Editor: W.J.M. Levelt

Volume 1 **Developing Grammars**
By W. Klein and N. Dittmar

Volume 2 **The Child's Conception of Language 2nd Printing**
Editors: A. Sinclair, R.J. Jarvella, and W.J.M. Levelt

Volume 3 **The Logic of Language Development in Early Childhood**
By M. Miller

Volume 4 **Inferring from Language**
By L.G.M. Noordman

Volume 5 **Retrieval from Semantic Memory**
By W. Noordman-Vonk

Volume 6 **Semantics from Different Points of View**
Editors: R. Bäuerle, U. Egli, and A. von Stechow

Volume 7 **Lectures on Language Performance**
By Ch. E. Osgood

Volume 8 **Speech Act Classification**
By Th. Ballmer and W. Brennenstuhl

Volume 9 **The Development of Metalinguistic Abilities in Children**
By D.T. Hakes

Volume 10 **Modelling Language Behavior**
By R. Narashimhan

Volume 11 **Language in Primates**
Perspectives and Implications
Editors: J. de Luce and H.T. Wilder

Volume 12 **Concept Development and the Development of Word Meaning**
Editors: Th. B. Seiler and W. Wannenmacher

Volume 13 **The Sun Is Feminine**
A Study on Language Acquisition in Bilingual Children
By T. Taeschner

*(continued after chapter 9)*

Diane J. Sawyer
Barbara J. Fox
Editors

# Phonological Awareness in Reading

## The Evolution of Current Perspectives

With 12 illustrations

Springer-Verlag
New York Berlin Heidelberg London
Paris Tokyo Hong Kong Barcelona

quisition. In W.E. Tunmer, C. Pratt, & M.L. Herriman (Eds.), *Metalinguistic awareness in children: Theory, research and implications* (pp. 144–68). New York: Springer-Verlag.
Tunmer, W.E., & Fletcher, C.M. (1981). The relationship between conceptual tempo, phonological awareness and word recognition in beginning readers. *Journal of Reading Behavior, 13*, 173–186.
Tunmer, W.E., & Herriman, M.L. ( 1984) . The development of metalinguistic awareness: A conceptual overview. In W.E. Tunmer, C. Pratt & M.L. Herriman (Eds.), *Metalinguistic awareness in children: Theory, research and implications* (pp. 12–35). New York: Springer-Verlag.
Tunmer, W.E., Herriman, M.L., & Nesdale, A.R. (1988). Metalinguistic abilities and beginning reading. *Reading Research Quarterly, 23*, 134–158.
Tunmer, W.E., & Lally, M.R. (1986, July). *The effects of letter-name knowledge and phonological awareness on computer-based instruction in decoding for pre-readers*. Paper presented at annual meeting of the Australian Reading Association, Perth, Western Australia.
Tunmer, W.E. & Nesdale, A.R. (1982). The effects of digraphs and pseudowords on phonemic segmentation in young children. *Applied Psycholinguistics, 3*, 299–311.
Tunmer, W.E., & Nesdale, A.R. (1985). Phonemic segmention skill and beginning reading. *Journal of Educational Psychology, 77*, 417–427
Tunmer, W.E., Pratt, C., & Herriman, M. (1984). *Metalinguistic awareness in children: Theory, research and implications*. New York: Springer-Verlag.
Valtin, R. (1984). Awareness of features and functions of language. In J. Downing & R. Valtin (Eds.), *Language awareness and learning to read* (pp. 227–260). New York: Springer-Verlag.
Vellutino, F., & Scanlon, D. (1987). Phonological coding, phonological awareness and reading ability: Evidence from a longitudinal and experimental study. *Merrill-Palmer Quarterly, 33*, 321–363.
Wagner, R., & Torgesen, J. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*, 192–212.
Wells, G. (1985) . Preschool literacy-related activities and success in school. In D. Olson, N. Torrance & A Hildyard (Eds.), *Literacy, language and learning: The nature and consequences of reading and writing* (pp. 229–255). London: Cambridge University Press.
Williams, J. (1986). The role of phonemic analysis in reading. In J. Torgesen & B. Wong (Eds.), *Psychological and educational perspectives on learning disabilities* (pp. 399–416). New York: Academic Press.
Yopp, H. (1988). The validity and reliability of phonemic awareness tests. *Reading Research Quarterly, 23*, 159–177.

## CHAPTER 2

# Phonological Awareness: A Bridge Between Language and Literacy

*José Morais*

I started investigating phonological awareness because of its relationships with literacy acquisition. There is, however, a further passionately interesting issue for cognitive psychologists, namely, how phonological awareness is related to the language system. In some sense, phonological awareness lies, like a bridge, between language and literacy. It belongs to either function. On the one hand, phonological awareness refers to a special category of phonological representations; on the other hand, some of its forms are part of the process of literacy acquisition and remain tied to literacy codes. The aim of this chapter is to embrace both issues in an integrative manner.

My interest in phonological awareness arose in 1976, when Paul Bertelson asked Jesus Alegria, Daniel Holender, and me to assist him in preparing a course on the cognitive psychology of reading. Bertelson had clearly understood that the seeking of analogies and differences between reading and speech perception could illuminate reading and, more particularly, reading acquisition. Writing systems represent spoken language at some constituent level. Therefore, the mastery of the alphabetic system, which represents speech at a highly analytic level—the phonemic level—should involve a great deal of explicit and implicit correspondences with speech.

At that time, the dominant conceptions, both apparently reasonable and both actually misleading, were the "central" view, claiming that reading essentially deals with context and redundancy, and the "peripheral" view, claiming that reading is essentially a matter of perception, either visual or auditory.[1] Both conceptions fail to recognize what is specific to

[1] It is symptomatic of the conceptual background underlying the peripheral view that Bradley and Bryant, in an experimental paper published in 1978, still refer to the reading issue as one of auditory perception, while they actually reason in terms of the relationships between speech and the alphabet.

reading and, more generally, to literacy. These kinds of considerations, I think, sparked our enthusiasm over the kind of paradigm for reading research that was emerging in the book *Language by Ear and by Eye*, edited by Kavanagh and Mattingly in 1972.

Bertelson had charged Alegria and me with addressing the reading-acquisition issues. At the risk of unjustly forgetting other pionering works, we were very much impressed by Isabelle Liberman and her colleagues' studies on phonological segmentation, by Rozin and his colleagues' experiment on backward readers trained to read English sentences written with Chinese characters, and by Savin's observations on the difficulty of dyslexics to manipulate Pig Latin (see, e.g., I.Y. Liberman, Shankweiler, Fischer, & Carter, 1974; Rozin, Poritsky, & Sotsky, 1971; Savin, 1972, respectively). We initiated our experimental work in this domain by replicating the 1974 study by Liberman et al. Then, Alegria focused more specifically on the study of children learning to read in a whole-word setting, and I turned to the study of adult illiterates in collaboration with Luz Cary from the University of Lisbon. These two populations had a feature in common: Neither had received explicit instruction in the alphabetic code. They thus provide a convenient source for inquiry into the relationships between reading acquisition and phonological awareness. We showed that children learning to read according to a whole-word method were specifically unable to manipulate phonemes, contrasting in this respect with children learning to read according to a phonic method (Alegria, Pignot, & Morais, 1982), and that illiterate adults display the same specific inability, contrasting with ex-illerate adults, that is, people of the same social background who have learned to read as adults Cary & Morais, 1980; Morais, Cary, Alegria, & Bertelson, 1979. At the time of these studies, some scholars still failed to realize the distinction between perception of speech and awareness of speech, as illustrated by the following anecdote: One of the reviewers of our former study on Portuguese illiterates did not believe that these subjects were unable to delete or add consonants; the reason, that researcher adduced, is that other research (e.g., Eimas, Scqueland, Jusczyk, & Vigorito, 1971) had found that American babies can discriminate consonants.

These two studies (Alegria et al., 1982; Morais et al., 1979) marked the initial phase of our work. Later on, our research students Alain Content, Regine Kolinsky, and Sao Luis Castro (the latter from the University of Porto) joined the group and contributed very systematic studies in different directions. Our work also greatly benefitted from collaboration and exchanges with colleagues from other universities, especially Beatrice de Gelder (Tilburg) and Leonor Scliar-Cabral (Santa Catarina).

The experimental evidence available today demonstrates, without a hint of doubt, that phonological awareness is a crucial factor for literacy acquisition in the alphabetic system. It is not the intention of this chapter to



quarrel with discrepant views. Thus, in this chapter I will take that statement for what I think it is, a scientific fact.

The structure of this chapter reflects the two main issues now being faced in relation to the concept of phonological awareness: how phonological awareness relates to literacy and how it relates to language. The first issue ought to be approached in a rather new way. For far too long a time, people have been concerned with the question of whether the development of phonological awareness is the cause or consequence of literacy acquisition. The answer our group has argued for is that one is dealing here with two processes, and that there is an interactive relationship between them. This answer, however, is not sufficient. One needs to know how those processes interact; in other words, one should describe their microgenesis, and for this, an information processing approach seems to be necessary. My feeling is that no one, ourselves (Morais, Alegria, & Content, 1987 a, b) included, has done more than propose some suggestions regarding the format of those phonological representations that are elaborated during the initial stages of learning to read and write and some suggestions regarding the role that these representations play in the elaboration of an orthographic lexicon. Likewise, as far as the second issue is concerned, no one has provided strong evidence that verifies the links that are supposed to exist between the conscious representations of the phonological units of speech and the processes of speech perception. I believe that this question is relevant to understanding the relations between phonological awareness and literacy, too. The process whereby the child is instructed in the sequence of the letters *c-a-t* yields representations of the phonological constituents of the written word *cat*. This then, consolidates into an orthographic representation, and both kinds of representations may alter in some way the child's conscious perceptual representation of the spoken word *cat*. Thus, both the nature of this perceptual representation and the processes available to analyze it, on the one hand, and the categorical nature of the alphabetic code and the kind of instruction provided in this code, on the other hand, may constrain the format of the conscious phonological representations elaborated by the child.

The considerations presented here explain why, standing on the bridge, it is difficult to decide what side shall be visited first: language or literacy. I decided to look at literacy first, on the basis of a functionalist type of argument. As a matter of fact, the function of the most important form of phonological awareness we are interested in, namely, phonemic awareness, is alphabetic literacy. However, the notion that there are different forms of phonological awareness and that not all of them are directly related to literacy compelled me to consider a previous question, namely, what phonological awareness exactly encompasses. A great deal of progress has already been made toward unpacking phonological awareness, as will be shown in the next section. Then, the literacy and language issues

contributions to phonological awareness will be discussed in following sections.

## Forms of Phonological Awareness

Phonological awareness is a special kind of phonological knowledge. It differs from the phonological knowledge used in comprehending and producing language by the fact that it refers to conscious representations of the phonological properties and constituents of speech. Indeed, this definition is a loose one unless we specify the criteria by which a phonological representation can be said to be conscious.

Someone who can make an appropriate verbal report of a phonological property or unit must be credited with awareness of this property or unit. However, one may consciously know something one cannot describe. Most people may respond correctly and without hesitation when asked to say, for instance, the initial or the final phoneme of a syllable, while being unable to provide a verbal account of the notion of phoneme. Those people must be credited with phonemic awareness. A problem arises, however, when the individual needs a few examples, or even practice trials with corrective feedback, to begin giving the right answer. He or she certainly learned this particular task, but it is by no means certain that he or she learned to segment syllables into phonemes. The individual may have elaborated a strategy that copes with the present difficulty but not necessarily with a different task, for instance, saying all of the phonemes of the syllable. Therefore, we have proposed elsewhere (Morais, Alegria, & Content, 1987a; see also Rozin, 1978; Content, 1985) that the ascription of phonological awareness—in the absence of verbal report or immediate success in a task supposed to involve this form of awareness—requires the observation of learning transfer effects. Caution is also required when interpreting spontaneous verbal behavior that seems to imply, at first sight, a specific manipulation. Unless this manipulation is shown to be available in an unfamiliar task, too, my suggestion is to maintain a more conservative position, that is, in those cases there is no unequivocal evidence of awareness.

To decide whether some form of phonological awareness is present in an individual is only part of the question. It is also important to determine whether each particular instance of awareness concerns a phonological operation, the product of this operation, or both. Awareness of a phonological property or unit could be present without awareness of the processes by which this property or unit is derived, judged, or manipulated.

Indeed, the end product of the perceptual processing of an utterance reaches consciousness allowing the listener to pay attention not only to the meaning of the utterance but also to its sound. More exactly, the speech



sounds that the listener is aware of are a sort of global (i.e., unsegmented) phonological form because spoken language can only be heard as speech. Here is a first deviation from the major function of speech processing, which is the extraction of meaning. On the other hand, this form of conscious awareness—the conscious perceptual representation of speech—is not what one has in mind when considering phonological awareness. Phonological awareness is awareness either of some particular phonological property, which may or not extend over the entire utterance, or of some constituent part. It seems to me important, for reasons that should become apparent later in this chapter, that these two categories of phonological awareness—holistic and analytic—be distinguished.[2]

Holistic phonological awareness, which should not be identified with the end product of the perceptual process, includes the capacity to consciously judge a number of suprasegmental properties of an utterance, such as phonological length, voice quality, and prosodic structure (melodic contour and amplitude and duration changes). Of course, this capacity can be applied to relational judgments, for example, between two utterances. Holistic phonological awareness may thus be sufficient to carry out tasks such as classification on the basis of overall similarity, rhyme appreciation, and the detection of mispronunciations.

