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Early linguistic abilities and reading development: A review and a hypothesis

CARSTEN ELBRO
University of Copenhagen, Denmark

Abstract. This article is concerned with aspects of phonological processing and linguistic awareness that may set the stage for initial reading development. The aims are first to provide a current review of phonological processes (both underlying and metaphonological) that have been found to be associated with initial reading achievement, secondly to present a new hypothesis relating differences in the nature of phonological representations in the lexicon to the development of phonological awareness and other phonological processes. The hypothesis is concerned with *distinctness* of phonological representations, i.e. the separateness of phonological representations. Phonological representations of high distinctness are distinguished from other representations by many features. The distinctness hypothesis is compared to the lexical restructuring hypothesis which suggests that lexical representations gradually become increasingly segmental between one and eight years of age. Implications of each hypothesis (emphasizing the distinctness hypothesis) for the development of language abilities and reading are presented, along with suggestions regarding future research directions.

Key words: Phonological representation, Phonemic awareness, Phonological processing, Early reading development, Reading difficulties

Introduction

During the last two decades a number of encouraging discoveries have been made about the importance of early linguistic abilities for reading development (Goswami & Bryant 1990; Brady & Shankweiler 1991; Kavanagh 1991). In particular, many studies have demonstrated the importance of early sensitivity to the phonological structure of words and of 'phonomic awareness', i.e. the ability to identify and manipulate phoneme-sized elements of spoken language (Blachman 1991, 1993 review this research). It seems both theoretically and empirically likely that a child with low sensitivity to the units of speech represented by written letters will find it difficult to learn to read and write. However, low phonological sensitivity at the beginning of reading instruction is not necessarily an indicator of later reading failure. Reading instruction is in itself probably the most efficient way of becoming phonologically aware (see discussion below). But, on the other hand, children who do not acquire some level of phonemic awareness during initial reading instruction are indeed at risk of failing to learn to read.

Apart from these consistent findings, differences in many other phonological processes have been shown to contribute to the variation in the ease of reading acquisition: phonemic discrimination (e.g. Werker & Tees 1987; Steffens, Eilers, Gross-Glenn & Jallad 1992), phonemic short-term memory (e.g. Snowling 1981; Brady 1991; Stone & Brady 1995), and slow access to phonological representations in the mental lexicon (e.g. Wolf & Obreg6n 1992). Furthermore, some studies have indicated that difficulties in linguistic abilities at higher levels may be related to specific reading disabilities. For example, dyslexic adolescents appear to be less able to manipulate morphemes in closed classes ('function words' and affixes) than younger normal readers at the same reading level (e.g. Elbro 1990). Sensitivity to word order (syntax) may also be related to differences in the ease of learning to read (e.g. Tunmer 1989; Scarborough 1991).

These findings raise the question: *How are various phonological and other linguistic abilities related to each other and to reading development?* Is there one fundamental factor, a 'general language ability', underlying all other language skills relevant for the development of decoding skills? Or do two or more basic processes contribute independently to reading development? It is also possible that different linguistic abilities are important to reading development at different stages.

These questions are far from being answered by existing research although researchers have underlined their importance for some time (e.g. Mattingly 1987; Wagner & Torgesen 1987; Näslund 1990; Siegel 1993; Wagner, Torgesen, Laughon, Simmons & Rashotte 1993). One reason for the lack of resolution is that most research into reading has concentrated on the importance of single processes. Another reason is the great methodological problems involved in a study of the relative importance of different phonological processes (Wagern & Torgesen 1987).

In the present article a unifying hypothesis is advanced. The hypothesis is concerned with the nature of phonological representations in the mental lexicon. It is an attempt to specify what might be the meaning when researchers describe representations as 'poor', 'under specified', 'incomplete' or 'imprecise' (e.g. Katz 1986; Snowling, Wagtendonk & Stafford 1988; Gathercole & Baddeley 1989b; Fowler 1991; de Gelder & Vroomen 1991). The hypothesis to be advanced is that differences in *distinctness* of phonological representations of lexical items is a cause of many of the diverse differences in phonological processing associated with success or failure in reading development. By distinctness is meant the magnitude of the difference between a lexical representation and its neighbours. The more distinctive features that separate a representation from its neighbours, the more distinct is the representation.

The distinctness hypothesis is in line with and aims at an extension of the theories about a unitary phonological deficit advanced by members of the Haskins group, especially Shankweiler, Crain, Brady & Macaruso (1992) and Fowler (1991). The hypothesis is an alternative to another theory of differences in phonological representation referred to as the 'segmentation' hypothesis by Fowler (1991) and as the 'lexical restructuring hypothesis' by Metsala & Stanovich (1995). This other hypothesis holds in brief that phonological representations of lexical items are gradually restructured from wholistic units into increasingly smaller segments, and ultimately into phonemes. The point is that the degree to which this lexical restructuring has taken place determines how easily the child may become phonemically aware and, subsequently, how easily he or she will learn to read and to write. Hence, both the distinctness hypothesis and the segmentation hypothesis are attempts to define causes which are (1) primary to other linguistic precursors, and (2) may explain differences in a variety of phonological processes which are already known to be important for literacy acquisition.

The structure of the article is as follows: First, an overview of some possible linguistic processes underlying the development of reading is presented. Each component is reviewed individually and its possible relation to reading is discussed. This overview is not a complete exposition of the major findings related to reading development. The main research areas are mentioned, but the presentation is guided by the general hypothesis that differences in phonological representations may be a common factor underlying many, if not most, of the differences in the component phonological skills. Secondly, the roots of differences in phonological awareness are traced back to differences in very early forms of phonological sensitivity. Next, the distinctiveness and the segmentation hypotheses concerning differences in phonological representations of lexical items are presented and compared. Both hypotheses, it is argued, have potential for explaining most of the different verbal deficits related to reading difficulties. The distinctness hypothesis is presented in detail here for the first time.

Phonological processes underlying reading acquisition

Phonological awareness

Phonological awareness is a type of linguistic awareness concerned with speech sounds. Phonological awareness is often operationally defined by tests that require comparisons of sounds and manipulation of sounds independent of the significance of the words and utterances of which the sounds are part (reviews are presented in Ball 1993; Skjelfjord 1987a, b). Examples of phonological awareness tasks include:

- rhyme: providing rhymes, categorizing by rhyme and judging rhymes (Bradley & Bryant 1978, 1985; Smith & Tager-Flusberg 1982; Olson, Kliegl, Davidson & Foltz 1985; Bryant, Bradley, MacLean & Crossland 1989);
- finding words that contain certain sounds: categorizing words by single sounds or strings of sounds and providing alliterations (Bradley & Bryant 1985; Bowey & Francis 1991);
- combining sounds into words: phoneme synthesis or blending (Lundberg, Olofsson & Wall 1980; Perfetti, Beck, Bell & Huges 1987);
- segmenting words into sounds by means of blocks, clapping, or counting sounds (Elkonin 1973; Lundberg et al. 1980; Lundberg, Frost & Petersen 1988);
- omitting sounds from words: phoneme deletion (Bruce 1964; Rosner 1975; Catts 1991);
- phoneme substitution, phoneme reversal, or phoneme games such as 'pig latin' (Lundberg et al. 1980; Olson et al. 1985).

