiments to ensure comparability of results, and the other reason is that the task used here is of greater relevance for educational instruction.

Experiment I.

The purpose of this experiment was to investigate the effects of task and word variables upon phonemic segmentation. Our aim is to get in this way more information how the process of segmentation is carried out.

The decentration hypothesis predicts that children who habitually direct their attention to the meaning of a word, would be able to concentrate better on the task at hand when they would analyze a spoken form without meaning. They would perform better on pseudo-words than on existing, structurally similar, words.

Wordproperties like length or syllabic structure can be investigated by complete segmentation of the word. Effects obtained could then be ascribed to processes within response preparation and response generation. If similar effects would be obtained, however, when subjects only have to produce the word initial phonemes, then explanations which employ the notion of Working Memory seem to be called for. Both taskvariants (complete segmentation and segmentation of inital phoneme only) have been employed therefore.

Wordproperties that might be relevant for phonemic segmentation (especially because they could influence the capacity of Working Memory) are among others: length, syhllabic structure and CV-structure. With respect to CV-structure the hypothesis has been offered in the literature that a syllable linguistically can be considered as consisting of an optional 'onset' (initial consonant or consonant cluster) and a necessary 'rime' (vowel plus possible consonants). This partition would also be relevant in speechperception and -production (Treiman, 1985). Onset and rime would be the primary constituents of a syllable. Phonemic segmentation on the boundary between onset and rime would be thus easier than segmentation within such a perceptual or productive constituent. Treiman has obtained some supportive evidence, but this was obtained with a variant of the phoneme monitoring task and not by phonemic segmentation as such. Helfgott's (1976) result that CVC patterns are easier to segment into C-VC than into CV-C, however, supports Treiman's hypothesis.

Though our results could also be analyzed qualitatively, we restrict ourselves here to the quantitative results of our investigations.

Method.

Subjects.

Subjects were 50 children from a primary school in Nijmegen, 26 boys and 24 girls. Their mean age was 6;3. The experiment was carried out in November. Given the Dutch educational system this entails that they had received about three months of reading and writing instruction.

Materials.

Starting point were thirty existing words that according to a target list (Kohnstam et al., 1981) would be known to this age group. Twelve of these were 'short' words (3 phonemes) and eighteen were 'long' (5 phonemes). The short words consisted of 4 CVC words, 4 VCC words, and 4 CCV words. The long words were mono- or bisyllabic. Of the monosyllabic words 8 were of the CCVCC type, 2 were of the CVCCC type, and 2 were of the CCCVC type. Bisyllabic words started with a CV pattern with one exception which started with a VC pattern.

By exchaning vowels, consonants, and consonant clusters thirty pseudowords were created which were phonotactically legal. Table 1 presents the actual word materials used.

Insert table 1 about here

Procedure.

All children analyzed all words and pseudowords. Half were fully segmented, of half only the initial phoneme was segmented by each subject. The design was such that, across all subjects, each word was segmented completely or only initially equally often. Each subject analyzed equally often existing and pseudowords of each structure. Order of presentation of the stimuli was randomized for each subject. Half of the subjects performed complete segmentation first, followed by initial phoneme segmentation; the other half of the subjects the reverse order. The two tasks were carried out in two different sessions, a number of days apart.

For the task of complete segmentation the instruction was: "... to say the little parts that you can hear in a word ...". This was explained using seven practice items (both words and pseudowords). The experimentor then pronounced each stimulus item. The segmentation as carried out by the child was both recoreded on tape and recorded on paper. The time necessary for complete segmentation was determined with an electornic stopwatch.

For the task of initial segmentation the subjects were instructed to say "... the first little part" of a word. This was practised again with seven items. Then the experimentor pronounced each stimulus items and wrote down the reaction of the subject.

Results.

Table 2 presents for each task and wordcategory the proportion of correct responses. Table 3 presents the time subjects needed for complete segmentation for the different wordcategories (computed across correct segmentations only). Reactiontimes (RT's) differing more than 2.5 standard deviations from their cell mean were discarded. Assuming that segmentation time and difficulty of the segmentation are correlated one can expect that selective drop-out (the most difficult categories will produce most drop-outs) leads to a systematic distortion in the mean RT's. For each wordlength, therefore, means were computed across 'complete cases', that is, across those subjects that segmented for each word category one or more words without error. Tables 4, 5, and 6, furthermore, present the results of a number of ANOVA's that were carried out on these data.

