PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

The Development of Phonological Skills

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The development of phonological skills

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SUMMARY

In this paper we consider the nature and consequences of the development of phonological skills in children. We begin with evidence for developmental refinements in phonological processes. These developments, in turn, affect a variety of other skills. We consider two particular examples: the relationship between the development of speech skills and verbal short-term memory and the development of children's phonological awareness. The development of phonological awareness is related to the acquisition of literacy, which, in turn, brings about further refinements in phonological skills.

1. INTRODUCTION

Phonological development refers to the processes by which children acquire and use the sound patterns of their native language in communication. Any adequate theory of the acquisition of phonology must take account of the information-processing mechanisms needed for a child to learn to talk. At a minimum, these must involve the processes necessary, on the one hand, for the perception and cognitive processing of speech and, on the other hand, those necessary for speech production. We will propose that the process of phonological acquisition may be considered as a process of learning the mappings between auditory speech inputs and the gestural control of speech outputs (cf. Browman and Goldstein 1989). We will relate studies in a number of areas to this general theoretical framework for phonological development. We begin with the process of learning to say (or to repeat) new words and argue for the necessity of distinguishing input and output processes. We proceed by considering speech production and suggesting that underlying phonological representations are gradually refined during development. Finally, we turn to two tasks that access phonological representations, verbal short-term memory and phonological awareness, and we consider their development and relationship to reading development.

2. LEARNING NEW WORDS

Young children are remarkably proficient at learning new words and it is estimated that by the age of six, a child has a productive vocabulary of some 14 000 items (Carey 1978). There is, however, a dearth of evidence on how the phonological forms of new words are learned.

Aitchison and Chiat (1981) carried out a pioneering study of the errors made by four- to nine-year-old children when learning unfamiliar animal names. Although the children could repeat the animal names correctly, they frequently had difficulty in recalling them and their recall errors were similar to the phonological errors found in younger children's speech.

Aitchison and Chiat argued that these errors occur when the child's memory is overloaded and not all of the features of the unfamiliar words can be stored. Whether or not a particular feature was preserved depended upon phonetic context. For example, initial consonants were remembered best when they directly preceded a stressed vowel and agreed in voicing with the following consonants, e.g. in 'bandicoot' and 'lemming'. Final consonants were recalled fairly well when they followed a stressed vowel, e.g. in 'racoon' and 'yak' but not when the final syllable was unstressed. In general, error processes seemed to be a function of the phonetic structure of the words, and Aitchison and Chiat speculated that the phonetic features of the words that were most salient were most likely to be retained in memory.

From a psychological perspective, Gathercole and her colleagues have also been interested in the relationship of memory and vocabulary acquisition and have argued that non-word repetition provides a good measure of the phonological storage capacity in memory that is needed for the acquisition of new vocabulary. In the first phases of a longitudinal study, they assessed four- and five-year-old children on tests of non-word repetition, vocabulary knowledge and non-verbal intelligence. Non-word repetition at age four predicted receptive vocabulary knowledge at age five even when the effects of age, non-verbal intelligence and vocabulary knowledge at age four were controlled (Gathercole & Baddeley 1989). Further studies showed that non-word repetition ability correlated with the speed with which new words were learned in a paired-associate learning

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task and that the vocabulary deficits of language-disordered children are associated with impairments of non-word repetition (for a review, see Gathercole & Baddeley 1993).

It is logical to assume, as these researchers have done, that memory limitations place an important constraint on the acquisition of new phonological forms. It is not clear, however, how memory, in this context, can be disentangled from word-learning itself. Rather than providing a measure of memory capacity, children's skill in repeating non-words might usefully be considered as an index of their language learning skill, since it requires mapping speech inputs onto outputs. Aitchison and Chiat have shown that phonetic structure places constraints on the development of these mappings. The work of Gathercole and her colleagues has shown that individual differences in non-word repetition, at least in the early stages of development, predict individual differences in vocabulary growth. However, we have argued elsewhere that lexical knowledge will influence the creation of these mappings (Snowling *et al.* 1991). Consistent with this notion is the finding that the rated word-likeness of a non-word predicts how easily it will be repeated (Gathercole *et al.* 1991).