Analytic phonological awareness includes the capacity to consciously isolate the constituent parts of an utterance. Different types of parts are hierarchically embedded. Syllables may be parts of an utterance; they are probably the units whose intentional extraction requires the least analytic effort because they roughly correspond to articulatory acts. The intentional extraction of phonetic and phonemic segments, by contrast, requires a high degree of analysis. The deepest analytic effort is probably needed for the conscious isolation of phonetic features. In addition, two units that lie between the syllable and the phoneme in the linguistic hierarchy, namely onset and rime, also may be consciously represented. The order of conscious recovery of the embedded parts may be from the largest to the smallest, both because highly embedded parts require more analytic effort than less embedded ones, and because their functional value tends to decrease with the degree of embeddedness (see, e.g., Marcel, 1983; Morais, 1985). In this chapter, I will deal mainly with phonetic and phonemic awareness. When it is inadequate or difficult to distinguish between these two, the general term *segmental awareness* will be used.

In relation to phonological awareness, one should consider the existence of articulatory awareness (consciousness of chord vibration, of places of contact of the articulators, etc.). Some observations suggest that each of

[2]Some might be tempted to draw an analogy of the holistic and analytic phonological awareness with a distinction proposed for describing hemisphere differences. They might incur a serious risk.

these forms of awareness may contribute to the development of the other (this point will be discussed later in this chapter).

As far as the distinction between holistic and analytic phonological awareness is concerned, it may be worthwhile to add that analytic awareness, at least at the final state, includes a metatheory about the corresponding phonological operations, whereas holistic awareness does not. The acquisition of conscious representations of phonological segments allows one to consciously carry out a variety of mental operations on those segments. People who know how to read an alphabetic language can describe the phonological relationship that exists between *tap* and *pat* because they consciously attend to representations of phonemes. Holistic awareness is different in this respect. With Luz Cary and Paul Bertelson (Cary, Morais, & Bertelson, 1989), I have tested a few illiterate poets, who were extremely good at both appreciating and producing rhyme; however, these poets were unable to give a precise definition of rhyme, to explain how they make rhymes, or to say why two words rhyme. When required to do such things, they usually provided more rhymes and commented that rhyming words sound alike. They never said, for instance, that two words rhyme when they are identical from the stressed vowel to the end. By contrast, people who have knowledge of an alphabet elaborated a segmental account of rhyme. Indeed, one could speculate that, at the unconscious roots of awareness, nothing separates holistic and analytic awareness. The holistic impression of rhyme could be nothing but the conscious tip of a mostly unconscious analytic processing. On the other hand, this unconscious processing is not necessarily the same as the unconscious processing that, after reconstruction, has led to analytic awareness.

It is important to remark that there is no simple relationship between the different forms of phonological awareness and the metaphonological tasks currently used. This is illustrated, as mentioned, by the case of rhyming tasks, which can be performed on the basis of either holistic impressions or explicit segmental analysis, but other cases of metaphonological tasks can be carried out in different ways: Content, Morais, and Bertelson (1987) have suggested that prereaders acquire, from corrective feedback, a procedure for deleting the initial consonant, which consists in finding the first vocalic sound as an attack point for the answer and which presumably differs from the operation that is used by literate people. Spagnoletti, Morais, Alegria, and Dominicy (1989) found results supporting the idea that Japanese children can perform correctly in the same task by resorting to the Kana matrix, which they learn at school. All this shows that one should not attribute a particular operation to a metaphonological task on an intuitive basis; some independent empirical evidence is required.

The search for dissociations in performance patterns regarding the literacy variable may constitute one useful way of supporting distinctions between metaphonological operations. This method was indeed used by



our group to demonstrate that rhyme appreciation (Morais, Bertelson, Carys, & Alegria, 1986), as well as phonological length judgment (Kolinsky, Cary, & Morais, 1987), do not necessarily require segmental awareness and can be reached by some other means. As far as rhyme is concerned, this conclusion is reinforced by converging results obtained by P. Karanth (personal communication) in India. Another task that is within the reach of illiterates is the detection of a prespecified phoneme at the initial position of a word. Given that illiterates are unable to delete or extract the initial phoneme of an utterance, this detection capacity must rely on some appreciation of similarity without analysis, that is, without the elaboration of a segmental representation.

In the remaining portion of this section, I will consider separately the development of the awareness of rhyme and alliteration, of syllables, of onset and rime, and of segments.

### Rhyme and Alliteration

Studies with illiterate adults and with preliterate children show that many individuals can develop rhyming abilities outside of literacy experience. More generally, sensitivity to rhyme develops without formal instruction. This does not imply that its development is not under the influence of particular experiences. For instance, Maclean, Bryant, and Bradley (1987) have shown that the knowledge of nursery rhymes is a good predictor of rhyming detection scores. Here, I will mention some observations that are potentially interesting for understanding what exactly those individuals are aware of when they are aware of rhyme and alliteration.

In a recent paper, Bertelson, de Gelder, Tfouni, and Morais (1989) tested Brazilian illiterates and literates (these had attended at most the second grade) on a rhyming discrimination task. Positive and negative examples, as well as corrective feedback during 24 trials, were provided to convey the notion of rhyme. Those subjects who attained a particular criterion for success were subsequently presented with a transfer task in which they were required to judge different cases of phonological relation as being or not being cases of rhyme. Illiterates accepted same-beginning pairs, like *faca–fado*, as rhyming much more frequently than same-ending pairs, like *bago–rago* (64% vs. 35%), while literates showed the opposite tendency (50% vs. 64%). It is worth noting that in all the cases the first syllable is stressed. Thus, illiterates seem to be more sensitive to the stressed parts than to the unstressed ones, and literates have probably assimilated, more than illiterates, the notion of rhyme as referring to phonological identity or similarity at the end of utterances. A further interesting observation is that cases of assonance, like *bota–sola*, were frequently accepted as rhymes (47% and 42%, by literates and illiterates, respectively). Thus, the subjects were probably taking the vowels into

account and disregarding a less apparent consonantic discrepancy. Provided one assumes that vowels contribute more than consonants to the overall similarity, this is consistent with the idea that, in most people with null or weak literacy, overall phonological similarity (probably at a syllabic level), rather than exact segmental identity, underlies rhyme judgments.

The ability of preschool children to intentionally produce rhymes as well as alliterations has been strikingly illustrated by Dowker (1989). Dowker found that these phonological relations are deliberately used as poetic devices by many such children, even under the age of 3. The frequency of rhymes was relatively constant across age, but alliterations tended to become rarer. The phonemes most frequently repeated in alliteration were stops. This is an interesting fact, given that stops appear to be the most difficult consonants in tasks of segmental manipulation (see, e.g., Content, 1985). Thus, preliterates' alliteration apparently is not based on conscious representations of segments. Moreover, the data argue against the hypothesis of a continuum between awareness of rhyme and alliteration and segmental awareness. The precocious alliteration ability exhibited by very young children may come from awareness that some articulatory recurrence gives rise to a particular form of phonological similarity. However, as the whole articulatory gesture produces a syllable rather than an isolated segment, the child remains unable to interpret this phonological similarity in terms of a common initial segment.

The fact that the use of alliteration tends to decline with age, at least from 3 to 6 years of age, is consistent with its relatively low occurrence in the poems of illiterate adult poets. By contrast, rhyme is a systematic feature of these poems. Our own inquiry into the illiterate poets' rhyming ability suggests that they possess a large rhyming organized lexicon. When they are presented with a word and asked to produce another word that rhymes with the former, they usually respond immmediately giving a few rhyming words, or even a poetic line. They also have no difficulty appreciating rhyme in nonwords; thus, they know that rhyme is a phonological relationship that is independent of the lexicon.

Contrary to nonpoet illiterates, the illiterate poets either have more precise, albeit unsegmented, phonological representations, or are more able to make fine phonological discriminations. As a matter of fact, the illiterate poets we have examined (see Bertelson & de Gelder, 1989, and especially Morais, in press, for somewhat more detailed descriptions) can easily distinguish between assonance and rhyme. They resolutely reject poems based on assonance, although they cannot explain why. In a categorization task that involves distinguishing between rhyme and assonance (e.g., to put together *lume* and *gume* from among *blue*, *lume*, *gume*), no illiterate control subject obtained more than 50% of correct responses, whereas the illiterate poets were perfect or almost so. Illiterate poets may judge rhyme



in the same way as illiterates who are not poets, that is, by evaluating phonological similarity. But, having a long practice of paying attention to the phonological aspects of speech, they would appreciate differences the others cannot.

One last point that is worth stressing is that acquiring segmental awareness gives clues for performing accurately on rhyming tasks (indeed, ex-illiterates as a group perform better than illiterates). What we do not know is what happens to the capacity of evaluating phonological similarity in people who have knowledge of segments. In more general terms, does this new knowledge simply add to previous capacities, or does it tend to replace them? As far as rhyming is concerned, does the capacity to evaluate phonological similarity tend to become impoverished as literacy increases? How do literate people appreciate rhyme when, as a consequence of some cerebral lesion, they lose the ability to represent segments consciously?

### Syllables

The precedence of syllabic awareness relative to literacy instruction has been well documented (I.Y. Liberman et al., 1974) by using a counting task as well as by observations (Ferreiro & Teberosky, 1979). These indicate that most 5-year-old preliterate children assume that letters stand for syllables. In a similar vein, our studies with illiterate adults showed that many of these subjects exhibited no difficulty deleting or reversing syllables. Others, however, were poor in these tasks. As a group, illiterates obtained lower scores than ex-illiterates. How can this large interindividual variation among illiterates be explained? Does it really reflect differences in syllable awareness? If syllable awareness is promoted by the fact that the perceptual experience of speech roughly corresponds to a sequence of syllables, one would not expect to observe large differences in performance on syllable-manipulation tasks. My impression is that the poor scores exhibited by some illiterate subjects (Cary & Morais, 1980; Morais et al., 1986; Scliar-Cabral, Nepomuceno, & Morais, in preparation) do not stem from illiterates having a different kind of conscious perceptual representation of speech or a lesser analytic capacity. In one study, in which we gave the subjects quite explicit instructions and provided them with corrective feedback (Morais, Content, Bertelson, Cary, & Kolinsky, 1988), all illiterates obtained perfect scores on syllable deletion after just a few trials. Of course, we had much more difficulty or even failed to elicit a similar learning effect as far as phoneme deletion is concerned. Rather than promoting syllabic awareness, the acquisition of a syllabic (see, e.g., Mann, 1986) or an alphabetic writing may simply provide supplementary cues of the syllabic structure of utterances, thus helping subjects to focus more rapidly or more consistently on this structure when induced to do so.

## Onset and Rime

Whatever the value of the onset–rime distinction as a linguistic notion, the existence of a stage of onset–rime awareness occurring developmentally between syllabic and segmental awareness has to be ascertained empirically. It is only fair to point out here the great importance and quality of the research conducted by R. Treiman (e.g., Treiman, 1985; in press) on this issue. However, before considering the empirical evidence, it is useful to reflect on the implications of the onset–rime partition for the questions of rhyming ability and segmental awareness. If one takes a consonant-vowel-consonant (CVC) syllable, C is the onset and VC is the rime. This means that if one is able to conceive of this CVC as made of C and VC, one must also be able to make rhyme judgements and to represent single consonants consciously. The Oxford group describes rhyming ability in exactly this way: "facility with rhyme is readily explained by the onset–rime distinction, because rhyming words are words with common rimes" (Kirtley, Bryant, MacLean, & Bradley, 1989). In other words, rhyme is rime, and young children appreciate rhyme because they extract rimes. My impression is that this kind of statement does not contribute to progress in understanding. At the best, one question has been replaced by another: Do young children really extract rime and how do they do it?

Kirtley et al. (1989) make two claims: (1) Prereaders "can isolate single phonemes when these form the onset", and (2) this fact demonstrates "a systematic awareness of phonemes among prereaders." Note that, even if this were true, a linguistic notion does not have the power to explain a mental capacity; as for rhyme and rime, it is not because an initial consonant is the onset that it is more easily isolated. Besides, I think that the findings obtained by Kirtley et al. do not warrant their conclusions. These investigators used classification tasks, and on the basis of above-chance performance on these tasks, they concluded that prereaders "can isolate some single phonemes." But this conclusion ignores two possible reasons for the above-chance performance: One is that the subjects may have managed to classify the items on the basis of unsegmented phonological similarity. I repeat that correct classification does not necessarily imply the extraction of the common element. The other possibility is that some of the children may already have developed an incipient segmental awareness through some acquaintance with letters (knowledge of letters was not assessed), although this acquaintance was still insufficient to promote word reading. Remark that illiterate adults perform at chance level in similar tasks of classification on the basis of initial consonant (data from our group in Portugal, as well as from P. Karanth in India).