Insert tables 2, 3, 4, 5, and 6 about here

Existing vs. pseudowords.

The decentration hypothesis predicts that pseudowords should be segmented faster and with less errors than existing words. For complete segmentation the difference is, however, in the opposite direction: performance on existing words is better than on pseudowords (.47 vs. .44). Wordlength seems to play a role here; for shorter words the difference is significant (see table 4b), for longer words it isn't (see table 4c). Segmentation time too, gives results that are inconsistent with the decentration hypothesis: if there is a difference at all, it is in the direction that pseudowords take longer to segment, again especially with the shorter words (table 6b) and not with longer words (table 6c). The results of segmenting the initial phoneme show the same pattern: a difference in the wrong direction, significant for shorter words only.

For any given wordlength none of the interactions with other structural variables was significant.

The decentration hypothesis can therefore be abandoned, unless the children that have been investigated, would already function in the concrete/operational stage where decentration does not pose problems anymore and where they can shift their attention so easily from meaning to form that using pseudowords would not facilitate the task at hand. Since, however, the concrete/operational stage starts at about the age of eight years (Flavell, 1963) and given the mean age of our subjects of 6;3, this is very probably not a reasonable assumption. A second possibility would be that we have not adequately tested the decentration hypothesis by using pseudowords. The decentration hypothesis then needs to be specified much more specifically to allow better testing.

Remarkable is that a positive effect of meaningfullness is only obtained for shorter words. Shorter words have more phonemically similar neighbours than longer words. (Of all phonotactically possible strings of three phonemes in Dutch, 27% have meaning; only 1% of all phonotactically possible monosyllabic patterns of five phonemes as were used in our research have a meaning.) Short pseudowords have therefore more neighbours which are words than longer pseudowords. Meaningfullness would thus not affect the process of segmentation itself directly, but could influence identification of the auditory pattern or could influence its processing in working memory.

Number of phonemes: 3 or 5.

Table 2a shows a (significant) advantage for the complete segmentation of shorter words both in terms of percentage correct (table 4a) and segmentation time: 1.9 vs. 2.6 sec.(computed across the 9 'complete cases'). These results were to be expected.

The influence of wordlength on performance in segmenting the initial phoneme only, is less self evident: performance is better for short words. Thus right at the onset of segmentation the length of the word(rest) plays a role. A reason could be that with longer words more phonemes compete for the status of initial phoneme. Longer words would, according to this account, thus lead to problems in selecting where to start segmentation. Another possibility is that the rest of a word occupies an amount of space in Working Memory which varies with the length and other structural properties of the word rest.

Number of syllables: one or two.

Longer words were either mono- or bisyllabic. Complete segmentation of bisyllabic words is performed significantly better than segmentation of monosyllabic words (tables 2a and 4c). Bisyllabic words do not take significantly more segmentation time than monosyllabic ones. Also with segmentation of initial phoneme only, bisyllabic words are easier. This facilitatory effect of a syllable boundary could be explained as a result of the diminishing of the selection problem mentioned before; the start of the word can now be determined from the (shorter) first syllable. An alternative explanation would be that a word rest would cost Working Memory less capacity when a number phonemes in it are represented as a syllabic unit. An increase in segmentation time can be expected when the segmentation into two syllabic units would also take time.

Short words: rime-onset boundary.

The shorter words consisted of two consonants and a vowel. They consisted of one of the three patterns: CVC, CCV, and VCC. If onset and rime would be the primary constituents of the syllable, then in the complete segmentation of CVC and CCV types, segmentation would cross a constituent boundary and would therefore be facilitated by this presence of an onset-rime boundary, while for VCC types segmentation would take place completely within a perceptual and/or productive unit. Tables 2a and 4a show a significant difference in terms of percentage correct for strings that contain an onset-rime boundary. The difference in segmentation time is not significant.