Despite the clearly different types of cognitive operations required, these tasks all tap the same underlying construct: the ability to shift attention from word meaning to the phonological form of spoken words (Mattingly 1972; Lundberg et al. 1980; Yopp 1988). Several longitudinal studies have demonstrated independently that the level of phonological awareness in the pre-school years is predictive of later success or failure in reading development at school. This has been found in many different cultures and in many languages, such as English (Mann & Liberman 1984; Bryant et al. 1989; Catts 1991; Wagner, Torgesen & Rashotte 1994), French (Alegria, Pignot & Morais 1982), Italian (Cossu, Shankweiler, Liberman, Katz & Toal 1988), Swedish (Lundberg et al. 1980), and Danish (Lundberg et al. 1988). In addition, training studies have provided evidence that pre-school children can benefit from early language games that direct their attention to phonemes (Bradley & Bryant 1985; Vellutino & Scanlon 1987; Ball & Blachman 1988, 1991; Lundberg et al. 1988; Arnquist 1989; Byrne & Fielding-Barnsley 1991, 1993). Furthermore, indications have been reported that adult dyslexics are less phonologically aware even than younger normal readers of similar reading ability, and a deficit in phonological awareness is still apparent in dyslexics who have attained a fluent reading ability through remedial teaching and much practice (Pratt & Brady 1988; Bruck, 1990; Pennington, et al. 1990; Fowler & Scarborough 1993). At present, phonological awareness is probably the single strongest predictor of reading development in both childhood and adulthood.

Recent discussions have been concerned mainly with the uniqueness of phonological awareness. These discussions consider the extent to which phonological awareness develops independently of exposure to written words and of other linguistic and cognitive skills.

Seeing written words is certainly beneficial for the development of phonological awareness (e.g. Ehri 1989; Morais 1991). While children in different cultures develop a sensitivity to phonological structure in terms of multiphonemic units before they are exposed to the phonemic principle of written language, they rarely develop an analytic awareness of single phonemes within spoken words (Read, Zhang, Nie & Ding 1986; Bowey & Francis 1991; but see Chaney, 1992, as for phoneme synthesis). Before the onset of reading instruction some preschoolers are able to 'pick the odd one out' based on identical rime parts of words (say the word that does not sound similar to the others: *deck, neck, fit*) or identical onsets (*draw, dry, slow*). In a study by Bowey & Francis (1991), four preschoolers out of 20 scored significantly above chance level in such tasks. However, none of the pre-schoolers were able to compare words in terms of single phonemes in medial position or in second position of an initial consonant cluster (e.g. *mat, man, mop* and *prow, pry, play*). This and other studies (e.g. Bentin, Hammer & Cahan 1991) have also found that exposure to reading instruction in first grade contributes much more to the development of phonological sensitivity and phoneme awareness than differences in age do. Learning to read is probably the most efficient way to become aware of phonemes.

Therefore, the relation between phonological awareness and early reading development appears to be one of 'mutual facilitation' or 'reciprocal facilitation' (Perfetti et al. 1987). Additional evidence is provided by some of the most selective studies into phonological awareness training which demonstrate effects on spelling before the effects become significant in reading (Bradley & Bryant, 1985; Lundberg et al. 1988). Furthermore, phonological awareness training has been shown to be more effective when letters are included to support the learning of speech sounds (e.g. Bradley & Bryant 1985; Tangel & Blachman 1995).

However, there are also indications that phonological awareness contributes to reading development independently of orthographic knowledge. For example, Bryant, MacLean & Bradley (1990) found that children's level of phonological awareness at the age of four years was predictive of later reading ability. None of the 4-year-old children were readers, so orthographic knowledge could not be causal factor. Bryant and his colleagues asked the children to 'pick the odd one out' from sets of words that included rhymes (*fish, dish, book*) or alliterations (*pin, pig, tree*). The children's abilities to solve these tasks were found to predict their later reading skills even when differences in the children's initial intelligence, general language skills and the educational level of the mothers were taken into account. Furthermore, Lundberg et al. (1988) were able to demonstrate that it is possible to help preschool children develop phonemic awareness outside the context of reading instruction and with no apparent effects on the size of the children's letter knowledge or vocabulary. To complete the picture, Ball & Blachman (1988) found that teaching letters and letter sounds to five-year-old preschoolers was much less efficient than teaching letters in combination with phonemic segmentation.

What the above studies suggest is that phonemic awareness may be the crux of phonological development as regards reading development. However, phonological awareness may still not be the only phonological or linguistic prerequisite, nor the most basic linguistic prerequisite.

Auditory phonological discrimination and identification

Phoneme discrimination is an elementary process in the sense that it is just one of many components in language processing and in various kinds of linguistic awareness. Phoneme discrimination is also a 'front end' component in the phonological system, hence, poor discrimination may have detrimental effects on several other components and result in reduced distinctness of phonological representations. Indistinct representations are probably more difficult to remember, to recall and to articulate than distinct representations. Hence, phoneme discrimination may, at least theoretically, contribute indirectly through other phonological processes to differences in reading acquisition.

Phoneme discrimination is usually studied by means of nonsense syllables or minimal pairs of words (i.e., words that are distinguished only by one phoneme), and subjects are asked to identify words or sounds or to judge whether stimulus pairs are identical or not. The evidence for the importance of phonemic discrimination skills is mixed, but strongest when listening is stressed either by noise (Brady, Shankweiler & Mann 1983; Elbro 1990) or by synthetic stimuli that tax categorical perception (Tallal 1980; Godfrey, Syrdal-Lasky, Millay & Knox 1981; Andersen & Spliid 1986; Werker & Tees 1987; Steffens et al. 1992).

A number of studies have found small but significant differences between the abilities of dyslexic and normal readers to identify synthetic /ba/ – /da/ – /ga/ syllables that are dispersed on a continuum of varying second formant transitions (Andersen & Spliid 1986; Werker & Tees 1987). Similarly, Steffens et al. (1992) found that dyslexic adults needed more time between an /s/ and the following vowel /a/ to distinguish /sta/ from /sa/ syllables. These differences suggest that dyslexia is associated with a deficit in phonemic perception.

On the other hand, Pennington et al. (1990) failed to find significant differences between normal and dyslexic adults with respect to phoneme discrimination and identification with noise as well as without noise. The adults in this study were not severely handicapped, however. They read at approximately the 8th grade level. The strongest evidence for deficits in phonemic perception thus comes from severely dyslexic persons.

Dyslexics categorize synthetic speech sounds using the same cross-over point as normal readers. But they tend to make more deviant categorizations across the whole continuum of sounds, and the same is true even with syllables that are normally classified 100% unanimously by normal readers. There is no evidence, however, that dyslexics have difficulties in discriminating natural sounds, i.e. non-speech sounds (Brady et al. 1983). Hence, a possible deficit is closely connected to discrimination and identification of *speech* sounds.

There are both theoretical and empirical reasons to believe that phonemic discrimination and identification is linked to the development of receptive language skills in early childhood (Elliott, Hammer & Scholl 1990). But to the present author's knowledge no data from longitudinal studies have been reported on the relations between phonemic discrimination and initial reading development. Therefore, early differences in phonemic discrimination and identification cannot be excluded from the list of possible causes of later differences in reading acquisition.

Verbal short-term memory

There is little doubt that poor readers are outperformed by normal readers in verbal short-term memory tasks (Snowling 1981; Jorm 1983; Brady 1986; Snowling, Goulandris, Bowlby & Howell 1986; Siegel & Ryan 1989; Rapala & Brady 1990; Hansen & Bowey 1984). A recent study by Stone & Brady (1995) indicated that among a number of verbal short-term memory tasks, accuracy of pseudoword repetition was particularly strongly correlated with reading ability in second and third grades. In this study, poor readers in the third grade were even outperformed by younger reading-age-matched normal readers. These results replicate and extend the findings of earlier studies (e.g. Taylor, Lean & Schwartz 1989; Hansen & Bowey 1994).