Treiman has collected substantial empirical evidence in favor of the hypothesis of a developmental process of awareness from syllable to onset–rime to segment (see, e.g., Treiman, in press). Some of our results (Morais et al., 1984) also suggest that, somewhere in development, it is easier to decompose an utterance at the juncture of onset and rime than within the onset. As a matter of fact, beginning readers exhibit much greater difficulty at deleting the initial consonant of a CCV syllable than of a CV one (26% of correct responses vs. 71%, respectively, in first graders; 55% vs. 95% in second graders: see, e.g., Morais, Cluytens, & Alegria, 1984). One problem, however, is that these and similar data are consistent with other formulations: For instance, it is easier to separate a consonant from the following vowel than to separate two adjacent consonants. Another problem is that, at least in the French language, it is easier to delete the final C of a CVC (thus to analyze the rime) than the initial C (Content, Kolinsky, Morais, & Bertelson, 1986).



In my opinion, not enough work has been conducted on the influence of coarticulation on segmentation performance to be sure that an effect that seems to arise at a relatively abstract level of description (like onset and rime) does not actually stem from coarticulation constraints. If, for example, the conscious analysis of some types of consonantic clusters was found to be of the same degree of difficulty as the conscious analysis of a CV, then the relevance of the onset–rime distinction for the comprehension of segmentation abilities would be largely reduced. It is probably the different articulatory properties of stops and fricatives that make fricatives much easier to isolate intentionally than stops. I suggest that future work be more inspired by the hypothesis of an influence of coarticulatory properties (and also by the occurrence of age changes in coarticulation) on the development of segmental abilities, rather than by the intent to merely confirm or disconfirm the onset–rime hypothesis.

## Segments

In the literature (e.g., MacLean, Bryant, & Bradley, 1987; Perin, 1983), the Brussels group is sometimes (at least more frequently than we had hoped) presented as defending the view that literacy acquisition is cause but not effect of segmental awareness. Although we have tried to clarify our position in recent papers (e.g., in Morais, Alegria, & Content, 1987a, 1987b), I have the uncomfortable feeling that some continue to misunderstand it. I thus feel the necessity of harking back to the subject.

First of all, I would like to call attention to two pitfalls that are usually present in this kind of discussion. One is the search for exceptional instances or confirmatory evidence of some claim with the risk of forgetting the real question at stake. The other, which concerns developmental issues, is to confound state and process.

When we published our study with illiterates (Morais et al., 1979), there was an important (perhaps less important now) question from both the theoretical and practical point of view. The question is whether segmental

awareness is acquired spontaneously in the course of cognitive growth or instead requires some specific training or experience. Our findings clearly undermined the assumption that segmental awareness "develops naturally, spontaneously, under the influence of the linguistic stimulations provided by current life" (Leroy-Boussion, 1975, p. 185). Therefore, it is dangerous to believe that one must wait for signs of segmental awareness before initiating literacy instruction. Based on our results, we proposed that the critical training or experience is usually learning to read and write in the alphabetic system, but we admitted that this is not necessarily the only effective experience.

In Morais et al. (1987b), we presented an interactive position regarding the relationships between segmental awareness and literacy acquisition. It concerned the developmental process rather than some particular developmental state (initial, intermediate, or final):

> The first step may result from instruction about letters or written words, as is the case for most people, or from exercises and games bearing on the phonological structure of speech. Where the first impulse comes from is, however, immaterial for the notion of an interactive process. The point is that, though state a (or a′, or a″) cannot be simultaneously cause and effect of state b (or b′ or b″), it is meaningless to say that the acquisition of A is either cause or effect of B, but not both, when multiple reciprocal influences occur throughout the acquisition process (with a influencing b, b influencing a′, etc.). In this case, the final state of A is affected to a more or less important degree by states of B, and the same is true for the final state of B. On the basis of the current knowledge, it may be claimed that alphabetic literacy and segmental awareness develop together, through a process of multiple reciprocal influences, at least to some level (p. 539).

I certainly agree with Bertelson (1986) when he wrote that segmental awareness and alphabetic literacy "are both too global to expect to observe a unidirectional causal relation between them" (p. 11). The main issue, given the present state of the art, is to attempt a description of the intermediate states of both segmental awareness and alphabetic literacy acquisition and of their interrelation.

Moreover, I have the impression that some discussions suffer from a too-imprecise use of vocabulary. Mann (in press) claims (1) that "some individuals can manipulate the phonemic structure of words without the benefit of having been taught to read an alphabetic orthography," then that (2) "some children are able to manipulate phonemes before they learn to read," and finally that (3) "some children are aware of phonemes before they are exposed to the alphabet." To me, these are different claims. First, the mere existence of children who both learn to read and develop segmental awareness without formal instruction is sufficient to agree with the first claim. The second claim is more ambiguous because one must decide what



learning to read is, exactly. For instance, does this expression concern only words, or does it include the attribution of sounds to letters? If the less restrictive interpretation is chosen, then claims 2 and 3 are almost equivalent.

In a similar vein, Kirtley et al. (1989) write that "some phoneme awareness precedes reading and cannot be the product of learning to read." What meaning do the authors attribute the word *reading*? If they attribute to it the notion of some ability to identify written words, I would agree that some segmental awareness can precede reading. Children who have been told the sounds of letters and who begin using these letters to spell words are developing segmental awareness; however, they may be totally unsuccessful at word-reading tests. Some of the prereaders tested by Kirtley et al. were unable to read any word but could classify words on the basis of common phonemes (we shall forget for a while that this is not conclusive evidence of segmental awareness). Unfortunately, we have no information about their knowledge of letter-to-sound correspondences. Most probably, they knew an important number of these correspondences. Most children now are exposed to letters, for example, in alphabet books (they even eat letters as candy, soup, pastry), and are told their sounds. This makes it very difficult to dissociate, at the onset of phonemic awareness, the role of experience with letters and the role of phonological games that are entirely oral. What we know is that prereaders who are good segmenters also have a fairly good knowledge of the sounds of letters. For instance, Stuart and Coltheart (1988) found a strong positive correlation between segmental analysis ability and letter-to-sound correspondence knowledge. I would not be surprised if no child were found who, displaying a high level of segmental analysis ability, would not display also a substantial knowledge of letter sounds.

An interesting study by A. Martini from Pisa (Martini, personal communication) documents the role of acquaintance with alphabetic material in the development of segmental awareness. He administered a word-spelling test and a large set of metaphonological tests to 48 kindergarteners. About one third of the subjects gave evidence of some understanding of the alphabetic principle. On the average, these subjects scored more than 50% at phonemic deletion, fusion, and segmentation. By contrast, the subjects who still did not grasp the alphabetic principle did not manifest segmental awareness. On average, they scored 10% on deletion, 4% on fusion, and 7% on segmentation.

The observations made by Martini suggest that the creative spellers described by Read (1986) are not exceptional cases, although there may be important individual differences. Mann (in press) takes the existence of creative spellers as indicating that "some children appear to arrive at the concept of the phoneme more-or-less spontaneously." This term "spontaneously" is quite misleading. Creative spellers not only have been ex-

posed to the alphabet but have been told the phonemic values of letters and frequently ask their parents questions about letter-to-sound correspondences. Rather than demonstrating a spontaneous development of segmental awareness, these observations support the idea that the experience of learning an alphabet is crucial. Whether this learning occurs at home, more or less informally, or in school, following a standardized procedure is not important to the present issue. This is not to deny that differences in instruction may affect the rate of segmental awareness acquisition.

Children who live in developed societies do not provide a suitable material for examining the question of whether segmental awareness develops without exposure to the alphabet. This is why we have been so much interested in studying illiterate adults (although some of them also know the values of some letters), and especially illiterates who display high ability at other forms of phonological awareness.

The illiterate poets we have tested (cf. Cary, Morais, & Bertelson, 1989; Morais, in press) are perfect in several tests of rhyme judgment and production but fail at deleting the initial consonant of an utterance. The behavior of one of them, F.J.C., in this task is particularly interesting. As some of his responses consisted of reversals (*JUT–TUJ; JIF–FIJ*), we presented him with a phoneme-reversal task. The instructions were quite explicit: "You have to say the utterance backwards. *BUP* gives *PUB*, you start with the last sound, and you finish with the first one." On 14 trials, all his responses were incorrect. Thus, phoneme reversals were observed in the deletion test but could not be obtained when required. Thus, reversal responses did not result from an intentional manipulation of segments. I suggest that the inappropriate reversals observed are articulatory "reversals." They presumably occur at the level of articulatory commands, under the pressure of the instructions (which the subject presumably understood as requiring him to change the utterance in a way that does not produce new sounds, i.e., without changing the position of articulators), rather than at the level of conscious segmental representations. Despite his expertise in rhyme and despite his high ability in tasks requiring sensitivity to subtle relationships of phonological similarity, F.J.C. is unable to isolate intentionally the phonemes of an utterance and to manipulate them. In these tasks, he is by no means better than illiterate nonpoets.

Our results with illiterate poets clearly show that segmental awareness does not evolve from rhyming ability. The Oxford group dislike this conclusion. They propose the notion of "a continuous development of phonological skills starting with sensitivity to rhyme and developing into sensitivity to phonemes" (Bryant, Bradley, MacLean, & Crossland, 1989). This notion is supported by the results that they obtained showing that both nursery rhyme knowledge at age 3 and rhyme detection at age $4\frac{1}{2}$ predict phoneme detection at age 6. The problem is that the authors used phoneme-oddity tasks, which, as illiterates' performance suggests, can be



accomplished to some extent on the basis of phonological similarity judgments, which is a process rather comparable to rhyme detection. Furthermore, the observation of a link between rhyming ability and true segmental analysis ability (at least moderate positive correlations are usually obtained, and the Oxford group of Bryant, MacLean, Bradley, and Crossland, in an unpublished manuscript, have adduced convincing evidence of such a link) does not imply that one evolves continuously from the other. The capacity to attend to the phonological form of speech, which is crucial to rhyme judgments, is also crucial for analyzing speech into segments. Thus, children whose capacity for this is highly developed will be advanced in rhyme detection and, presumably, will be also advanced in segmental analysis later. I do not deny the existence of a relationship between the abilities of rhyming and of segmental analysis, because they both share an underlying capacity. What I deny is the spontaneous transformation of one into the other, that is, that sensitivity to rhyme eventually leads to the awareness of segments. Segmental awareness requires something more than that which is crucial for rhyming.

In my view, this additional capacity is a capacity of analysis. But, because the segments are not given to consciousness in the perceptual representations of speech, a concrete medium for the establishment of correspondences is necessary. Segments appear to consciousness from the moment that corresponding units (letters) are seen outside and must be referred to components of speech. Mann (in press) prefers a different view. To her, "knowledge of an alphabetic orthography" might be replaced with "experience in manipulating the internal structure of words." There are other situations than alphabetic literacy in which this manipulation is necessary, namely, secret languages. Indeed, the description of procedures used in secret languages is impressive. In many of these languages, a consonant may be inserted with reduplication of the vowel (*omusajja* becomes *o-zo-mu-zu-sa-za-jja-za*), the order of the consonants may be scrambled (*kaatab* may become *baatakn*, *taakab*, etc.); and complex operations seem to occur involving both separation, insertion, and fusion of segments (*ma* becomes *la mi*) (sources of these examples are mentioned by Mann, in press). The *la-mi* game in particular is assumed by Mann to involve a phoneme-level mechanism. The same view is expressed by Ellis and Beattie (1986). Given that many of these games are played in nonalphabetic communities and/or by preliterate children, Mann concludes that "knowledge of the alphabet is not the only constraint on phoneme awareness."

I think that, instead, there is once again the risk of ascribing the mental processes used by the speakers of these secondary languages to our own conception of phonology. Although empirical evidence is still missing (Mann [in press] rightly proposes to assess whether the observed ability transfers easily to nonhabitual phonemic manipulations), I am tempted to

believe that those who speak secret languages need not resort to segmental awareness.

I have already mentioned some observations of the illiterate poet F.J.C. that are relevant to this discussion. He produced reversal responses without being able to reverse segments. Moreover, both the normal and abnormal development of phonology show evidence of sporadic or systematic speech production errors that can be described as involving a segmental operation but that one can hardly ascribe to conscious manipulation of segments. For instance, the omission of all word or syllable initial consonants and the use of only one consonant per utterance are examples of systematic errors in developmental phonological disorders (Ingram, 1976; Shriberg, 1982). The latter phenomenon, consonant harmony, is used extensively by children up to 2 years of age (Dodd, 1975).

