

The nature and use of sublexical inferences in early reading

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Abstract

This thesis considers the nature and use of orthographic sublexical inferences by 6 year old children. Previous research by Goswami (1986) appears to demonstrate that even young children are able to use sublexical inferences. Typically, Goswami has shown children a clue word such as 'beak' and then shown previously unknown analogous target words such as 'peak' sharing orthographic rimes (medial vowel and terminal consonant(s)) with clue words, 'bean' which shares the head (initial consonant(s) and medial vowel), and control words such as 'bank'. Children typically read more target words which share rimes with taught clue words than other targets, suggesting that rime inferences are privileged in early reading.

One problem with Goswami's task is that both clue and target word are presented concurrently, possibly supporting the strategic use of inferences. Experiment 1 therefore contrasted inference use when clue words were either pretaught or concurrently presented. Inference use was evident in the presence of concurrent reminders of clue word pronunciation, but was not evident when a clue word was pretaught. Subsequent experiments investigated inference use when children were given greater prior exposure to clue words sharing orthographic and phonological patterns with targets, but where concurrent prompts were avoided. Rime inferences (e.g. 'leak' - 'peak') and vowel inferences (e.g. 'meat' - 'peak') were contrasted. Results revealed equivalent improvements for both sets of words, suggesting a) that children can make inferences in the absence of concurrent clue words as long as they have had substantial exposure to other words sharing analogous letter-sound patterns, and b) that there is no advantage for words sharing rimes over words sharing other orthographic units such as vowel digraphs when tested under such conditions. The results of these studies and parallel correlational studies are interpreted in terms of models of vowel digraph inferences.

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The nature and use of sublexical inferences in early reading

Introduction

This thesis considers the nature and use of sublexical orthographic inferences in early reading in normal English speaking 6 year old children. An orthographic inference model holds that when children are shown a word and told its pronunciation, they may be able to infer the pronunciation of similar words that they meet subsequently. Thus if a child is shown the spelling and pronunciation of the word 'cap', for example, this may help them to read subsequently encountered words such as 'lap' or 'cat' which share letters and sounds. Theorists have suggested a range of ways by which an inference strategy could facilitate reading development (Baron, 1977; Ehri, 1992; Frith, 1985; Goswami, 1986; Goswami & Bryant, 1990; Seidenberg & McClelland, 1989; Share, 1995; Stuart & Coltheart, 1988; Thompson, Cottrell, & Fletcher-Flinn, 1996). At the heart of all of these views is the notion that inferring letter sound relationships from print experience provides a powerful self-teaching mechanism.

Purely on theoretical grounds the use of an inferential strategy to learn print to sound associations is a sensible strategy in a 'quasiregular' orthography such as English (Seidenberg & McClelland, 1989) in which the application of grapheme to phoneme rules yields correct pronunciations for many words, but where the orthography admits many exceptions to pronunciation rules. This argument also suggests that some parts of a word particularly the 'rime body' (the medial vowel and terminal consonant(s) of a syllable) may be especially important in such a strategy. As English orthography admits of many exceptions to pronunciation rules, attending to rime body pronunciations may provide more consistent pronunciations than smaller grapheme to phoneme correspondences. The word 'light' for example has a consistent pronunciation when compared against its orthographic rime neighbours such as 'fight'

and 'sight' but is an irregular word when considered in terms of grapheme to phoneme correspondences (Bryant & Bradley, 1985).

Another reason for suspecting that rime body units may influence the development of young children's orthographic representations is suggested by research on the development of explicit phonological awareness. Young children appear to be sensitive to phonological rimes before learning to read, and some research suggests that individual differences in reading ability once in school are predicted by preschool rime awareness (Bryant & Bradley, 1985; Maclean, Bryant, & Bradley, 1987). One possibility is that rime inference use may reflect the link between phonological rime awareness and reading ability (Goswami & Bryant, 1990). If true this account would provide a powerful causal model of early reading acquisition. This model of rime inference is therefore considered in detail in this thesis.

Research by Goswami (1986) appears to demonstrate that even young children are able to use orthographic rime inferences. Typically Goswami has shown children a clue word such as 'beak' and then asked children to read previously unknown analogous target words such as 'peak' sharing orthographic rimes with clue words, 'bean' which shares the head, as well as control words such as 'bank' sharing common letters with the clue word. A standard finding is that children are particularly good at reading words which share rimes with taught clue words, suggesting that rime inferences are privileged in early reading. One problem that has been identified with the clue word analogy task is that both clue and target word are presented concurrently, thus supporting the use of an inference strategy (Muter, Snowling, & Taylor, 1994; Savage, 1997). Goswami's research does not provide evidence for spontaneous use of inferences of the type required by children in more natural situations.

In the present thesis, Experiment 1 therefore contrasted the use of inferences across a range of conditions in which clue words were either pretaught minutes before

the posttest or concurrently presented during the posttest. There were two concurrent prompt conditions: in the first condition the clue word was present in front of the child and the pronunciation of the clue word was also given; in the second condition only the clue word pronunciation was given. Improvements in target word reading were evident in the presence of concurrent reminders of the pronunciation of a clue word, even when no clue word orthography was taught, but were not evident when a clue word was pretaught minutes before the posttest.

Subsequent experiments investigated the use of inferences when children were given greater prior exposure to clue words sharing orthographic and phonological patterns with targets, but where concurrent prompts were avoided. Rime inferences (e.g. 'leak' - 'peak') and vowel inferences (e.g. 'meat' - 'peak') were contrasted. Results of these studies showed equivalent improvements for both sets of words, suggesting a) that children can make orthographic inferences in the absence of concurrent clue words as long as they have had substantial exposure to other words sharing analogous letter-sound patterns; b) that there is no advantage for words sharing rimes over words sharing only vowel digraphs when tested under such conditions. A final study investigated individual differences in the use of spontaneous inferences. Results showed that inference use was not correlated with phonological rime awareness ability. Inference use was associated with reading ability and with the proportion of pretest target word reading errors preserving initial and final consonants. Findings do not therefore support the interactive analogy model advanced by Goswami (1993). Results are interpreted in terms of models where the use of vowel inferences emerges after significant reading experience (Ehri, 1992, 1995).

The thematic organisation of this thesis

Theoretical chapters

In chapters 1, 2, and 3 previous research on reading is considered. In chapter 1 the general theoretical issues relevant to reading acquisition are considered in detail.

Criteria for evaluating models of reading acquisition are considered in section 1 of that chapter. Five criteria for evaluating developmental models are advanced. Two issues are discussed in detail in chapter 1: The first issue is the evidence for the existence of two distinct procedures for reading regular and exception words. The second issue discussed in section 2 of the chapter concerns the role of phonological skills in reading. Both of these issues are discussed further in chapter 2 where a range of developmental models of reading acquisition are considered. In chapter 3 a detailed analysis of research on orthographic rime use is considered alongside alternative models which emphasise the inference of smaller graphemic units in early reading acquisition. Goswami's interactive analogy model is analysed in detail and theoretical and empirical weaknesses identified prior to the discussion of empirical research on inference use in chapters 4-8.

Empirical research

Five experiments are described in this thesis. The empirical research can be considered in two sections. Research is presented in chapters 4 and 5 which seeks to clarify the role of concurrent prompts in the existing rime inference task used by Goswami (1986), and the correlates of individual differences in target word reading. In chapters 6, 7, and 8 the new inference task is developed and tested. Here research on prior exposure to a greater number of examples of words embodying common letter-sound relationships is considered. This task suggests clearly that children can use orthographic inferences to rime and vowel analogous words at age 6, though this ability is not associated with rime awareness. A parallel set of correlational analyses investigated the association between measures of phonological awareness, orthographic knowledge and inference use across five experiments. These analyses revealed that inference use was correlated with reading ability and with the proportion of pretest target word paralexias children made which preserved initial and final phonemes of targets. The implications and limitations of these findings are considered in chapter 9, and suggestions for further research are made.

Chapter 1

Reading Acquisition - Issues and Skills

Summary

This chapter considers some of the central theoretical and empirical issues involved in understanding reading acquisition. The aim is to provide a background to the specific models of literacy acquisition outlined in the second and third chapters. Section 1 discusses what a successful model of reading development must achieve and identifies five criteria by which models of reading development can be evaluated. One issue discussed in detail is whether models must assume the existence of either one or two routes in order to be able to read both regular and exception words. Another particularly important aspect of causal models of literacy is to consider the role of skills that are known to be closely associated with reading development. One such skill is phonological awareness. Section 2 reviews the role of phonological awareness in reading. Three views of the relationship are considered: A) phonological skills are causal in developing reading skills; B) phonological skills arise as a result of learning to read; C) phonological skills and reading share a complex interactive causal relationship with each other. The view that some phonological skills predate, and have causal influences upon reading development while other phonological skills emerge as a consequence of reading acquisition is also considered in detail.

Section 1

Theoretical issues in modelling literacy development

Before discussing specific accounts of how children may learn to read, it may be useful to consider what one might expect such a model to reasonably accomplish. Five criteria by which models may be evaluated are discussed.

Developmental models should be causal in nature

The most important role of a model of reading development must be to explain change, to show why children can read a word or a passage of prose when previously they could not. A minimum requirement of such theoretical accounts must therefore be that they are able to describe this underlying change that has allowed a child to read a word (Goswami & Bryant, 1990). Theoretical models of the process of literacy acquisition must offer more than just a descriptive account of change, even if that description is couched in terms of processes and strategies. A full account of literacy development must be able to show not only that a change in reading ability occurs, but also why that change occurs. In order to do this, the model must discuss the nature of mechanisms that cause change. It is only this kind of model that can explain the existence of individual variability in reading ability, or of qualitative differences in reading behaviour. Theoretical models based upon claims to have established causal links in reading development must consider the many sources of information and different sorts of experience that can be involved in the reading process. These are likely to include the role of formal teaching and informal learning experiences prior to, and contemporaneous with, reading instruction.

Once identified, any specified causal factor must be placed within a formal information processing model of reading ability which explains both how the cognitive and linguistic representations and processes operate to allow reading to take place, and how these representations and processes develop with reading ability (Rack, Hulme, & Snowling, 1993). This level of explanation is only likely to be manageable if reading is fractionated in some way. There is substantial agreement among researchers (Frith, 1980, 1985; Goswami & Bryant 1990; Hoover & Tunmer, 1993; Perfetti, 1985, 1991, 1992; Rack, Hulme & Snowling, 1993; Stuart & Coltheart, 1988) that the process of word recognition is a central skill in information processing theories of reading acquisition. Theories concerning causal influences on word recognition are therefore considered in this thesis.

Evidence for models must be ecologically valid

An additional factor in the evaluation of theoretical models of literacy concerns the nature of the empirical support for such accounts. An experimental, evidence-based approach must be central to the exposition of current theories, given the explicit aim of elucidating causal links. However, empirical work bearing upon such causal links must also reflect reading in more natural environments, as models of literacy development are, by their nature, models of behaviour in the classroom, or the home. Evidence that purports to support theoretical positions must, therefore, be demonstrably relevant to natural reading situations. This issue of the ecological validity of experimental research is, of course, a well established one in cognitive psychology (Neisser, 1967), and in literacy research (Baron, 1977; Adams, 1990; Goswami & Bryant, 1990; Strickland & Cullinan, 1990). The present research methodology attempts, however, not to make a rigid and perhaps rather unhelpful distinction between pure 'experimental' research and 'naturalistic' research, as many others have done (Adams, 1990; Goswami & Bryant, 1990; Strickland & Cullinan, 1990). It is argued rather that there is a need for work that is essentially experimental in nature, whilst reflecting at least some of the most important learning demands of reading in natural environments.

Empirical research must address the role of the additional task demands necessary in the everyday execution of specific, experimentally tested reading skills. Failure to address the issue of ecological validity sufficiently leaves open the possibility that the pattern of data reported in empirical studies may simply reflect a particular set of testing procedures used. Neisser famously described the art of experimentation as "the creation of new situations which catch the essence of some process without the circumstances that usually obscure it" (Neisser, 1967, p 305). Such an art, of course, is a difficult but nevertheless crucial one to master when developing causal models of literacy development. A central argument of the present thesis is that some of the existing and highly influential experimental work may have failed to catch the essence of the literacy acquisition process. Further consideration of the issue of ecological

validity also informs both the methodology used in the present research work outlined, and the conclusions drawn from these studies. This central issue is addressed in greater depth in the review of analogy literature undertaken in chapter 3.

Models of reading development should be comprehensive

A successful causal model of reading development should be able to offer a comprehensive explanation of progress. That is, the best models of reading acquisition will explain the process of reading, not just in the initial phases of literacy but will also provide cogent accounts of how higher levels of competency are achieved. As Frith (1986) has argued, comprehensive theories of reading development should be able to bridge “the gulf between the child who scribbles on a page and the highly literate adult”. Therefore in order to provide a theoretically cogent account of reading, developmental models must, at least potentially, be compatible with current adult models of literacy (Stuart & Coltheart, 1988). Models of adult reading are therefore considered below. Models of adult reading, like developmental models, are also influenced by the nature of the orthography to be read, therefore the nature of English orthography is considered briefly in the next section prior to a discussion of adult models of reading.

Models of reading should consider the role of the orthography

Purely upon theoretical grounds, considerations about the nature of the orthography that children must learn to encode are an important component of theoretical models of reading. Many theorists have drawn quite different conclusions concerning the possible processes that children might use in learning to read (Baron & Strawson, 1976; Baron, 1977; Coltheart, 1978; Goodman, 1967, 1969; Smith, 1988). In fact, much of the heat that has characterised debate upon the nature of reading development and of the suitability of pedagogic methods can be attributed to the different conclusions drawn by theorists concerning the nature of the English orthography.

How then does the orthography influence models of reading? Some theorists have been impressed by the historical fact that, while many different systems for representing speech have been invented, the idea of representing sound in print through a limited number of abstract orthographic elements has only been invented once (Rozin & Gleitman, 1977). The phylogenetically unique task of representing print in terms of abstract phonemic identities may also be reflected in the ontogenetically demanding task of learning to read (Gough & Hillinger, 1980). From this observation, Gleitman and Rozin argue that children should initially be introduced to syllabic information, with phonemic analysis introduced later in reading instruction. However, most theorists have argued that the realisation that the English orthographic system utilises an 'alphabetic principle' is central to reading acquisition. The ability to take advantage of this system is dependent upon the ability of apprentice readers to segment and represent the speech stream in abstract phonemic terms (Liberman, Cooper, Shankweiler, & Studdart-Kennedy, 1967; Tunmer & Nesdale, 1985).

Psychologists concerned with modelling the process of reading development have also been acutely aware that the alphabetic principle is only partly realised in written English. English orthography could, in many regards, be seen as a 'deep orthography', in that it often represents underlying morphological units at the expense of phonological consistency. The words 'nation' and 'national', for example, share an underlying morphological root which is represented in orthography, but not in phonology (Katz & Feldman, 1981). Similarly, other morphological information is often represented in the orthography at the expense of phonological consistency. This process is evident in the representations of words such as 'sign' and 'bomb', in which the silent letters flag relationships with other words, such as 'signal' or 'bombardment' (Chomsky & Halle, 1968).

English orthography also attempts to represent the real or imagined etymological origins of some words. Spellings of the words 'debt' and 'subtle', for example, were

altered to reflect their historical origins in the Latin words 'debitum' and 'subtilis' respectively (Ellis, 1984). However the orthography is also highly unreliable as a guide to morphology. The words 'pretend' and 'demist', for example, indicate the bound morphemes 'pre-' and 'de-', but 'precise', and 'delight' do not. The letters 'ph' sometimes straddle a morphemic boundary, (e.g. 'shepherd') but at other times represent a grapheme (e.g. 'cellophane'), (Henderson, 1982; Smith, 1988).

A further problem facing a child learning to read is that there is much inconsistency in the way phonemic information is represented in the orthography. The reasons for this are diverse. In some cases, inconsistency reflects historical pressures on the process of transcription. For example, more phonetically regular representations of words like 'women' were altered to facilitate transcribing print by hand. In other cases, inconsistency is the result of the historical drift in pronunciations from their original orthographic instantiations. For words such as 'would', the original pronunciation matched the orthography more closely. Many other inconsistencies exist in the mapping between phonemes and graphemes. Two, three, or even four letters can represent a single phoneme (e.g. 'ch', 'igh', 'eigh'). Furthermore, multiple representations of vowel sounds are also permissible, (e.g. the vowel digraphs in the words 'street', 'leaf', 'brief'), (Venezky, 1970), as are distinct phonological representations of the same orthographic units (e.g. 'ove' in 'move', 'cove', 'dove'), (Patterson & Morton, 1985), and the infamous 'ough' letter string (Adams, 1990).