While these studies certainly suggest that poor readers' phonological processing and memory are less accurate than those of normal readers, they do not provide a more detailed insight into which of the many phonological processing components that may be the cause(s). Poor non-word repetition may have several causes such as poor auditory perception, inaccurate phonological encoding, a limited phonological storage, retrieval problems, or even difficulties with articulation.

So far, longitudinal studies have failed to provide solid evidence that differences in verbal short-term memory contribute to differences in reading development when differences in other phonemic abilities are taken into account (Pennington, Van Orden, Kirson & Haith 1991; Wagner et al. 1994; but see Gathercole & Baddeley 1993). Further evidence against the short-term memory hypothesis was found in a comparison of normal and dyslexic adults (Pennington et al. 1990). The dyslexic adults scored lower than the controls on a measure of verbal short-term memory, but the difference disappeared when differences in phonemic awareness (a 'pig latin' task) were taken into account.

Rapala & Brady (1990) reported from a cross-sectional study of 4, 6, and 8-year-old children that verbal short-term memory appears to be related to speed and accuracy in pronunciation of polysyllabic words and accuracy in a tongue-twister task (repeat 'si/shi' as rapidly as possible) when differences in age are taken into account (see also Brady 1991).

Further indications of a link between articulation speed and reading abilities have been reported by Ackerman, Dykman & Gardner (1989), and by Torgesen, Rashotte, Greenstein, Houck & Portes (1987). In the study by Ackerman et al. (1989), articulation rate still accounted for a significant part of the variation in reading ability even when differences in age and rapid naming of digits and letters were partialled out.

Brady interprets the correlation between verbal short-term memory and articulation efficacy as an indication that verbal short-term memory is dependent on the *quality* of the phonological system. It seems reasonable to assume, as Fowler (1991) does, that the efficiency of verbal short-term memory depends on the quality (e.g. segment size or distinctness) of the phonological representations in the mental lexicon. This possibility is further discussed below.

In line with this assumption, Gathercole & Baddeley (1989a, b) have reported evidence that differences in non-word repetition at the age of four years contribute unique variance to vocabulary size at the age of five years (see also Nelson & Warrington 1980; Aguiar & Brady 1991). Gathercole and Baddeley suggest that learning new words depends, at least in the initial stages, on the ability to represent unfamiliar phonological forms. And they speculate that variation in phonological memory skills may result from differences in the degree of 'richness and redundancy of phonological representations' (1989b: 254).

Retrieval of phonological representations

Slow and inaccurate naming of pictures, digits and geometrical figures is one of the best documented linguistic correlates of reading difficulties. Several studies have shown that poor readers name pictures more slowly and produce more errors than normal controls do (Katz 1986; Snowling et al. 1988; Catts 1991). In addition, poor readers take longer time than normal controls to name rows of colours, digits and letters (Wolf & Goodglass 1986; Wolf & Obregón 1992; Bowers & Wolf 1993). These differences with so-called rapid automized naming (RAN) have also been shown to predict reading development in the first grade (Felton & Brown 1990) and in 3rd and 4th grade (Badian, McAnulty, Duffy & Als 1990; Wolf & Obregón 1992). Naming speed with digits and letters appears to be most predictive, which is hardly surprising given the symbolic value of these units.

Further studies of the nature of naming difficulties associated with poor reading indicate that they are *not* explained by a limited vocabulary, as may be the case for dysphasic children (Wiig & Becker-Caplan 1984). Among others, Snowling et al. (1988) found that young dyslexics performed at the same level as normal controls when they heard a word and were asked to point to the right picture. But the dyslexics were slower at naming the same pictures than normal readers. Aguiar & Brady (1991) reported differences in acquiring phonological representations of new words, but no difference on the semantic contents of the words. This pattern of results indicate that dyslexics may have specific difficulties with recall of phonological representations rather than with semantic representations of words in the mental lexicon (Glaser 1992; see also Elbro, Nielsen & Petersen 1994).

This interpretation is supported by Griffiths (1991) who investigated naming without using pictures. The study comprised 10-year-old dyslexics and groups of chronological-age-matched controls and younger, reading-level-matched controls (8 years old). The three groups were asked to produce words which (1) begin with a specific letter, (2) begin with a specific sound, or (3) words that can follow a specific adjective (e.g. *big* ... elephant). The dyslexics outperformed both of the normal groups in the third, semantic task. But the dyslexics performed more poorly than even the younger reading level matched controls with the first task, and the dyslexics performed at the level of corresponding to their reading abilities with the second task using initial sounds.

While difficulties with phonological retrieval have sometimes been interpreted as indications of difficulties with lexical retrieval, articulatory motor assembly and output etc., they may also be a result of problems with the phonological representations themselves (Katz 1986; Snowling et al. 1988; Fowler 1991). Poor readers may possess words that are represented phonological indistinctly or otherwise inefficiently.

Phonological processes in a developmental perspective

A central aim of dyslexia research is to be able to distinguish between the *primary* underlying processing difficulties and other, related difficulties. Other difficulties may just be (*secondary*) consequences of the basic difficulty, or they may be coincidentally co-occurring in the same person. With the increasing number of single phonological deficits shown to relate to differences in reading, the task of sorting out the causal relations have been increasingly important and difficult.

The studies mentioned so far have all been restricted to comparisons between reading development and earlier language skills measured at a particular point in time, mainly during kindergarten. None of these studies have looked at possible predictors at different stages of language development before the onset of literacy instruction. Thus, some of the inconsistencies between the results may be a consequence of other developmental differences. Another source of difficulty in assessing the relative strength of the predictors is that the relative importance may vary from birth to the onset of reading instruction.

The conditions for the development of phonological awareness seem to have attracted special interest. This is understandable since these conditions are possible earlier links in the chain of causes that ultimately leads to essential differences in reading ability. If the cause or causes underlying differences in phonological awareness were known, it might be possible to predict and perhaps even prevent reading difficulties long before the onset of reading instruction.

Emergent phonological awareness

According to classic Piagetian theory, concrete operational thought does not develop before the age of six to seven years. Consequently, one might believe that children were unable to reflect on the structure of language and unable to become aware of phonemes before that age (e.g. Tunmer 1989). However, a number of studies have shown this to be a misconception. Even 3-year-old children show clear signs of phonological sensitivity and ability to reflect on speech sounds independent of the meaning of the words. Chaney (1992), for example, demonstrated that more than half of a group of 3-year-old children were able to solve metalinguistic tasks at both phoneme, morpheme and word levels. At the phoneme level, most of the children were able to synthesize phonemes into words ('h..a..t' > *hat*). At the morpheme level, the children were able to select the correct endings of words in sentences (plural *-s/-z* or nomen agents *-er*) and to correct other speakers' errors. At the word level, the children were able to segment word chains into single words (e.g., 'balloontreeshirt' > *balloon, tree, shirt*), they could distinguish real words from non-words, and they could distinguish between word and referent and answer questions using new words for familiar objects. About one-third of the children were both able to judge whether two words rhymed or not and to produce rhymes themselves.

Of course, children at this age cannot solve the phonemic awareness tasks used in kindergarten. But they are able to solve many tasks provided that the words are short and frequent, that the tasks are presented in a form which is linguistically and cognitively simple, that no linguistic terms like *word* or *phoneme* are used, and that the children are given examples and practice trials.

The validity and importance of these results are underlined by findings of correlations between early linguistic awareness and emergent literacy skills. Chaney (1992) found strong correlations between three-year-old children's degree of language awareness and their knowledge of letters, writing conventions and books. In particular, the relation between phoneme sensitivity and letter concepts was strong even when age differences were accounted for. This is a connection of obvious importance for the later reading development of the children because letter knowledge at school starting age is a predictor of success in reading (Badian et al. 1990).