Stemberger (1989) has recently described the errors that his two children made between the ages of 1 and 5. The analysis of these errors shows that spoonerisms ("bolar pears" for "polar bears"), anticipations ("pig piece" for "big piece") and perseverations ("too ticult" for "too dicult") are relatively frequent. Deletions ("pay" for "play") and additions ("prink" for "pink gray") are also observed. Regularities are found in child's speech as well as in adults: consonants exchanged between words tend to occupy the same position in the syllable (see also Fromkin, 1971). Obviously, speech errors and speech game utterances are not equivalent. Whereas speech errors imply either an articulatory or a representational deficiency, in speech games there is an intentional control of articulation. But this control of articulation might conform to a unique pattern of transformations in a highly automatized way without involving, or having involved at any moment during acquisition, conscious operations on segments. It is known that several aspects of the articulatory process can be controlled independently. For instance, duration and tonality can be expressed irrespective of the phonetic sequence (this accounts for the permanence of a double vowel in the first syllable of *baatak* as regards to *kaatab*). Thus, it could be possible to perform some articulatory transformation within a few parameters. For example, after each articulatory gesture, the articulators might be placed in the usual way to produce a *z* while keeping them for the production of the same vocalic sound (this would account for one of the games mentioned above). Although my own description of the phenomenon refers to segments, it is known that segments are transmitted in parallel by the articulatory gesture. So, in language games, there would be no sequential manipulation of segments. There would be, instead, independent manipulation of articulatory parameters according to some transformation rule and their combination within a single event. My impression is that the secret language users have simply put under intentional control what children and adults do, either inadvertently or as a consequence of the lack of maturation or of some disorder, in their speech errors.



## Segmental Awareness and Alphabetic Literacy Acquisition

Before attempting a more thorough consideration of the role of segmental awareness and of segmental analysis abilities in the acquisition of alphabetic literacy, I will make some comments on two connected issues: the idea that rhyming abilities have a direct effect on the acquisition of literacy, and the idea that the use of grapheme–phoneme (or of larger units) correspondences (phonological reading) is necessarily preceded by some global association between written words and their pronunciations (logographic reading).

### Rhymes and Reading

The Oxford group has recently carried out a series of interesting experiments aimed at showing that rhyming abilities contribute directly and strongly to literacy acquisition. Bryant et al. (1989) found that prereaders' knowledge of nursery rhymes predicts their success in reading and writing 2 to 3 years later, even after the effects of initial phonological sensitivity have been ruled out. The relation between nursery rhyme knowledge (RK) and literacy (L) disappears when rhyme detection (RD) enters in the regression analysis. This suggests that RK affects RD, which in turn affects L. More exactly, in the pathway to reading, the contribution of rhyme detection is mediated by phoneme detection, whereas in the pathway to spelling it is direct. However, as I have indicated previously, what Bryant et al. call phoneme detection does not really involve segmental analysis.

Thus, a relationship exists between some nonanalytical ability and later achievement in reading as well as in spelling. The problem is that, in the absence of any consideration of segmental abilities, such findings do not allow any suggestion about whether rhyming abilities influence literacy acquisition directly or indirectly. One could be even more sceptical, because the results of the regression analysis, while excluding an intervention of the other variables considered on the relation between rhyme and literacy, do not force one to conclude that it is a causal relation. Moreover, memory capacity is an important aspect of the task used to assess rhyming judgment ability in children. Therefore, the predictive value of the rhyming measures may be due to not only the underlying capacity of paying attention to the sound aspects of words but also the capacity to maintain in memory the phonological representation of a few words during the time necessary for comparing these words. Further work by Bryant et al. (unpublished manuscript) has attempted to take segmental analysis into account by including phoneme-deletion and tapping tasks (deletion being of either initial or final consonant). Another original task, however, that is assumed by the authors not to imply segmental analysis most probably actually involves it.

This is joint rhyme–alliteration choice: The subject, presented with *coat*, *coach*, *boat*, is asked which one begins with the same sound as *code* and ends with the same sound as *rote*. What a difficult task! First, memory capacity is quite important for carrying out this task (five items are to be retained during the time required for at least six comparisons), and second, the child must have an appropriate and systematic strategy for making comparisons. Moreover, if the subject appreciates phonological similarity in an overall fashion, he or she cannot distinguish between *coat* and *boat* (unless the initial and the final phonemes do not contribute equally to the judgment). Thus, it seems exceedingly unlikely that the examiner's requirement can be satisfied by comparing the global utterances rather than the constituent segments. Because the "rhyme/alliteration" task of Bryant et al. is, in fact, a highly demanding segmental analysis task, it is not at all surprising that it correlates the highest among all tasks with measures of reading and spelling. Contrary to what Bryant et al. conclude, I think that they failed to demonstrate that rhyme contributes to literacy independent of the awareness of segments. What their findings really show, once again, is that segmental analysis ability strongly predicts later success in reading and writing. My co-workers and I have always supported the idea that segmental analysis ability contributes to the acquisition of literacy (see, e.g., Morais et al., 1979; Morais et al., 1987a).

Based on the fact that many words with a common "rime" also share a common orthographic pattern, some have taken the view that rhyming ability influences the acquisition of reading and spelling. Goswami (1986, 1988a) has shown that children are more likely to read a new word like *peak* if they know the pronunciation of a word like *beak* than if they do not. A similar finding has been obtained for spelling (Goswami, 1988b). According to Bryant and Goswami (1987), this demonstrates that children can take advantage of their rhyming ability to make analogies about the pronunciation of new words. It seems to me that before one attributes rhyming ability some responsibility in this way of reading or spelling one must understand more exactly the analogy mechanism. Goswami (1988b) has admitted two possible mechanisms for the particular case of spelling: One, which she calls analogy, uses whole-word spelling knowledge; the other, which involves "large-unit rule," operates via the retrieval of known orthographic sequences such as *-eak* (for reading, the same kind of distinction can be made).

Personally, I am tempted to favor the "large-unit rules" hypothesis, because I can hardly figure out how the analogy ensures correct pronunciation of the whole new word. Correct pronunciation of, for example, *light*, given the knowledge of *fight* or *might*, implies a separation (thus, a level of analysis) between the letter that stands for the onset, on the one hand, and the letters that correspond to the rime. Furthermore, knowledge of grapheme-to-phoneme correspondence is necessary to correctly decipher



the onset.[3] In my view, rhyming ability is not directly involved in this "large-unit" reading. The ability to appreciate rhyme is merely an instance of the phonological sensitivity that is necessary to become aware, when taught the pronunciation of a sequence of letters (each of which is a unit), that some recurrent subsequence corresponds to a part of the word sound. Whether the subsequence is a single letter or three or four may be of relatively little significance. Thus, the mechanism would not differ fundamentally from the one that allows the child to learn grapheme–phoneme correspondences. It is therefore not surprising to find evidence of the use of supraphonemic units, as well as of phonemes in written word recognition, by beginning readers.

### Does Logographic Reading Precede Phonological Decoding?

The dominant conception in the literature is that a stage of logographic reading precedes the use of sublexical spelling-to-sound correspondences. There is, however, some inconsistency about what logographic reading is. We owe to the work of Ehri (see, e.g., Ehri, 1987) and to Stuart and Coltheart (1988) both a clear-sighted criticism of this concept and relevant evidence against the notion that children begin reading in a non phonological way.

The term *logographic reading* has been used to cover two forms of written word recognition.[4] One is like picture recognition (see, e.g., Morton, in 1989): words are recognized from environmental cues (including linguistic context) so that letter changes go unnoticed (Masonheimer, Drum, & Ehri, 1984). This form of recognition does not allow recognition of the word when it is presented out of its usual context. Therefore, this is not reading. Such behavior characterizes prereaders, although it may persist in literate people when their attention is diverted.

The other form of written word recognition resorts to some salient visual cues or letters of the word itself, for instance, the presence of up or down strokes. The process of word recognition would consist of looking through the mental lexicon for an item visually related to the target word. This kind of reading would characterize the incipient reader and would stem naturally from the prereaders' contextually driven recognition. Ehri and Wilce (1985), however, have convincingly shown that, whereas pre-

[3] This is why I disagree with Goswami's (1988a) suggestion that a stage of lexical analogy may precede a stage of analysis of words into grapheme–phoneme units. On the contrary, the analogy can only be successful if it includes some analysis.

[4] As Stuart and Coltheart, 1988, point out, the four-stage theory of Marsh, Friedman, Welch, and Desberg, 1981, distinguishes the two forms of logographic reading, but the theories of Frith, 1985, and of Seymour and MacGregor, 1984, confound them.

readers who do not know the sounds or names of letters use visual cues to recognize words, children who have just moved into word reading know at least some letter sounds and use this knowledge to retrieve word pronunciation. Thus, the first stage of reading is not logographic but is based on letter-sound cues. In a similar vein, Stuart and Coltheart (1988) have found that reading level within the first grade is well predicted by the combination of segmental analysis ability and of letter–sound correspondences knowledge, both of these having been measured before the first grade. Thus, children who possess these competences to some extent as they begin formal learning do not pass through an initial stage of logographic reading.

### Segmental Awareness and Letter-Sound Knowledge

The strong association between segmental analysis ability and letter-sound knowledge in prereaders (see, e.g., Stuart & Coltheart, 1988) suggests that it is by learning the association of sounds to letters that the child usually initiates the acquisition of segmental (at first phonetic, later on, phonemic) awareness. This idea is further supported by the finding that training preliterate children on both segmental analysis and letter–sound correspondences produces a stronger effect on literacy acquisition than training them on only one of these competencies or on other metaphonological abilities (see, e.g., Bradley & Bryant, 1983; Hohn & Ehri, 1983; Share & Jorm, 1987). These studies, however, do not allow us to conclude that letter-sound knowledge has a direct effect on the acquisition of reading and writing or that it has an indirect effect through its presumed role in the elicitation of segmental awareness. A recent study by Ball and Blachman (1988) suggests that increasing letter-sound knowledge, in itself, has no impact on word reading, whereas increasing both segmental analysis ability and letter-sound knowledge has a strong one. One may thus think that training on letter-sound knowledge influences reading via segmental awareness. The problem with this conclusion is that Ball and Blachman's (1988) study showed no effect of increasing letter-sound knowledge on segmental analysis scores. The absence of such an effect, however, may be related to the fact that at the time of pretest the children already exhibited a substantial knowledge of letter–sound correspondences.

I suspect that not all ways of acquiring the knowledge of letter–sound correspondences are releveant for the development of segmental awareness. A sound may conceivably be associated to the corresponding letter as a global entity, in other words, without involving the analysis of an articulatory unit. This way of acquiring letter-sound knowledge presumably does not induce the awareness of the segmental constituents of speech. To understand the very start of segmental awareness, it seems that more attention should be devoted to how children begin learning the sound values of letters.



Ehri and her collaborators have convincingly shown that, once children know letter sounds, they begin to form and store associations between printed words and their pronunciations. More exactly, they associate some letters, often the initial and final consonants, with sounds heard in the word's pronunciation. These associations are retrieved the next time the word is seen (see, e.g., Ehri, 1987). Ehri (1989) reports that most of the misspellings collected early in first grade include only one letter corresponding to a sound of the target word. Later in the school year, most of the errors include two such letters. It is worth noting that, by that time, correct spellings are nonexistent or nearly so. A similar developmental trend occurs in word reading. It is known that at the very start of reading acquisition most reading errors begin with the first sound of the target; soon thereafter, misreadings include the sounds corresponding to both the initial and final letters. It is only somewhat later that both spelling and reading incorporate median letters and sounds. Stuart and Coltheart (1988) have proposed the same developmental sequence. Note, however, that this sequence, which has been noticed for English, may not hold for languages that use open syllables predominantly. Whatever the position of the cues used for storing and recognizing printed words, this stage of literacy corresponds to a rather low level of segmental awareness, presumably phonetic (i.e., essentially perceptual and dependent on articulatory context). At this stage, the child may have realized that the words *beam* and *blonde* begin in the same way but is still unable to separate all the segments of phonologically complex syllables.

### Segmental Awareness and Grapheme–Phoneme Conversion Rules

Having learned the sound values of some letters, the child can make associations between letters in words and corresponding sounds in their pronunciations. A form of segmental (phonetic) awareness has arisen. But a much larger set of individual sound representations is necessary if the child is to develop a more complete representation of the printed word. To extend phonetic awareness so that most of the segments of speech can be extracted from their articulatory context and represented in isolation is not simply a matter of being taught the sound values of more and more letters. Children with a similar level of letter-sound knowledge may largely differ in segmental awarenes, depending on how this knowledge is used and how much children employ it to operate intentionally on the phonology of their language. Thus, segmental awareness may, in itself, (i.e., to the extent that it is not completely determined by the level of letter-sound knowledge) have an influence on a relatively precocious stage of literacy acquisition. It is reasonable to assume that some level of segmental awareness is indispensable to elaborate a system of grapheme-to-phoneme (and phoneme-to-grapheme) conversion rules, although this seems to be phonetic rather

than phonemic. Stuart and Coltheart (1988) rightly suggest that, when we evaluate the role of phonological processing in reading, we have to focus not only on children's ability to translate from print to sound but also on their ability to translate from sound to print. In other words, we must take into account the orthographic expectancies that beginning readers derive from the segmental awareness and the letter knowledge they possess.