Vowel phonemes are generally more unreliably represented than consonants (Venezky, 1970), and children find vowels significantly harder to read than consonants (Fowler, Liberman, & Shankweiler, 1977; Shankweiler & Liberman, 1972; Stuart & Coltheart, 1988; Weber, 1970). The result is a highly opaque orthography in comparison to other scripts such as German or Spanish that were originally, like English, based upon the Roman alphabet. In light of these sorts of observations, Seidenberg and McClelland (1989) describe the English orthography as one that

partially encodes syntactic, morphemic, and phonological information simultaneously. In their terms, English orthography is at best 'quasiregular'.

Data driven versus theory driven models

In the light of such problems Goodman, (1967) and Smith, (1988) have argued that readers should not direct their attention to the 'data driven' process of analysing print, but should focus upon higher level, 'top-down' analyses of meaning, where prediction from semantic context may facilitate word recognition. This view, although influential in some educational circles, has been eschewed by many researching the process of reading. One problem for this general class of models is that the predictability of individual words from context is very low. Gough (1983) asked undergraduate readers to produce an appropriate word to finish an incomplete sentence. Choices rarely matched the actual word in a text, and the predictive accuracy for content words was only 10%. Young children's ability to use holistic or contextual approaches to learning word identity have been found to have a very low correlation with reading ability. In one study by Firth (1972) the ability to learn arbitrary word-specific associations did not correlate with reading ability, whereas ability to pronounce nonwords did strongly correlate with reading ability. A modest correlation between reading and contextual prediction skill was also found. However, after controlling for nonword reading skill, no other correlations remained significant (Firth, 1972, cited in Baron, 1977).

Poor readers use contextual prediction to a greater degree than good readers, who appear to rely more upon decoding strategies (Stanovich, 1986). The nature of eye movements in reading also suggests a highly analytic approach to word identification (Rayner & Pollatsek, 1987), as does the close relationship between reading success and phonological skills outlined later in this chapter. In theoretical terms, top-down models of reading have generally failed to specify how a child ever internalises print knowledge from contextual experience. Without this mechanism, stored lexical knowledge cannot

provide a context to read other words in the future. As a consequence, many have argued that, at least at the global level, the top-down versus bottom-up controversy has been resolved (Perfetti, 1985; Stanovich, 1991).

Many researchers have argued that, despite the inconsistencies of the orthography, very few words are represented in English as true logograms; that is to say, very few word representations lack any regular grapheme to phoneme correspondences. From this observation they, and many others have argued that children will progress in learning to read to the extent that they master the alphabetic principle - the understanding that a limited number of abstract graphemic elements represent the underlying phonemic nature of the language (Adams, 1990; Ehri, 1992, 1995; Frith, 1985; Gleitman & Rozin, 1977; Gough & Walsh, 1991). Developmental models have therefore generally attempted to address ways in which a child can learn how to represent this quasiregular system.

Dual route models of reading

The highly complex structure of English could, in theory at least, be partly mapped by a series of correspondence rules that run between phonological and orthographic representations of words. In such a formulation, phonological knowledge derived from print and subsequently blended to form a word would allow access to semantic and articulatory codes. However, given the inconsistent nature of the orthography, many traditional accounts of reading acquisition have also assumed that, simply on logical grounds, there must be two ways to pronounce a written word (Baron, 1977; Coltheart, 1978) ¹. Words can either be read by matching a stimulus letter string to a stored lexical representation which connects to word meaning and pronunciation (i.e. by 'lexical' processing) or by applying abstract grapheme-to-

¹ Most current models in fact specify at least three routes to reading (Morton & Patterson, 1980). These are: an assembled route, whereby pronunciations are derived from the synthesis of orthography to phonology correspondence rules; an addressed route, in which semantic knowledge is consulted prior to articulation; and a second addressed route where semantic knowledge is not necessarily consulted prior to articulation. The role of semantics is beyond the scope of the present thesis, and the standard 'dual route' nomenclature is adopted here to describe reading procedures.

phoneme correspondence rules to the letters of a word, and then blending these into a pronunciation (i.e. by 'sublexical' processing). In early versions of the dual route model, sublexical processing operated solely via abstract grapheme to phoneme correspondence (GPC) rules (Coltheart, 1978; Morton & Patterson, 1980). In some more recent versions (Patterson & Morton, 1985), larger orthographic rule mechanisms have also been posited in addition to grapheme to phoneme rules. These Orthography-to-Phonology correspondence (OPC) rules represent the relations between print and sound for 'rime body units' such as the 'ove' rime body in 'move', and the 'eak' rime body in 'beak'.

In the dual route model both the lexical and sublexical procedures are necessary for the fluent reading of English (Coltheart, 1978). Sublexical processing works well for the majority of words in the English orthography and can be used equally well to derive pronunciations for novel or nonwords. Its particular strength lies in the notion that it can be seen as a self-teaching mechanism for unfamiliar words (Jorm & Share, 1983). This theoretical approach to word identification can be seen to relate to the 'phonics' approach to reading instruction. However for the numerous irregular words in English such as 'sword' or 'island', which do not conform to regular, 'major correspondences' (Venezky, 1970), a recoding method would not yield accurate pronunciations. It is assumed that these irregular words would thus need to be learned by rote, by associating the printed form of a word directly with a stored meaning and/or pronunciation. This approach has been associated with 'whole word' approaches to reading instruction.

Evidence from adult normal readers

The dual route system has generally assumed that lexical processes operate faster than sublexical processes and largely govern pronunciation in skilled readers. Word recognition devices, originally operationalised as a series of 'input logogens' (Morton, 1979), are held to respond to word-specific orthographic information, and to

be sensitive to the frequency of their own prior activation. Thus, a sublexical route to word pronunciation will only produce an output as fast as the lexical route for low frequency words. This approach has been characterised as a 'horse race' model (Henderson, 1982; Norris & Brown, 1986). Evidence in support of this view comes from the finding of regularity by frequency effects in word pronunciation experiments (Andrews 1982; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Seidenberg, 1985). Regularity effects, which are understood as the latency advantage for naming regularly pronounced words over irregularly pronounced words, are evident only in the pronunciation of low frequency words. As many irregular words are high in written frequency, this has the net result of minimising the impact of irregularity on word processing (Seidenberg & McClelland, 1989).

Baron & Strawson (1976) have argued that significant individual differences in reading ability exist in the normal population which can be understood to reflect the use of a word-specific and an abstract rule-based mechanism. College undergraduate subjects were asked to read nonwords (e.g. 'burb'), and pseudohomophones (e.g. 'caik'), and asked to identify the pseudohomophonous words. One group of individuals, who Baron and Strawson label 'Chinese' readers, made many mistakes on this task. Another group, labelled 'Phoenician' readers, were much more accurate on this task. The use of word specific and abstract, rule-based procedures respectively corresponding to Chinese and Phoenician scripts was assumed to underlie performance differences. In a second phase, the same subjects were given words to spell without the opportunity to check spelling accuracy. Errors were then compared against correct spelling of these words in a forced choice test. Baron and Strawson reasoned that spelling is undertaken using an assembled phoneme-to-grapheme procedure, with the evaluation of spelling accuracy then assessed using a visual check procedure. Large improvements in spelling accuracy in a forced choice decision task therefore correspond to a 'Chinese' or 'direct' contribution to reading. Again, substantial individual differences were reported.

These two groups of readers were then asked to read regular and exception word lists in either upper case letters, lower case letters or in mixed case, which alternated across the letters of a word. Results showed that exception words were specifically affected by the disruption provided by case alternation. There was also an interaction between reading group and reading speed for regular and exception words. Those subjects earlier labelled as Chinese readers tended to read exception words quicker than regular words in their lower case and upper case formats, but not in the mixed case format. The Phoenicians, in contrast, tended to read the regular words quicker than the exception words (though unexpectedly, not in the upper case format). These results were interpreted to suggest that there are individual differences in the extent to which skilled readers use direct and indirect strategies to read words.

Evaluation of the evidence from adult normal readers

The interpretation of many of the results such as the word frequency effect and individual differences in reading ability observed by Baron and Strawson has proved to be controversial. While such results are consistent with dual route accounts of reading, they do not provide a crucial test of the hypothesis in question, as alternative accounts, such as 'analogy' models (discussed below) could also arguably explain the same results. The central problem is that theoretical explanations of such evidence are open to the charge of circularity. As Frost (1998) and Van Orden, Pennington and Stone (1990) point out, there is an implicit assumption made in such work that dual routes exist, evidence is accumulated which is seen as supporting the initial view and the results then validate the underlying concept. At no point is the central assumption in any serious danger of being falsified. In the words of Van Orden et al - "method, data, and theory perpetuate each other through mutual confirmation".

Evidence from cognitive neuropsychological analyses of acquired dyslexia

The dual route approach has often been seen to gain its strongest support from cognitive neuropsychological analyses of the pattern of single word reading following

neural injury (Coltheart, 1982; Funnell, 1983; Marshall & Newcombe, 1973; Shallice, Warrington, & McCarthy, 1983). Surface dyslexic patients rely on sublexical processing, reading regular words and nonsense words well, but making regularisation errors to irregular words, (e.g. 'pint' read as if it rhymed with 'hint'), (Shallice et al, 1983). The Surface dyslexic reading pattern (Marshall & Newcombe, 1973), is held to result from disorder to the lexical reading routine, but with sublexical processing undamaged. Phonological dyslexic patients are able to read regular and irregular words normally but are either significantly impaired in reading, or entirely unable to read, even the simplest nonwords (Beauvois & Derouesne, 1979; Funnell, 1983; Patterson, 1982; Shallice & Warrington, 1980). The phonological dyslexic reading pattern is held to result from disorder to the sublexical reading routine, but with lexical processing undamaged. Pure cases of phonological dyslexia are extremely rare. One example of pure phonological dyslexia is the patient W.B. reported by Funnell (1983). W.B., unlike other phonological dyslexics reported in the literature, made no derivational errors to real words, and was completely unable to read nonwords.

Despite the apparent strength of evidence, the traditional interpretations of the reading behaviour of acquired dyslexic patients have also proved to be controversial. Kay and Marcel (1981) point out that many of the characteristic patterns of reading performance in such patients do not fit neatly into the standard dual route approach. Many surface dyslexics show a 'pseudohomophone effect' in their nonword reading performance, for example reading nonwords such as 'brane' better than other nonwords such as 'brone'. Reading error responses are not well explained purely in terms of sublexical grapheme to phoneme rules, for example, misreading of 'incense' as 'increase' could indicate the use of a lexical rather than, or as well as, a sublexical process (Marcel, 1980).

Other problems with the evidence from cognitive neuropsychological analyses of reading disorders concern the impurity of the vast majority of dissociations (Shallice,

1988; Van Orden, Pennington, & Stone, 1990), and the relative rarity of disorders such as phonological dyslexia (Van Orden et al, 1990). Van Orden et al also point out that there is a problem in evaluating the premorbid abilities of such patients. It is possible that many patient's post-traumatic reading performance may, in fact, reflect preexisting developmental reading disorders. Alternatively, many patients responses are consistent with the wide individual differences in word reading noted in normal development. Evidence for both of these alternative views comes from a study by Pennington, Lefly, Van Orden, Bookman, and Smith, (1987). They report data from some adult developmental dyslexics and some adult control subjects, both of whom were unable to name any nonwords, thus suggesting that brain lesions are not necessary to explain the patterns of word reading errors observed in phonological dyslexic patients.

Theoretical issues and alternatives to the dual route approach

Many theorists have voiced more general concerns with dual route models of reading (Barron, 1986; Glushko, 1979; Kay & Marcel, 1981; Van Orden Pennington & Stone, 1990). Glushko, (1979), argued that the dual route model has confused distinct conceptions of the nature of orthographic rules. In his account, one view of an orthographic rule is that it is an abstract linguistic description. Such descriptions can include historical and morphological information as well as a reader's knowledge of the orthography and the procedures and mechanisms involved in pronouncing words. Glushko and others (Kay & Marcel, 1981) thus view dual route approaches as confounding linguistic definitions with psychological processes. This linguistic definition is then erroneously used as a basis for the reification of separate functional psychological 'routes ' to reading.

Another criticism of early versions of the dual route model, wherein a reader was assumed to store a vast number of separate and supererogatory pairings between whole word orthography and phonological patterns, is that this seems inconsistent with principles of cognitive economy (Gough, 1972). In the adult literature, observations

such as the word superiority effect, whereby an adult is quicker at identifying letters when those letters are embedded in a word context (Reicher, 1969; Wheeler, 1970), has led some to suggest a more interactive relationship between letter and word knowledge (McClelland & Rumelhart, 1981). In McClelland & Rumelhart's implemented computational model of reading, the process of word recognition commences by the activation of specific letter knowledge which also quickly acts as a constraint upon the activation of candidate word level representations. Furthermore, the resolution of identification processes for letter information need not be completed before information is passed on to the word level of representation. In their view, cascading parallel activation is undertaken between highly connected letter and word level stores of information. The notion of interactivity between feature, letter and word level information has been conceded by dual route theorists. In the most recent dual route models of reading, Rumelhart and McClelland's interactive network is instantiated as a lexical route, which is independent of a sublexical route to reading which uses grapheme to phoneme conversion rules (Coltheart, Curtis, Atkins, & Haller, 1993).

Even in more recent formulations of dual route models of word pronunciation, lexical and sublexical routes are assumed to operate independently and in parallel without computations in one route adjusting and benefiting computations in the other route (Baron, 1977; Stanhope & Parkin, 1987). Some experimental studies have appeared to contradict this view. Glushko (1979) reported that word level information influences the pronunciation of nonwords. In a first experiment (Glushko, 1979), words such as 'DEAF' and 'MEAN' and nonwords such as 'HEAF' and 'HEAN' were compared. HEAF shares with real words a rime body unit that could be described as an exception (e.g. 'eaf' in 'deaf' vs 'leaf') whereas HEAN does not ('ean' in 'mean', 'bean' etc). The 'regular' words and 'regular' nonwords were quicker to name than their 'exception' word and nonword counterparts. In a second experiment, only regular and exception nonwords were used to avoid possible priming effects on nonwords

from lexical materials. Latency advantages were still present for 'regular' nonwords over 'irregular' nonwords.

Glushko, (1979) and Kay and Marcel, (1981) theorise on the basis of this position that reading may be undertaken solely by the use of a process of lexical analogy. Herein a single route is posited for the reading of both regular and exception words². This alternative theoretical model assumes that true regularity must involve the comparison of a word with the set of words that most closely resemble it in terms of shared orthography and phonology (Van Orden, Pennington, & Stone, 1990). The interpretation of observations such as those by Glushko and Kay and Marcel have however been hotly debated (see Patterson & Coltheart, 1987 for a review), and it is now clear that early findings by Glushko and Kay and Marcel may be explicable by either traditional or modified dual route models of reading. For example, the generally slower naming speeds for all nonwords compared to real words, is consistent with the view that separate processes act upon the two classes of stimuli. The observed effects of rime body consistency on nonword reading could be accounted for by assuming that the sublexical routine utilises conditional rime body rules (Orthography-to-Phonology Correspondence or OPC rules) as well as grapheme to phoneme conversion rules (Patterson & Morton, 1985).

In conclusion there appears to be no one generally accepted model of adult reading. Both single and dual route models have been advanced and are able to explain a range of observations in the literature. Developmental models are likely to reflect this absence of a unifying theory whilst suffering the additional complexity of explaining the development of reading mechanisms. However, in contrast to this theoretical impasse, there are some empirical observations that appear to require explanation on all accounts of reading: one of the most important is the emergence of orthographic rime body units

² Some more recent 'Connectionist' models of reading extend this view. Lexical representations do not appear at all and all letter-sound rules are eschewed in such accounts (Seidenberg & McClelland, 1989). Implemented connectionist and dual route models are considered as general classes of developmental models and are discussed in more detail in chapter 2.

in reading. Clearly developmental models which aim to be compatible with adult models of reading must be able to explain this phenomenon.

Models of reading development must consider the role of phonological awareness

A final constraint upon models of reading development is that they should also be able to explain the role of skills that have been shown to be closely related to reading development. In recent years, much research activity has focused on the sound manipulation abilities or 'phonological awareness' of beginning readers. There is now a vast literature on this topic, and the accumulated results of this body of work are highly complex. A relatively brief and necessarily selective review of some of the most influential studies of phonological awareness and its relation to literacy acquisition is attempted in section 2 of this chapter. The central issue of the review concerns the nature of the relationship between phonological awareness and reading. A preliminary issue that is considered below is the definition of phonological awareness.