In an attempt to trace the roots of phonological awareness, Bryant et al. (1989) studied three-year-old children's knowledge of nursery rhymes (mean age 3:4 years). The children were presented with the first part of five traditional nursery rhymes and asked to say as much of the rhymes as they knew. Practically all children knew at least parts of some of the rhymes. Furthermore, the children's knowledge of nursery rhymes predicted their ability to identify rhyming words at the age of four and their phonemic awareness at the age of six. Bryant *et al.* suggest that early exposure to and sensitivity to nursery rhymes pave the way for later phonemic awareness which in turn is a critical factor in early reading development. This suggestion has strong practical implications, and it is important that other studies try to replicate the results, preferably with more measurements of early language, so as to provide better control for spurious correlations.

When results of studies of linguistic awareness are seen in a developmental perspective, sensitivity to rhymes appears to be a much stronger predictor at the age of three to four years than later, when it is not very predictive (Stanovich, Cunningham & Cramer 1984; Lundberg et al. 1988; Yopp 1988; de Gelder & Vroomen 1991). While this appears to be the case for middle-class children the rhyme abilities of disadvantaged children often have not fully developed by kindergarten, and individual differences appear to still be associated with later achievement (see for discussion Brady, Fowler, Stone

& Winbury 1994; also Bowey, 1995). Phonemic awareness appears in turn to be more important at the onset of reading instruction. The discussion below will consider whether these developmental changes in the ease of access to segments of spoken words may be determined by an increasing distinctness of the phonological representations.

Development of other language skills prior to phonemic awareness

If phonological awareness were the only important linguistic basis for reading development, one would expect children who later experience reading difficulties to lag behind their peers in phonological awareness right from the age of three years. Or, conversely, if dyslexia were caused by some deficiency in oral vocabulary, one would expect to find deficiencies in vocabulary in future dyslexics of any age. However, this does not appear to be the case.

Scarborough (1990, 1991) followed the language development and later reading development from 2:6 years of age until the end of second grade at school in a study of 32 children of dyslexic parents. At the end of second grade, 20 of the 32 children turned out to be poor readers. Comparisons of these 20 children and the 12 normally achieving children showed significant differences even at very early ages. At 2:6 years, groups differed as regards pronunciation of consonant clusters, mean length of utterance, and syntactic complexity of spontaneous speech. At three years, groups differed in both receptive and expressive vocabulary (measured by the PPVT and Boston naming tests, respectively). And at five years, the children who subsequently became poor readers were outperformed in letter naming, expressive vocabulary, and phonological awareness. One interesting aspect of these findings is that no single factor appeared to distinguish between the two groups of children from two to five years of age.

Scarborough (1992) explained this pattern of results as an indication of a difference in some underlying language ability which is seen only in areas where language development is particularly rapid. Her hypothesis is that poor readers suffer from a general 'lag' in language development, but that this 'lag' is only clearly visible in certain areas of rapid language growth.

According to this hypothesis, dyslexic children will be expected to catch up with their peers at some later time. This implication does not seem to be true, however. While a variety of language problems are observed in childhood, there is now compelling evidence that individuals with dyslexica do not fully 'catch up' (Pratt & Brady 1988; Bruck 1990; Pennington et al. 1990; Fowler & Scarborough 1993). This raises the possibility that their impairment should be viewed as a more permanent underlying weakness which impacts on various areas of language development as each becomes the next hurdle in language acquisition. Again, in the discussion below, the pervasiveness of the effects of indistinct representations will be considered as a possible explanatory underlying weakness.

Differences in phonological representations that may influence the development of several phonological processes

Many of the apparently diverse language deficits that are characteristic of poor readers may, at least theoretically, stem from a unitary deficit. The Haskins group have pioneered the view that a candidate for such a deficit is most likely to be found in the phonological system (see Shankweiler & Liberman 1989; and Brady & Shankweiler 1991). Shankweiler and Crain, have suggested that even the comprehension difficulties that poor readers have with certain spoken sentences may be attributed to a *limitation* in their processing of phonological material rather than to a failure to comprehend complex syntactic structures (Shankweiler et al. 1992). Crain & Shankweiler (1990) found evidence that the complexity of the syntactic structure is not causing problems in itself, rather the problems in comprehension are related to the demands on phonological memory that may exceed the capacity of the phonological system.

One possible cause of limitations of the capacity of the phonological system may be inadequate or inefficient phonological representations. Several researchers have referred to this as a possible explanation of various linguistics deficits in dyslexia (e.g., Katz 1986; Snowling et al. 1988; Gathercole & Baddeley 1989b; Fowler 1991). In the next section, two hypotheses about variations of phonological representations are presented, and it is suggested how each of them may explain many of the linguistic deficits that are found in dyslexics. The first hypothesis concerned with the size of the segments of the phonological representation has been presented in detail elsewhere (Fowler 1991) and is thus only briefly presented here.

Segmental phonological representations

As long as the child knows only a few words, these words may well be represented as unsegmented gestalts, such as complete perceptuomotor structures. But, as the vocabulary grows, this way of representing spoken words becomes less viable. The most accessible and economic unit (in terms of demands on storage) may then depend upon the particular language spoken by the child. Japanese children may choose to represent lexical items in syllabic segments because there is a very limited number (about 50) of different syllables in Japanese. But children growing up with Germanic languages (such as English and Danish) have to store a much larger amount of different syllables (in the order of 2000 or more), so they may ease the burden on memory by mentally representing spoken words by means of phoneme-size units (of which there is a very limited number) rather than by syllables.

Fowler suggests that 'lexical representations become increasingly segmental between 1 and 8 years of age' (1991: 98). This suggestion is in accordance with much research on children's access to and awareness of still smaller units of spoken language – as suggested in the sections above (see for a review also Walley 1993). On this basis, Fowler proposes a 'segmentation hypothesis' suggesting that differences in segment size of phonological representations may be a factor underlying differences in linguistic and metalinguistic development that are critical for reading development. If dyslexics, for one reason or another, develop less segmental phonological representations, this may explain why they have difficulties in becoming aware of phoneme size units and why they, in turn, develop insufficient orthographic representations.

Direct evidence that dyslexic adults possess fewer segmented phonological representations than normal readers is scarce. But, for example, de Gelder & Vroomen (1991) found that normal adults classify words on the basis of a single common phoneme (e.g. [p] in [pɪm] and [pas]) more often than dyslexic adults do. Instead, dyslexic adults are more inclined to classify words on the basis of a general phonetic similarity (e.g. [pɪm] – [bi:n]). However, it is not clear whether these differences are consequences of the reading difficulties or an underlying cause.

The segmentation hypothesis accounts quite well for the development of phonemic awareness because phonemic awareness may be seen as a manifestation of the very nature of lexical representations. If a child is asked to decide whether two words share a common phoneme, the task is solved most easily if the words are represented in phoneme segments by the child. The task is much more difficult if the unit of representation does not allow for a direct comparison at the requested (phoneme) level. It may also be noted that the segmentation hypothesis is in accordance with the ordinary progression in materials for phonemic awareness training, which typically begins with segmentation of sentences into words and proceeds towards phonemes.