Children become able to produce spellings that contain letters for all of the sounds in words in what Ehri (1989) calls the phonetic stage. In particular, children in that stage can spell vowels correctly, albeit most words are still spelled incorrectly. This is because the child interprets the orthographic system systematically in a phonetic way. Such a phonetic representation may be a necessary step for correct spelling. In fact, it seems to provide an efficient way to retain individual spellings so that attention can then be focused on irregular and context-dependent spellings. Stuart and Coltheart (1988) have expressed the same idea: Mismatches between orthographic expectancies based on phonetic analyses and the actual printed word allow "the child to absorb information about spelling patterns which would otherwise not be noticed" (p. 174). This shift from phonetic to correct spelling apparently occurs during the second grade.

Ehri and Wilce (1987) carried out an interesting experiment in which a group of first graders, called "cipher" readers, was taught to decode sets of similarly spelled nonwords, and another group, called "cue" readers, rehearsed isolated letter–sound relations. At the posttest, nonword reading was performed at a very high level (81%) by the cipher readers but remained almost out of reach of cue readers (16%). Cipher readers also outscored cue readers in word reading. Learning to discriminate between items that are orthographic neighbors presumably enhances segmental awareness, and this in turn contributes to the rendering of more precise orthographic representations.

Three interesting aspects of Ehri and Wilce's (1987) data concern performance on a spelling posttest as a function of consonant type. First, the initial and final consonants were rendered by the "cue" group at a relatively high level, almost as high as in the "cipher" group (79% vs. 90%, respectively). This suggests that "cue" readers have reached the stage of representing the associations between boundary letters and their corresponding sounds. Second, consonant clusters were much better spelled by the "cipher" than by the "cue" group (70% vs. 12%, respectively). Decoding training possibly allows the analysis of consonant clusters into two segments. Although the novice reader may notice the phonological difference between /pant/ and /plant/, he or she treats /pl/ as a unit and therefore has no alternative but to use the same letter, /p/. But, as Stuart and Coltheart (1988) note, "from seeing the word in print, the child will be able to infer that /pl/ is not a single unit, and that it does not map on to the letter p, but is spelt pl" (p. 176). Third, Ehri and Wilce (1987) found that the cipher



group remained as unable as the cue group to carry the preconsonantal nasal into their spellings. This is probably because their level of segmental awareness is still phonetic and because the preconsonantal nasal and the preceding vowel are articulated simultaneously. The fact that decoding training makes the child sufficiently aware of the existence of two segments in /pl/, while not eliciting the same inference for *an* in, for example, *plant*, is theoretically interesting because it suggests that segmental awareness is not a mere reflection of spelling knowledge; there are also perceptual constraints in the development of this form of awareness.

As complete as it can be, phonetic spelling remains based on the associations between individual letters and their sounds. Thus, the grapheme–phoneme rules used at this stage are context free, and speech maps onto print in a piecemeal way. The child still must discover both the existence of multigraphs (especially digraphs) corresponding to only one phoneme, and the fact that correct spelling often requires reliance on rules that specify contextual dependencies. Many of these rules may be learned implicitly. But the multigraphic spelling of single phonemes may contribute powerfully to the transformation of the phonetic awareness typical of phonetic spelling into phonemic awareness. Indeed, a multigraph is a source of a disturbing mismatch between the familiar phonetic values of the constituent graphs and the segment they represent. Phonemic awareness may be necessary to go beyond these mismatches, as well as to develop the ability to parse word letter strings into graphemes. Although graphemic parsing may be stimulated by the partial orthographic recognition units that are postulated by Stuart and Coltheart (1988) and which specify initial and final consonants, it will not be complete without the mapping of the intermediate letters into phonemes. Phonemic awareness thus plays a crucial role in the constitution of the orthographic lexicon. On the other hand, the process of developing this lexicon probably involves the elaboration of multiphonemic orthographic units. Finding some facilitation from previous phonological analyses in a first step, consonant clusters as well as dipthongs may come to be treated as orthographic units. Children at the same level of phonemic analysis abilities may therefore read and write at different levels: They may differ both in their knowledge of context-dependent rules and in their orthographic representations.

Where do the difficulties of dyslexics arise in this developmental sequence? Most dyslexics know the phonetic values of letters, have developed some phonetic awareness, and attempt to read and spell using a local phonetic approach. But dyslexics have only incomplete orthographic representations of printed words (see an illustration in Ehri, 1989). Others have more complete representations but still base these representations on phonetic associations with individual letters. Werker, Bryson, and Wassenberg (1989) have observed that disabled readers consistently make liquid intrasyllabic additions and homorganic closure additions when trying to

read nonwords. I suggest that homorganic closure additions (e.g., /pap/ for ap) may be related to the fact that multigraphemic units have not been elaborated: Decoding of the successive graphemes one by one, retention of their values and of their order in the sequence, and finally blending—all these processes together leave room for these kinds of errors. The following illustration may account for liquid intrasyllabic additions: Assume that, due to insufficient segmental awareness, the letter *p* is used both for /p/ and /pl/. Presented with *p* followed by a vowel, the child has no way to decide between /p/ and /pl/, and sometimes will read /pl/ incorrectly. In my view, the difficulties of dyslexics and poor readers may arise, roughly speaking, at two main stages: (1) at a relatively early stage, if readers have not developed a sufficient level of phonetic awareness to rapidly find the phonetic correspondences of all the letters of words and to blend them and (2) at a later stage, if readers have not established higher level correspondences between graphemes and phonemes; misapprehension of these correspondences prevents them from accomplishing appropriate graphemic parsing, extracting context-dependent rules, and creating larger orthographic units for rapid lexical access.

To unravel the relationships between the development of the different forms of segmental awareness and the acquisition of literacy, a good research strategy may be to relate individual data obtained in segmental analysis tasks with information concerning the reading mechanisms in the novice reader. One interesting question is whether all children who can use phonological decoding to some extent, as measured through the ability to read nonwords, also appear to have developed a significant level of segmental awareness. The converse question, namely whether all children who are unable to make phonological decoding also lack segmental awareness, is no less interesting.

When addressing these questions, however, one may be led to wrong conclusions if one evaluates segmental awareness inappropriately. This is, in my view, what happened to Tunmer and Nesdale (1985) in an otherwise very interesting study. They tested first graders on a tapping task and analyzed the individual scores in relation to nonword reading. They concluded from the results that segmental awareness is not a mere facilitator of phonological decoding, given that no child who had nonword reading ability did not have segmental awareness, and that segmental awareness is not a mere epiphenomenon of reading, given that many children had segmental awareness but not nonword reading ability. The authors further conclude that the difficulties of these children at phonological decoding were not due to an insufficient possession of the grapheme–phoneme correspondence rules.

The problem with Tunmer and Nesdale's (1985) conclusions is that the tapping task may not provide a good indication of segmental awareness. Before saying why, I wish to comment on Tunmer and Nesdale's criticism about our use of the reversal task in Alegria, Pignot, and Morais (1982).



They say that the reversal task is not a clean test because it involves extraneous cognitive processes. Indeed, the reversal task requires that the subject separate the segments, hold them in memory for the time necessary to execute the reversal operation, and finally blend them. But all these processes give testimony to the ability to consciously represent segments and to intentionally manipulate them. This is why we obtained so huge a difference between first graders taught to read according to a phonic method and their peers taught to read according to a whole-word method. And it is probably because the tapping task does not necessarily require that the subject conceive of segments in isolation that Tunmer and Nesdale (1985) did not find any effect for instructional method.

One way of doing the tapping task is by using a spelling strategy. Tunmer and Nesdale (1985) have demonstrated the manner in which children resort to a spelling strategy by showing that words with digraphs yield much more overshoots than words without digraphs. The fact that this effect appears in first graders is striking because it means that a spontaneous strategy consisting of generating an orthographic representation of the word may be easier, at least for many of them, than a strategy that uses the conscious perceptual representation of the stimulus to count segments. This stresses the difficulty, for beginning readers, of operating on segments.[5] On the other hand, those children who are unable to generate a graphemic representation can perform the tapping task by attending to duration cues. In a recent study (Alegria, Morais, & D'Alimonte, 1990), we found that many children who succeed in the tapping task fail in the deletion of initial consonants (see also Perfetti, Beck, Bell, & Hughes, 1987). Thus, it is by using tasks that really rely on segmental awareness that one can appreciate whether or not phonological decoding is critically dependent on the knowledge of segments.

Among approximately 60 first graders taught to read according to a whole-word method, we (Alegria, Morais, & D'Alimonte, 1990) have found a minority of children who were able to read nonwords but unable to delete the initial consonant. All of these exceptional subjects were from a highly literate milieu. At first sight, then, it could be possible to develop phonological decoding without segmental awareness. But that result could actually be artificial. First, all exceptional subjects were surprisingly poor in syllable deletion, so perhaps they failed the consonant-deletion test for reasons other than the lack of segmental awareness (the fact that items comprised both words and nonwords might not be irrelevant). Second, the nonword-reading test was created by changing only one consonant in words that were highly familiar to the subjects, so perhaps these items were

[5] Likewise, in skilled readers presented with phonemic tasks, orthographic manipulations may be subjectively easier to accomplish, and even more difficult to inhibit, than phonemic manipulations.

read by introducing some local phonetic correction rather than through full phonological decoding.

The next year we (Alegria, Morais, & D'Alimonte, 1990) examined 37 first graders from the same setting. Using words in the deletion test and nonwords that differed in every consonant from familiar words in the reading test, we found no exceptional subject: All children who manifested phonological decoding also displayed segmental awareness. On the other hand, given that the deletion task is more difficult than the tapping task, we did not find in either of the two experiments, contrary to Tunmer and Nesdale (1985), a single subject displaying segmental awareness without manifesting also phonological decoding. Phonological decoding and segmental awareness go hand by hand.

If, as it seems to be the case, phonological decoding, even on a phonetic basis, implies segmental awareness, then it is quite implausible that grapheme–phoneme correspondences (at least, as far as context-free rules are concerned) can be learned without explicit knowledge of the segmental structure of speech. Grapheme–phoneme correspondences are learned in an explicit way, through deliberate attention to phonemic identity and constancy (i.e., despite the existence of allophonic variation). An analogy with simulation attempts may be worth making. I have heard of no associative network that can dispense with the explicit knowledge of segments and nevertheless learn to read. In the NETtalk case (Sejnowski & Rosenberg, 1986), the information given to the network during training is a huge set of examples of grapheme–phoneme correspondences; thus, both grapheme parsing and segmental analysis are solved outside the network, and this network only learns the context-dependent rules. As mentioned before, NETtalk "may be taken to illustrate the importance of segmental awareness rather than the reverse" (Morais et al., 1987b, p. 545). To be fair to the creators of networks, I have little doubt that a network that does not require segments to be specified in order to learn to read will eventually be found. Its validity, however, as a simile of the natural course of learning to read would still be constrained by the exigence of an amount of training presentations that would be nonprohibitive for a child. Using a new-fashioned terminology, the acquisition of literacy is an outstanding instance of supervised learning in which segmental awareness plays the role of superviser; that is, it allows both phonological decoding and the development of orthographic representations (I am indebted to Tim Shallice for this analogy).

## Segmental Awareness and Language

The notion of awareness is still embarrassing for many psychologists. Discussing it in relation to the present topic, Marshall and Cossu (1987) write



that it is "a difficult concept to assimilate into any theoretical system except as 'a ghost within the machine'" (p. 486). I think that we are making progress in treating phonological awareness not as a ghost but as a constituent part of the machine. Phonological awareness is a general term that designates "perfectly serviceable cognitive states" (I borrow this expression from Pylyshyn, 1980, p. 166, when he discusses "consciousness"). The services furnished by phonological awareness, and particularly by segmental awareness, are multiple. First, the conscious representations of segments enable us to recognize these units in current speech. This is a case of "object" recognition that critically depends on consciousness; however, this is also a case of postperceptual processing. Second, as I have argued, the conscious representations of segments play a crucial role in the acquisition of alphabetic literacy. For some time during literacy acquisition, the recognition of written words involves using those representations. Third, phonemic awareness may influence the child's own processes of spoken word recognition at some relatively late stage (see, e.g., Morais, Castro, & Kolinsky, 1988; Morais, Castro, Scliar-Cabral, Kolinsky, & Content, 1987). In the last two cases, the conscious representations of segments serve in the recognition of objects other than the segments themselves.

Another important issue is how the conscious representations of segments relate to the implicit representations used in speech processing. My feeling is that we are now in a position to be rid of a polemic, which turned only to extremes, about whether phonemic awareness results from access to (retrieval of) implicit phoneme representations or from an entirely arbitrary construction. To put the whole thing in a nutshell: by asking the two main questions, namely, how the conscious representations relate to the primitive and unconscious ones (the language-to-awareness question), and how they may contribute to new unconscious processing (the awareness-to-language question), and by progressively collecting theoretical and empirical elements to answer these questions, we render the ghost a more human carnation and give it a place in a computational theory of mind.