Section 2

The nature of phonological awareness

Most attempts to define explicit phonological awareness emphasise that it is a skill requiring conscious access to, or ability to consciously reflect upon, the phonological structure of oral language (Mattingley, 1972; Adams, 1990). Phonological awareness, rather than constituting a single identifiable skill, can be understood as a blanket term that subsumes a number of phonological skills (Goswami & Bryant, 1990; Morais, 1991). At its most primitive level, explicit phonological awareness could be seen as the ability to 'decentre' from attending to the meaning symbolised by a word, and to focus instead upon its phonological form. As Fowler (1991) notes, this idea accords with the Piagetian description of the Concrete Operational stage of cognitive development, during which children first demonstrate the ability to shift readily from one symbolic aspect of a stimulus to another. It has often been assumed that the primary

focus of beginning readers is upon the semantic nature of the language. Some empirical work supports this view. For example, prior to formal instruction, when asked for a 'long' word, children might reply with 'train', because 'there are a lot of carriages' (Papalanpadrou & Sinclair, 1974). The child's response reflects a focus upon object properties rather than orthographic or phonological knowledge of the stimulus.

However it cannot necessarily be assumed that children find it difficult to focus upon phonology or orthography rather than word meaning. In certain circumstances children can show substantial preference for the phonological aspects of language over meaning. A recent study by Cardoso-Martins and Duarte (1994) asked young Brazilian speakers of Portuguese to choose a word that was 'most like' a standard target word. For a standard word like 'passarinho' (bird) children could choose semantically related words such as 'urubu' (vulture) or 'gaiola' (cage), or phonologically related but semantically unrelated words such as 'espinho' (horn), or 'pavio' (wick). Marked preferences for phonological similarity were evident for 4 and 5 year old prereaders as well as in a group of six and a half year old kindergarten children who were being taught to read. Naturalistic observations by Chukovsky (1963) also show that young children are proficient users of rhyme and alliteration who will often emphasise phonological characteristics of language at the expense of meaning. Such preferences are evident in children's spontaneous poetic constructions such as "the red house made of strouss" in which the word 'straw' is partly corrupted to fit into the rhyming structure of the sentence.

Are there different kinds of phonological awareness?

A central question concerns the existence of different kinds of phonological skill. Stanovich, (1986) distinguishes between 'phonological sensitivity', which he suggests refers to a fairly rudimentary ability to recognise phonological components of oral language such as rhyme and alliteration, and 'phonological awareness', which is held to represent a more concrete awareness of individual phonemes that constitute oral

language. A similar distinction is made by Morais Bertelson, Cary and Alegria (1986) who refer to 'sensitivity to sound similarity' as a description of global and non-analytic awareness of speech sounds, which can include all speech units larger than the phoneme. These units are seen as more isolable, salient, and less abstract than units identified through explicit phonological awareness. Morais, Alegria, and Content, (1987), additionally propose the existence of 'phonetic awareness' which can be understood as the awareness of speech as a combination of phonetic elements which allow perceptual differentiation, and 'phonemic awareness' which is the ability to represent speech as a sequence of phonemes. They argue that formal experience of an alphabetic orthography is the likely cause of the development of phonemic awareness, whereas awareness of phonological strings and phonetic awareness skills may not require formal tuition in order to develop.

Phonemic awareness skills have been operationalised in a number of ways. Bruce (1964) reported the earliest study of sound manipulation skills in children. He gave phoneme deletion or 'elision' tasks to children with mental ages of between five and nine years. One condition of the test required children to remove the first sound from a set of orally presented monosyllabic words. Thus for the stimulus 'jam' - the correct answer would be 'am'. In another condition, the task was to delete the middle sound (e.g. 'snail' - 'sail'), and in a third condition, to delete the last sound (e.g. 'fork' - 'for'), from a set of words. The results showed, somewhat surprisingly, that none of the five year olds were able to perform this task in any trial, and that even the seven year olds on average succeeded on less than a third of their trials. Only the eight and nine year olds managed to get more than half of the words correct. This strongly suggests that young children have difficulty with tasks that involve manipulating phonemes. These results have been replicated many times (Rosner & Simon, 1971; Fox & Routh, 1975).

Liberman, Shankweiler, Fischer, and Carter (1974) asked children to tap with a dowling rod for every speech sound that they heard in a given word. In one condition the task was to tap out the number of syllables in words such as 'butterfly', 'butter' and 'but'. In the second condition the task was to tap out the number of phonemes in stimuli such as 'boot' 'boo' and 'oo'. Liberman et al reported that children found the syllable task much easier than the phoneme task. Of the kindergartners, 46% correctly tapped the number of syllables, but none tapped the number of phonemes correctly. The first grade students completed the task with a 90% success rate for the syllable task, and with a 70% success rate for the phoneme task. Again, these studies have been replicated many times (Tunmer & Nesdale, 1982, 1985; Treiman, 1992). The results of these tasks and those of Bruce (1964) suggest that, prior to formal reading instruction, children experience difficulty with tasks that involve manipulating phonemes. The development of the phonemic awareness skill with greater reading experience suggests, however, that these skills are closely associated with reading acquisition.

Awareness of onsets and rimes

More recently, researchers have followed theoretical developments in phonological theory (Fudge, 1969; Hockett, 1973; Selkirk, 1982) in arguing that there are structures intermediate between that of the syllable and that of the phoneme, which represent a further distinct, and 'psychologically real' level of phonological awareness. Treiman (1992) argues that as well as being divisible into phonemic components, the syllable can be divided into the onset, which corresponds to the initial consonant or consonant cluster, and the rime, which corresponds to the medial vowel or vowels and terminal consonant or consonant cluster of a syllable. Onsets can represent single phonemes (e.g. 'c' in the word 'cup') or consonant clusters (e.g. 'cl' in 'clap'), and are not mandatory because some words such as 'east' or 'oat' have no onsets. Rimes, however, are mandatory, in the sense that every word contains a rime unit.

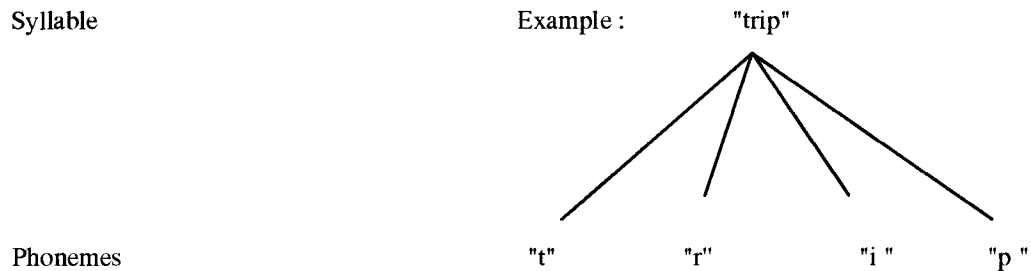
Awareness of peak and coda units

Treiman (1992) suggests that it is possible to further differentiate components of rime. According to some linguists (Fudge, 1969; Hockett, 1973; Selkirk, 1982) the rime itself contains a 'peak' or vowel nucleus, which may incorporate 'weak' consonants such as liquids (/l/, /r/) or nasals (e.g. /m/, /n/) (Fudge, 1969). Thus the two medial phonemes in the word 'milk' or 'mint' could be considered the syllabic peak. The coda is the terminal consonant or consonant cluster of the rime. The coda can represent a single letter (e.g. in the word 'milk') or letter pairs (e.g. in the word 'whisk'). The idea that there is an onset-rime structure and a further peak-coda structure that represents an intermediate level between syllables and phonemes has been called a 'Hierarchical' view of the syllable (Treiman & Zukowski, 1991). The linear and hierarchical views of the English syllable are represented visually in figure 1.1.

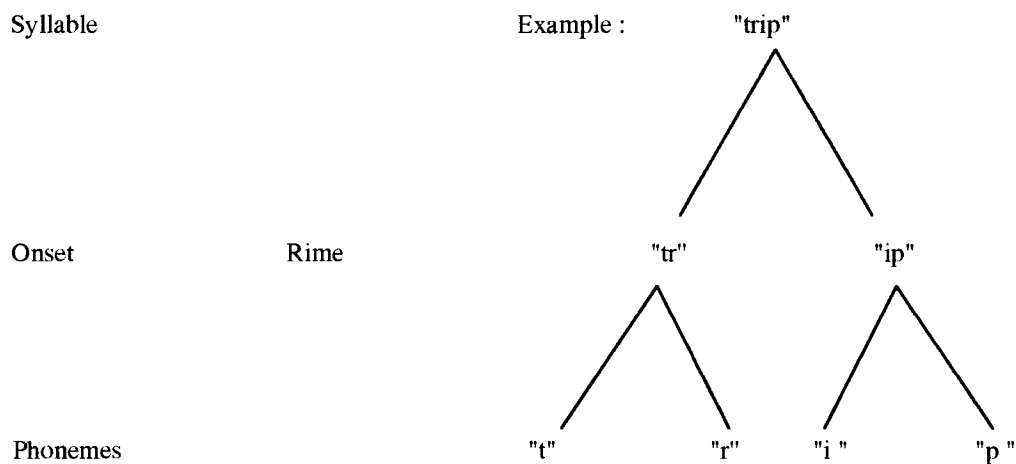
Evidence in support of the idea that certain groups of phonemes are more likely to behave as units than others has come from the preferences shown by adults, in experimental situations, to blend two words at the onset rime-level, rather than in ways that do not respect the onset-rime boundary. Where adults are asked to combine parts of two words such as 'packed' and 'nuts' into a single novel stimulus, they are more likely to respond with a response such as 'puts' which respects the onset rime boundary than a response such as 'pats' which does not (Treiman, 1986). Evidence from spontaneous speech errors (e.g. Mackay, 1972; Stemberger, 1983) also suggests that such errors combine competing responses at the level of the onset-rime. For example the speech error 'don't shell' appears to reflect a particular combination of the responses 'don't shout' and 'don't yell', and appears to be more common than other possible subsyllabic combinations, such as 'don't shoull' (Mackay, 1972).

Figure 1.1. The linear and hierarchical views of the syllable.

Linear view of the syllable:



Hierarchical view of the syllable:



Evidence in favour of the hierarchical view also comes from several experimental studies of childrens phonological awareness. Treiman (1985, Experiment 2) introduced children with an average age of 5 years and 5 months to a novel word game using the device of a puppet controlled by the experimenter. Children were presented with a tape recorded list of syllables such as /spa/, /sap/, /sa/, and /nik/. They were told that the puppet liked certain sounds (e.g. those associated with the letter 's' in this case), and the task was to state whether the puppet would like the syllable or not.

Treiman reasoned that if children could analyse words into onset units then they should be able to detect the 's' in /sap/, however the identification of units within an onset may be rather more difficult. Thus the identification of the 's' in /spa/ should prove to be more problematic. The linear view of the syllable would not predict such effects. Results showed that children failed to identify the /s/ in spa significantly more often than the /s/ in /sap/ or /sa/ stimuli (28% versus 14% versus 12% respectively).

In a further study by Treiman and Zukowski (1991, Experiment 1) kindergarten, first grade, and second grade children's awareness of onsets, rimes, and single phonemes was evaluated in a word pair comparison game. Children were again introduced to a puppet, controlled by the experimenter, who liked words which sounded the same. The children's task was to choose the word pairs that the puppet would like. In each of the three conditions in the study there were similar and dissimilar word pairs. Two of the conditions used the same syllable and phoneme levels investigated in the study by Liberman et al (1974). For each level there were two sorts of words: pairs of words which shared their first syllables e.g. 'hammer' - 'hammock' (the beginning condition) or pairs of words that shared the second syllable e.g. 'compete' - 'repeat' (the end condition). In the phoneme condition there was also a beginning (e.g. 'pray' - 'plea') and an end condition (e.g. 'rat' - 'wit'). In addition, a third condition was based on onsets (e.g. 'plank' - 'plea') or rimes (e.g. 'spit' - 'wit').

Treiman and Zukowski reported that at each age level tested, children found the onset and rime judgements easier than the phoneme judgements. The preschoolers had a 25% accuracy on the phoneme task and a 56% accuracy for the onset and rime task. The first grade children succeeded with a 39% accuracy rate on the phoneme tasks but achieved a 74% accuracy rate on the onset and rime tasks. One problem with this study is that the judgements which refer to different linguistic levels within a syllable are perfectly confounded with the physical size of the units in each case. However evidence from a further study (experiment 2) is not confounded in this way. In this study

children were again presented with word pairs in the same way as in experiment 1. This time children were asked to make judgements about word pairs in which common phonemes were the complete consonant onsets (e.g. 'pacts'-'peel', 'thick'-'thorn'), or were part of the onset consonant cluster (e.g. 'plan'-'prow', 'crab'-'clean'). The proportion of correct identifications was .88 and .80 respectively, indicating that the children found the former task easier. Treiman and Zukowski (1996) have reported very similar proportions in their replication of this study.

Finally, onsets and rimes were also compared to phonemes in a study by Kirtley, Bryant, Maclean, and Bradley (1989). They asked 5, 6, and 7 year old children to perform an 'oddity task' which required them to choose the odd word out in a set of three. In one condition the word sets contained either one word with an anomalous letter in the initial consonant position (e.g. 'doll', 'deaf', 'can'), or in the final consonant position (e.g. 'mop', 'lead', 'whip'). In another condition, two out of three words either shared rimes (e.g. 'top', 'rail', 'hop'), or shared equivalent numbers of letters in the initial position of the word, (e.g. 'cap', 'doll', 'dog'). Results showed that for all age groups, the children were significantly better at detecting the anomalous word if the other words shared rimes, rather than when the words shared letters that did not respect the rime. Together with the study by Treiman and Zukowski (1991), the data from Kirtley et al (1989) suggest that children do show a greater awareness of the onset and rime units of syllables than the constituent phonemes of syllables prior to reading instruction.

Evaluation of the hierarchical syllable approach

The idea that there is a level of awareness between that of the syllable and the phoneme is an attractive idea for many researchers. The present evidence is not, however, without some problems of interpretation. A theoretical issue concerns the role of experience in development of onset and rime awareness in children (Carlisle, 1991). The problem of distinguishing the role of experience from a facility which presumably

lies in the fundamental structure of phonology itself, is likely to be a highly complex problem. Carlisle also points out that there are certain empirical inconsistencies in Treiman's data. In the initial study by Treiman (1985), there is some considerable variability in performance in judging the acceptability of different onset units. Two units in particular appear to contribute a substantial amount to the scores, casting doubt upon the uniformity of proposed levels of awareness for onsets investigated. A further problem is that at least some of the results (Treiman & Zukowski, 1991, Experiment 1; Treiman & Zukowski, 1996, Experiment 1) could suggest that ceiling effects may have been evident in performance. In the 1991 study no information on the statistical significance of the crucial comparison across conditions was reported.

Morais (1991) reported evidence from the study of the phonological abilities of two Portuguese illiterate poets, F. J. C. and A. B. Despite a well developed ability to detect rhyme, tested by presenting similar (e.g. 'povas'-'movas'), or dissimilar pairs (e.g. 'chomba'-'zonta'), and a well developed ability to detect rime oddity, which was tested by presenting word triples in which two of the words presented rhymed and one did not, (e.g. 'bule', 'gume', 'lume'), neither of the poets could learn to delete the initial consonant from a word where that consonant represented the whole onset. This appears to provide clearer evidence of the distinction between global awareness of rime and the analytic ability to reflect upon onset and rime structures that may be important in facilitating reading. Morais argues that alliteration and rhyming skill cannot be equated with the ability to analyse syllables in terms of onsets and rimes.

A study by Seymour and Evans (1994) has provided some experimental support for the view that global rime awareness differs from explicit rime segmentation. Their study also suggests that the ability to explicitly segment syllables into graphemes may be more important than rime segmentation in early reading. Seymour and Evans contrasted the predictions from a 'progressive top down' model of phonological awareness such as that of Treiman (1992) in which onsets and rimes emerge prior to

phonemic awareness and a 'disjoint' model in which early syllabic awareness is followed directly by the emergence of explicit phonemic awareness, possibly as a consequence of alphabetic tuition. They compared subsyllabic segmentation skills amongst prereading nursery children and children in years 1 and 2 of schooling who had started to read. The main focus of the study was on the ability of children to explicitly segment words such as 'ground' into either onsets and rimes (gr - ound), onsets peaks and codas (gr - ou - nd), or phonemes (g - r - ou - n - d). Children were also given a rhyme production task.

Results indicated that both the nursery children and year 1 children showed floor effects in their performance on all segmentation tasks, despite a reasonable facility in the rime production task, suggesting that rime production and explicit rime segmentation tasks make very different demands on young children. The children in year 2 showed some skill in segmenting syllables, but demonstrated a greater ability to segment words into phonemes than into either onsets and rimes or into onsets, peaks and codas. Subsequent experiments replicated this initial pattern of findings and confirmed that the results could not be explained by either order effects in stimulus presentation, or the occasional existence of embedded words in stimuli (such as 'lay' and 'play' in the stimulus word 'splay'). The results were interpreted to suggest that phonological awareness does not necessarily develop in the hierarchical manner described by Treiman (1992) but may instead often reflect explicit teaching of letter-sound relationships.