In segmentation of the initial phoneme one would expect an onset-rime advantage for CVC types but not for CCV types because in the last case the onset-rime boundary does not coincide with the place of the intended segmentation, the boundary between first and second phoneme. The computation of the contrast between CVC compared with both CCV and VCC types shows indeed a (marginally) significant difference.

Summary and discussion.

The wordproperties under investigation indeed influence performance in phonemic segmentation. Pseudowords are more difficult to analyze than existing words when both are 3 phonemes long. The difficulties with short pseudowords only, suggest the role of identification problems or problems in keeping the string to be segmented in Working Memory. This interpretation would indicate a potential problem for children with reading problems. One of the ways in which they differ from other children is by having more problems with identification and discrimination of speech (Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Brady, Shankweiler, & Mann, 1983). Using pseudowords will affect dyslectic children therefore more negatively than other children.

Other word properties play a role too. Longer words are more difficult to segment than shorter ones. Furthermore less errors are made in the segmentation of both syllabic words and syllabic pseudowords.

Effects of wordlength and syllabic structure are also obtained in the task where only the initial phoneme has to be segmented. This suggests that at a very early stage in the segmentation process properties of the rest of the word play a crucial role, either by influencing some limited capacity process or store, or in terms of the size of the unit in which the initial phoneme has to be located.

At this point, however, a rather different type of explanation has to be discussed. Some of our effects can also be explained by the existence of consonantclusters in the materials. Consider mono- and bisyllabic words consisting of five phonemes, for instance. The crucial difference between these two categories lies in the number of vowels; either one or two. Given the same length, bisyllabic words have by definition an extra vowel. Furthermore, with bisyllabic words, consonants can occur at one more place, that is, between the two vowels. Bisyllabic words have, in general, therefore less clusters of consonants. Monosyllabic words of equal length have either two clusters of consonants, or a large cluster of three consonants. Clusters of consonants seem to be difficult to analyze. Carver (1967, mentioned in Valtin, 1984) concludes, for instance, that a consonant is more difficult to identify when followed by another consonant then followed by a vowel. Similarly, Marcel (1980) found problems in the segmentaion of consonant clusters.

The differences in segmentation of monosyllabic and bisyllabic words that we have obtained could thus be caused by a difference in number and size of consonant clusters.

The same holds for the effect of word length. The number of clusters in our longer words is almost three times that of the number of clusters in shorter words. Consider segmentation of the initial phoneme only. There is no difference between short and long words which start with the sequence CV. However, there is a significant difference ($t(49) = 1.75$, $p \leq .05$) between short and long words which start with the sequence CC (CCV vs. CCVCC), with worse performance on longer words. The effect of wordlength on segmentation of the initial phoneme can therefore not be contributed entirely to the nature of the beginning of the word. Effects of wordlength were, however, in experiment I confounded with other factors, except for only a limited number of words. Effects of wordlength will therefore be examined again in experiment II for a larger number of words starting with a CV-sequence.

Differences between the three different types of three phoneme words used in our experiment were in correspondence with the hypothesis of the distinction between onset and rime. Again these findings can also be explained by the assumption that consonantclusters determine the difficulty of segmentation. Given the materials used in experiment I, this possibility is not testable. In experiment II the onset-rime hypothesis will be tested again with words of equal length which have no consonant clusters. We wil see there that the onset-rime boundary indeed facilitated the segmentation process.

When we compare segmentation of the complete word with segmentation of the initial phoneme only, then for CVC words increasing the number of phonemes to segment does not influence performance that much (.91 vs. .95). Some large effects were obtained with words of VCC and CCV type: for these complete segmentation is much more difficult than segmenting the initial phoneme. In the case of the VCC-type this can be explained by the fact that only for complete analysis the difficult cluster had to be segmented. But this does not hold for the CCV-type words; here the difficult cluster has to be segmented in both tasks. Segmenting the first phoneme may be more difficult from a cluster than from a single consonant or vowel (.87 vs. .95 and .95 correct) but it has to be the segmentation of the second consonant that caused the small proportion of correct answers

(.47) in complete segmentation of CCV words. (It is improbable that this low performance is caused by the presence of the vowel, because otherwise performance in complete segmentation of CVC-type words, or initial segmentation of VCC-type words would also be at a similar low level.) Some results of Marcel (1980) support this idea.