The awareness-to-language question, which is currently the object of a research program carried out in our laboratory, is examined in a separate paper (Morais, Castro, & Kolinsky, in press). A somewhat related, but distinct question that concerns the influence of orthographic knowledge on phonological judgments (see mainly Ehri, Wilce & Taylor, 1987; Seidenberg & Tanenhaus, 1979), will not be discussed, either. Here, only the language-to-awareness question will be dealt with, and this will be done in three steps: First, the claim (already expressed in Morais, in press) that segmental awareness is a reconstruction of unconscious representations of segments will be justified; second, I will try to defend the idea that the elaboration of conscious representations of segments takes advantage of developmental changes in the underlying phonological representation of the language; and third, I will attempt to specify the kinds of cues that are

present in the perceptual representations of speech and that can be used by the child to elaborate conscious segmental representations.

### Segmental Awareness as Reconstruction of Unconscious Representations of Segments

The production and perception of speech rely on a phonetic module specifically adapted for producing phonetic structures and for recovering them (A.M. Liberman, in press; A.M. Liberman & Mattingly, 1985). The analysis that the phonetic module accomplishes probably consists of specifying phonetic features together with information about their position in the (planned or heard) utterance. As least as far as perception is concerned, the frame for phonetic analysis is probably the syllable, because this is the main unit of coarticulation and because syllables are easily segmentable on an acoustic basis. Within the syllable, the position of the phonetic features must be specified to allow the correct perception of syllables with more than one vowel or consonant. Following this analysis of each syllabic frame, the phonetic features must be integrated into a representation—the phonetic percept, which is the output of the phonetic module. All the processes mentioned (feature extraction, position specification, and feature integration) may undergo developmental changes in early childhood, but at least at the final state, the phonetic percept is probably a sequence of discrete segments.[6] This is because the phonetic percept feeds another module, which is concerned with the automatic extraction of morphophonological structures (i.e., of word forms). These structures are sequences of abstract units, consonants and vowels, that correspond, through the action of factors as diverse as context, dialect, and speech rate, to phonetic structures.[7] The output of this morphophonological module, however, if it is really a phoneme-by-phoneme description, does not reach consciousness in this format. This is likely for two reasons: one is that a segmental format is not adequate for identification purposes; the other is that the morphophonological output can still be reelaborated according to lexical expectancies, orthographic knowledge, and other factors. One may speculate that these factors influence the process of transformation of either the phonetic or the morphophonemic percept into the global phonological representation that we become aware of when we listen to speech.

By both definition and necessity, modules operate without awareness. Bertelson and de Gelder (in press), discussing the access view of segmental awareness, rightly note that "the notion of a module which is normally not accessible, but becomes so if sufficient insistence is applied, is somehow unsatisfactory, and creates difficulties for the modular view." The work with illiterates shows that segments are not represented as such in the conscious phonological representation of speech. Processes of intentional analysis have no access to the results of the unconscious phonetic analysis or to the correspondent phonemic representation, because these representations are hidden by the global phonological representation. It is a matter of fact, however, that conscious representations of segments (either at a phonetic or a phonemic level) can be elaborated. This is, I assume, because the global phonological representation does contain some cues of phonetic or phonemic information). On the other hand, the notion of elaboration implies that the conscious and the unconscious representations are not identical, and that we cannot infer the exact content and format of the unconscious representations from what we know about the conscious ones.

I agree with Bertelson and de Gelder's (in press) position that the question of the role of segments in perception and that of segmental awareness are logically orthogonal. This does not mean that there are no relations between on-line segmental processing and segmental awareness. When examining this question, it is important to take into account the fact that not all on-line speech processing is accomplished by modular devices. Bertelson and de Gelder mention our (Morais, Castro, et al., 1987) finding that the occurrence of phonetic feature blendings in dichotic word recognition, which they take as favoring the hypothesis of on-line segmental processing, is independent of the degree of segmental awareness. On the other hand, they reason that the access interpretation of segmental awareness, which they do not seem to believe in, predicts some degree of penetration of the speech module: "speech processing might be modified by the availability of explicitly segmented representations." What I wish to make clear (not against Bertelson and de Gelder, who indeed have not made the error of logic) is that this last inference can be true even if the access hypothesis is not. Speech identification and recognition may include extra-modular strategical processes, among which some could be prompted by segmental awareness, and other findings reported by Morais, Castro, et al. (1987) suggest that such strategical processes exist. The phonetic blending phenomenon, by contrast, probably occurs within the phonetic module.

Many authors have discussed whether the alphabet has been invented or discovered. Some who conclude that the alphabet has been invented were tempted to extend the conclusion to the segments of speech that the alphabet represents. I agree with Günther (1985), although I do not concur with his rejection of the perceptual role of segments, that the alphabet had to be based on features of reality. As Günther says, Watt did not invent the power of steam—this is what he discovered—but he invented the steam-

[6] In this view, segmentation—the process that yields a representation segment by segment—results from integration (of features) rather than the reverse.

[7] Phonemic structures, although they have been elaborated to represent words, may represent nonsense words, too.

engine. What, in the case of the alphabet, did humans discover and invent? We can answer this question using A.M. Liberman's (in press) words: "The discovery—surely one of the most important ever made—was that the words people had been speaking for so many thousands of years did not differ from each other holistically, but rather by an internal structure made of a small number of phonological units. The invention that exploited this discovery was the notion that, if these units were to be represented by arbitrary optical shapes, then reading and writing would be possible for all who knew the language, provided they could become reasonably aware of its phonological structure, and so appreciate what the optical shapes were all about." Like the alphabet, the conscious representations of segments, and especially of phonemes, are half discovery, half invention. We have no access to the representations of segments that are elaborated within the language modules. Most probably, these representations would have been inadequate to the functions that segmental awareness fulfills (the phonetic and the morphemic percepts would have been too little and too abstract, respectively). Moreover, our conscious representations of segments are influenced by the medium—the alphabet—through which we acquire them. On the other hand, it is hard to believe that the mind can analyze language or matter successfully (i.e., so that they can be transformed in a way that leads to behavioral or physical changes) at a level beyond the real structure of language and matter. The conscious representations of segments must reflect the same underlying reality as the unconscious, if the alphabetic writing is—and no one doubts it is—well suited to the encoding of spoken language. In other words, one may oppose the notion that the phoneme is a pure creation of an arbitrary writing system by arguing, as Studdert-Kennedy (1987) does, that this system could not control linguistic behavior so easily if it did not correspond to units of perceptuomotor control.

## Phonological Development and Segmental Awareness

The literature shows growing interest in the development of speech perception and production abilities. Indeed, the fact that these abilities are supported by modules does not reduce the importance of developmental processes. On the contrary, it is an intensely interesting task to try to understand how "nature" and "nurture," biology and environment, and maturation and experience, combine to give the module its final competence.

Infants are very good, actually better than adults, at discriminating speech sounds on an acoustic–phonetic basis. In the second half of their first year, they begin to ignore the contrasts that are not used in the parental language. In other words, they begin to assimilate the phonological regularities of this language. This process prepares the young child for the acquisition of a lexicon. His or her first words use the same kind of articula-



are holistic patterns of gestures corresponding to syllables. Indications that the syllable is the first unit of speech available to the child are observed soon after birth, as far as perception is concerned. Bertoncini and Mehler (1981), for instance, have found that neonates do not discriminate /pst/ from /tsp/ but do better with /upstu/ and /utspu/, which means that they can discriminate phonetic contrasts provided that they are embedded in syllables (see also Mehler, Dupoux, & Segui, in press). The phonetic form of the syllable is, by 5 months and probably earlier, represented in association with the optical cues of the facial gestures that go with its production (Kuhl & Meltzoff, 1982; MacKain, Studdert-Kennedy, Spieker, & Stern, 1983). It is likely that, as the neural control of articulatory structures increase, these structures become associated with that amodal perceptual representation of speech, thus allowing the imitation of speech sounds.

In the beginning of the second year of life, the control of articulation is still global, that is, with no differentiation of the parameters that specify consonants and vowels within the syllable. The absence of control at the segmental level justifies both the inability to change the place of articulation within a syllable, thus leading to consonant harmony (*gog* for *dog*) and the inability to maintain segmental identity in different contexts (*n* correctly executed in *no*, but as *m* in *night*) (for references, see Studdert-Kennedy, 1987, from whom I borrowed many aspects of the present description). According to Studdert-Kennedy (1987), the pressure of lexical accumulation leads both to the diversification of articulatory routines and to the narrowing of the domain within a word to which an articulatory routine applies; "the logical end of the process (usually reached during the third year of life, when the child has accumulated some 50–100 words) is a single articulatory routine for each phonetic segment" (pp. 53–54). The emergence of the phonetic segment as a perceptuomotor unit would enable the child to constitute the adult lexicon and to recognize thousands of words.

One should not conclude from the inferred lack of segmental control in production until the third year of life that there is, simultaneously, no segmental representation in perception. It is probable that, in this case too, perception forestalls production. Although consonant harmony is observed in production, the neonate can discriminate /tap/ from /pat/ (Bertoncini & Mehler, 1981). Even if one attributes this particular competence to auditory rather than phonetic discriminability, it is unlikely that the young child who recognizes the words *pack* and *cap* spoken by different speakers in different rates does so on an auditory basis. Taking phonetic processing for granted, only a segmental specification of the phonetic features present in the syllable allows the discrimination.[8] In the same vein, the child who says

[8]However, this argument does not hold if the real unit of processing is not the syllable but demisyllables—CV and VC in the case of a CVC—as has been suggested for speech percep-

*might* for *night* can discriminate between the two words. The reliance on production data is justified by the notion that phonetic and phonemic segments are perceptuomotor units rather than units belonging to two related subsystems: one for perception and the other for production. This conceptual economy, however, may be misleading. First, the notion that speech is perceived by reference to the conditions of its production does not imply that a single representation underlies perception and production. The different requirements of perception and production may create the necessity for distinct representations of lexical phonology, as contemplated, for instance, in Morton and Patterson's (1980) version of the logogen model. Furthermore, neuropsychological evidence (e.g., Bramwell, 1897) demonstrates a dissociation between input and output lexical representations, namely, word-meaning deafness in the presence of intact spontaneous speech, which Allport and Funnell (1981) consider to be of great theoretical significance. There is also some evidence of such a distinction from a case of abnormal phonological development: In a 5-year-old child examined by Chiat (1983), fronting of velars was observed in production but not for all words (thus, suggesting that it occurs in lexical representations); nevertheless, velars were perfectly discriminated in input.

The notion that phonetic information used in perception may be specified on a segmental basis from an early age is not inconsistent with some later development toward more sharply defined segments. Consistent with this idea, Nittrouer and Studdert-Kennedy (1986) have found that 3-year-old and, to a lesser extent, 5-year-old children are less sensitive than adults to the steady-state friction of fricatives as well as to the vocalic formants, and more sensitive to the transitions that depend on both segments. Thus, it seems that speech perception becomes more segmental as the child develops. Allen and Norwood (1988) report results that seem to be discrepant with the previous findings: Voice onset time (VOT) was relatively more important for children than for adults, in comparison with closure and initial vowel duration, as the cue for intervocalic /t/ and /d/. The discrepancy can be solved, however, by assuming that syllable chunking is sharper in children and that children's perception is, more than adults', affected by within-syllable cues.

It would not be surprising if production showed a similar developmental trend. This seems to be the case. Repp (1986) found a greater intrasyllabic coarticulation in one 4-year-old than in one 9-year-old. Nittrouer, Studdert-Kennedy, and McGowan (1988) and McGowan and Nittrouer (1988) found greater effects of vowel context within the fricative noise of children than of adults. The adult pattern was not reached by the age of 7, in contrast with the perception results. Thus, in production, children contrast phonetic segments less clearly than adults. The study of production errors also suggest that, in the planning of articulation, segments are less prominent in children than in adults. Compared to feature reversals ("gall



for pristmas," instead of "ball for Christmas"), segment reversals ("graphossers" instead of "grass-hoppers") are less frequent in children but more frequent in adults (Stemberger, 1989). In perception, there is no evidence of more feature blendings in children than in adults (Castro & Morais, in preparation). Stemberger's data, however, were obtained in children younger than those who served in our study. Direct comparison of reversal errors in perception and production remains to be done.

Developmental changes in the mode of processing and producing speech from less segmental toward more segmental representations may make development of segmental awareness easier. This is possible not because awareness amounts to access to the internal operations of the module but because the conscious phonological representation reached through a more segmental mode of processing may present clearer cues for segments. For instance, the confounding of vowel and fricative in the noise portion, as well as the greater reliance on transitional cues, may thwart the attempts of the child to segment intentionally a fricative–vowel syllable. Perceptual cues (both phonetic and articulatory) are of overwhelming importance at this stage. Content (1985), testing prereaders, has in fact shown a huge difference in the segmentation task, depending on whether the segment to be produced is a fricative or a stop: Fricatives yielded much better performance than stops. This is presumably because contextual effects are less important in fricatives than in stops. Initiating segmental instruction with fricatives might thus take into account the favorable developmental changes that occur in the phonetic module.