The potential role of onset-rime awareness

Despite these criticisms, the notion that phonological skills at the level of the onset and the rime represent an intermediate step between syllable and phoneme awareness has excited considerable interest. One reason for this is the interest generated by research in the adult literature on rime bodies discussed earlier (Glushko, 1979; Kay & Marcel, 1981). One possibility is that phonological rime awareness may underpin the

development of orthographic rime units in developmental analogy models of reading. This role for onset-rime awareness has been contrasted with phoneme awareness which has traditionally been associated with the development of grapheme to phoneme correspondence rules (Bryant & Bradley, 1985; Goswami & Bryant, 1990). A further element to this debate is that as children appear to be able to manipulate onsets and rimes prior to formal schooling this holds out the possibility that children might use such units to develop reading-related skills before entering the school system, or to facilitate reading immediately upon school entry. This view has also been embraced by the Oxbridge school of researchers (Bryant & Bradley, 1985; Goswami & Bryant, 1990). Given the potential significance of different kinds of phonological awareness in reading development, research on the relationship between onset-rime awareness, phonemic awareness and reading ability is considered carefully below, and in chapter 3 where developmental rime analogy models are discussed in detail.

A note on nomenclature

One consequence of the debate about the role of various types of phonological awareness in reading is that there is often a rather inconsistent use of nomenclature. Researchers have sometimes used terms such as 'phonemic awareness' where access to purely phonemic information is not necessarily required (Tunmer & Nesdale, 1985; Adams, 1990). In this thesis, the term 'phonemic awareness' is reserved for tasks that unambiguously require access to single phonemes³. Onset-rime awareness is used where these larger units are implicated, and the generic term 'phonological awareness' is used where a less specific aspect of the segmental properties of speech is indicated.

³ One complication of this taxonomy is the categorisation of single phoneme onsets (such as the sound associated with 'c' in 'cat'). As Maclean, Bryant and Bradley (1987) point out, these units can be seen as phonemes or as larger 'onset' units. Similarly the initial letter of the word 'open' could be seen as being simultaneously a syllable, a rime or a phoneme, (Mann, 1991). Thus, evaluation of the status of such units can perhaps only be made by comparison with performance on other phonological tasks (e.g. awareness of other phonemic units at the end or middle of a word), or versus other onset-rime awareness tasks (e.g. consonant cluster onsets), if at all. The status of individual tests of initial sound awareness are always likely, therefore, to be controversial. Comments on individual tests and studies are reserved for the main body of the text.

Phonological skills and learning to read

Early research on the relationship between phonological skills and reading acquisition sought to establish whether a correlation exists between phonological skills and learning to read. Such studies reported strong positive correlations between the two skills (e.g. Calfee, Lindamond, & Lindmond, 1973), and these results have been replicated repeatedly in subsequent studies (e.g. Carr & Levy, 1990). Correlations are only the first step in research on literacy, as they do not of course, in themselves, provide evidence of causal relationships. One of the central goals of recent attempts to develop causal models of reading development has been to elucidate the precise role of phonological awareness (Goswami & Bryant, 1990; Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgeson, & Rashotte, 1994). Theroretically, there are three possibilities (Morton & Frith, 1993; Wagner, Torgeson, & Rashotte, 1994): A) phonological awareness is a causal factor in reading development, B) phonological skills arise as a result of reading, C) there is a complex reciprocal relationship between phonological skills and reading. These views are considered in turn in the following section.

Causal relations between phonological skills and subsequent reading

The view that phonological skills play a causal role in developing reading skills is supported by a number of longitudinal studies of the development of reading in English (Bradley & Bryant, 1983; Maclean, Bryant, & Bradley, 1987; Stuart & Coltheart, 1988; Vellutino & Scanlon, 1987; Wagner, Torgeson, & Rashotte, 1994) that have shown a link between preschool awareness of phonology and subsequent reading ability. In the study by Stuart and Coltheart, for example, 36 four year old children were given a series of phonological test prior to entering school. Tests included rhyming tasks such as rime production, and rime detection, as well as measures of phonemic awareness, including the production of a final sound of a word presented by the experimenter, and the identification and segmentation of the initial phoneme in a word.

Results showed that all of the phonological measures were strongly intercorrelated. A combined measure of these phonological tests did not predict reading in the first year of school, but did predict reading ability in the second, third, and fourth years. By the third and fourth years, phonological skills emerged as stronger predictors of reading ability than standard measures of intelligence. Furthermore, when a combined measure of letter sound knowledge and phonological awareness was considered, a significant relationship between these measures and reading ability emerged even in the first year of school. Stuart and Coltheart argue that, at least for the phonologically able child, reading ability is strongly determined by phonological skills from the earliest point in reading acquisition. In the most recent follow up of these children, (Stuart & Masterson, 1992), the relationship between early phonological awareness and reading was still evident six years after initial testing.

The interpretation of some aspects of these results is not entirely straightforward. Wimmer (1990) has suggested that the failure of the single measure of phonological skills to predict reading in the first year of school is consistent with views of early reading which assume that children use a non-analytic or 'logographic' approach in the earliest stages of reading. One further problem in this study is the interpretation of the results of the combination of phonological and letter-sound knowledge. It is not clear that a linear and additive relationship between phonological skill and letter-sound knowledge can be assumed. Furthermore, in order to evaluate the role of combined letter-sound and phonological awareness on reading measures, it is also important to know to what extent letter-sound knowledge on its own predicted reading ability. Previous studies have found letter-sound and letter-name knowledge to be one of the strongest associates of reading ability (Bond & Dykstra, 1967; Vellutino & Scanlon, 1987; Adams, 1990). However as the results of multiple regressions with letter-sound knowledge as a predictor are not reported, the necessity of positing a combined letter-sound and phonological awareness measure is difficult to evaluate.

Further evidence for a causal link between phonological skills and reading ability comes from a study by Wagner (1988), in which meta-analyses were undertaken on nine longitudinal studies of early phonological awareness and subsequent reading and seven intervention studies, which had sought to train phonological skills. There were over 1200 children in the combined sample. Studies were selected on the basis of the ability to calculate the relationship between kindergarten phonological skills and reading ability, while holding initial reading ability constant through partial correlation. Results showed a strong and consistent predictive relationship between phonological skills and reading. The median correlation for the combined longitudinal studies was .38, whereas for the training studies the median correlation was .70, indicating that, in both types of studies, a strong causal relationship exists between early phonological skills and subsequent reading ability.

Finally, Liberman and Liberman (1992) in an overview of the role of phonology in reading, point out that the relationship between phonological skills and subsequent reading ability has not only been demonstrated in studies of the acquisition of English orthography, but also in Swedish (Lundberg, Olofsson, & Wall, 1980), French (Morais, Cluytens, & Alegria, 1984), Spanish (De Manrique & Gramigna, 1984), Italian (Cossu, Shankweiler, Liberman, Tola, & Katz, 1988) and Russian (Elkonin, 1973). Subsequent studies have extended the generality of these findings to other languages including German (Wimmer, Landerl, & Schneider, 1994), Danish (Lundberg, Frost, & Petersen, 1988), and Czech (Caravolas & Bruck, 1993). There appears to be substantial support for the general view that phonological skills predict success in reading acquisition in alphabetic orthographies.

Relations between reading ability and subsequent phonological skills

The alternative view that phonological skills emerge as a result of experience of learning to read (Ehri, 1992, 1995) is supported by evidence from a number of sources.

One important source of evidence on this issue comes from the study of the relationship between phonological skills and reading in non-alphabetic scripts.

Phonological skills and reading in nonalphabetic scripts

Logographic writing systems which are based upon distinct, word specific, orthographic representations provide a fertile testing ground for the role of phonological skills in reading ability (Mann, 1986, 1991; Read, Zhang, Nie, & Ding, 1986). A study by Mann (1986) indicated that children who were educated in both the Japanese 'Kanji' system based upon logographs and the 'Kana' system based upon a syllabary, performed significantly less well than American first grade children on phonological tasks involving explicit phoneme awareness, such as phoneme counting and phoneme deletion. Such results are consistent with the view that learning to read an alphabetic orthography causes the development of explicit phonemic awareness (Morais, 1991).

Interpretation of this evidence is not entirely straightforward, as some first grade Japanese children were able to perform the phonemic tasks quite well. Furthermore some improvement for the Japanese children was shown, with performance equalling that of the American first grade children by the fourth grade, despite the absence of direct experience of phonemes through the orthography. This could suggest that maturation plays a role in the development of phonemic awareness (Mann, 1986, 1991). Alternatively, the presence of some orthographic indicators of phonemic values in Kana, (such as diacritical marks, which distinguish voiced from unvoiced consonant phones), or the practice of teaching initial consonant onsets of syllables in families (e.g. 'ka', 'ko', 'ki'), may be sufficient to allow the development of some phonemic awareness. Nevertheless, despite these concerns, performance was very poor in relative terms for these Japanese children, suggesting that experience of an alphabetic orthography has a powerful effect in developing explicit phonemic awareness.

Phonological skills and reading in alphabetic scripts

Additional support for the view that phonological skills develop as a consequence of exposure to alphabetic orthographies is provided by Morais, Bertelson, Cary and Alegria (1986). In their study, Portuguese adults who were either recently literate or entirely illiterate, were asked to perform a series of phonological awareness tasks. One task was a syllabic task which required the deletion of a syllable from a two syllable word, the second task was to delete a single phoneme from a word. They were also given a rime awareness task. Results showed that the illiterates demonstrated significantly poorer performance on all of the tasks, but were particularly poor on the phoneme deletion task.

One problem with this study is that the syllabic tasks and the phoneme tasks were not equivalent. While the size of the unit was equated (with a single phoneme being deleted in each case), for the syllable task the deletion task involved a vowel, whereas for the phoneme task the unit to be deleted was a consonant. This leaves open the possibility that differences in the perception or production of consonants over vowels (Hooper, 1972), rather than the linguistic level of the units involved, contributed to the observed pattern of results. One possibility is that a voiced vowel used to represent an initial syllable may be more salient to the illiterate subjects than the unvoiced phoneme unit used to represent the initial phoneme of a word. A second kind of problem concerns extraneous factors which may have influenced performance on the phonological tests. The influences on literacy are unlikely to be entirely random, and may reflect other differences between the literate and illiterate groups. The interpretation of experimental results thus needs to be undertaken with great care in the absence of a random allocation of subjects to experimental conditions.

Experimental evidence from normal readers also supports the view that phonological awareness is a consequence of reading acquisition. Ehri and Wilce (1980) showed fourth grade children familiar words such as 'pitch' and 'rich'. Children were



then given a phonemic task in which they were asked to lay down a counter for each sound in a word. Results showed that there was a significant tendency to erroneously place four counters for words such as 'pitch', while only placing three counters down for 'rich'. A second study extended these findings by first teaching children nonwords such as 'zitch' or 'zich', and then giving them the same phonological task administered previously. Results revealed that the group taught the words with silent letters tended to place an additional counter for these words, suggesting that children can consult their knowledge of the orthography to carry out phonemic awareness tasks. Similarly, Tunmer and Nesdale (1985) and Perfetti, Beck, Bell, and Hughes (1987) have found that spelling knowledge influences a child's conception of subsyllabic phonology. Children tended to produce 'overshoot errors' for the words containing digraphs when asked to tap out the number of phonemes in familiar words. Thus children would tap four times for the word 'book' even though it contains only three phonemes.

In a similar vein Stuart (1990a) reports a study using a difficult phoneme deletion task. Twenty three nine year old readers were asked to delete the weaker consonant of a final consonant cluster. The study ingeniously took advantage of the fact that for words like 'cold', the deletion of the liquid, using a purely phonological strategy yields the response 'code', whereas use of an orthographic strategy would yield the response 'cod', if the resultant orthographic unit was identified correctly and subsequently reblended. Children were divided into 2 groups of above and below average spellers. Results of the study showed that phonological responses outweighed orthographic responses by a factor of nearly two to one. There was also a significant interaction between ability in spelling and the use of an orthographic strategy to complete the phoneme deletion task. The good spellers were significantly more likely to use an orthographic strategy. This supports the view that reading helps to develop phonological awareness skills.

Interactive relations between phonological skills and reading

The view that there is a complex bidirectional or other interactional relationship between reading ability and phonological awareness is supported by a number of studies (Goswami & Bryant, 1990; Perfetti, Beck, Bell, & Hughes, 1987; Stuart & Coltheart, 1988; Stuart, 1990a; Wagner, 1988; Wagner, Torgeson, & Rashotte, 1994). Stuart (1990a) provided evidence in support of an interactive relationship between phonological and reading skills from an experimental and longitudinal study. The children described above who were able to make use of orthographic information to perform the phonological task of consonant deletion were the better readers and spellers. Furthermore, careful tracking of these children had taken place since preschool (Stuart & Coltheart, 1988), and analysis of the longitudinal data revealed that the children who were good readers and were using orthographic strategies had significantly higher scores on preschool phonological tests than the other children.

Another large and long term study of the relationship between a whole range of phonological skills and reading development was undertaken by Wagner, Torgeson, and Rashotte (1994). They compared five phonological variables which yielded quite consistent individual differences over three years. A latent variable analysis of the five combined phonological measures: analysis, synthesis, phonological memory, naming, and letter knowledge - showed a highly significant relationship between phonological variables and early reading even after autoregressive effects of early decoding were controlled. However there was considerable redundancy between measures, suggesting that measures were addressing similar underlying variance. Causal path analyses revealed that while phonological skills predicted subsequent reading ability, reading ability in first grade did not predict subsequent phonological awareness as long as the autoregressive effect of concurrent phonological skill was controlled. Letter-name knowledge however, did have a modest predictive relationship with subsequent phonological awareness in grade 2, even after initial phonological skills were controlled.

Reciprocal relations between different levels of phonological skills and reading

One drawback of the combined latent variable analysis approach used by Wagner et al is that it ignores the possibility that different kinds of phonological skill may share different relationships with reading ability. An influential alternative approach to bidirectionality is the idea that there may be different 'levels' of phonological awareness that influence reading ability at different points in literacy acquisition (Goswami & Bryant, 1990; Treiman, 1991, 1992). From this view, some sorts of subsyllabic phonological skill such as onset and rime awareness predate reading and are causal in developing reading, while other levels of subsyllabic phonological skill such as explicit phonemic awareness are, at least in part, the consequence of reading acquisition. Psycholinguistic evidence considered earlier in the chapter provided some support for this hierarchical development of phonological awareness. An important question that follows is whether this awareness of onsets and rimes plays a causal role in reading acquisition.

The Oxford studies of reading development

In a seminal publication, Bradley and Bryant, (1985) sought to establish the existence of a causal link between preschool rime awareness and later reading ability. They argued that a predictive relationship was not in itself evidence for a causal link because of the possibility that the relationship was due to some other factor that was not measured. They argued that convincing proof of a causal connection between sound categorisation and reading ability could only be established from the combined evidence of a longitudinal study and an intervention study designed to train children in phonological skills.

The longitudinal study

In the first Oxford study, Bradley and Bryant selected a large group of 403 four and five year old children, none of whom could read at the beginning of the project. These children were first measured on their ability to categorise words using an oddity

task. The children's task was to say which of a set of spoken words was the odd one out, (e.g. 'sit' in the set 'pin', 'win', 'sit', 'fin'). Children were subsequently followed up when they were seven or eight years old, where a further battery of tests, including one of reading ability was administered.

Bradley and Bryant found a strong and specific relationship between children's preschool sensitivity to rhyme and the improvements that the children made in reading and spelling over a three year period, even when differences in children's measured I.Q., vocabulary, and digit span recall were controlled in regression analyses. No predictive relationship was found between rime phonological awareness and subsequent measured mathematical ability, suggesting that this phonological relationship was a specific one. However the relationship between onset awareness and subsequent mathematical ability was significant, forcing the authors to conclude that onset awareness skill may tap a rather wider ability. The authors argued that their evidence provides powerful support for the view that children's preschool phonological abilities strongly influence the development of reading ability. Similar patterns of results have been found in longitudinal studies in Sweden (Lundberg, Olofsson, & Wall, 1980), and in the U.K. (Maclean, Bryant, & Bradley, 1987) and in cross-sectional studies in the U.K. (Ellis & Large, 1987, 1988; Gathercole, Willis & Baddeley, 1991).