Conclusion: apart from contrary results with respect to the decentration hypothesis and support for Treiman's analysis of the syllable in term of onset and rime, our data point to the possibility that it is especially the occurence of consonant clusters that causes problems in phonemic analysis. Possible effects of wordlength and syllabic structure should therefore be investigated in a way that the presence of consonant clusters is controlled for.

Experiment II.

The first experiment has shown that in segmenting the initial phonemes from a word, its length and syllabic structure can influence performance. The effects obtained, however, could also be explained as resulting from the presence of difficult to analyze consonant clusters.

The way in which properties of the word rest influence analysis in an earlier part of the word can tell us something about the way the process is carried out. No effect indicates a serial process in which each phoneme is sequentially identified and in which a later occuring phoneme only can influence processing in as far as it belongs with the preceding phoneme to a configuration that is difficult to segment (as is the case with consonant clusters). If there is an effect then this would point to the possibility of a process which is not strictly serial. An adverse effect of longer words would indicate that the wordrest is stored decomposed into units in Working Memory. A positive effect of a syllable boundary in the wordrest would be expected when syllables would be stored as undecomposed units which will only be analyzed further when their phonemes should be identified. Syllabification, therefore, might cost time, but would decrease the load on Working Memory.

In experiment II effect of length and syllable boundary were investigated using words which started with an identical pattern (CV), but which differed in length and with respect to the occurence of a syllable boundary (CV, CVC, CVCC, CV-CVC, CVC-CVC). We investigated whether accuracy and RT for analyzing the first two phonemes (the same CV pattern) differed as a function of the above mentioned properties of the word rest.

On the assumption of an effect of length WIE should be easier to segment than the corresponding part WIEL. If a syllable boundary facilitates segmentation, than the effect of the increase in length going from WIEL to WIELEN should be less than would be predicted purely by its increase in length (which would be twice the effect of increasing WIE to WIEL). In both cases the string WIE is increased by one element, in one case a phoneme, in the other case a syllable unit. The same reasoning applies to the prediction that BA in BAL is more easy to segment than BA in BALK and that BA in BALK maybe faster but nog more accurate than in BALKEN. In triplets of the type WIE, WIEL, WIELEN performance on the initial CV will be better than in triplets of the type BAL, BALK, BALKEN because these have one phoneme more. There is no interaction predicted between base word (CV or CVC) and type of lengthening (none, plus -C, plus -CVC).

One other point might be important to note here: Dutch children tend to segment words of the type -VCV- before the consonant (van den Broecke, & Westers-van Oord, 1985).

The results of the first experiment were as predicted by the onset-rime hypothesis, but could also be explained by the presence of consonant clusters. In experiment II this hypothesis was tested again, but now using words which consisted only of a vowel and a consonant. The prediction is that CV words will be easier to segment than VC words with the same phonemes, because for CV words the boundary for the first segmentation coincides with the primary boundary between syllabic constituents (onset and rime) while for VC words all segmentation takes place within a consituent which thus provides no facilitating constituent boundary.

Method.

Subjects.

Subjects were 48 children from a primary school in Nijmegen. Their mean age was 6 years, 4 months. The experiment was carried out in November, thus the children had received about three monthse of formal instruction in reading and writing.

Materials.

The basematerial consisted of a list of 30 CV words and 30 CVC words. They were chosen such that existing words could be formed from them, by adding a consonant or CVC pattern. Table 7 presents these base words together with the words that were derived from them.

Insert table 7 about here

The base words and their 'derivations' were in general known to our subjects according to the norms of Kohnstam et al. (1981). The CV words and their derivations did not differ from the CVC words and their derivations with respect to estimated familiarity.

Adding the derivations resulted in a master list of 180 words. From this list three lists of 60 words were composed. Each list consisted of ten base words of each pattern (CV or CVC); twenty words that were formed by adding a consonant to ten other base words of each pattern; to the remaining twenty basewords a CVC pattern was added. From each list two randomly chosen different presentation orders were determined. All in all this resulted in 6 lists of stimuli.