According to Fowler (1991) the segmentation hypothesis can also account for differences in phonological short-term memory between dyslexic and normal readers. The reason is that a less segmental representation may render it difficult to assign novel stimuli (non-words) into a recoverable representation. If an unfamiliar word can be analysed and encoded as a string of well-known units it may be easier to represent and reproduce than if it is perceived as one lengthy chunk of gestural information. Further, Fowler suggests that the segmentation hypothesis may account for differences in phoneme discrimination, and for differences in articulatory control. 'It would seem that any task that requires reconstruction of the syllable would be aided by a segmental analysis and by refined, well-articulated prototypes of those segments to which the input must be compared' (1991: 108). While the first part of the argument refers to the segmentation hypothesis, the second part about the quality of the segments might rather relate to the distinctness hypothesis discussed next.

Distinctness of phonological representations

When children mispronounce words they usually preserve the general acoustic form, e.g. *volcano* > 'tornado', *globe* > 'gulb' (Katz 1986). This tendency suggests that children have access to some under-specified form of the correct word. They know the word, but the phonological representation is not sufficiently specific to enable them to recall the correct form.

Many researchers have previously suggested that problems in establishing complete phonological representations in long-term memory may be an underlying cause of developmental reading difficulties (Katz 1986; Snowling et al. 1988; de Gelder & Vroomen 1991). A variety of terms have been applied to this potential problem. In just one page Snowling et al. (1988: 80) use expressions like 'faulty or impoverished (phonological) representations', they are not 'full phonological specifications' or 'fully specified' or 'precise phonological representations'. In this section an attempt will be made to outline a more specific hypothesis about the possible lack of 'completeness' of phonological representations in dyslexia. The term proposed is *distinctness.*

Distinctness of a phonological representation relates to the magnitude of the difference between the representation and its neighbours. A phonological representation is relatively distinct if many distinctive features (in a general sense) serve to distinguish it from its neighbours. For example, the word *and* is regularly pronounced either [ænd] or (unstressed) [ənd] or [ən]. The lower distinctness of [ən] is apparent by the homonymy with unstressed *an* [ən]. Similarly many words may be represented and pronounced at varying levels of distinctions; the second vowel of *cabinet* may be both [ɪ], [ə], or assimilated into the following [n], the *e* in *boisterous* may or may not be represented, *crepuscule* may be represented as [krɪˈpʌskju:l], [ˈkrepəskju:l], or [kɪˈpʌsl] (optionally spelled *crepuscle* in American English).

The distinctness hypothesis, which was first advanced by Elbro et al. (1994) and is further specified here, proposes that children who become dyslexic have *poorer access to the most distinct variants of spoken words* than other children. This poor access may have several causes which are not specified by the hypothesis: (1) poor readers may not possess as distinct phonological representations of words as normal readers, (2) their prototypical representation (preferred variant) of many words may be less distinct, or (3) they may have difficulties with associations between different levels of distinctness.

Distinctness is related to common metaphorical descriptions of the quality of phonological representation in fairly simple ways. If 'freedom of ambiguity' is what is meant by *clarity* of a phonological representation, then 'clarity' is the same as distinctness. Distinctness is not related to the *strength* of a representation if *strength* means activation threshold. However, if *strength* means 'robustness', insensitivity to disturbances like noise, then clearly, strength has to do with distinctness.

The distinctness hypothesis can account directly for some variation in reading acquisition. Children with poor access to the most distinct representations are disadvantaged because the written forms are always closest to the most distinct spoken variant. For these children the spelling of written words is less predictable from their mental representation than it is for children with easy access to more distinct variants. More importantly, it will be argued that the distinctness hypothesis can account for differences in many phonological processes that distinguish poor readers from normal readers.

First, however, the concept of phonological distinctness needs to be explained more. For a start, some examples of directly observable variations in distinctness in natural oral language will be given to provide the reader with some idea of the concept of distinctness. Then, moving to the abstract realms of mental representations, variation in distinctness is briefly described within the framework of each of two psycholinguistic models of phonological representation: a structuralist and a probabilistic model of distributed representation. It will further be discussed how the distinctness hypothesis differs from the segmentation hypothesis, and where the two hypotheses connect. Finally, some of the central phonological deficits related to dyslexia will be discussed in terms of the distinctness hypothesis.

Examples of distinctness variation in common oral language

Short forms like *sub* for *submarine* and *auto* for *automobile* are examples of less distinct *lexical* forms. The short forms are less distinct than the full forms because they have more close neighbours than the full forms. Both short forms even have identical 'neighbours'. *Auto* is also short for 'automatic', and *sub* means 'submarine', 'substitute', 'subway', 'substratum', and other things such as 'sub-scription' or 'subsidy'. Hence the *probability of overlap* and confusion is greater for *sub* than for *submarine* because the number of distinctive features is fewer. Short forms are, of course, extreme examples of less distinct variants; but they are illustrative of the phonological and phonetic issues to be discussed.

A main source of variation in distinctness in ordinary speech is general reductions made by some but not all speakers of English. Some examples of optional *phoneme omissions* are *coyote* [kaɪ'əuti:] reduced to ['kaɪəut] (in analogy with the pronunciation of *vote, note* etc.), *crepuscule* optionally reduced to *crepuscle* (in analogy with *muscul(us) > muscle*), and words like *human, what,* and *nar-whale* (also spelled *narwal*) with facultative omission of [h]. The lower distinctness of some of the reduced forms is indicated by homophones like *w(h)at = Watt, (h)uman = Yuman* (a group of Indian languages).

Reduction of *vowel quality* is another type of reduction tied to syllable stress. In late Old English unstressed vowels were reduced to a schwa [ə]. Modern English has a similar tendency towards reduction of loan words. However, in many cases the reduction is not a phonological 'rule', but optional, as in *crayon* with the last vowel pronounced either [ɔ] or [ə]. Combinatorial ('bound') variation occurs in some of the most frequent words, *a* [eɪ] > [ə] (unstressed), *an* [æn] > [ən], *and* [ænd] > [ənd] or [ən], *of* [ʌv] or [ɔv] > [əv] (*of course*).

Some schwas may even be omitted altogether from medial positions in words with three syllables or more, e.g. *extr(a)ordinary* and *plat(i)num.*

The choice between alternate forms at various levels of distinctness is (more or less consciously) determined by a number of factors such as listening conditions (noise and other distracters), frequency, neighbourhood density of the words, and the speaker's presumptions about the listener's knowledge of the subject. High degrees of distinctness are required under noisy conditions, when words are infrequent and belong to dense neighbourhoods, when the subject is new and the words are unpredictable for the listener.

As to *phonetics*, there may be a clear step between the vowel [ə] and a full reduction of the syllable. Compare, for example, an 'over-distinct' pronunciation (1) [plætənəm] (*platinum*) with the standard pronunciation (2) [plætn:əm] and with the reduced standard pronunciation (3) [plætnəm]. The intermediate step (2) is equivalent to the more distinct pronunciation (1) in terms of phonology, because the same phonemes are present. In (2) the [ə] has been assimilated into an [n:] with syllabic quality. However, at a phonetic level [ən] is more distinct than [n:] because the syllabic character is articulatorily (featuring an opening before the nasal) and acoustically more pronounced so that [ən] is more different from [n] than [n:] is.

Another example of distinctness variation at the phonetic level concerns the difference between voiced and unvoiced fricatives (e.g. [f]–[v] and [s]–[z]). The phonological difference in initial position of stressed syllables is realized phonetically by means of voice *and* articulatory power. This means that if a speaker uses only one of the distinctive features (e.g. voice), the distinction between e.g. *zinc* and *sink* is smaller than otherwise. In final position, the difference between e.g. [z] and [s] depends mainly on the quantity of the preceding vowel (*eyes* is primarily distinguished from *ice* by a longer vowel), but the distinction may (optionally) be enhanced by an additional difference in voice.