3. INPUT AND OUTPUT PHONOLOGICAL PROCESSES

Aside from this work on normal development, there is a body of research on children's repetition and naming that has been concerned with exploring differences between good and poor readers. Studies of children with reading difficulties have played an important part in the development of theories of phonological skills because of the strong association between reading difficulties and phonological problems. Poor readers have consistently been found to have difficulty in repeating unusual words or pseudo-words although there has been debate as to whether these difficulties reflect problems with input (Brady *et al.* 1983) or output (Snowling *et al.* 1986) processing. Evidence that poor readers typically have more severe deficits in output, rather than input, phonological processes comes from the finding that they typically perform less well than controls on tests of object naming (Denkla & Rudel 1976) but not on measures of receptive vocabulary (Snowling *et al.* 1988).

A direct comparison of input and output phonological processing was made when exploring the phonological processing deficits of JM, a developmental dyslexic studied by Hulme & Snowling (1992). At the age of 13 years, JM was presented with 40 pairs of non-words in an auditory discrimination task which he then also had to repeat. His performance on the two tasks was compared with that of controls reading at the same level.

The repetition and discrimination tasks were of equivalent difficulty for normally developing children. JM, in contrast, performed almost perfectly on the discrimination task but was severely impaired in non-word repetition. We concluded that JM had a selective deficit of output phonology. A second child LF (S. Stothard, M. Snowling & C. Hulme, in preparation), in contrast to JM, showed a selective deficit in input processing. LF had considerable difficulty with the discrimination task yet her repetition, though weak as might be expected given difficulties with input processing, was not as severely impaired.

Further support for a demarcation between input and output processing can also be found in studies of children with speech disorders. Locke & Kutz (1975) studied a group of five-year-old children who misarticulated /r/ as /w/. These children had adequate input processes since they could discriminate the /w/ /r/ distinction; but they did not represent this distinction in their speech production or in their subvocal memory responses.

Evidence of a slightly different sort comes from the case of a child with a severe phonological disorder (Bryan & Howard, 1992). This five-year-old child (DF) showed the very unusual pattern of being better at repeating non-words than words. However DF was able to recognise words that he was completely unable to repeat and his productive vocabulary was far more impaired than his receptive vocabulary. The pattern of performance shown by DF once again indicates that input phonological processes are separate from those responsible for output. Apparently, for many words he could recognise, DF had established faulty mappings from input to output.

Overall, these findings support the idea that the input and output systems responsible for processing phonological information are (at least partially) separate during development. Arguably less obvious is the possibility of setting up adequate output representations in the face of deficits in input processing. However, this finding can be explained by assuming that, although learning may be delayed, eventually normal output representations can be established from impoverished inputs.

4. DEVELOPMENTAL CHANGES IN PHONOLOGICAL REPRESENTATIONS

One issue for any theory of phonological development is the nature of the representations that underlie phonological skills and how these representations change with age. Evidence from a number of sources points to the representations of speech becoming more refined with development, and apparently this refinement continues over a very long developmental period. In infancy, Bertoncini *et al.* (1988), compared the ability of newborn and two-month-old infants to detect phonetic differences between syllables. There was no evidence that these infants' representations of syllables were structured in terms of phonetic segments. However, there was some evidence of a change from global to more differentiated representations in the older infants.

A parallel pattern has been found in much older children using a variety of techniques. Treiman & Breaux (1982) showed that four-year-old children tended to categorize syllables on the basis of their global phonetic similarity, whereas adults were more sensitive to common initial consonants. Similarly, in a

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

paired-associate learning task, the children tended to confuse syllables that were globally similar, whilst again adults more often tended to confuse syllables that shared an initial consonant. Thus in both tasks young children appeared to rely on a less well differentiated phonological representation than adults.

A similar pattern has also been found in children ranging in age from three to seven years. Nittrouer *et al.* (1989) present evidence for a gradual refinement of output phonological representations with age. They argue that children initially organize their speech gestures over larger-sized units, approximating the syllable, but gradually come to organize their patterns of gestures in roughly phonemic-sized units. Evidence for this claim came from a study of the spectrographic patterns of children's and adults' articulation of fricative-vowel syllables. As children got older there was less coarticulation of fricatives with the following vowels. In an earlier study of perceptual judgements (Nittrouer & Studdert-Kennedy 1987) children were more sensitive to coarticulatory effects on the transition between fricatives and vowels than were adults.

These diverse experimental findings suggest a model of phonological development whereby children start out by learning to map relatively large acoustic segments onto relatively undifferentiated sets of articulatory gestures. Gradually, as vocabulary size increases, these mappings become more refined so that they come to embody information about the regularities that exist between input and output at a level that approximates that of the phoneme.