At present, the literature shows an increasing interest in exploring the idea that the difficulties of reading and spelling disabled children in developing segmental awareness may be tied to subtle perceptual anomalies. Groups of developmental dyslexics and normal readers, for instance, are compared on specific perceptual tasks. I cannot examine this literature here, although it is of great interest. The problem with this line of research is that it is not easy to choose a priori, among so many possibly relevant perceptual factors and phenomena (e.g., kind of acoustic cues processed, extraction and integration of features, sharpness and position of the boundary in categorical perception, lifespan of the phonological representations, etc.), the one or ones that are actually critical. Thus I suggest that researchers also explore, more systematically, the implications of patent phonological deficits for segmental awareness and literacy acquisition. One way to proceed is to consider first the arrests of development and deviances that may occur in the acquisition of phonology and then examine whether groups or single cases defined by these phonological deficits show characteristic difficulties in tasks of segmental manipulation and in reading and spelling. Of course, this approach may be guided by certain hypotheses, such as the importance of having developed adequate phonetic processing for elaborating unconscious segmental representations or of

having developed a segmentally structured output lexicon for abstracting categories from allophonic variations and for assimilating the phonotactic regularities of the parental language. Two illustrations of posssible research, one concerned with perception, the other with production, follow.

It is becoming clear that children with a history of recurrent otitis media, but normal hearing and normal or delayed linguistic abilities at the time of the study, show marked deficits in categorical perception (Clarkson, Eimas, & Marean, 1989). One may thus hypothesize that such children will display great difficulty at developing segmental awareness, even at the phonetic level and that they will be hampered in the acquisition of simple grapheme–phoneme correspondences. Another kind of phonological disorder is the occurrence of deviant speech errors (i.e., not observed during normal phonological development), such as the omission of all word-initial consonants or the marking of all intervocalic consonants by a glottal stop, in the absence of word-recognition deficits and not attributable to articulatory disorders. Children who make consistent deviant errors cannot distinguish phonologically legal nonsense words from phonologically illegal ones (Dodd, Leahy, & Hambly, 1989), thus suggesting that, at the time their output lexicon should have expanded, they did not elaborate correct hypotheses about word structure. Although their phonetic module seems to have developed normally, their morphophonemic module has not. Therefore, they should have no difficulty acquiring elementary segmental awareness or in understanding simple grapheme–phoneme correspondences, but they should display some trouble at inferring context-dependent grapheme–phoneme rules. As a matter of fact, when it comes to spelling words with a strict grapheme–phoneme correspondence and words that have rare spellings, these children do not differ from normal-speaking controls matched for reading age but do differ on the spelling of words that need the use of context-dependent rules (e.g., representing /k/ as *ck* after a short vowel) (Dodd & Cockerill, 1986). More systematic work along these lines would be welcome.

Tallal (1980) has suggested that the ability to use phonological decoding in reading is conditioned by auditory, rather than phonetic, discrimination abilities. Tallal found a very high correlation between nonword reading and performance on a test indicating the temporal order of two rapidly presented nonverbal auditory stimuli. The notion offered by Tallal that difficulties with temporal pattern perception, or with the processing of rapidly changing stimuli, underlie reading disabilities by hampering phonological decoding must be refused. First, it would be a theoretical mistake to ignore the evidence in favor of a precognitive phonetic module that responds directly to the acoustic information presented in the speech signal, as well as to ignore the many indications of speech-processing difficulties in reading disabled subjects that are not accompanied by comparable nonspeech difficulties. Second, it would be a methodological mistake to take



the observed correlation mentioned above as a proof of a direct relation. Although a module is by definition domain specific, the deficits in its operation, whatever their origin (genetic or experiential), need not be so. Deficits may simultaneously affect several independent abilities. Third, it is possible that the fine temporal resolution of stimuli has access to a process that, albeit general, or because it is general, is employed within the phonetic module, too. What is specific to a module may not be its modes of processing but the particular knowledge that underlies its functioning and the representations it elaborates, which, in the case of the phonetic module, is the knowledge of how the speech apparatus produces speech sounds and the representations of phonetic features that are elaborated from the acoustic information.

## Cues for Discovering Segments

Instruction on the sound values of letters is, of course, not sufficient to discover the segments of speech. The segmental counterpart of letters can only be extracted from the speech sounds if these contain cues for segments and if the child can attend to them. Some consonants can be produced and heard in isolation. Others can be produced either before a *schwa* or at the end of a syllable. Attention to these conditions and variants presumably helps the child to discover the segmental structure of speech.

In previous texts (Morais et al., 1987b; Morais, in press), we have stressed the importance of articulatory cues. Although training studies that insist on these cues are generally highly successful, few attempts have been made to examine children's awareness of their own articulation. One such attempt is reported in Zei (1979). Introspective reports show that at age 5, the earliest considered in the study, children possess some awareness of the movements involved in speech production. For instance, one subject was able to describe tongue movement and its relation to the teeth when producing a /s/, as well as the glottal blocking and the lip closure when producing /ga/ and /ba/, respectively. This study, however, did not provide any performance measure.

An unjustly neglected study is that of Montgomery (1981). This author asked dyslexic children and 9-year-old normal readers matched for reading to indicate which of several schematic drawings corresponded to the position of their tongue, teeth, and lips for a given phoneme. The normal readers performed at about 80% correct, whereas the dyslexics were much poorer (22% and 51% in two different samples). Having decided to include Montgomery's test in future studies of segmental awareness and literacy acquisition, we have recently employed this test with 5-year-old children; we found an average performance of 80% correct, which means that preliterates are prepared to use articulatory awareness as a means to develop segmental awareness, that there seems to be no ulterior development of

articulatory awareness for a period of about 4 years, and last but not least, that the dyslexics tested by Montgomery had severe trouble in appreciating speech gestures, which cannot be explained by their reading disability. It is worth noting that Montgomery (1981) also employed a phoneme-segmentation task. In this task, the average dyslexic score was only slightly inferior (but showed high intragroup variability) compared to the normal readers. Thus, even when the dyslexics have eventually managed to represent the segments separately, they remain behind the normals in their awareness of articulation. Because dyslexics are only poorly aware of articulatory properties, one may conclude that they have probably developed segmental awareness on the basis of phonetic cues.

The phonetic cues can be sufficient to allow the emergence of segmental awareness as suggested by recent findings of Bishop (Bishop, 1985; Bishop & Robson, 1989a). Congenitally speechless (anarthric) subjects can spell monosyllable nonwords even when these include consonant clusters: one subject out of eleven was correct on all items, and five subjects correctly represented, on average, up to 72% of the phonemes. Thus, although a phonemic segmentation task was not used,[9] it is clear that the availability of articulatory routines is not strictly necessary to work out grapheme–phoneme correspondences and, by inference, to learn to analyze heard speech into segments. On the other hand, Bishop and Robson (1989a) found that lack of opportunity to learn articulatory programs leads to poorer word and nonword spelling as compared to children with cerebral palsy but with normal speech. In sum, these results converge with the previously mentioned evidence to suggest that articulatory cues contribute to the acquisition of segmental awareness. It is not certain that phonetic cues alone are sufficiently powerful to allow children to attain a high level of segmental awareness, except perhaps in exceptional cases.

## References


Alegria, J., Morais, J., & d'Alimonte, G. (1990). *The development of speech segmentation abilities and reading acquisition in a whole word setting.* Manuscript submitted, for publication.

Alegria, J., Pignot, E., & Morais, J. (1982). Phonetic analysis of speech and memory codes in beginning readers. *Memory and Cognition, 10*, 451–456.

Allen, G.D., & Norwood, J.A. (1988). Cues for intervocalic /t/ and /d/ in children and adults. *Journal of the Acoustical Society of America, 84*, 868–875.

Allport, D.A., & Funnell, E. (1981). Components of the mental lexicon. *Philosophical Transactions of the Royal Society (London), B*(295), 397–410.

Ball, E.W., & Blachman, B.A. (1988). Phoneme segmentation training: Effect on reading readiness. *Annals of Dyslexia, 38*, 208–225.


[9] In Bishop and Robson (1989b), a rhyming judgment task was used, but, as I have repeatedly argued, this ability does not necessarily require segmentation.




Bertelson, P. (1986). The onset of literacy: Liminal remarks. *Cognition, 24*, 1–30.

Bertelson, P., & de Gelder, B. (1989). Learning about reading from illiterates. In A.M. Galaburda (Ed.), *From neurons to reading* (pp. 1–23). Cambridge, MA: MIT Press.

Bertelson, P., & de Gelder, B. (in press). The emergence of phonological awareness: Comparative approaches. In I.G. Mattingly & M. Studdert-Kennedy (Eds.), *Modularity and the motor theory of speech perception.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Bertelson, P., de Gelder, B., Tfouni, L.V., & Morais, J. (1989). Metaphonological abilities of adult illiterates: New evidence of heterogeneity. *European Journal of Cognitive Psychology, 1*, 239–250.

Bertoncini, J., & Mehler, J. (1981). Syllables as units in infant speech perception. *Infant Behavior and Development, 4*, 247–260.

Bishop, D.V.M. (1985). Spelling ability in congenital dysarthria: Evidence against articulatory coding in translating between phonemes and graphemes. *Cognitive Neuropsychology*, 2, 229–251.

Bishop. D.V.M., & Robson, J. (1989a). Accurate non-word spelling despite congenital inability to speak: Phoneme–grapheme conversion does not require subvocal articulation. *British Journal of Psychology, 80*, 1–13

Bishop, D.V.M., & Robson, J. (1989b). Unimpaired short-term memory and rhyme judgement in congenitally speechless individuals: Implications for the notion of "articulatory coding." *Quarterly Journal of Experimental Psychology, 41A*, 123–140.

Bradley, L., & Bryant, P.E. (1978). Difficulties in auditory organisation as a possible cause of reading backwardness. *Nature, 271*, 746–747.

Bradley, L., & Bryant, P.E. (1983). Categorizing sounds and learning to read: A causal connection. *Nature, 301*, 419–421.

Bramwell, B. (1897). Illustrative cases of aphasia. *Lancet, i*, 1256–1259. (Reprinted in *Cognitive Neuropsychology*, 1984, *1*, 245–258.)

Bryant, P.E., Bradley, L., MacLean, M., & Crossland, J. (1989). Nursery rhymes, phonological skills and reading. *Journal of Child Language, 16*, 407–428.

Bryant, P.E., & Goswami, U. (1987). Beyond grapheme–phoneme correspondence. *Cahiers de Psychologie Cognitive, 7*, 439–443.

Bryant, P.E., MacLean, M.E., Bradley, L.L., & Crossland, J. *Rhyme and alliteration, phoneme detection and learning to read.* Unpublished manuscript.

Cary, L., & Morais, J. (1980). A aprendizagem da leitura e a consciência da estrutura fonética da fala. *Revista Portuguesa de Psicologia, 14*, 97–106.

Cary, L., & Morais, J., & Bertelson, P. (1989). As habilidades metafonológicas dos poetas analfabetos. In *Anais do simpósio Latino-Americano de psicologia de desenvolvimento. Recife* (pp. 160–166). Brazil: Editores Universitária da EFPE.

Castro, S.L., & Morais, J. (in preparation). The development of dichotic word recognition: An error analysis.

Chiat, S. (1983). Why Mikey's right and my key's wrong: The significance of stress and word boundaries in a child's output system. *Cognition, 14*, 275–300.

Clarkson, R L., Eimas, P.D., & Marean, G.C. (1989). Speech perception in children with histories of recurrent otitis media. *Journal of the Acoustical Society of America, 85*, 926–933.

Content, A. (1985). *L'analyse segmentale de la parole chez l'enfant.* Unpublished doctoral dissertation. Université Libre de Bruxelles.

Content, A., Kolinsky, R., Morais, J., & Bertelson, P. (1986). Phonetic segmentation in prereaders: Effect of corrective information. *Journal of Experimental Child Psychology, 42*, 49–72.

Content, A., Morais, J., & Bertelson, P. (1987, September). *Phonetic segmentation in prereaders: A transfer of learning approach.* Paper presented at the Second Meeting of the European Society for Cognitive Psychology, Madrid.

Dodd, B. (1975). *The acquisition of phonological skills in normal, severely subnormal and deaf children.* Unpublished doctoral dissertation. University of London.

Dodd, B., & Cockerill, H. (1986). Phonological coding deficit: A comparison of spelling errors made by deaf, speech disordered and normal children. In J. Clarke (Ed.), *The cultivated Australian: Vol. 48. Beitrage zur Phonetik und Linguistik.* Hamburg, West Germany: Springer-Verlag.

Dodd, B., Leahy, J., & Hambly, G. (1989). Phonological disorders in children: Underlying cognitive deficits. *British Journal of Developmental Psychology, 7,* 55–71.