Ten of our CV words produced in reverse order an existing VC word. Two additional reversible CV words were added. These two combined with the 12 VC words were divided into two groups. Words of one group were added to one of the two random orders of one basic list, the words of the other group to the other random order of that basic list. Each list presented finally to a subject thus contained 67 words.

Procedure.

The words in each list were analyzed by 8 subjects. The instruction was to say "the little parts that you can hear in a word" and to try to start as soon as possible. Then some practice was carried out with similar material. Then each stimulus word was presented with a taperecorder. A list was presented in two sessions. Each session was also recorded on a taperecorder.

A response was scored as correct when the first two phonemes (CV or VC) were correctly identified. RT was measured from stimulus offset to completion of the second phoneme with the aid of electronic stopwatches.

Results.

Tables 8 and 9 show the proportions of correct responses and the RT's. RT's tha differed more than 2.5 standard deviations from their cell mean were discarded.

Assuming that RT's correlate positively with the difficulty of segmentation, one car expect that selective drop-out distorts the RT's. The mean RT's in each task are computec therefore across 'complete' cases, i.e., across those subjects that analyzed at least 40% o the words within a catgory without error. Tables 10 and 11 show the results of some MANOVA's.

Insert table 8, 9, 10, and 11 about here

Length and syllable boundary.

The results were only partly as predicted. The first two phonemes from patterns with CV as a base word were analyzed better than the first two phonemes from patterns with CVC as a base word. The RT's did not differ significantly. A signifiant effect for type o lengthening (none, plus -C, plus -CVC) was obtained, both for proportion correct anc for RT as the dependent measure. The interaction of base word and type of lengthening is also significant, both for proportion correct and RT. The difference in accuracy between base word and base word plus -C differs with respect to the type of base word. The same holds for the difference in accuracy between base word and plus -C and base word plus - CVC. With RT as the dependent measure there is only a sifnificant interaction betweer base word and lengthening with either -C or -CVC.

This pattern does not fit our predictions that either the full word is preprocessed o that the word is segmented serially. The main effect of type of base word argues against a strict serial model as does the main effect of lengthening of CVC-type base words Increasing the length of a word can influence segmentation at the first part of a word, but apparently not in all cases. Words with a CV type base, do not show this effect o lengthening, their results would fit a serial model.

Predictions about the effect of a syllable boundary were also not confirmed Increasing a CVC base word with a syllable does not yield the same result as lengthening with only one consonant, but shows less accuracy.The difference between CVC + C and CVC + CVC is less though, than one would predict on the basis of the difference between CVC and CVC+C. Furthermore, lengthening of CV base words doesn't show the facilitating effect that the syllable boundary was predicted to have on the segmentation of the second phoneme.

The results with RT as dependent measure do not fit our predictions of a serial mode at all. For longer words segmentaiton of the first two phonemes is faster. For words that have a CVC base, an effect of syllable boundary is obtained, but it concerns a inhibitory, instead of a facilitatory effect.

Onset-rime boundary.

The comparison of CV and VC words gave results that are predicted by the onset rime boundary (see table 9), according to which the onset-rime boundary should facilitate segmentation in CV words. Words of the CV type were indeed segmented both more accurately ($t(47) + 4.4$; $p < 0.01$) and faster ($t(39) + 5.9$; $p < 0.01$) than words of the VC type.

Summary and discussion.

Both a strictly serial model and our notion of prior decomposition of the word have to be rejected. The results show that properties of the word rest influence the accuracy of analyzing a word's initial two phonemes. This influence is not only determined by the number of phonemes in the word rest but also by structural aspects. A syllable boundary does not facilitate: for words of the type CV adding a CVC syllable has no facilitatory effect, for words of the type CVC adding a CVC syllable has an inhibitory effect (though small in comparison with its increase in length).