Distinctions between phonemes may be realized by means of differences in a single dimensions, such as voice onset time which distinguishes voiced from voiceless stop consonants in many languages, or the starting point of formant transitions which may distinguish various stop consonants from each other (such as [b], [d] and [g]). Even if perception is categorical it is still meaningful to speak of distinctness: the closer a speech sound is to a categorical boundary the less distinct, because the greater the risk of confusing it with its neighbouring sounds.

At this level only trained linguists can detect differences in distinctness with the aid of spectrograms. However, when it comes to phonological representations within the mental lexicon, there is no method by which they can be observed directly. Hence, to further clarify the distinctness hypothesis, we need to look at it in terms of theoretical *models* of phonological representation.

Distinctness variation in speech is a 'surface' phenomenon and as such of minor interest to the dominant phonological theories (cf. Rischel 1990: 408). And phonological representations of lexicalised items are fully specified in most theories of language representation. However, this does not preclude distinctness variation from being compatible with theories of phonological representation. Two examples of such incorporation are given below.

Distinctness variation in two models of phonological representation

Distinctness in a structuralist model. In the structuralist model by Chomsky & Halle (1968), lexical items (so-called 'formatives' like *inn, sing* and *past* (tense)) are represented as syntactical units having some systematic, 'packed' phonological properties. These 'packed' properties are 'unpacked' by means of lexical redundancy rules (a kind of 'readjustment' rules) which may recreate a full phonological representation. During the act of speaking, this phonological representation is used as input to the speaker's phonological component. The phonological component is a system of transformational rules which transforms phonological representations into concrete phonetic realizations.

The input to the phonological module is a fully specified phonological representation. It is fully specified in the sense that each phoneme is represented by a complete set of distinctive features. For example, the word *string* is represented by 9 – 11 distinctive features per segment (Scheme 1).

/s	t	r	i	ŋ/
−syll.	−syll.	−syll.	+syll.	−syll.
+cons.	+cons.	+cons.	−cons.	+cons.
−high	−high	−high	+high	+high
−back	−back	−back	−back	+back
−low	−low	−low	−low	−low
+ant.	+ant.	−ant.	−ant.	−ant.
+coron.	+coron.	+coron.	−coron.	−coron.
			−round	
			−tense	
−voice	−voice	−voice		+voice
+contin.	−contin.	−contin.		−contin.
−nasal	−nasal	−nasal		+nasal
+strid.	−strid.	−strid.		−strid.

Scheme 1.

However, the *lexical* representation may be much less specific. Recent developments in generative phonology have also suggested that neither phonological nor even phonetic representations are necessarily fully specified (e.g. Archangeli 1988). Most of the features above are redundant if the only requirement is that the lexical item be uniquely defined. For example, /*i*/ is the only vowel in English that is [+high] and [−back] making the rest of the distinctive features redundant. Further taking contextual constraints into consideration, /r/ is the only [+cons.] following initial /st-/ rendering all other features superfluous. Since speech production and perception involves many 'left-to-right' processes (Levelt 1991), a way of 'packing' the phonological information of lexical items would simply be to go from left to right and delete any redundant features. A 'packed' and much less redundant representation might look like this (with only 10 distinctive features needed for the last four segments, Scheme 2):

/s	t	r	i	ŋ/
−vocal.	+cons.	+cons.	+vocal.	+back
+cons.	+ant.		−cons.	+nasal
−high	+coron.		+high	
−back			−back	
−low				
+ant.				
+coron.				
−voice				
+contin.				
−nasal				
+strid.				

Scheme 2.

Notice that although the word is uniquely defined by the lexical representation, its segments are not. That is, a subject with such a highly under specified phonological representations may be perfectly able to identify words, remember them, and pronounce them, but rather handicapped as to solving phonological awareness tasks with the words. Imagine, for instance, that a person with the above representation of *string* were asked to say 'string' without the initial /st-/. The first segment would then be the /r/ but in this representation specified only as a consonant. Hence, any three-phoneme word beginning with a consonant and ending '-ing' would match the remainder of the 'packed' representation. Therefore, the person would be completely unable to solve the phoneme subtraction task correctly.

However, 'packing' is mainly necessary for economic reasons, just as packing and unpacking data files in computers are necessary mainly because of storage limitations. With more storage space available a lower degree of packing and a higher degree of specification of the data would be more safe and versatile. In the above example, 21 bits are used to store *string*, excluding information about position. A full specification of *string* with 9–11 distinctive features per phonological segment (Chomsky & Halle 1968: 176) would required 53 bits. These additional bits of information would surely be redundant, but they would provide greater distinctness of the lexical item. Furthermore, a full specification would give direct access to the identity of each of the constituent segments ('abstract phonemes' to use a term Chomsky & Halle (1968) deliberately avoid). Differences in distinctness might thus occur at the lexical level of representation. Consequently, the acquisition of reading ability would be directly dependent on distinctness as far as 'conventional orthography is . . . a near optimal system for the lexical representation of English words' (Chomsky & Halle 1968: 49).

Another possibility is that differences in distinctness occur at the input level of the phonological component. In Chomsky and Halle's theory, the phonological component needs fully specified phonological representations as input, otherwise the transformations will not work. In real life phonological representations might nevertheless be under specified for several reasons, one being that the lexical redundancy rules might not efficiently 'refill' all distinctive features. Of course, at some point the speaker would need the information required to articulate the word. It is outside the scope of this paper to explain how this might be accomplished. However, one possibility would be that (even indistinct) phonological representations are closely associated with articulatory programmes that contain the necessary information (see also Archangeli 1988).

No matter whether differences in distinctness occur at the lexical level or at the input level of the phonological processor, the point is that the lexical item *as a whole* may still be fully specified although the single phonological segments may not be.

An implication of differences of distinctness within this theoretical framework is that speech sounds which correspond to the most redundant segments should be harder to identify than speech sounds corresponding to less redundant phonological segments. This is certainly true for the second and third consonants of initial consonant clusters. These are much harder for children to identify than are single consonants that cannot be 'packed' as much. However, other implications are open to empirical testing (see the discussion section).

Distinctness in a probabilistic model of distributed representation. Siedenberg & McClelland (1989) have outlined a computational model of lexical representation in which the phonological representation of each lexical item is distributed over many units (e.g. over 16 units of a total of 460 units as in Seidenberg & McClelland's model). Each unit contains a piece of information about each of three consecutive phonemes. For example, a hypothetical unit α [stop, vowel, stop] would activate three-phoneme sequences like *get, kid, cut* and *bag* among many others. (For the sake of simplicity, word boundaries are not represented here). When unit α is activated in combination with unit β [bilabial, unrounded, velar], the number of possible words is reduced dramatically. Some possibilities are *pack, peg, bake, buck,* and *bag*. In further combination with the unit γ [voiced, front tongue, voiced] only a few sequences are activated, *big, beg,* and *bag*. As the number of units increases, the string of phonemes becomes more well defined, i.e. distinct.

In such a network model, the *number* of units determines the highest average level of distinctness. With many units representing each lexical item, chances would be that any two items might share some units while at the same time being distinguished by many other units. Such representations would provide grounds for judgements of both similarities and differences whereas similar judgments (or analyses) would be more difficult with fewer units.

The *size* of the units, on the other hand, corresponds to the segment size of the phonological representations. Instead of representing information about three consecutive phonemes, each unit might represent any unit size, say from single distinctive features to whole words or even phrases.