Dowker, A. (1989). Rhyme and alliteration in poems elicited from young children. *Journal of Child Language, 16,* 181–202.

Ehri, L.C. (1987). Learning to read and spell words. *Journal of Reading Behavior, 19,* 5–31.

Ehri, L.C. (1989). The development of spelling knowledge and its role in reading acquisition and reading disability. *Journal of Learning Disabilities, 22,* 356–365.

Ehri L.C., & Wilce, L.S. (1985). Movement into reading: Is the first stage of printed word learning visual or phonetic? *Reading Research Quarterly, 20,* 163–179.

Ehri, L.C., & Wilce, L.S. (1987). Cipher versus cue reading: An experiment in decoding acquisition. *Journal of Educational Psychology, 79,* 3–13.

Ehri, L.C., Wilce, L.S., & Taylor, B.B. (1987). Children's categorization of short vowels in words and the influence of spellings. *Merrill-Palmer Quarterly, 33,* 393–421.

Eimas, P.D., Siqueland, E.R., Jusczyk, P., & Vigorito, J. (1971). Speech perception in infants. *Science,* 171, 303–306.

Ellis, A., & Beattie, G. (1986). *The Psychology of language and communication.* Hillsdale, & NJ: Lawrence Erbaum Associates.

Ferreiro, E., & Teberosky, A. (1979). *Los sistemas de escritura en el desarrollo del nino.* Mexico City: Siglo Veintiuno Editores.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K.E. Patterson, J.C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading* (pp. 301–330). Hillsdale, NJ: Lawrence Erlbaum Associates.

Fromkin, V. (1971). The non-anomalous nature of anomalous utterances. *Language, 47,* 27–52.

Fujimura, O. (1976). Syllables as concatenated demisyllables and affixes. *Journal of the Acoustical Society of America, S55.*

Goswami, U. (1986). Children's use of analogy in learning to read: A developmental study. *Journal of Experimental Child Psychology, 42,* 73–83.

Goswami, U. (1988a). Orthographic analogies and reading development. *Quarterly Journal of Experimental Psychology, 40A,* 239–268.

Goswami, U. (1988b). Children's use of analogy in learning to spell. *British Journal of Developmental Psychology, 6,* 21–33.

Günther, H. (1985, August). *Was the alphabet discovered or invented? On the alleged common processes in speech and writing.* Paper presented at the International Conference "Graphematics and Orthography," Siegen.

Hohn, W.E., & Ehri, L.C. (1983). Do alphabet letters help prereaders acquire phonemic segmentation skill? *Journal of Educational Psychology, 75,* 752–762.

Ingram, D. (1976). *Phonological disability in children.* Amsterdam, The Netherlands: Elsevier.

Kavanagh, J.F., & Mattingly, I.G. (1972). *Language by ear and by eye: The relationships between speech and reading.* Cambridge, MA: MIT Press.

Kirtley, C., Bryant, P., MacLean, M., & Bradley, L. (1989). Rhyme, rime, and the onset of reading. *Journal of Experimental Child Psychology, 48,* 224–245.

Kolinsky, R., Cary, L., & Morais, J. (1987). Awareness of words as phonological entities: The role of literacy. *Applied Psycholinguistics, 8,* 223–232.

Kuhl, P.K., & Meltzoff, A.N. (1982). The bimodal perception of speech in infancy. *Science, 218,* 1138–1144.

Leroy-Boussion, A. (1975). Une habileté auditivo-phonétique nécessaire pour apprendre à lire: La fusion syllabique. *Enfance, 2,* 165–190.

Liberman, A.M. (in press). Reading is hard just because listening is easy. In C. von Euler (Ed.), *Wenner-Gren International Symposium Series: Brain and reading.* Hampshire, England: Macmillan.

Liberman, A.M., & Mattingly, I.G. (1985). The motor theory of speech perception revised. *Cognition, 21,* 1–36.

Liberman, I.Y., Shankweiler, D., Fisher, M.F., & Carter, B. (1974). Explicit syllable and phoneme segmentation in the young child. *Journal of Experimental Child Psychology, 18,* 201–212.

MacKain, K.S., Studdert-Kennedy, M., Spieker, S., & Stern, D. (1983). Infant intermodal speech perception is a left hemisphere function. *Science, 219,* 1347–1349.

Maclean, M., Bryant, P., & Bradley, L. (1987). Rhymes, nursery rhymes, and reading in early childhood. *Merrill-Palmer Quarterly, 33,* 255–281.

Mann, V.A. (1986). Phonological awareness: The role of reading experience. *Cognition, 24,* 65–92.

Mann, V.A. (in press). Are we taking too narrow a view of the conditions for development of phonological awareness? In S. Brady & D. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Marcel, A.J. (1983). Conscious and unconscious perception: An approach to the relations between phenomenal experience and perceptual processes. *Cognitive Psychology, 15,* 238–300.

Marsh, G., Friedman, M., Welch, V., & Desberg, P. (1981). A cognitive-developmental theory of reading acquisition. In G.E. MacKinnon & T.G. Walker (Eds.), *Reading research: Advances in theory and practice,* (Vol. 3). New York: Academic Press.

Marshall, J.C., & Cossu, G. (1987). Segmental analysis: Modular representations and processes. *Cahiers de Psychologie Cognitive, 7,* 482–487.

Masonheimer, P.E., Drum, P.A., & Ehri, L.C. (1984). Does environmental print identification lead children into word reading? *Journal of Reading Behavior, 16,* 257–271.

McGowan, R.S., & Nittrouer, S. (1988). Differences in fricative production between children and adults: Evidence from an acoustic analysis of /S/ and /s/. *Journal of the Acoustical Society of America, 83,* 229–236.

Mehler, J., Dupoux, E., & Segui, J. (in press). Constraining models of lexical access: The onset of word recognition. In J. Altman (Ed.), *Cognitive models of speech processing.* Cambridge, MA: MIT Press.

Montgomery, D. (1981). Do dyslexics have difficulty accessing articulatory information? *Psychological Research, 33,* 235–243.

Morais, J. (1985). Literacy and awareness of the units of speech: Implications for research on the units of perception. *Linguistics, 23,* 707–721.

Morais, J. (in press). Constraints on the development of phonemic awareness. In S. Brady & D. Shankweiler (Eds.), *Phonological processes in reading: A tribute to Isabelle Y. Liberman.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Morais, J., Alegria, J., & Content, A. (1987a). The relationships between segmental analysis and alphabetic literacy: An interactive view. *Cahiers de Psychologie Cognitive*, *7*, 415–438

Morais, J., Alegria, J., & Content, A. (1987b). Segmental awareness: Respectable, useful, and almost always necessary. *Cahiers de Psychologie Cognitive*, *7*, 530–556.

Morais, J., Bertelson, P., Cary, L., & Alegria, J. (1986). Literacy training and speech segmentation. *Cognition*, *24*, 45–64.

Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition*, *7*, 323–331.

Morais, J., Castro, S.L., & Kolinsky, R. (1988, August–September). *Speech perception in illiterates*. Paper presented at the 24th International Congress of Psychology, Sydney, Australia.

Morais, J., Castro, S.L., & Kolinsky, R. (in press). La reconnaissance des mots chez les illettrés. In R. Kolinsky, J. Morais, & J. Segui (Eds.), *La reconnaissance des mots dans les différentes modalités sensorielles: Données et modèles en psycholinguistique cognitive*. Paris: Presses Universitaires de France.

Morais, J., Castro, S.L., Scliar-Cabral, L., Kolinsky, R., & Content, A. (1987). The effects of literacy on the recognition of dichotic words. *Quarterly Journal of Experimental Psychology*, *39A*, 451–465.

Morais, J., Cluytens, M., & Alegria, J. (1984). Segmentation abilities of dyslexics and normal readers. *Perceptual and Motor Skills*, *58*, 221–222.

Morais, J., Content, A., Bertelson, P., Cary, L., & Kolinsky, R. (1988). Is there a critical period for the acquisition of segmental analysis? *Cognitive Neuropsychology*, *5*, 347–352.

Morton, J., & Patterson, K.E. (1980). A new attempt at an interpretation, or, an attempt at a new interpretation. In M. Coltheart, K.E. Patterson, & J.C. Marshall (Eds.), *Deep dyslexia* (pp. 91–118). London: Routledge & Kegan Paul.

Morton, J. (1989). An information-processing account of reading acquisition. In A.M. Galaburda (Ed.), *From reading to neurons* (pp. 43–66). Cambridge, MA: MIT Press.

Nittrouer, S., & Studdert-Kennedy, M. (1986). The role of coarticulatory effects in the perception of fricatives by children and adults. *Haskins Laboratories: Status Report on Speech Research*, *SR-88*, 73–93.

Nittrouer, S., Studdert-Kennedy, M., & McGowan, R.S. (1988). The emergence of phonetic segments: Evidence from the spectral structure of fricative-vowel syllables spoken by children and adults. *Haskins Laboratories: Status Report on Speech Research*, *SR-93/94*, 1–21.

Perfetti, C.A., Beck, I., Bell, L.C., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merrill-Palmer Quarterly*, *33*, 283–319.

Perin, D. (1983). Phonemic segmentation and spelling. *British Journal of Psychology*, *74*, 129–144.

Pylyshyn, Z. (1980). Cognitive representation and the process-architectural distinction. *The Behavioral and Brain Sciences*, *3*, 154–169.

Read, C. (1986). *Children's creative spelling*. London: Routledge & Kegan Paul.

Repp, B.H. (1986). Some observations on the development of anticipatory coarticulation. *Journal of the Acoustical Society of America*, *79*, 1616–1619.

Rozin, P. (1978). The acquisition of basic alphabetic principles: A structural approach. In C.A. Catania & T.A. Brigham (Eds.), *Handbook of applied behaviour analysis* (pp. 410–453). New York: Irvington.

Rozin, P., Poritsky, S., & Sotsky, R. (1971). American children with reading problems can easily learn to read English represented by Chinese characters. *Science*, *171*, 1264–1267.

Samuel, A.G. (1989). Insights from a failure of selective adaptation: Syllable-initial and syllable-final consonants are different. *Perception and Psychophysics*, *45*, 485–493.

Savin, H.B. (1972). What the child knows about speech when he starts to learn to read. In J.F. Kavanagh & I.G. Mattingly (Eds.), *Language by ear and by eye* (pp. 319–326). Cambridge. MA: MIT Press.

Scliar-Cabral, L., Nepomuceno, L.A., & Morais, J. (in preparation). Diferenças de capacidade de apagamento de vogal e de consoante em sujeitos brasileiros: Efeito da alfabetizaçao.

Seidenberg, M.S., & Tanenhaus. M.K. (1979). Orthographic effects on rhyme monitoring. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 546–554.

Sejnowski, T.J., & Rosenberg, C.R. (1986) . A parallel network that learns to read aloud. *Reports of the Cognitive Neuropsychology Laboratory*. John Hopkins University (Report No. 13).

Seymour, P.H.K., & MacGregor, C.J. (1984). Developmental dyslexia: A cognitive experimental analysis of phonological, morphemic and visual impairments. *Cognitive Neuropsychology*, *1*, 43–82.

Share, D.L., & Jorm, A.F (1987). Segmental analysis: Co-requisite to reading, vital for self-teaching, requiring phonological memory. *Cahiers de Psychologie Cognitive*, *7*, 509–513.

Shriberg, L.D. (1982). Towards a classification of development phonological disorders. In N.J. Lass (Ed.), *Speech and language: Advances in basic research and practice* (Vol. 8, pp. 1–17). New York: Academic Press.

Spagnoletti, C., Morais, J., Alegria, J., & Dominicy, M. (1989). Metaphonological abilities of Japanese children. *Reading and Writing: An Interdisciplinary Journal*, *2*, 27–50.

Stemberger, J.P. (1989). Speech errors in early child language production. *Journal of Memory and Language*, *28*, 164–188.

Stuart, M., & Coltheart, M. (1988). Does reading develop in a sequence of stages? *Cognition*, *30*, 139–181.

Studdert-Kennedy, M. (1987). The phoneme as a perceptuomotor structure. *Haskins Laboratories: Status Report on Speech Research*, *SR–91*, 45–57.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. *Brain and Language*, *9*, 182–198.

Treiman, R. (1985). Onsets and rimes as units of spoken syllables: Evidence from children. *Journal of Experimental Child Psychology*, *39*, 161–181.

Treiman, R., & Zukowski, A. (in press). Levels of phonological awareness. In S. Brady & D. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabelle Y. Liberman*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Tunmer, W.E., & Nesdale, A.R. (1985). Phonemic segmentation skill and beginning reading. *Journal of Educational Psychology*, *77*, 417–427.

Werker, J.F., Bryson, S.E., & Wassenberg, K. (1989). Toward understanding the problem in severely disabled readers. Part II: Consonant errors. *Applied Psycholinguistics*, *10*, 13–30.

Zei, B. (1979). The psychological reality of phonemes. *Journal of Child Language*, *6*, 375–381.