One other important source of evidence on the nature of phonological representations and their refinement during development comes from the speech errors that children make in spontaneous conversation. Stemberger (1989) analysed some 576 unsystematic speech errors made by his two children between the ages of one and five years. Overall, the children's errors were remarkably similar to those from an adult corpus suggesting that the mechanism for retrieving the phonological form of words from a semantic specification is similar at all ages. The child error corpus did, however, differ from that of adults in a few ways. First, they appeared to make a larger proportion of word substitution errors that were phonologically related, e.g. corn → CORNERS. Second, more of their phonological errors involved feature errors, e.g. ball → GALL; Christmas → pristmas, rather than the whole segment errors that were characteristic of adults, e.g. big → SIG and a significantly greater proportion of errors yielded clusters in child errors (big → BRIG) than in adult errors. From these data, Stemberger argued that children's phonological representations gradually become differentiated into tightly bound phonemic units, echoing the arguments presented earlier.

5. VERBAL SHORT-TERM MEMORY

Verbal short-term memory skills are intimately related to the mechanisms responsible for speech. Many studies have shown that increases in memory span with age are closely tied to changes in speech skills (see Hulme & Mackenzie 1992, for a review). There is a close, quantitative relationship between increases in maximal speech rate with age and increases in memory span. Traditionally these findings have been attributed to the idea that changes in speech rate cause an increase in the rate at which material can be rehearsed within an articulatory loop.

However, Cowan *et al.* (1992) found that performance was better when the words to be repeated first in forward recall were short rather than long and, in backward recall, it was the words at the end of the list whose length made a difference. From these findings it was argued that the effects of word length on memory span were largely due to output effects. Developing this idea, Cowan (1992) reported a temporal analysis of four-year-old children's spoken responses in a memory span task. Cowan found that the overall time for which a subject spoke when recalling the lists correlated well with their short-term memory performance. However, when this time was analysed in terms of periods of speaking and silences between items, the interword pause durations correlated with span, not the mean word durations. Cowan amassed evidence for a model of memory span in which items yet to be recalled are 'reactivated' in the intervals between items being spoken. These intervals, however, are short and would not allow time for the items to be covertly rehearsed, so the method of reactivation would have to involve a more rapid search of memory.

Following on from these findings Cowan *et al.* (1994) studied memory span, speech rate, and output timing relationships in four- and eight-year-old children. It was found that older subjects not only remembered more than younger subjects; they did so in responses that included shorter interword pauses than younger subjects. The length of words in the responses, however, did not differ with age. Subjects also recalled more of the shorter than longer words but, in contrast to the effects of age, word length did not affect the duration of interword pauses in the responses; it affected only the duration of words in the response. The theoretical interpretation offered was that age and word length affect different mechanisms. Word length affects how long it takes to say each word, and therefore how much time there is for subsequent words in the list to be lost from short-term memory before they can be pronounced. On the other hand, age affects how rapidly and efficiently the subject engages in covert memory search processes during interword pauses. These processes may not only permit the pronunciation of the next item, but also help to refresh the short-term memory representations of subsequent items.

In summary, there is a close association between speech skills and short-term memory skills. One fairly radical view of this evidence is that we might consider short-term memory mechanisms to be no more than a by-product of the mechanisms subserving speech. In this view, when studying the development of short-term memory processes what we are doing, indirectly, is studying the development of the input and output mechanisms that exist primarily for the perception and production of speech.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

6. DEFICITS IN SHORT-TERM MEMORY SKILLS IN CHILDREN WITH LANGUAGE IMPAIRMENTS

If short-term memory processes reflect the operation of speech perception and production mechanisms then it is natural to expect disorders of these processes to be associated with disorders of short-term memory. There is abundant evidence from studies of children suffering from speech and language difficulties and reading difficulties for such associations.

Raine *et al.* (1991) studied the short-term memory skills of children with speech disorders who were compared with a group of normal control children of the same age. The speech-disordered children had lower short-term memory spans, and showed smaller word-length effects, and less evidence of speech motor activity during rehearsal periods, than the normal children of the same age. However, van der Lely & Howard (1993) compared a group of children diagnosed as having specific language impairment with a group of younger normal children matched for language ability. These two groups did not differ in short-term memory skills and both groups showed evidence of using speech-based codes. In both studies the short-term memory skills of the language-disordered children were impaired to the extent expected, given their slow speech rate.