The second Oxford study by Bryant, Maclean, Bradley, and Crossland (1990) sought to investigate the causal relationship between different levels of phonological skill and reading ability in greater detail. Sixty four children were tested at 4 years and six months and then followed over a period of two years. Rime and alliteration tests were given on the first two occasions and phoneme awareness tests were given on the final two occasions. In the final session, the outcome measures of reading, spelling, and arithmetic were taken. The results of multiple regressions showed that rime awareness predicted later reading ability even when phonemic measures were entered as a prior step in analyses. This suggests that rime awareness makes a unique contribution

to reading development. Further regression analyses indicated that rhyme had a second influence upon phonemic awareness itself, and may therefore influence reading in an indirect, as well as a direct manner.

The training study

Bradley and Bryant (1983) sought to evaluate the effects of an extended intervention to train children with poor phonological skills to recognise rhyme on subsequent ability to read. Bradley and Bryant selected 65 of the poorest readers aged between six and seven years from the 403 children in their larger longitudinal study. These children were allocated into four groups. One group were given training in rhyme and alliteration awareness. A second group were given a similar training which was augmented by the use of plastic letters, which were used to represent the rhyming sounds. In a third group children were taught how to group the words into semantic categories e.g. animate versus inanimate objects. The fourth group were an unseen control group. Children were trained by a skilled clinician in forty ten minute, one to one study sessions, over a two year period. Bradley and Bryant then measured the ability of these children on a battery of cognitive tests.

Results showed that there was no advantage for a group trained in semantic classification. However a strong and significant advantage was evident for the group taught the relationship between phonological awareness and orthographic representation of the sounds. There was a small advantage in reading ability for the group trained in phonological skills, but this escaped significance in the crucial comparison with the semantic categorisation control group. The results therefore provide some support for the idea that training the phonological skills of young children will help them to improve their reading ability, at least when the connection between phonological and orthographic information is stressed. Similar improvements have also been reported in more recent studies when the link between orthographic and phonological elements have been stressed (Hatcher, Hulme, & Ellis, 1994; Iversen & Tunmer, 1993) but no

marked improvements in reading ability have been reported when only phonological skills are trained (Hatcher et al, 1994).

The origin of rime skills

An important question concerns the origin of rime and onset categorisation skill. One plausible hypothesis is that the awareness of rimes and onsets develops from children's experience with rhyming and alliteration. The experience and manipulation of rime is an important part of children's linguistic environments both before and during formal schooling (Chukovsky, 1963; Opie & Opie, 1987) and rhyme awareness therefore represents a skill potentially accessible to all children at an early age. A study by Maclean, Bryant, and Bradley (1987) sought to investigate the relationship between early rime awareness and rhyme knowledge.

Maclean et al first saw 65 children when they were 3 years old and asked them to recite common nursery rhymes which had a high rhyme content such as 'Humpty Dumpty'. Children were then seen 15 months later and their phonological awareness skills were measured using the rime oddity task used by Bradley and Bryant (1983). There was a strong relationship between children's knowledge of nursery rhymes and their subsequent performance on the rime oddity task. Furthermore this relationship remained after differences in the mother's I.Q. and educational level were partialled out in a multiple regression. This could suggest that children's early experiences with rhyme helps them to approach the task of categorising sounds. They argued that, via developing rime and onset sound categorising skill, nursery rhyme knowledge is an important predictor of early reading success.

Evaluation of the Oxford studies

Interpreting the intervention

The Oxford team's intervention study has been widely seen as supporting the view that rime phonological skills can be trained to facilitate reading ability. However

the fundamental comparison in this task was between the group of children trained in phonological skills and the control group who were given semantic classification training, but who received no tuition in phonological skills. Results showed that this crucial comparison failed to reach significance, so findings do not support this version of the causal hypothesis. However the consistent benefits found by training *both* phonological and orthographic skills in this study and in other studies (Hatcher et al, 1994) suggest different hypotheses about the role of phonology in reading. Training of phonological skills combined with explicit tuition directing children towards the link with the orthography can be seen as support for a 'direct mapping' model of reading (Hatcher et al, 1994).

General problems also exist in the interpretation of training studies. One fundamental logical problem concerns the inappropriateness of drawing specific conclusions about the nature of reading from training studies. It is not sufficient to assume that children developed a rime-based approach to reading as a result of rime-based training. It is quite possible that the training programme with its consistent patterning helped the children to develop phonemic or other levels of awareness. Furthermore, as Bryant and Bradley did not include a letter-only group the possibility exists that orthographic knowledge rather than phonological skill is developed in their combined training condition. Finally, there have also been occasional ethical criticisms of training studies where control groups are given prolonged exposure to tasks specifically designed to be of little educational value (Drummond, 1986).

The longitudinal relationship

The study by Bryant, Maclean, Bradley and Crossland (1990) has often been seen as powerful evidence of a causal link between rime awareness and reading ability. However, there are a number of fundamental problems with this study (Rack et al, 1993). One problem is that the possible effects of early reading ability upon rime awareness were not considered. Causal links can only be established when the

autoregressive effects of previous reading ability on subsequent ability are first controlled. Another problem with this study is the amalgamation of rime and alliteration scores into a single measure of phonological awareness. It is not clear that these two abilities tap the same level of skill. In fact, evidence against this view that onset and rime awareness are functionally equivalent can be found in Bryant and Bradley's own longitudinal data. In their 1983 study, regression analyses revealed that rime awareness was specifically associated with reading and spelling ability, whereas preschool onset awareness abilities while associated with reading skills were also a significant predictor of mathematical ability, forcing Bradley and Bryant to conclude that onset awareness may tap a more general skill than rime awareness.

The reliability of the association between rime awareness and reading ability

The predictive relationship between performance on the oddity task and subsequent reading ability reported in the first and second Oxford studies have been replicated by other researchers (Ellis & Large, 1987, 1988; Gathercole, Willis, & Baddeley, 1991). Many studies have however failed to report a concurrent relationship between rime awareness and learning to read (Stanovich, Cunningham, & Cramer, 1984; Yopp, 1988; Høien, Lundberg, Stanovich, & Bjaalid, 1995; Nation & Hulme, 1997), or a longitudinal relationship between rime awareness and reading (Lundberg, Frost, & Petersen, 1988; Muter, Hulme, Snowling & Taylor, 1997). Given the strong claims for a causal link between rhyme awareness and reading the evidence requires careful consideration.

Bradley and Bryant (1991) and Mann (1991) argue that the reasons for the failure of some of these studies to replicate the previous findings may lie in the simplicity of the rime test materials used, which have included some relatively simple rhyme tasks. Another explanation may be that the children in some of these studies were substantially older than in the Oxford studies. Both of these problems could lead to ceiling effects for rime measures. The degree to which these and other explanations

of failures to replicate the Oxford studies are considered below. Studies investigating a concurrent link are considered first and longitudinal studies are considered subsequently.

Failures to find concurrent links between rime awareness and reading ability

Stanovich, Cunningham and Cramer (1984) followed 49 children with an initial mean chronological age of six years and two months over one year. The predictive validity of a range of rime and phonemic awareness tasks was evaluated. Phonemic tasks included initial and final consonant matching tasks, phoneme deletion, and phoneme substitution. Rhyming tasks included a rhyme choice task (where children were asked to select a word that rhymed with a target e.g. 'pet' from three alternatives e.g. 'barn', 'net', 'hand'), and rhyme supply (where the children were asked to give further examples of a word that rhymed with a test word). All of the phonemic tasks were strongly inter-correlated, and together predicted reading ability a year later. The rhyme scores also tended to cluster together, but did not predict reading ability. Scores were rather high for the rime tests. Mean scores were also associated with small standard deviations and with some signs of negative skew. Other problems were also evident in this study. One problem is the relatively small sample size which suggest that the results of analyses should be taken with some caution (Stanovich et al, 1984; Yopp, 1988). Furthermore intelligence was not systematically controlled in the multiple regressions (Goswami & Bryant, 1990).

Yopp (1988) investigated the reliability and validity of 10 phonological awareness tests used in the literature on reading development. The subjects were 104 kindergarten children with a mean age of five years and ten months. Measures of rime awareness included a rhyme choice test (based upon Calfee, Chapman & Venezky, 1972) where children were asked to indicate whether word pairs (e.g. 'sandles' / 'candles', or 'run' / 'green') rhymed or not. Phonemic tests included a measure of phonemic segmentation, in which a child was asked to segment a verbally presented

word into its constituent phonemes (e.g. 'old' into 'o' - 'l' - 'd'), a test of phoneme isolation in which the child was asked to identify the beginning, middle, or final sounds of words such as 'what sound does 'jack' start with?', the phoneme deletion task used by Bruce (1964), and the phoneme tapping task used by Liberman et al, (1974).

The results revealed that relative to the other tasks, the rime task was the easiest to perform. All tests were significantly intercorrelated. In a second phase of analysis, the scores on the phonemic tests were correlated with a concurrent measure of children's ability to read novel words. Six three letter consonant-vowel-consonant nonwords such as 'hof', 'dap', and 'gos', were taught. Results of a series of stepwise multiple regression analyses, with the 10 phonological tasks as the independent variables, revealed that only the phoneme isolation and the Bruce phoneme deletion task were significant predictors of nonword reading performance. While the nonword learning task could be seen as a rather imperfect measure of reading ability (Goswami & Bryant, 1987), measures of the speed of word learning are generally strongly correlated with reading ability (Savage, 1994). There was no evidence that the tasks were markedly affected by ceiling effects. I.Q. was again not controlled in the regressions so the results may be open to more than one interpretation.

Nation and Hulme (1997) have also presented evidence for an association between phonemic awareness tasks and reading ability but not between rime awareness tasks and reading ability. In their cross-sectional study, a total of 75 children aged between six and nine years were given reading and spelling tests and measures of phonemic segmentation skill and onset-rime awareness. In both tasks children were asked to segment spoken monosyllabic nonwords. A grid with boxes was presented to indicate how to segment words: two boxes would indicate onset-rime segmentation, four boxes would indicate segmentation into four phonemes. Results indicated that phonemic segmentation skill developed across age and reading and spelling ability,

whereas onset-rime segmentation remained constant across ages and did not correlate strongly with reading and spelling.

A series of stepwise multiple regressions in which chronological age was entered as the first step and onset-rime segmentation and phonemic segmentation were entered alternatively as final steps were carried out. These revealed that phonemic segmentation explained unique variance in reading and spelling ability, and onset-rime segmentation did not explain unique variance in either reading or spelling. The study is not without flaws as no measure of intelligence was taken, and it is unclear whether the link between phonemic segmentation skill and reading and spelling is a specific one, as no measure of the association between phonological awareness and other skills such as mathematical ability were taken. Nevertheless the study does suggest that phonemic rather than onset-rime awareness is central to reading and spelling development.

Finally Høien, Lundberg, Stanovich and Bjaalid (1995) also found a stronger concurrent relationship between phonemic awareness and reading ability than between rime awareness and reading ability in Norwegian. In an exemplary study they investigated the rime awareness, phoneme segmentation and reading ability of 1637 children. Separate rime, syllable and phoneme measures were taken in two samples of children aged between 6 years 5 months and 8 years 4 months. The results of regression analyses showed that rhyme and syllable factors made a small but significant contribution to reading ability but the phonemic factor was by far the more important factor, explaining more than 25% of the variance in reading ability. In contrast, rime awareness explained only around 1% of the variance in reading ability.

Failures to find longitudinal links between rime awareness and reading

Bradley and Bryant, (1991) argue that the clearest test of the predictive link between rime awareness and reading ability is to investigate transfer under conditions similar to those that they investigated, where young preschool children's phonological

ability and subsequent reading in school are measured. However, even this claim has been questioned by the results of two studies. Lundberg, Frost, and Petersen (1988) took advantage of the fact that Danish children are not taught about reading until comparatively late in their development (at around 7 years) to investigate the effects of training phonological skills prior to formal reading instruction. One advantage of this approach is that phonological skills can be assessed independently of reading instruction. A highly structured intervention was given to 235 preschoolers daily over a period of 8 months. Training included focus upon syllabic, rime, and phonemic awareness. A range of phonological awareness measures was taken, both prior to entering the programme and after the programme was completed. Phonemic tasks included phonemic segmentation and deletion. Rhyme awareness was assessed using the rhyme choice task. The relationship between these scores and subsequent reading and spelling ability in the first and second years of formal instruction was computed using multiple regression.

Results showed that there was a significant relationship between a combined phonemic awareness score at the end of the phonemic programme and subsequent reading ability; there was also a very strong relationship between the same measure and subsequent spelling ability. No other measures reached significance. Investigation of the scores on these test reveals that while one of the measures of rime awareness, taken at the end of the training programme showed signs of ceiling effects (with means of 19.1 and 18.3 out of a possible 21 for the experimental and control groups), a similar measure of rime awareness at pretest produced means of 15.8 and 16.1 out of a possible 21. This suggests that the test was neither strongly influenced by ceiling effects, nor that the rime task was too simple for the children.

The pretraining scores do not appear to be so affected by ceiling effects, so it seems reasonable to conclude that the link between rime awareness and subsequent reading and spelling was genuinely not supported in this study. The strong link

between phonemic awareness and both reading and spelling was however found. Importantly, the same pattern of results held even when language comprehension was entered as the second step in the regressions. The results appear to show genuinely that phonemic awareness but not onset-rime awareness predict subsequent reading ability.

Muter, Hulme Snowling, and Taylor (1997) also failed to find a predictive relationship between rime phonological awareness and later reading ability in their longitudinal study of reading development, but did find a link between phonemic awareness and subsequent reading ability. This study followed 38 children between the ages of 4 and 6 years. Preschoolers were given standard intelligence tests and phonological awareness tests. Muter et al used a new version of the oddity detection task, which was based upon that of Bradley and Bryant, but in which the oddity word sets were presented in pictorial form, as well as a rhyme production task to test rime awareness. Children were also given measures of phoneme awareness (phoneme deletion and identification). These tests were readministered in the first two years of school. In addition, reading, spelling, letter knowledge and mathematical tests were also administered.

The results of path analysis of these results revealed a significant relationship between preschool phonemic awareness and progress in learning to read at age 5 and 6, but the relationship between rime measures and subsequent reading was not significant at either age. A similar pattern of results was evident for spelling ability, with preschool segmentation skill predicting later spelling ability, but there was no significant association between preschool rime awareness and later spelling skill, though rime awareness in school children at age five did predict spelling at six years. Together these studies provide strong support for the view that preschool phoneme segmentation skill rather than rime awareness is crucial to early progress in learning to read.

The nature of rime awareness measures

It is not entirely clear why modified versions of the oddity task produce a different pattern of results. In Muter et al (1997) pictorial rather than verbal materials were used to measure rime awareness in order to overcome the possible effects of memory load on the traditional rime oddity measure. One early view was that the traditional rime awareness task, which requires a great deal of active memory storage and processing skills could be seen as a measure of phonological working memory (Baddeley, 1986, 1990; Wagner & Torgeson, 1987). The pictorial version of the oddity task used by Muter et al (1997) could therefore be seen as a way of supporting the limited processing capabilities of working memory.

An important theoretical problem therefore concerns the construct validity of the traditional oddity task. Several studies have attempted to study the nature of the contributions of phonological awareness and other purported measures of working memory to reading development using cluster or factor analytic techniques (Gathercole et al, 1991; Rohl & Pratt, 1995). Studies have generally found that the purported working memory measures and the phonological awareness measures tend to cluster as separate factors indicating that the two skills make independent contributions to reading development. However the interpretation of these studies is often further complicated by the fact that the construct validity of some measures of working memory has also been questioned. Gathercole et al (1991), for example, used a nonword repetition task which requires a child to repeat auditorally presented nonsense stimuli such as 'loddnapish' or 'confrantly' back accurately to the experimenter. This task may be better seen as measure of the quality of representations in 'output phonology' (Snowling, Chiat, & Hulme, 1991) rather than as a measure of working memory.

More direct evaluation of the role of phonological working memory and phonological skills comes from recent studies of information processing factors affecting performance on the rime oddity task. Snowling, Hulme, Smith, and Thomas

(1994) presented groups of normal reading children between the ages of six and eight years with sets of words similar in structure to those of Bradley and Bryant (1983). The odd word out in these word sets varied in terms of phonetic qualities either in voice and place of articulation compared to the other words, or on only one of these qualities. Word sets also differed in terms of the length of the lists, with either three, four or five words presented. Snowling et al found that the phonetic difficulty of discriminations had a significant influence on rime detection performance. Snowling et al found that list length did not have a systematic effect upon oddity detection performance, leading them to conclude that sound categorisation tasks are not limited by the storage capacity of short-term memory, and to suggest that the rime awareness task taps speech perception ability, rather than memory ability.

One problem with this study concerns the interpretation of the failure to find a list length effect on oddity performance. It is not clear for the longer lists of words, that children do have to actively hold on to the items in memory to perform the oddity task successfully. One possibility is that performance may reflect strategic factors. Purely on logical grounds once two rhyming words have been identified, the analysis of subsequent rhyming stimuli is not required to derive the odd word out. Words sharing rimes with two other stimuli already identified can simply be ignored or discarded, thus reducing memory load in the task. If children acted in this way during the task then list length would not be expected to affect performance.