It seems as if word length as used in our experiments only affects the segmentation of the word's initial two phonemes in the case where lengthening brings about consonant clusters in the word. As long as there are no problematic points, segmentation proceeds successfully (a CVCVC word is segmented as adequately as CVC and CV words). Consonant clusters, however, can even influence negatively segments which occur earlier in the word; CVCC is more difficult than CVC. An increase in length now causes adverse effects: CVCCVC is more difficult than CVCC. These results indicate that processing of the word rest is carried out in a way that processingcapacity is influenced by properties of the word rest that has yet to be segmented.

This difference between bisyllabic words on the basis of a CV word and bisylabic words on the basis of a CVC word can perhaps be explained by articulatory properties of the word rest. For words that have a CV word as a base word it is the case that after segmenting the initial two phonemes a word rest remains that is phonotactically legal in itself, and has a form that could be rehearsed on the basis of an articulatory code. For our other type of words (CVC, CVCC, CVCCVC) the comparable word rest is not pronounceble after the initial two phonemes have been segmented. To keep this pattern in Working Memory could take more capacity. For the effect obtained with lengthening with one consonant the same reasoning applies (since one consonant (from a CVC word) can generally be pronounced more easily than two (from a CVCC word)).

This account predicts that the problems start at the moment that the second phoneme is segmented; after the first phoneme all word rests are pronouncable. Furthermore there should be an effect of the particular type of consonant cluster: not all are unallowed at the begin of a syllable. Indeed, CVCC patterns which end with the more or less pronounceble cluster -ST are analyzed more accurately (.80) than the other patterns (.63). The CVCCVC patterns that contain -ST- are also segmented more accurately (.78) than the other patterns (.24).

The results with RT's as the dependent measure were completely unexpected. For longer words segmentation of the first two phonemes took less time (except for CVCCVC words). Maybe the subjects noticed that some patterns (longer patterns or patterns difficult to pronounce) were more difficult to keep in Working Memory. They could therefore be inclined to analyse them as fast as possible, thereby relieving their Working Memory.

Finally, comparing CV's and VC's consisting of the same phonemes gave results that favor the onset-rime hypothesis. In words of the type CV phonemes could be segmented more accurately and faster than in VC words.

All put together our results can be summarized as follows:

1. We have obtained strong indications that the onset-rime distinction is relevant for the task of segmenting a spoken word into its constituent phonemes.
2. The meaning of a word seems to have no influence on the process of segmentation.
3. Many of the effects obtained can be explained by the (apparently disruptive) presence of consonant clusters, which are not only difficult to segment themselves, but affect also the processing of segments earlier in the word adversely.

4. This leads to the conclusion, furthermore, that a simple serial model according to which from a word (rest) always the next phoneme is segmented, cannot be adequate.
5. One of our background assumptions had been that a phonological code form the basis for the process of segmentation and that it is a phonological code which is kept in Working Memory during the segmentation process. Our results indicate however, that perhaps rather an articulatory code is the object of segmentation, because some of our results seem to have to do with the pronouncability of the word rest in Working Memory. Whether properties of the articulatory code on the process of segmentation can explain differences between children in the skill of segmentation is an open question that awaits further research.

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Table 1. Words used in experiment I.

Existing words:
doos, hout, wijn, muur, arm, eend, erwt, acht, vla, knie, trui, slee, prins, vriend, kwast, schelp, slurf, speld, klomp, plaats, markt, dorst, streep, schrik, zebra, ballon, muziek, gitaar, konijn, agent.

Pseudo words:
dijp, houk, wom, mar, orm, ant, urt, aacht, vlui, knoo, tra, sle, preelt, vraats, kwilp, schemp, slens, sparf, kleest, pluunt, dierkt, narst, strim, schrees, kabro, boggan, mizaat, ganier, reezijn, ulent.

Table 2a. Complete segmentation: proportion correct.

	Short				Long			Tot.
	CVC	VCC	CCV	Tot.	One syllables	Two syllables	Tot.	
Existing	.95	.56	.47	.66	.25	.57	.35	.47
Pseudo	.86	.47	.47	.60	.25	.50	.33	.44
Total	.91	.51	.47	.63	.25	.53	.34	

Table 2b. Segmentation of initial phoneme: proportion correct.