Dyslexic children also typically do poorly on measures of short-term memory (Jorm 1983). However, it appears that dyslexic children use speech coding in short-term memory just as normal children do, though the system in dyslexic children appears to operate less efficiently (Hall *et al.* 1983; Johnston *et al.* 1987). A recent study by McDougall *et al.* (1994) clarified the relationship between memory span and reading skill in good, average and poor readers. As expected, differences in reading skill went hand in hand with differences in short-term memory span. However, the differences in memory span between the groups were well explained in terms of differences in speech rate. Thus, poor readers appear to have memory-span limitations that result from impairments in the rate of processing information in short-term memory as indexed by speech rate.

Overall, the results from these studies of short-term memory processes in children with speech and reading difficulties suggest that the impairments seen in both groups can parsimoniously be explained in terms of a deficit in the speed of processing phonological information in short-term memory tasks.

7. PHONOLOGICAL AWARENESS

So far, we have discussed the processes of acquiring and accessing phonological representations in speech perception and production tasks and maintaining them in short-term memory tasks. We now turn to consider developments in the child's conscious awareness of phonological representations. Phonological awareness refers to the ability to reflect upon the sound structure of spoken words. It is a metalinguistic skill that emerges relatively late, once much of the child's language development is complete.

A wide variety of tasks have been devised to assess the development of phonological awareness. In a now classic study, Liberman *et al.* (1974) showed that phonemes are relatively inaccessible units of speech to young children, at least before they had learnt to read. Treiman (1983) argued, however, that the sub-syllabic components of onset and rime are natural units of spoken language for young children. The onset of a syllable is the consonant or consonants that precede the vowel and the rime is the vowel and the succeeding consonant or consonants. In a large number of experiments, Treiman and her colleagues have shown that children find it easier to divide words at the onset/rime boundary than at other points such as between the two consonants of a cluster or between the vowel and the succeeding consonant.

Ironically, Treiman's demonstration that children are sensitive to the onset/rime distinction in words suggests that they can deal with phonemes in certain word positions (onsets) if not in others. Kirtley *et al.* (1989) found that even pre-readers could categorize words on the basis of a single phoneme when it was part of an onset but not when it was only part of a rime. Adding a common vowel helped end-sound judgements much more than beginning sound judgements because it meant that words sharing end sounds shared common rimes.

Thus, onsets and rimes play a considerable role in children's phonological awareness, especially between five and seven years of age. Snowling *et al.* (1994) extended these findings to show that phonetic factors within the rime influence performance on sound categorization tasks. Children aged between six and eight years found it more difficult to identify the odd word out in a series of spoken words if it differed from the other items by a single phonetic feature than if it differed by two features. Children also found place changes more difficult to detect than changes in voicing, and both of these single feature changes were harder than place and voice changes.

The relative ease of word segmentation can also be seen in language games. In one such game, 'Pig Latin', the task is to move the onset from the beginning of a word to the end and then to add 'ay'. Thus, 'please listen to us' becomes 'easeplay issenlay ootay usay'. Cowan (1989) followed the acquisition of Pig Latin in a boy from age 5;3 to 6;5 and noted that there was a striking consistency in the errors that he made in learning the game.

Overall, the findings of Cowan's study were consistent with those of experimental studies showing that children can divide words into onset and rime units. The child could generally segment and shift the initial onset without difficulty. His ability to do so was compromised, however, when the first syllable was unstressed. In cases where it was the second syllable that was stressed, the child tended to segment before the second vowel.

It can be concluded from their performance on tasks requiring phonological awareness, that children's segmentation ability is determined at least in part by the nature of underlying phonological

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

representations. From an early age, children are aware of the onset/rime divisions of spoken syllables though stress patterns place a constraint on the accessibility of these structures and within segments, children are sensitive to phonetic factors.

8. PHONOLOGICAL AWARENESS AND LEARNING TO READ

A major theoretical issue is the relationship between phonological awareness and reading skill. There is good evidence for a connection between children's awareness of the sounds in spoken words and their success in learning to read (Bradley & Bryant 1983; Lundberg *et al.* 1988). Following a period of intense debate over the extent to which awareness of the phonological segments of spoken words is a consequence of literacy, the view that awareness of the rhyming relationships between words precedes literacy, whilst awareness of phonemes is, at least in part, a consequence of learning to read has become widely accepted (Morais 1991).

An influential hypothesis, proposed by Goswami & Bryant (1990), is that awareness of rhyme is a precursor of reading but that phoneme awareness which arises later (possibly partly as a consequence of learning to read) is important for learning to spell. Goswami and Bryant proposed a mechanism to account for the relationship between sensitivity to rhyme and reading development. Their suggestion was that children's categorization of spoken words according to rhyming relationships directs their attention to the orthographic relationships between printed words.