A study by McDougall, Hulme, Ellis, and Monk (1994) investigated the relationship between individual variability in reading ability, short-term memory and phonological awareness. Results of multiple regression analyses showed a stronger relationship between phonological awareness and reading than between memory measures and reading ability, after age and I.Q. were partialled out. However the results of a regression analysis, in which speech rate was entered prior to rime awareness, found that this eliminated the contribution of rime awareness to variability in

reading. This result could be seen to be consistent with the view that individual differences in working memory contribute to variability in the traditional version of the sound categorisation task.

An alternative explanation of the different pattern of results in the Muter et al version of the oddity task over the traditional version of the task is that the two tasks differ markedly in their attentional demands. The Bradley test of auditory organisation involves the administration of a total of 36 experimental sets of words as well as 6 practice sets, often within one experimental testing session. One concern must be that the successful completion of this task requires a great deal of sustained attention from very young children. Younger children may find it particularly hard to maintain performance over the many trials required. The Muter et al task may be a less demanding one upon the attentional resources of very young children as only ten trials are administered. Furthermore the pictorial format is probably more engaging for young children. Together then, there are a number of reasons for suggesting that the pictorial version of the task may be a superior measure of rime awareness in very young children.

There appear therefore to be some significant theoretical and empirical problems in the Oxford model of reading development. It also seems reasonable to note in concluding, that more specific models of the process of reading, such as developmental analogy models which place rime awareness in a central position in early reading acquisition, (Goswami, 1986, 1993, 1996), may be less well underpinned than is often assumed. This issue is discussed further in the third chapter where Goswami's rime analogy model is considered in detail.

Conclusion

This chapter has sought to outline criteria by which models of reading development may be evaluated. Five criteria for evaluating models of reading have been discussed. Models of reading development must be causal, ecologically valid, comprehensive, and explain how children cope with a quasiregular orthography. Research on adult models of reading provides no compelling reason for preferring single or dual route explanations. Developmental models must also explain the role of phonological awareness, which is intimately involved in reading development. A review of the available evidence suggests that while there appears to be substantial evidence in support of the view that phonological skills have a causal role in facilitating reading development, some more specific claims of a link between different types of phonological skill and reading ability have not been so clearly supported.

Evaluation of the influential Oxford model which emphasises the role of rime awareness in reading development revealed that some substantial inconsistencies exist in the research evidence. Methodological problems; failures to find crucial predicted patterns of results; and the failure of others to replicate basic findings have all been noted. The proposal that there is a specific link between preschool rime awareness and later reading should therefore be treated with some caution. Clearly, the next stage of research is to specify in a more precise way the nature of the interactive relationship between orthographic and phonological knowledge and how this influences children's developing word recognition skills. Influential developmental models of reading are therefore considered in the second and third chapters.

Chapter 2

Models of reading development

Summary

In this chapter, a range of influential models of reading development are outlined and evaluated in terms of the criteria discussed in chapter 1. A central issue concerns the relationship between various kinds of phonological skills and the quasiregular orthography of English. Two classes of models of reading acquisition are considered. Early cognitive developmental models generally assumed that both abstract grapheme to phoneme rules and word-specific knowledge are required in an irregular but essentially alphabetic orthography. These notions were formulated into 'stage' models of reading acquisition which characterised reading development by the use of qualitatively different approaches at different points of expertise. Frith's stage model of reading development is evaluated. Following more recent distributed models of skilled reading, recent models of reading development outlined in the second half of this chapter propose that there exists a complex and interactive relationship between phonological and orthographic information, where either large rime bodies, onset, peak and coda clusters, or graphemes are functional sublexical units in developmental systems. Formal simulations of dual route and distributed systems of reading acquisition are considered in the final section of the chapter.

Stage models of reading development

The first generation of cognitive developmental models of reading acquisition were strongly influenced by the theoretical and empirical evidence then available on adult reading. They generally followed the then dominant dual route models of adult reading in assuming that two distinct procedures are required to read an irregular but essentially alphabetic orthography. Early developmental models of reading sought to incorporate the idea that children acquire both abstract, rule-based knowledge and

word-specific knowledge during reading acquisition. Where such models have been applied they have additionally assumed that word reading strategies are used to different degrees at different points in reading acquisition. In some such accounts, the early development of reading ability is characterised by the use of nonanalytic and wholistic reading strategies. As a result of learning the alphabetic principle, a phonological recoding strategy replaces an increasingly inefficient visual learning system. Finally this acquisition process is replaced by a more rapid and automatic direct route that is akin to adult reading. Frith's influential stage model of reading development is considered below.

Frith's model of reading development

Frith's early model of the development of reading skills (Frith, 1985) assumes that there exist qualitatively different reading strategies that are used at different points in reading acquisition. Frith characterises the first stage of reading development as 'logographic' in nature (see figure 2.1). A child in this stage of reading development utilises a nonanalytic visual processing strategy whereby salient letter cues such as ascenders and descenders are used to form selective associations between aspects of the orthography and pronunciations. Thus a child might read the word 'yellow' by noticing the salient 'll' in the middle of the word. Word representations are underspecified and accordingly children will make many errors to words which share only superficial similarity to target words. The word 'follow' for example, might elicit the response 'yellow' (Frith, 1985), or the word 'dog' may produce the response 'dinosaur' due to the presence of minimal shared stimulus features (Biemiller, 1970; Marchbanks & Levin, 1965; Williams, Blumberg, & Williams, 1970; Gough & Juel, 1991). Children in this stage are seen as having particularly poor knowledge of the internal letter order of words. They will also find learning visually distinct words easier (Ehri & Wilce, 1985), and show no advantage for learning regular over irregular words (Gough & Juel, 1991). In their spelling they may include numbers as well as letters, indicating their lack of awareness of the cipher (Gough, Juel & Roper/Schneider, 1983). Only

when children pass to a second stage of alphabetic decoding, and from there to a mature, analytic orthographic strategy, will children start to fully represent the structure of the orthography.

Figure 2. 1. Frith's (1985) six stage model of reading and writing acquisition.

Step	Reading	Writing
1a	Logographic 1	(Symbolic)
1b	Logographic 2	-----> Logographic 2
2a	Logographic 2	Alphabetic 1
2b	Alphabetic 2	<----- Alphabetic 2
3a	Orthographic 1	Alphabetic 3
3b	Orthographic 2	-----> Orthographic 2

Where '1' represents a very basic level of skill, and where '2' is more advanced and so on. Arrows represent causal relationships between reading and writing skills, following Frith (1985).

This three stage model can be broken down into a more detailed six stage account (see figure 2.1.). This subdivision reflects a central theoretical aspect of the model, whereby normal reading and writing development are characterised as proceeding out of step. Frith argues that an alphabetic strategy is first adopted for writing, whereas the logographic strategy is used for reading. This theoretical position emerges from the consideration that while writing may be facilitated by the use of a relatively small number of letters, this limited set will create many ambiguities in reading text. Empirically this view is supported by the finding that there are a significant number of words that children can read but not spell. There are also a number of words that children can spell, but not read (Bradley & Bryant, 1979; Gough, Juel & Griffith,

1992). The former are generally irregular words, the latter are generally regular words (Bradley & Bryant, 1979).

While reading and spelling skills are developmentally out of step, Frith nevertheless suggests that it is the unification of these skills that produces significant advances in reading ability. The recognition of words in the first stage draws attention to the potential spelling of words, and is a weak source of knowledge about the orthography. This process is symbolised by the first causal arrow in Figure 2.1. Later, because spelling necessarily draws children's attention to letter level representations within words and because phonological skills can often be successfully applied in spelling (Frith & Frith, 1980), it is the development of spelling skills that first draws children's attention to the alphabetic principle. Accordingly, in step 2a, it is writing skill that is the pacemaker for alphabetic development. Finally the third causal link comes initially from orthographic reading through the application of an automatic and expert word recognition skill. This more precisely represented knowledge of the orthography can then serve to provide a basis for spelling, through the application of orthographic analogies or higher order rules. This skill is achieved only relatively late in reading development.

Evaluation of Frith's model

Frith's model has been an influential descriptive account of reading development, in both its normal forms (Seymour & MacGregor, 1984; Seymour & Elder, 1986) and as a theoretical model of abnormal reading development (Snowling, 1987). One of its strengths lies in its descriptive comprehensiveness and in its invocation of a complex and interactive relationship between the processes of spelling and reading. It also provides a more complex description of the process of change from one developmental strategy to another, as a merging of initially separate approaches in reading and spelling to reach developmental goals. The goal of automatic word recognition might be set in the logographic stage, however only when combined with

phonological skill will it provide a breakthrough to the alphabetic stage. Similarly an analytic approach to the orthography and the use of higher level rules is combined to move to the orthographic stage. Thus, unlike other traditional stage based models of developmental processes such as those of Piaget (Piaget & Inhelder, 1958) in Frith's model, the stages of development represent points of greatest change rather than points of relative stability (Morton, 1989).

There are however a number of problems with Frith's approach. One difficulty lies in the descriptive terms used. It is highly unlikely that Frith's logographic stage in which a child learns to 'read' via the salient visual features of a word, in the absence of phonological ability, is comparable to the process used by fluent readers of logographic scripts¹. Such a skill shows a visual analytic ability that is probably far superior to that of the young child, and as such, use of the term for children's reading may be misleading. Secondly, direct evidence for the existence of a logographic stage, in which phonological skills play no part has proved to be rather difficult to find (Goswami & Bryant, 1990). Supporting evidence often comes in the weak form of the absence of relationships between phonological measures and reading (Snowling, 1987; Wimmer, 1990). It remains possible, however, that children may learn to read using a more direct route in the absence of phonological skill. Thus, Byrne (1992) refers to the normal acquisition procedures in which phonological awareness plays a central role as 'default procedures'.

A related problem involves the extent to which a logographic strategy acts as an entry into more fluent reading. Many of the purported demonstrations of 'logographic' reading (Masonheimer, Drum & Ehri, 1984; Gough & Juel, 1991) do not show that children use or understand orthographic word information at all in this phase. In a well known study by Masonheimer et al (1984), 102 children between the ages of 3 and 5

¹ It is also worth noting that some logographic scripts such as Chinese contain some orthographic guides to pronunciation that stand beside the lexical character. These phonetic 'radicals' are not a consistent guide to pronunciation, and could be said to provide irregular and regular character pronunciations, (Butterworth & Wengang, 1991).

were shown 10 words which were familiar from a child's print environment. Examples included commercial signs such as 'Pepsi' or 'McDonalds' presented in their familiar typeface. Many prereading children were able to name these logograms, but the same children were insensitive to changes in the letters of the word as long as the words retained their familiar visual format. Overall, seventy four percent of responses involved misnaming stimuli such as 'XEPSI' or 'PEPSO' as 'PEPSI'. Equally when the same words were presented in normal manuscript typefaces, only 23 percent of children were able to read them. Perhaps even more compelling was the finding that when placed side by side, children were unable to detect any difference between the original and an altered logo on 65 percent of trials. A small number of children (6 out of 102) were able to read the words in either typeface. These children were able to read other words in isolation, and knew significantly more letter sound relationships than the other children, suggesting that they were using a qualitatively different alphabetic strategy to read.

Similarly, Gough and Juel (1991) consider the process of early word naming as one of selective association between salient aspects of a stimulus and the response. They describe a study in which 4 to 5 year old children were shown 4 words to read. One of the four words contained a thumbprint on the lower left corner. They found that every child would name the card with the thumbprint quicker than the other three. However, when the thumbprint was absent children would be unable to read the word. Furthermore, if the thumbprint was placed on another card, then this word would be misread as the original card. While such logographic approaches may signal a child's more general awareness of the significance of words, in terms of developing fluent word recognition strategies, logographic and alphabetic approaches are probably best seen as discontinuous (Adams, 1990; Bertelson, 1986; Gough & Hillinger, 1980; Stanovich, 1991). The consequence of this of course is that children need not pass through a logographic stage in the development of normal reading.

A different kind of problem concerns Frith's conception of the alphabetic phase of development. Frith's model may underestimate the complexity of the task of mapping the highly variable relations between phonology to orthography noted in chapter 1. Stuart & Coltheart (1988) point out that the description of letter-sound rules at the heart of Frith's alphabetic stage is unclear. Unless this stage refers to the ability to parse words graphemically, then such a mechanism would yield accurate pronunciations only for the words which share the most simple letter to sound correspondences. However, if this stage does refer to the use of grapheme to phoneme correspondences, then it does not explain how this ability to parse words graphemically emerges. In either case the theory does not explain how a child might learn to parse complex orthographic strings such as 'light' or 'chain'. In this regard the account is substantially underspecified and essentially descriptive rather than causal in nature.

One of the novel aspects of Frith's model of reading development is the notion that while reading and spelling strategies are initially different in nature, and separate in operation, with development, spelling strategies that involve phonemic analysis are applied to reading. The idea that spelling and reading strategies may initially be separate also predicts that dissociations between reading and spelling may be found in cases of developmental disorder. There is some evidence to support this: Frith (1980) reports the existence of a significant number of children who show unexpected spelling problems, despite normal reading ability and intelligence. However, in normal reading and spelling development, it is less clear whether these two skills should really be seen as separate. Firstly, correlations between these two skills are generally very high: Malmquist (1958) reports positive correlations of between .5 and .8, and similar results have been reported by Shanahan (1984) in second and fifth grade children. Secondly, causal modelling of the relationship between reading and spelling has suggested a complex reciprocal pattern of influences between the two skills (Cataldo & Ellis, 1988; Shanahan & Lomax, 1986). Cataldo and Ellis, for example, demonstrated using a

causal modelling technique (LISREL), a causal influence of spelling knowledge on reading performance in the very earliest phases of development.

A third problem for Frith's view is that evidence which appears to suggest an initial dissociation between reading and spelling skills is open to other interpretations. Ehri & Wilce (1987) referring to Bradley and Bryant's (1979) study, and Gough, Juel, and Griffith (1992), referring to their own replication study, point out that the words that children read but cannot spell and can spell but cannot read represent less than 20% of words presented. The majority of words presented in these studies are both read and spelled correctly. Ehri and Wilce also argue that the dissociation between reading and spelling systems may reflect the unstable nature of representations of word knowledge in very young children. Gough, Juel & Griffith (1992) have recently provided some support for the view that the pattern of results reflects the inconsistent application of knowledge rather than independence of reading and spelling skills. They compared the accuracy of reading and spelling performance across two testing sessions. Results showed the same level of inconsistent performance across sessions within both reading and spelling as was found between the two skills. That is to say that they were inconsistent in reading or spelling a word correctly for about 20 percent of words they saw. Gough et al (1992) concluded that the most parsimonious explanation of findings was to assume that reading and spelling represent closely related skills applied inconsistently across time.

Dual or single route models in reading acquisition?

Early developmental stage models were based upon dual route architecture. As discussed in chapter 1, in the adult literature, the assumption that there are two distinct procedures for reading English has been the focus of intense debate. Dual route assumptions have also been questioned by recent developmental research. The debate for and against developmental dual routes has followed a very similar pattern to that

highlighted for skilled readers in chapter 1. This evidence is therefore briefly discussed here and a range of more recent theoretical models is then considered.

Evidence from developmental reading disorders

One line of evidence for comparing dual and single route accounts of reading development has been to attempt to identify two distinct classes of children that correspond to the two classes of acquired dyslexias: surface and phonological dyslexia, discussed in the first chapter. The existence of developmental surface dyslexia (Coltheart, Masterson, Byng, Prior, & Riddoch, 1983), was inferred from the greater difficulty experienced by some children in reading irregular over regular words, and from the frequency with which they made regularisation errors. Such a pattern of difficulties was interpreted as reflecting damage to the lexical route to reading. Developmental phonological dyslexia (Temple & Marshall, 1983) was inferred from the greater difficulty some individuals showed in reading long regular words and nonwords. This pattern of difficulties was interpreted as reflecting damage to a sublexical route to reading. Similar attempts to isolate subsets of poor readers have used a statistical regression technique to compare performance of groups of poor readers against those of normal readers (Castles & Coltheart, 1993), and have also suggested the existence of subgroups of developmental and surface dyslexics.