	Short				Long			Tot.
	CVC	VCC	CCV	Tot.	One syllables	Two syllables	Tot.	
Existing	.97	.97	.90	.95	.82	.96	.86	.90
Pseudo	.93	.92	.83	.89	.81	.95	.86	.87
Total	.95	.95	.87	.92	.81	.96	.86	

Table 3a. Mean RT's for short words in seconds (stand. dev.) across "complete cases" (n=17).

	CVC	VCC	CCV
Existing	1.82(.41)	1.88(.50)	1.73(.28)
Pseudo	1.94(.43)	2.18(.80)	2.07(.44)

Table 3b. Mean RT's for long words in seconds (stand. dev.) across "complete cases" (n=17).

	Number of syllables 1	2
Existing	2.48(.31)	2.67(.61)
Pseudo	2.67(.33)	2.69(.70)

Table 4. Complete segmentation: analysis of variance for proportion correct.

a. Factors are: A. existing vs. pseudo words, B. wordlength (3 vs. 5 phonemes).

Factor	df	MS	F	p
A	1	800.00	5.51	.02
Error	49	145.24		
B	1	39824.69	149.76	.00
Error	49	265.92		
A * B	1	200.00	1.13	.29
Error	49	176.38		

b. Short words. Factors are: A. existing vs. pseudo words, B. wordtype (CVC, VCC vs. CCV).

Factor	df	MS	F	p		df	MS	F	p
A	1	2700.00	6.16	.02					
Error	49	438.10							
B	Wilks' Lambda = .42	df = 2,48		p = .00					
					(CVC + CCV) vs. VCC				
						1	19837.50	16.80	.00
					Error	49	1181.04		
					CVC vs. CCV				
						1	94612.50	50.94	.00
					Error	49	1857.40		
A * B	Wilks' Lambda = .95	df = 2,48		p = .28					

c. Long words. Factors are: A. existing vs. pseudo words, B. number of syllables (1 vs. 2).

Factor	df	MS	F	p
A	1	501.00	1.27	.27
Error	49	393.86		
B	1	41568.05	71.46	.00
Error	49	581.66		
A * B	1	612.50	2.40	.13
Error	49	255.36		

Table 5. Complete segmentation: analysis of variance for RT's.

a. Short words. Factors are: A. existing vs. pseudo words, B. wordtype (CVC, VCC vs. CCV).

Factor	df	MS	F	p
A	1	1.62	6.23	.02
Error	16	.26		

B Wilks' Lambda = .91 df = 2,15 p = .50

A * B Wilks' Lambda = .87 df = 2,15 p = .34

b. Long words. Factors are: A. existing vs. pseudo words, B. number of syllables (1 vs. 2).

Factor	df	MS	F	p
A	1	.18	.70	.42
Error	16	.26		
B	1	.19	.70	.42
Error	16	.28		
A * B	1	.11	1.05	.32
Error	16	.11		

Table 6. Segmentation of initial phoneme: analysis of variance for proportion correct.

a. Factors are: A. existing vs. pseudo words, B. wordlength (3 vs. 5 phonemes).

Factor	df	MS	F	p
A	1	460.06	6.81	.01
Error	49	67.58		
B	1	1753.64	20.51	.00
Error	49	85.52		
A * B	1	264.50	3.24	.08
Error	49	81.77		

b. Short words. Factors are: A. existing vs. pseudo words, B. wordtype (CVC, VCC vs. CCV).

Factor	df	MS	F	p		df	MS	F	p
A	1	2133.33	9.33	.00					
Error	49	228.57							
B Wilks' Lambda = .89	df = 2,48		p = .06						
					CVC vs. (CCV + VCC)	1	1350.00	3.71	.06
					Error	49	363.61		
					CCV vs. VCC	1	3200.00	4.57	.04
					Error	49	700.00		
A * B Wilks' Lambda = .99	df = 2,48		p = .84						

c. Long words. Factors are: A. existing vs. pseudo words, B. number of syllables (1 vs. 2).

Factor	df	MS	F	p
A	1	28.13	.23	.63
Error	49	120.25		
B	1	10153.13	31.55	.00
Error	49	321.78		
A * B	1	.35	.00	.96
Error	49	129.32		

Table 7. Words used in experiment II.