How the distinctness hypothesis may account for other phonological deficits related to dyslexia

Returning to the oral language correlates of dyslexia, it will be argued that the distinctness hypothesis can account for many of the observed language deficits related to dyslexia. The more basic language processes will be considered first, followed by differences in phonological awareness.

As argued by others, 'incomplete' (and thus less distinct) representations are not as easily *retrieved* as complete phonological representations are (e.g. Katz 1986; Snowling et al. 1988). This explains the well-documented difficulties of dyslexic children with tasks such as naming pictured objects or symbols (see above). When the phonological representation of a well-known semantic entity is sought, it is effortlessly retrieved given that the necessary cues are many and that they uniquely define the representation.

The deficits in *articulatory efficacy* reported in dyslexia are not explained as easily as deficits in verbal retrieval. An indistinct representation may even be reduced in a way that makes it less complicated to articulate than a more distinct representation. However, if the level of distinctness is controlled externally, for example, by asking subjects to repeat strings of well-defined syllables (e.g., 'say *see-she* ten times as fast as possible'), these syllables have to be represented by the subjects. And, again, distinct representations will provide a less ambiguous (and thus better) input to the articulatory system. The effect of differences in distinctness will depend on how heavily each pronunciation cycle draws upon the phonological representation.

Differences in distinctness may also explain deficits in *phonological short term memory* associated with dyslexia (see Gathercole & Baddeley 1989b). A low level of distinctness may hamper both the encoding and the retrieval of the material to be remembered. With real words, encoding is impeded because the words are less easily recognized and less unambiguously stored. In the case of non-word material, the representation is made even more difficult because there are fewer distinctive features available for the representation of the spoken material. Poor readers do generally have smaller vocabularies, but even when this is not the case, they do worse on nonword repetition (Stone & Brady 1995). The more remote a nonword is from real words the fewer are the readily available distinctive features likely to be. This may be an explanation why persons in general do better with nonwords that are more like real words than with nonwords which are less wordlike (Snowling, Chiat & Hulme 1991; Gathercole 1995; Dollaghan, Biber & Campbell 1995).

As mentioned in the introduction to the present section about distinctness, a possible difference in distinctness at the level of single distinctive features (of phonemes) might be expressed as a decrease of categorical stability, i.e. the phonetic values of the distinctive features would approach each other and the risk of confusion would increase. This would explain the findings of a less sharp categorical perception of phonemes in dyslexia. Similarly, it might also explain why dyslexic persons may be especially susceptible to noise in *auditory speech perception*. The noise may mask some distinctive features but leave sufficient information preserved to enable listeners with distinct representations to identify the spoken words – while listeners with less distinct representations would be deprived more easily of the features that they represent and use for recognition. Another possibility is that smaller differences between phonological representations may make it more difficult to distinguish between words because the differences in stimuli may not match differences in representations. Consequently, although a poor reader may perceive a difference between two words, he or she may not be aware of this difference because it does not correspond to a difference that is familiar to him or her.

Finally, indistinct representations are an inferior basis for the acquisition of *phonological sensitivity* – and later for development of *phonemic awareness* and for phoneme manipulations, such as those required by standard tests of phonemic awareness. Rhyme judgement (and appreciation) depends on phonological representations that are sufficiently distinct to enable the child to perceive both the similarity and the dissimilarity between the rhyming words. As concerns *phoneme segmentation* and *phoneme identification*, phonological representations may be uniquely defined without fully specified constituent segments (cf. the *string* example above). This implies that even if a child can perceive and produce words accurately, he or she need not have access to the constituent segments. Not even the existence of minimal pairs (i.e., words distinguished by only one phoneme) is a guarantee that the child will have access to full specifications of the different segments. For example, *grade* and *glade* differ only by one phoneme but, as mentioned earlier, each of these phonemes need only be specified by two (of 13) distinctive features for the words to be uniquely defined. A phonological representation based on phoneme-size segments will only tell the child that there is some differing segment between the /g/ and the /a/. It will not automatically give the child access to the identity of the sound. Only a fully distinct representation of each phoneme will provide sufficient information for a direct identification of the segments. Therefore, phoneme segmentation requires both access to segments at the phoneme level *and* access to a distinct representation of these segments.

Present empirical evidence for the distinctness hypothesis

There has only been a limited amount of work in relation to distinctness of phonological representation in dyslexia. However, in a study of adult dyslexics Elbro et al. (1994) found indications of less distinct phonological representations when compared to those of normal adults – in both word recognition and word production. The adult dyslexics performed at a normal level with a vocabulary test using semantically close alternatives (point to the picture of a *wagon*, given pictures of various trains and cars). But they performed below average in a similar test with phonologically close alternatives (which of the following words means 'capital punishment': *excursion,* *exclusion*, or *execution*?). The interaction between subject groups and vocabulary tasks was significant even when differences in education, amount of daily reading, *and* phoneme awareness were accounted for. Furthermore, the dyslexic adults tended to pronounce words with three or more syllables less distinctly than the normal controls, although they pronounced the words more slowly.

Indirect support for the distinctness hypothesis is provided within the framework of the neighbourhood activation model of word recognition by Luce, Pisoni & Goldinger (1990). Distinctness can be thought of in terms of neighbourhood density: a word in a dense neighbourhood is one with many other words just one phoneme away (by substitution, deletion or addition). A word in a dense neighbourhood is less separated from other words than a word in a sparsely populated neighbourhood. Luce and his co-workers have demonstrated that when presented in noise, words in dense (frequency-weighted) neighbourhoods are more easily confused with others than words in sparse neighbourhoods. Furthermore, nonwords in dense neighbourhoods are more slowly classified as nonwords, and words in dense neighbourhoods are repeated more slowly than words in sparse neighbourhoods following an oral presentation. These results may parallel the performance of dyslexics in the sense that the average performance of a dyslexic is similar to that of normal readers with words in dense neighbourhoods. Dyslexics more often confuse words, they have problems with lexical decision, and they are poor at repeating nonwords.

Another type of indirect support relates to the implication that indistinct representations are supposed to result in greater difficulties with phoneme segmentation and subtraction than with phoneme addition. The reason is that subtraction requires 'refilling' of the distinctive features that are redundant and optionally left out in the context of the whole word (cf. the *string* example above). Conversely, phoneme addition (or synthesis) does not require a similar distinctness step-up because all – or maybe more than all – the distinctive features necessary to identify the word are present in the stimuli. Therefore, the prediction is that measures involving segmentation and deletion are more predictive of dyslexia than measures, like synthesis, which do not require addition of distinctive features. Certainly, synthesis has been reported to be more 'primitive' (acquired earlier) than deletion (e.g., Perfetti et al. 1987; Yopp 1988; Chaney 1992). But to the present author's knowledge the full implication of the distinctness hypothesis regarding the predictiveness of various phoneme awareness tasks has not yet been subjected to empirical study.

Discussion

The development of reading abilities is dependent on phonological abilities such as phonological awareness, and storage and retrieval of phonological representations from both short-term memory and long-term memory. At present, however, it is not fully clear how these and other possible linguistic bases are related to each other, to reading development, and to dyslexia. It is not known whether they each play an independent role in dyslexia or whether they are just associated symptoms of some underlying processing difficulties.

Many researchers have suggested that 'incomplete' or 'under specified' phonological representations may be an underlying cause of many, if not all, of the apparently diverse phonological deficits characteristic of specific reading disabilities. In this paper, this possibility has been explored in terms of levels of distinctness of phonological representations. A *distinctness hypothesis* is advanced which proposes that children who become dyslexic have relatively poor access to the most distinct variants of spoken words. The hypothesis does not specify whether this problem resides with the phonological representations themselves or with their accessibility. The hypothesis is specified in the context of two prominent theories of phonological representation of lexical items, Chomsky & Halle's classic structural theory, and a probabilistic distributed theory of phonological representation. Further, it is argued that low phonological distinctness may account for the most well-documented linguistic deficits related to reading disabilities, even some observed in very early language development. Importantly, it is argued that a phonological representation may on the one hand uniquely specify a word and be organized in segments of phoneme size while, on the other hand, some segments may be grossly under specified.