As in the adult literature a fundamental problem with these sorts of studies is the lack of relevant control conditions against which to compare the performance of purported dyslexic children. In particular, insufficient account has been taken of the qualitative variability in reading ability within the normal ability range. Bryant & Impey, (1986) gave a group of 16 normal reading children the same lists of lists of regular and irregular words, and nonsense words as given to the previously identified developmental dyslexics. They found some normal reading children who showed as strong a pattern of regularisation and nonword reading strengths as surface dyslexics, and other children with as strong a pattern of irregular word reading ability alongside

poor nonword reading ability as phonological dyslexics. Bryant and Impey concluded that none of the patterns of reading exhibited by the dyslexic children were qualitatively different from that shown by normal reading children. The only caveat to this argument was the finding that there were no children in their relatively small sample who made as many derivational errors (e.g. 'weigh' for 'weight') or nonword reading errors as the phonological dyslexic patient. This result is consistent with the dominant view of classical developmental dyslexia that it is caused by an underlying disorder of functioning across the phonological domain (Frith, 1985; Olson, Wise, Connors, & Rack, 1990; Snowling, 1987; Vellutino, 1979).

Essentially the same debate has been played out in the studies of dyslexia subgroups such as that reported by Castles and Coltheart (Snowling, Bryant, & Hulme, 1996). Reading performance of the poor reading children in their study was made against a chronological rather than a reading age matched control group of children. When performance of such children is compared against the appropriate reading age match control condition there is little evidence to support the existence of developmental surface dyslexia, though a number of children who exhibited specific deficits in the phonological domain can be observed (Stanovich, Siegel, & Gottardo, 1997). The evidence from individual differences in developmental dyslexic reading then provides no support for the existence of developmental dual routes to reading.

Evidence from normal reading children

The study of individual differences in reading performance within normal readers has also been seen as supporting the existence of a dual route architecture. Baron (1979) claimed to identify groups of children who could be seen to read as 'Chinese' readers rather than 'Phoenicians'. 'Chinese' children read familiar words relatively well, but were poor readers of nonwords. In contrast, 'Phoenician' children read nonwords well, but were less likely to read irregular words correctly, where 'regularisation errors' were observed. These patterns of reading conform very closely

to patterns of individual differences reported in the reading of adults discussed in chapter 1 (Baron & Strawson, 1976). Treiman (1984a) has extended the findings of the developmental study by Baron (1979) to investigate the pattern of correlations between 46 third and fourth grade readers ability to read sets of regular words (e.g. 'dome'), exception words (e.g. 'come'), and nonwords (e.g. 'gome'). A similar set of words were used for a measure of spelling.

Correlations between reading accuracy for regular and exception words (.75), were as strong as those between regular and nonwords (.81), and both correlations were significantly stronger than that between nonwords and exception words (.55). This was interpreted as being consistent with a view whereby lexical and sublexical procedures exert distinct influences on regular word reading. Analysis of the pattern of relationships between spelling different types of words, revealed that the correlation between spelling accuracy for regular and exception words (.73) was less strong than that between regular and nonwords (.89). The correlation between the regular and the exception words was not significantly stronger than that between the nonwords and the exception words (.67). Treiman interpreted this result as consistent with the view that spelling takes advantage of a more indirect procedure than reading.

Gough and Walsh (1991) have re-evaluated the idea that individual differences in children's reading indicate the existence of separate reading strategies. They note that previous findings, such as those by Treiman (1984a), which show that the ability to read regular and exception words is highly correlated, could be held to suggest substantial overlap between the processes used to read such words. They compared the ability of 93 first, second, and third graders to read the 36 regular, exception, and nonwords used by Baron (1979) and Treiman (1984a). A similar pattern of correlations was observed between the word types, with very strong relations between regular and exception words (.80), and regular and nonwords (.76), but with a weaker relationship between exception word reading and nonword reading (.66). However, an inspection

of the scatterplots of the exception words against the nonword reading revealed a more complex pattern of distributions in which high scores for exception word reading were always associated with ability to read nonwords, whereas the inverse relationship was not necessarily true. That is to say, ability to read nonwords need not be associated with ability to read exception words. Gough and Walsh suggest that this indicates that knowledge of the alphabetic cipher is necessary to read regular and nonwords, and is necessary but not sufficient to read exception words.

Gough and Walsh also found a very strong correlation ($r = -.56$) between the speed of exception word learning and the ability to read nonwords. They argue that rather than seeing children as either proficient 'Chinese' or 'Phoenicians', readers can be better conceptualised as varying unidimensionally in their aptitude in becoming Phoenicians. A similar conclusion can be drawn from the pattern of results reported in a study by Jorm (1981). In this study, the ability to read irregular words correlated strongly with nonword reading, but only weakly with a measure of abstract paired associate learning. This was interpreted as supporting a model in which irregular and nonsense words were read using a similar procedure, this is the 'common process hypothesis'. Finally, Jorm and Share (1983), and Stuart and Masterson (1992) argue that, at a practical level, the use of the alphabetic principle not only allows a child to read regular words, but also to notice, and hence internalise, irregular spellings. So the development of an accurate lexical route to reading is always likely to be closely associated with the development of an accurate sublexical strategy. In fact, few words in English are so arbitrary that they conform to no letter-sound spelling conventions. Seen in this way, even the most irregular spellings are only partially irregular. Two of the three phonemes, for example, in the famously irregular word 'yacht' have regular letter to sound correspondences. So both /y/ and /t/ could provide useful phonemic information to aid children in their representation of the orthographic sequence 'yacht' in lexical memory (Ehri, 1992; Share, 1995).

The role of phonological skills

Another source of controversy in evaluating dual route models has surrounded the role of phonological skills in reading. Typically such skills have been associated with the use of a sublexical strategy involving left to right graphemic parsing. One problem is that this approach requires that readers understand, represent, and manipulate highly abstract phonemic elements of the language and apply them to their knowledge of the orthography. While normal adults may demonstrate such skills readily, there is, as noted in the first chapter, quite strong evidence that children do not fully develop the ability to manipulate phonemes until they have had quite substantial reading experience (Bruce, 1964; Liberman, Shankweiler, Fischer, & Carter, 1974), and it would appear that the development of this skill is a gradual one (Stuart, 1990a; Treiman, 1992). The fully developed ability to apply grapheme phoneme correspondences in a left to right manner to all graphemes in a word may not be available until as late as eight or nine years. This observation may prove to be rather problematic for models of reading that assume that children start to read using a recoding strategy and then move towards more direct procedures of translating print into meaning (Frith, 1985). Barron (1986) reviewed much of the experimental literature then available in support of such models, and concluded that there was little clear evidence in support of such a position ².

Until recently models of reading development have rarely considered the possibility that children at first might use a partial or less efficient phonological procedure (Ehri, 1992; Share, 1995). Previous developmental models of reading development aimed to specify distinct stages wherein different strategies were used. In

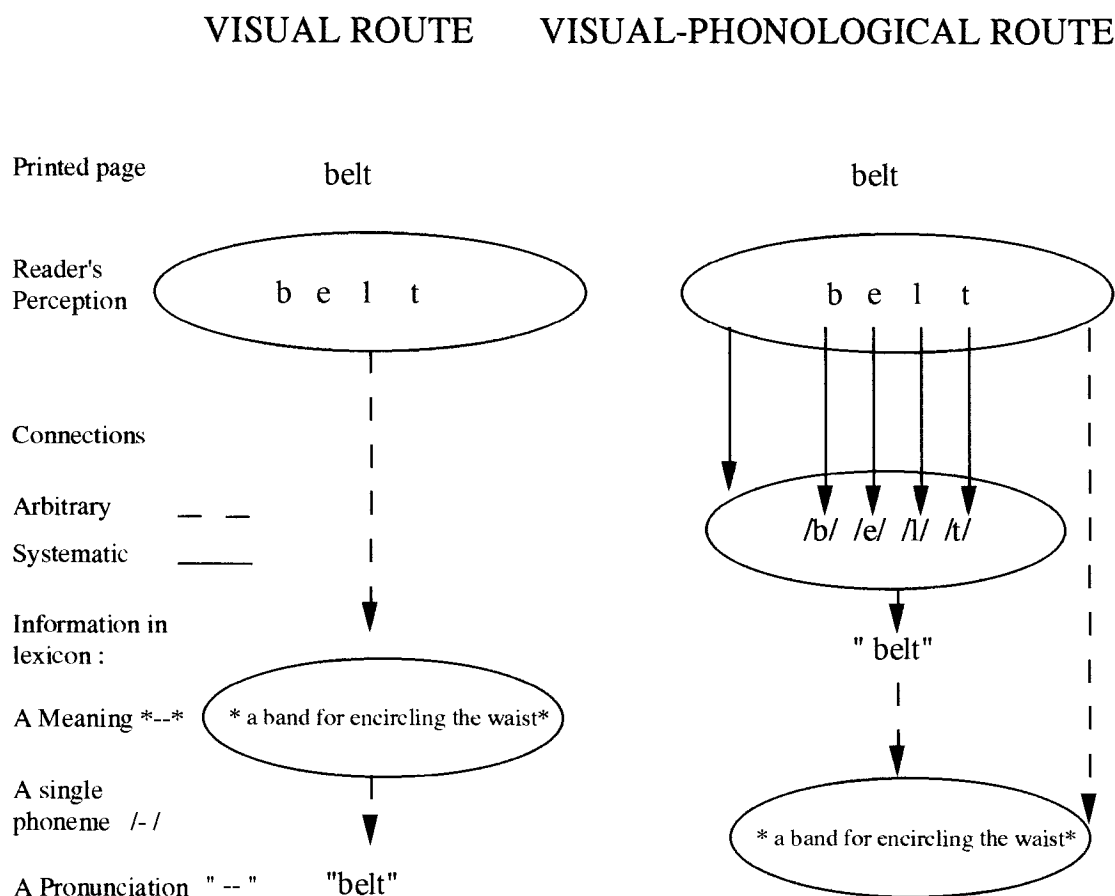
² Barron (1986) in fact reviewed two general classes of models of reading acquisition. The first conceptualised reading development as initially using an indirect route which is later bypassed by a direct print to meaning route. A second bypass model conceptualised reading as the initial use of a direct route which is supplanted by an indirect route later in development. The evidence reviewed did not clearly support either theory, nor did it support the notion that children used different routes to different degrees during development (Jorm & Share, 1983). Much of the difficulty with the early work lies with an overly simplistic view both of the role of phonological skills in reading and of experimental methods that might reveal such processes, (Barron & Baron, 1977; Doctor & Coltheart, 1980; Reitsma, 1984). This work is not therefore reviewed in detail here.

doing so they ignored the possibility of seeing the role of phonological skills as one of consistent but gradual application of knowledge to reading development. More recent models advanced by Ehri (1992, 1995), Stuart and Coltheart (1988), and Perfetti (1992), have generally taken a more gradualist and interactive approach to the development of phonological skills. Another theoretical development is that recent models have considered the possibility that phonological skills can be applied to the development of a lexical route to reading.

Ehri's stage model of reading development

Ehri's (1992) account of reading development attempts to provide a stage model of development of a single lexical route to reading. In standard conceptions of this procedure, children use a non-phonological strategy to establish a link between orthography and meaning or a pronunciation. Following other theorists (Gleitman & Rozin, 1977; Gough & Hillinger, 1980), Ehri argues however that a rote learning procedure would only be used for relationships that are entirely arbitrary and unsystematic. Her conception of the direct route to reading uses a visual-phonological route to access pronunciations and subsequently to access word meanings. Ehri argues that children will take advantage of a phonological process because they are adept at interpreting letters as symbols for sounds as soon as they learn letter names. The use of systematic links between letters and sounds allows children to deal more successfully with the 'access problem' - the ability to efficiently access individual words in the lexicon while ignoring thousands of other words. Letters in spellings are linked to enough phonemes to distinguish many words from their neighbours. Direct links from spelling to meaning do not provide such cues. This model is presented visually below in figure 2.2.

Figure 2.2. A simplified diagram contrasting the connections that are established in reading words by the visual-semantic route of dual route theory and by the visual-phonological route of Ehri's theory (Ehri, 1992).



Ehri also allows for systematic links between orthographic rimes and their pronunciations in more skilled readers. These representations are not shown here for the sake of clarity.

Ehri's model thus suggests a close relationship between phonological and orthographic information. The very earliest stage may be logographic, and such a strategy does not involve phonological skills. However, as soon as phonological information is available (for example when children start learning letter names and sounds) they will apply that knowledge to reading and representing orthographic letter strings. Phonological and orthographic word information are closely tied together from the beginning of learning to read. The combination or amalgamation of information

provides the basis for well specified representations of individual words. She argues that the matter of connections is a crucial one, for this is what determines how easy it is for readers to retrieve words in memory from the visual forms that they see. This combination of orthographic and phonological information is termed an 'orthographic image'. In Ehri's model, development is conceptualised as the increasingly accurate specification of these visual-phonological images.

Ehri (1992, 1995) has operationalised these notions as a series of developmental stages. The first stage of Ehri's model is termed the visual cue stage. It shares many features with the first stage of Frith's model, and has also been termed 'logographic'. Reading develops however when children use phonetic cues as a rudimentary alphabetic stage of reading development. Research by Ehri and her colleagues has indicated that, in the earliest stages of reading, children apply their incomplete knowledge of letters and sounds, rather than wait upon recoding strategies that require relatively complete letter-sound knowledge. In a study by Ehri and Wilce (1985), five year olds were sorted into three groups on the basis of their ability to read 40 preprimer and primer words. Prereaders read 2% of the words, 'novices' read 11% of the words, and 'veterans' read 44% of the words. The prereaders knew fewer letter sounds (26%) than the novices (77%) and the veterans (83%). Children were then given a paired associate learning task made up of two sorts of letter strings. The first string type consisted of letters that sounded something like the name for a picture associate. These were letter strings such as 'JRF' (giraffe), and 'SZRS' (scissors). The prereaders performed less well on this task than on a comparison task that involved learning an association which was graphically distinct e.g. 'qDjK' (scissors).

One possible problem with interpreting this result is that the words conveying phonological cues also have greater visual similarity with the conventional spelling of the real words. In order to investigate this possibility, Rack, Hulme, Snowling, and Wightman (1994) presented five year old children with abbreviated spellings of words

similar to those used by Ehri. All words contained cues that corresponded to phonemes in spoken words. In one set of words there was an exception letter that corresponded to a phoneme that was articulated in a similar manner to the real phoneme, e.g. BZN for the word 'basin'. For the other set of words, the exception letter corresponded to a phoneme that was dissimilar, e.g. BFN for 'basin'. The pronunciation of the exception letters in the similar phonemic cue words was similar to that of the corresponding letter sounds in the real words in terms of articulatory place, but differed in terms of voicing. Rack et al argued that varying the letters on this dimension maximised their similarity. Results showed that children took greater advantage of the words that shared phonetic cues to learn the associations. This confirms that children are taking advantage of phonetic information when learning the association between print and pronunciations. Rack et al also varied the position of the exception letter from the beginning to the middle of the word. Changes to the position of exception letters did not significantly influence the pattern of word reading performance.

Substantial support exists for the idea that letter sound knowledge and names play an important part in early reading. Early research (Bond & Dykstra, 1967; Chall, 1967), found that letter name knowledge was the strongest predictor of reading success. More recent longitudinal studies (Stuart & Coltheart, 1988; Vellutino & Scanlon, 1987; Wagner et al, 1994) and cross sectional studies (Ellis & Large, 1988) discussed in chapter 1 have also found similar predictive validity for early letter name knowledge. Furthermore, as noted in the first chapter, the study by Wagner et al (1994) found a complex interactive relationship with reading ability whereby letter name knowledge predicted subsequent reading ability even when concurrent reading ability was held constant.

Another source of support for the idea that children can use incomplete letter sound and letter name knowledge comes from the study of children's spellings, (Chomsky, 1979; Read, 1971). These have shown that young children often use

'invented spellings' based upon often incomplete letter-sound and name information to represent the phonology of words. The early application of rather incomplete letter sound knowledge is evident in spellings such as 'WRD', (word), 'HRT' (Heart), 'JRIV' (drive), or 'PPL', (People). More recently, Treiman, Goswami, Tincoff and Leevors (1997), have presented cross-cultural evidence that knowledge of a word's pronunciation influences the conception of the word's spelling. They report that American children who made spelling errors are likely to represent for example, the word 'girl' as 'GRL' whereas English children of the same age and reading ability represent it as 'GIL'. This could be understood to reflect the application of pronunciation knowledge to the partial representation of the orthography of those vowels in spelling.

In Ehri's third or Cipher stage of reading development, children apply spelling rules to the reading of words in a more thorough and systematic manner. As well as a quantitative change in word knowledge, the quality of the specification of individual words is also seen to be changing. Representations of phonology change to become phonemic, based upon letter sound knowledge rather than more selective phonetic cues. Spelling knowledge also appears to be applied to the reading process. Ehri and Wilce (1987) selected a group of children who knew many letter names and a few words, but who did not show decoding skills. Half of the children were given decoding training with mainly nonword stimuli such as 'SAB', or 'STUM', and were labelled 'cipher' readers as a consequence of this training. The other half were given training in isolated spelling to sound correspondences, and were thus labelled 'phonetic cue' readers. At posttest, ability to read real words containing similar letter-sound relationships to nonwords was assessed by presenting all words over seven consecutive testing trials. The spelling-trained children learned these words much faster, and retained this advantage on the final trial over the control group. The spelling performance of the two groups was also compared. Words were generally recalled better by the cipher readers. However there were also some interesting differences in the quality of representations

of words. Medial vowels and consonant blends were better read by the cipher readers 78% versus 49% and 70% versus 12% respectively, but there was no significant difference between the number of initial and final consonant representations that children made in either group (79% versus 90%).