CV	CV+C	CV+CVC	CVC	CVC+C	CVC+CVC
bij	bijl	bijlen	bal	balk	balken
bui	buik	buiken	bel	belg	belgen
die	dier	dieren	buur	buurt	buurten
doe	doek	doeken	dan	dans	dansen
toe	toet	toeten	gas	gast	gasten
hoe	hoek	hoeken	haas	haast	haasten
ja	jaar	jaren	kam	kamp	kampen
koe	koek	koeken	kan	kant	kanten
kei	kijk	kijken	mis	mist	misten
la	laat	laten	dol	dolk	dolken
ga	gaap	gapen	rit	rits	ritsen
lui	luik	luiken	rot	rots	rotsen
ma	maan	manen	pol	pols	polsen
mee	meer	meren	hel	help	helpen
mij	mijn	mijnen	vel	velg	velgen
moe	moet	moeten	ram	ramp	rampen
na	naam	namen	wol	wolk	wolken
nee	neem	nemen	val	valk	valken
pa	paal	palen	wil	wilg	wilgen
po	poot	poten	man	mand	mantel
ree	reep	repen	hoes	hoest	hoesten
rij	rijm	rijmen	wal	wals	walsen
roe	roer	roeren	pet	pets	petsen
thee	teen	tenen	dor	dorp	dorpen
vee	veer	veren	pon	pont	ponten
wie	wiel	wielen	kas	kast	kasten
zee	zeem	zemen	men	mens	mensen
zie	ziek	zieken	kus	kust	kusten
zo	zool	zolen	lam	lamp	lampen
zij	zeil	zeilen	wel	welp	welpen

Table 8a. Segmentation of two initial phonemes. Effects of type of base word and length. Proportion correct (stand. dev.)

		Lengthening		
		---	+C	+CVC
Base word:	CV	93(.10)	.93(.09)	.88(.13)
	CVC	.84(.15)	.67(.20)	.52(.24)

Table 8b. Segmentation of two initial phonemes. Effects of type of base word and length. RT in seconds (stand. dev.).

		Lengthening		
		---	+C	+CVC
Base word:	CV	1.45(.17)	1.34(.19)	1.24(.18)
	CVC	1.37(.20)	1.29(.20)	1.32(.19)

Table 9. CV vs. VC.

	CV	VC
Proportion correct (stand. dev.)	.92(.15)	.73(.25)
RT in seconds (stand. dev.)	1.39(.24)	1.57(.25)

Table 10. Analysis of variance for proportion correct in Experiment II.

a. Factors are: A. base word (CV vs. CVC), B. increase in length (none, C vs. CVC).

Factor	df	MS	F	p		df	MS	F	p
A	1	2268.02	135.54	.00					
Error	47	16.73							
B Wilks' Lambda = .39			df = 2,44	p = .00					
					base word vs. base word+C	1	128.89	31.50	.00
					Error	47	4.09		
					base word+C vs. base word+CVC	1	160.78	25.02	.00
					Error	47	6.43		
A*B Wilks' Lambda = .49			df = 2,44	p = .00					
					base word vs. base word+C, by base word	1	135.67	18.32	.00
					Error	47	7.41		
					base word+C vs. base word+CVC, by base word	1	38.35	7.72	.01
					Error	47	4.97		

Table 11. Analysis of variance for RT's in Experiment II.

a. Factors are: A. base word (CV vs. CVC), B. increase in length (none, C vs. CVC).

Factor	df	MS	F	p		df	MS	F	p
A	1	849.97	1.89	.18					
Error	28	449.04							
B Wilks' Lambda = .39 df = 2,27 p = .00									
					base word vs. base word+C	1	9722.79	20.69	.00
					Error	28	469.86		
					base word+C vs. base word+CVC	1	1730.21	4.83	.04
					Error	28	358.14		
A*B Wilks' Lambda = .56 df = 2,27 p = .00									
					base word vs. base word+C, by base word	1	173.83	.38	.54
					Error	28	447.76		
					base word+C vs. base word+CVC, by base word	1	4568.83	13.80	.01
					Error	28	331.04		