A second hypothesis is presented in brief, in this paper mentioned as the *segmentation hypothesis*. This hypothesis (presented in detail by Fowler 1991) suggests that phonological representations are gradually restructured during the first five to eight years of language acquisition. Phonological representations, which are initially wholistic, are gradually reorganized into increasingly smaller segments, ultimately segments of phoneme size. In the remainder of this section some differences between the distinctness and the segmentation hypotheses will be discussed. In the absence of numerous empirical studies bearing on the two hypotheses, it is suggested how different implications of the two hypotheses might be compared in future studies.

Distinctness versus segment size of lexical representations

The segmentation and the distinctness hypotheses both aim at an explanation of many of the same language problems associated with reading and writing difficulties. Within comparable psycholinguistic frameworks both hypotheses explain why some children have easier access than others to segments of spoken words. At the same time both hypotheses account for the fact that many pre-school children who later become dyslexic do not display overt signs of receptive or productive language deficits.

Like the segmentation hypothesis, the distinctness hypothesis focuses on the phonological representations of words in the mental lexicon. But the two hypotheses differ as to their assumptions of the exact form of the representations. Unlike the segmentation hypothesis, the distinctness hypothesis does not presuppose that representations of spoken words are wholistic, phonemic, or morphemic for that matter. Conversely, the segmentation hypothesis does not specify the distinctness of the representations, only their sizes. Distinctness is theoretically unrelated to segment size, at least for the segments sizes recently proposed for the mental lexicon (Walley 1993). For example, the word *bag* may be represented as one, unanalysable unit #A# at several different levels of distinctness, just as *bag* may be represented as a string of phonemic segments /bæg/ each of which may be more or less specified, i.e. distinct. Hence, the two hypotheses are not mutually exclusive. This is important to bear in mind in the following comparison. There is even an important connection between the two hypotheses. When, for example, a phonological representation is fully specified (distinct) in the Chomsky & Halle model, the single segments ('abstract phonemes') are as well.

It may be the case that the two hypotheses explain different associations between linguistic processes and reading development. For example, the distinctness hypothesis might account for the association between reading difficulties and some more widespread language problems, while the segmentation hypothesis accounts for cases of reading difficulties without associated language problems – apart from poor segmental awareness. It is easy to see that less distinct phonological representations may be harder to retrieve and pronounce distinctly than more distinct representations. It requires more reasoning to see that segmental representation has something to do with ease of retrieval and pronunciation. On the other hand, the logical step from an increasingly segmental representation to a growing segmental awareness is short, whereas distinctness and segmental awareness are less obviously related. One reason is that distinctness may apply to the phonological representation of a lexical item as a whole.

The two hypotheses have different implications which may be used in comparisons. The driving force behind the increasingly segmental representations is supposed to be vocabulary growth. From a developmental perspective this implies that vocabulary size at an early age is expected to predict segment size at a later age as it is reflected in, for example, phoneme segmentation ability. In contrast to this size-first implication, the distinctness hypothesis would predict quality to come first, i.e. distinctness of representations at a very early age would predict subsequent vocabulary growth.

However, such a comparison of what comes first (vocabulary size or quality of representation) may run into trouble with the segmentation hypothesis. Considering the many minimal pairs (i.e., words that differ by only one phoneme) in the expressive vocabularies of children as young as three years (Dollaghan 1994), one may wonder why it takes normal children so long to develop phonological representations with phoneme-size segments. In a study of 407 non-homophonic monosyllabic words in the expressive vocabulary of one-to-three-year-olds, Dollaghan (1994) found that 80% of the word neighbourhoods contained at least two words differing by a single phoneme. Thirty-nine percent had four or even more neighbours. Consequently, there is a basis for representations of phoneme-size units from very early on in language development. For example, [l] may be extracted from the words *lamb* and *am*, [b] could be extracted from *beach* and *each*, etc. 'Rather than beginning with lexicons characterized by a majority of phonologically unique and acoustically discriminable entries, it appears that toddlers and preschoolers are required to distinguish among phonologically similar entries from the earliest stages of lexical acquisition' (Dollaghan 1994: 264).

This does not imply that the segmentation hypothesis is necessarily wrong. Yet, it raises two questions. First, why are phonological representations not fully segmented in phonemes from a very early age, such as three years? Second, what is the impetus for segmentation (restructuring) if it is not vocabulary growth in itself? One answer to the latter question might be that driving forces behind lexical restructuring are experiences with language games, with letters, and, of course, with initial reading and writing.

In any case, the question of what drives the development of phoneme awareness, vocabulary size (and ensuing restructuring) or distinctness of representations may be answered empirically. The same is true for the effects on reading development which are even more important from a practical perspective. A longitudinal study of precursors of reading difficulties might be set up to include measures of vocabulary size, distinctness of phonological representations, and phoneme awareness. The distinctness hypothesis would predict that distinctness of representations would explain variance in reading development even after controlling for vocabulary size and phoneme awareness, whereas the segmentation hypothesis would predict that vocabulary size and phoneme awareness would explain variance in reading after controlling for differences in distinctness.

The two hypotheses do not predict different effects of variations in neighbourhood density. Both hypotheses would predict that the quality of phonological representations improves with increasingly neighbourhood density.

Take, for example a repetition task with nonwords. If a nonword belongs to a dense neighbourhood (i.e., it resembles many different real words), the distinctness hypothesis predicts that the nonword will be easier to represent and pronounce. Seen in the context of a distributed probabilistic model of phonological representation, this is so because there will be a relatively large number of 'nodes' available from the representations of the real neighbouring words. Similarly, according to the segmentation theory dense neighbourhoods will further the segmental restructuring and thus make available a more fine-grained system for phonological coding and representation.

The study of the nature of phonological representations as related to phonological sensitivity and to initial reading and spelling development is really in its infancy. Nevertheless, it has great potential. A future discovery of a common core deficit in phonological representation could push back the time when dyslexia may be diagnosed – and perhaps enable even earlier treatment of dyslexia than is possible today. Furthermore the discovery of a common core deficit would provide an important link to other areas of research on dyslexia, such as neuropsychological, neurolinguistic, and genetic research.

However, much work remains to be done before these or other hypotheses concerning the nature of phonological representations can be either rejected or accepted. On the theoretical side, the implications of distinctness variation for theories of phonological representation need further exploration. So far computer simulations have focused on the impact of the number of 'hidden units' used for conversion between phonological and orthographic representations. In future simulations computer models could be used to study possible types of performance degradations in oral language following decreased distinctness of phonological representations.

On the empirical side, many links between phonological processes and distinctness variations should be explored further. Some central questions are: does the quality of children's phonological representations (e.g. segment size and/or phonological distinctness) influence the development of phonological awareness? Is segment size more or less important than distinctness level for the development of phonological awareness? And do differences in distinctness explain significant variance in simple phonological processes such as phonemic discrimination and ease of lexical access?

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Address for correspondence: Carsten Elbro, Department of General and Applied Linguistics, University of Copenhagen, 86 Njalsgade, DK–2300 Copenhagen S, Denmark
Phone: +45 35 32 86 56; Fax: +45 35 32 86 35; E-mail: ce@cphling.dk