Two predictions follow from Goswami & Bryant's (1990) theory. First, measures of children's rhyming ability taken before they learn to read should predict their reading progress in the early years. More specifically, children's rhyming skill should predict their ability to use orthographic analogies in reading (Goswami 1990). Second, phoneme segmentation should predict spelling better than reading performance in young children. Recently, Muter (1994) tested these predictions in a longitudinal study of children aged between four and six years.

At the beginning of the study, when none of the children could read or spell, they completed tests requiring different levels of phonological awareness. Contrary to expectation, it was phoneme segmentation and not rhyming skill that predicted both reading and spelling at five and at six years of age. Furthermore, it was concurrent measures of both rhyme and phoneme segmentation, not pre-school rhyming ability that predicted the use of analogies at six (Muter *et al.* 1994).

Thus, there remains uncertainty about the precise relationships between different levels of phonological awareness and reading and spelling. However, once a child learns to read, there is no doubt that their conceptualization of spoken words changes. Read (1973) found that pre-readers categorized spoken words beginning with [tʃ] as in 'chop' with words beginning with [tr] as in 'train'. These preliterate responses conformed to a surface phonetic representation. In contrast, children who could read classified words beginning with [tr] together with words beginning with [t], conforming to a more abstract phonological representation and to orthography. Similarly, Ehri & Wilce (1980) found that good readers thought that words like 'pitch' contained an additional sound compared to phonologically analogous words such as 'rich' (presumably because of the presence of the letter 't' in pitch).

The most parsimonious theory must be that there is a reciprocal relationship between phonological awareness and learning to read and there may be individual differences in the extent to which one skill might be claimed to play a causal role in facilitating the other. However, the importance of conscious awareness of phonological structure for learning to read may have been over-stated. Cossu *et al.* (1993) have described a number of individuals who have been unable to succeed on phonological awareness tasks, because of low intelligence, but who, nevertheless, have learned to read well. The existence of such cases suggests that phonological awareness is at best an indirect measure of the phonological processes that are required for learning to read. We have argued that it is the integrity of underlying phonological representations rather than their accessibility to consciousness that is important for learning to read (Hulme & Snowling 1992).

Thus, it is important to draw a distinction between underlying phonological representations, which we would argue are the substrate for the development of mappings between phonology and orthography (cf. Seidenberg 1992), and access to these representations in phonological awareness tasks. A number of authors have drawn a similar distinction between the representations used for speech perception and production, and those accessed in metaphonological tasks. Cowan *et al.* (1985) argue from their data on 'backward-talkers' that such individuals access metaphonological representations that are different from the phonological representations automatically used in speech perception and production. From the perspective of reading difficulties Mattingley (1991) has argued that the phonological grammar is faulty in disabled readers; reading difficulties can occur as a direct result of these faults or because of difficulties with the cognitive processes that use the grammar.

9. CONCLUSIONS: MODULARITY AND ITS LIMITATIONS IN A DEVELOPMENTAL CONTEXT

The view that we have pursued here is a variant of the view that language is a modular system; phonology represents one domain of processing that may develop and show impairments that are relatively independent of other aspects of language processing. The 'symptom complex' of poor readers, characterized by specific phonological processing deficits, provides support for this view (Shankweiler & Crain 1986). Beyond this, we have argued for further segregation; that systems dealing with input (speech perception) are partially

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

separate from those for output (speech production). In learning to talk the child must set up representations underlying both these aspects of language processing and learn the mappings between them. However, we would emphasize that, during development, there is interaction between different systems; to take an obvious example that we have touched upon, the development of speech production skills must depend upon adequate speech input systems.

We have focused on the process of acquiring and refining phonological representations and the consequences of these developments for other cognitive skills. It appears that the phonetic form of inputs exert important constraints on the acquisition of phonological representations. The development of phonological skills in turn has important consequences for other aspects of development. Two examples of this are short-term memory skills and reading. In short-term memory tasks there is clear evidence that the development of phonological representations and the speed with which they can be processed has important consequences for improvements in memory skills with age. In the case of reading skills, much of the research has focused on the development of phonological awareness and its role in facilitating the development of reading. There are good reasons for believing that phonological awareness tasks tap a metaphonological level of representation that is itself partly a product of literacy skills. We have suggested, however, that what is far more important for reading development is the quality of underlying 'primary' phonological representations which are only tapped indirectly in phonological awareness tasks.

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PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

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