In the final stage of development, sometimes referred to as the Consolidated Alphabetic stage (Ehri, 1995), children rapidly acquire large lexicons because of the quality of existing 'orthographic images' in the lexicon. These representations of spellings of sight words in memory contain full information about a word's orthography and phonology. Another development is that large or consolidated letter units may be used for the first time in reading. These are seen as being particularly useful at this stage as they reduce the memory load in storing sight words. Thus the unit '-EST' might emerge as a unit from the experience of reading 'NEST', 'BEST', and 'WEST'. Common large letter string units may emerge, such as 'TION', or 'ING', which would aid in the fluent reading of polysyllabic words, (Venezky & Massaro, 1979). Many of these larger units are seen to emerge as a result of the amalgamation of existing phonemic level representations.

Perfetti's restricted-interactive model of reading development

Perfetti (1992) has also advanced a model of reading development which is similar in some respects to that of Ehri. Perfetti's theoretical perspective upon reading development also focuses upon the issue of representation of word knowledge. The aims of his account are to explain the nature of representations of word knowledge, the change in those representations with reading development, and the development of automatic access to the lexicon. In order to understand this process, Perfetti first considers the nature of reading in adults. Adult models of reading, while sometimes differing fundamentally in terms of central assumptions about the rule-like or emergent nature of representations, share three key notions about the fully encapsulated, autonomous and deterministic nature of lexical access. That is, word recognition is an

isolable language subsystem. Activation of lexical representations is generally highly constrained by the information that recognition units will accept, but only weakly constrained by semantic or syntactic context (Forster, 1979). Input features inevitably activate corresponding lexical representations. Internally, however, the lexical module is highly interactive, with bidirectional links between feature, letter, and word level knowledge (McClelland & Rumelhart, 1981).

The form or quality of the internal representation of word knowledge in the lexicon is crucial to understanding reading development according to Perfetti. One way to characterise reading development is in terms of increasing specificity and quality of children's internal representations of phonological and orthographic word knowledge. Perfetti holds that the acquisition of precise functional lexical representations will be partly determined by the number of entries that children have in their internal lexicons, as exposure to and storage of words sharing common letter patterns leads to the development of more precise representations of these shared letter strings. However, a central place is allocated for the application of phonological skills to reading, and reading development is achieved by the amalgamation of phonological and visual representations of words. Importantly, there is only one route to read any word in Perfetti's model. Regularity, for example, has no bearing upon lexical processing since expert representations comprise specific words and their constituent letters, regardless of whether they have more or less predictable pronunciations. Finally, like Ehri's account, the model assumes that the same lexical representation is consulted for spelling and reading. One consequence of this is that the quality of a representation will be reflected in idealised spelling performance³.

An important aspect of Perfetti's model is that the initial representations of word knowledge are poorly specified, with the initial letter perhaps being the only accurately

³ Spelling performance is described by Perfetti as 'idealised' because actual spelling can be affected by production problems such as sequencing, memory, and pattern verification that are independent of the lexical representation.

represented letter (Weber, 1970). Vowels are more likely to be unspecified and have more diffuse mappings than consonants (Liberman, Shankweiler, Orlando, Harris, & Berti, 1971). Changes in representation precision over three hypothetical skill levels in the acquisition of reading for the words 'IRON', 'TONGUE', and 'UKELELE' are shown below in figure 2.3.

Figure 2.3. Perfetti's model of representational change at three theoretical levels.

LEVEL 1	LEVEL 2	LEVEL 3
ir*n	iron	iron
t*g*	t*ng**	tongue
uk*	ukil*	uk*l*l*

(Following Perfetti, 1992, asterisks denote free or unspecified representations).

Perfetti holds that there is a complex facilitative interaction between the actual and potential number of lexical entries. The more powerful the context-sensitive decoding rules or analogic capacities, the more entries the learner can acquire, and the more entries, the more powerful the decoding rules. Thus an increase in reading skill is intimately tied to the quality of word representations. This growth in the precision of orthographic representations is determined in large part by the representation of phonemic values, which leads to an increase in the number of redundant information sources. Initially, less precise information such as the names of letters as well as letter sounds may assist in lexical search. Thus early orthographic representations may produce a proliferation of phonemic representations. For example the letter 'r' might activate a diffuse set of phonemic representations, such as /ar/, /r/, /ru/ and /ro/. With developing knowledge of phonology and greater precision in the mapping of phonemic information this proliferation of connections is reversed, and eventually, fully specified and integrated phonemic and orthographic representations replace the incomplete and

unspecified ones. This qualitative progression towards completeness and specification is termed the 'Precision Principle', and is broadly similar to Ehri's notion of the 'amalgamation' of information sources.

Stuart and Coltheart's model of reading development

Stuart and Coltheart (1988) have developed a model of reading development which also assumes a gradualist approach to reading development. Their model has not been as explicitly implemented as previous accounts, but contains several important elements not discussed by the other models. While working from a dual route perspective, they have assumed, like Ehri and Perfetti, that phonological skills are not just influential in the development of assembled routes to reading, but may be applied to the development of a direct route to reading. Representations of word knowledge are also held to be incomplete in the early stages of reading acquisition. As previously noted, in their analysis (Stuart & Coltheart, 1988), word reading errors were classified on the basis of the amount of overlap they shared with target words. Words which accurately represented the initial and final letters of words were one of the largest categories of paralexia and were also the only word error type to be positively correlated with reading ability and longitudinally, with phonological awareness.

As discussed when considering Frith's model of reading development, Stuart & Coltheart (1988) have pointed out that the use of letter sound rules would yield accurate pronunciations only for the words which share the most simple letter to sound correspondences, whereas the ability to parse a complex orthographic string such as the words 'light' or 'chain' has not yet been adequately explained. Stuart and Coltheart argue that partial representations of words incorporating expectancies based upon initial phonological awareness, letter-sound, and possibly also letter name information may help to develop the capacity for left to right grapheme to phoneme recoding. They point out that a child could initially form a partial representation of, for example, the word 'LIGHT' as 'L ... T', based upon the phonemic skill of segmenting initial and final

consonants, in conjunction with the knowledge of the consonant sound to letter rules /l/ -> L, and /t/ -> T, without having actually encountered this word in print. On subsequently meeting this word in print, the mismatch between the child's representation of the word and the orthographic representation encountered in print will eventually lead the child to conclude that the 'IGH' component represents the medial phoneme of 'LIGHT'. Armed with this knowledge the child will be able to parse both this word and other words sharing this irregular grapheme to phoneme relationship. Thus in Stuart and Coltheart's model phonological knowledge need not initially be applied in a serial left to right manner as earlier stage models assumed.

Stuart (1990b) has investigated the possibility that children form partial word recognition units on the basis of their expectancies about print regularity. The strong form of this hypothesis argues that children who have the ability to segment a word into its constituent phonemes and who also have knowledge of letter-sound relationships may be able to form an expectancy of the orthographic form of a word, despite not having formal experience of that word in print. For regular words this would yield accurate word recognition units. For irregular words, these expectancies are then disconfirmed by subsequent print experience, and the result is then incorporated into an accurate word recognition unit. Stuart showed eight prereading children pictures of real objects (e.g. 'pan' or 'wheel'), or of invented objects which were a set of 'monsters' with names (e.g. 'moz' or 'bof'). Children were asked to match these pictures to orthographic representations of these objects which were either real words ('pan'), pseudohomophones ('wel'), or nonwords (e.g. 'moz'). These targets were presented along with distractors which shared either the initial, the final, or both the initial and final letters in common with a target word.

Results showed that some children were equally capable of carrying out the auditory-visual matching irrespective of the lexical status of the target. Other children were equally incapable of doing the task irrespective of the lexical status of word types.

Performance on all versions of this task was closely related to phonemic segmentation skills. Results are not therefore consistent with a view that children initially learn to read words without using sublexical phonology (Frith, 1985). However the results are also not consistent with the strong view advanced by Stuart and Coltheart (1988), that children form lexical recognition units prior to formal print experience by applying their phonological insights.

In Stuart and Coltheart's early model of reading, most theoretical discussion was directed to the idea that phonological analysis and particularly the analysis of sounds associated with the initial and final letters of monosyllables allows the establishment of partially specified orthographic representations in which consonants at syllabic boundaries are phonologically underpinned and consequently represented in word recognition units. However the hypothesis that initial orthographic representations are based upon phonemic analyses is only partly supported by Stuart and Coltheart's (1988) error category analysis. The problem with their error category analysis is that it is based upon boundary letters in monosyllables rather than boundary phonemes. A taxonomy based upon initial and final phonemes clearly provides a more appropriate test of their hypothesis concerning the role of phonemic analysis and initial orthographic representations of monosyllables. Representations based upon initial and final phoneme awareness may provide a more plausible model of the role of partial representations of the orthography. For example, if a child looks at the word 'LIGHT' and knows that the L is associated with /l/ and the T is associated with /t/ they can then establish a phonological frame /l...t/ which can be used to search the phonological lexicon, and children may thus arrive at an incorrect response such as 'lit'.

A re-analysis of the Stuart and Coltheart's original data was therefore undertaken to evaluate the relationship between paralexias preserving initial and final letters and paralexias reflecting initial and final phonemes. Differences in phoneme voicing were ignored ('hats' versus 'hads') as some analyses have shown that these

differences do not appear to be perceived by young children (Stuart, unpublished data). Analysis revealed that of the 774 errors which retained initial and final letters, 686 (89%) also represented initial and final phonemes, suggesting that their initial and final letter category may overlap with a taxonomy based upon the representation of boundary phonemes in monosyllables. Of the paralexias not included in this phoneme-based analysis but present in Stuart and Coltheart's initial and final letter analysis, the majority were words such as 'like' or 'live' in which silent terminal '-e' letters were present. Clearly further research is necessary to clarify whether an error category based upon phonemes is important in early reading. In particular it will be important to demonstrate whether the proportion of such reading errors are associated with standard measures of reading and phonological awareness in the manner originally described by Stuart and Coltheart. This question is addressed in the experimental research in this thesis.

General evaluation of interactive models of reading development.

Interactive models reviewed in this section have several advantages over previous models. They explain how the demonstrable influence of phonological skills and the ultimate aim of developing accurate direct lexical access might go together. Such models have represented the role of phonological skills as one of gradual application of developing skills to reading, rather than as a discrete developmental stage. Such a conception is more in line with experimental and longitudinal research evidence. Where reading is conceptualised as a series of discrete stages (Ehri, 1995) it is acknowledged that development is perhaps less rigid than the stages suggest. The idea that there is a close interactive relationship between phonological skills in reading and spelling is supported by experimental and longitudinal studies (Cataldo & Ellis, 1988). Another attractive aspect of these models is that they allow for the integration of several knowledge sources (e.g. letter name knowledge, letter-sound knowledge, formal tuition, and orthographic experience).

Theoretical problems in interactive models of reading

There are however some problems with interactive models of reading. One problem with Perfetti's model concerns the model of mature reading upon which it is based. McClelland & Rumelhart's original Interactive Activation (IA) model of reading has been criticised on several grounds (see Quinlan, 1991, for a review). One central problem concerns the IA model's use of positional specific recognition units. These units result in computationally unwieldy systems when large lexicons are implemented (McClelland, 1985). Furthermore, the results of some orthographic priming studies (Humphreys, Evett, & Quinlan, 1990) have suggested that relative positional, rather than positional specific detectors characterise adult word recognition systems. Another problem is the empirical finding that word level knowledge does not influence the discriminability of ambiguous letter stimuli in the manner predicted by the IA model (Massaro, 1988).

There are also more general problems associated with applying the IA model to reading development. The first is that it is not clear precisely what role developmental increases in phonological skill might play in such a model. The original IA model is often seen as embodying a lexical rather than a sublexical procedure (Coltheart, Curtis, Atkins, & Haller, 1993), in which sublexical phonological processes play no part. The role of phonological awareness in Perfetti's version of the IA model has not been clarified. A second issue concerns the support computational IA models provide for developmental theories. The original implemented IA model has been superseded by parallel distributed connectionist models (Seidenberg & McClelland, 1989) because these newer classes of model implement learning algorithms and are able to simulate the development of reading ability. IA models represent static accounts of relatively skilled reading behaviour, and as such represent questionable models of reading acquisition. A precise account of how feature, letter and word level information develop together to aid word recognition for example is at present lacking. In short the account remains a descriptive rather than a causal model of reading acquisition.

The evidence for causality in Ehri's and Perfetti's model

Other aspects of Ehri and Perfetti's model of reading also lack clear evidence of causation. In particular the causal role assigned to letter name knowledge in early reading has been questioned (Gough, 1972; Samuels, 1972; Barron, 1986). As Barron (1986) argues, it has often been considered that while knowledge of letter names is highly correlated with early reading success, experimental interventions that have sought to improve reading by training only letter name knowledge have produced disappointing results (Ohnmacht, 1969; Samuels 1972; Ehri, 1983). As Adams (1990), has pointed out, this pattern of findings leaves the role of letter names in reading as something of a mystery. Ehri (1983) has argued that many of the early letter name training studies may be inconclusive as sufficient depth of training was not ensured, artificial letters were sometimes used, and children were not given enough opportunity to display transfer.

As was noted in chapter 1, more recent training studies that have sought to teach letter sound and phonological awareness skills have only been successful where these two skills have been closely integrated (Ball & Blachman, 1991; Hatcher, Hulme & Ellis, 1994; Iversen & Tunmer, 1993). It was also noted that some longitudinal studies have also found stronger earlier correlations between a combined measure of phonological awareness and letter name knowledge and early reading, but weaker correlations when only phonological awareness is considered (Stuart & Coltheart, 1988). Experimental evidence also suggests that letter name knowledge and phonological awareness are crucial in developing assembled procedures for reading. Two studies have confirmed this idea. Byrne and Fielding Barnsley, (1989) taught children between the ages of 3 and 5 the words 'mat' and 'sat'. They were then given a forced choice task in which they were asked to identify, from their printed forms, which of two words 'mow' or 'sow' represented the word 'mow'. Transfer on this task was said to represent an understanding of the alphabetic principle. This task was

only successfully completed by children who were able to segment the initial phoneme of a word and who also knew the graphic symbols for the sounds /m/ and /s/.

In a similar vein, Tunmer, Herriman, and Nesdale, (1988) gave nonword decoding tests, phonological awareness tests, and letter name knowledge tests to 105 children who were in their first year of schooling. Multiple regression analyses, with nonword decoding as the criterion variable revealed that the product of phonological awareness and letter name knowledge explained a greater amount of the variance in reading than the linear combination of the two variables. In a second phase, the children were divided into four groups on the basis of their phonological skills (high or low) and their letter-name knowledge (high or low). Children with good phonological skills and good letter name knowledge were the best readers of nonwords. This supports the view that children must have some minimal level of phonological skill before they can derive much benefit from letter name knowledge (Tunmer, 1991). Adams, (1990) points out that letter name knowledge may also indirectly measure phonemic awareness because letter sound and name information are sometimes quite similar. Adams also considers the possibility that letter name knowledge is an indirect measure of verbal efficiency, which may reflect the ability to rapidly automatise naming processes.

Seymour's Dual Foundation Model

An alternative model of reading development has been advanced by Seymour (Seymour, 1997; Seymour & Bunce, 1994; Seymour, Bunce & Evans, 1992; Duncan, Seymour, & Hill, 1997). Seymour's account incorporates elements from both dual and single route architectures. The model shares Frith's assumption that children use logographic, alphabetic and orthographic strategies in reading development. Seymour, like Frith also assumes that use of these qualitatively different mechanisms at different points in reading acquisition represents distinct stages of development. He also assumes that poor readers can be arrested at any stage in reading development.

In the earliest stage of reading, children take advantage of either logographic or alphabetic strategies to read words. However Seymour suggests that skilled reading and spelling are both dependent upon the subsequent establishment of a 'single central lexical resource' which is affected by phonological, lexical-semantic, and morphological sources of constraint. This network is similar to that described in some distributed single route models (Seidenberg & McClelland, 1989). In addition Seymour assumes, unlike Frith, that the final stage of reading development is qualitatively different from the orthographic stage, involving morphological knowledge. The final stage is thus termed the 'morphographic stage'. The model is considered in detail below.

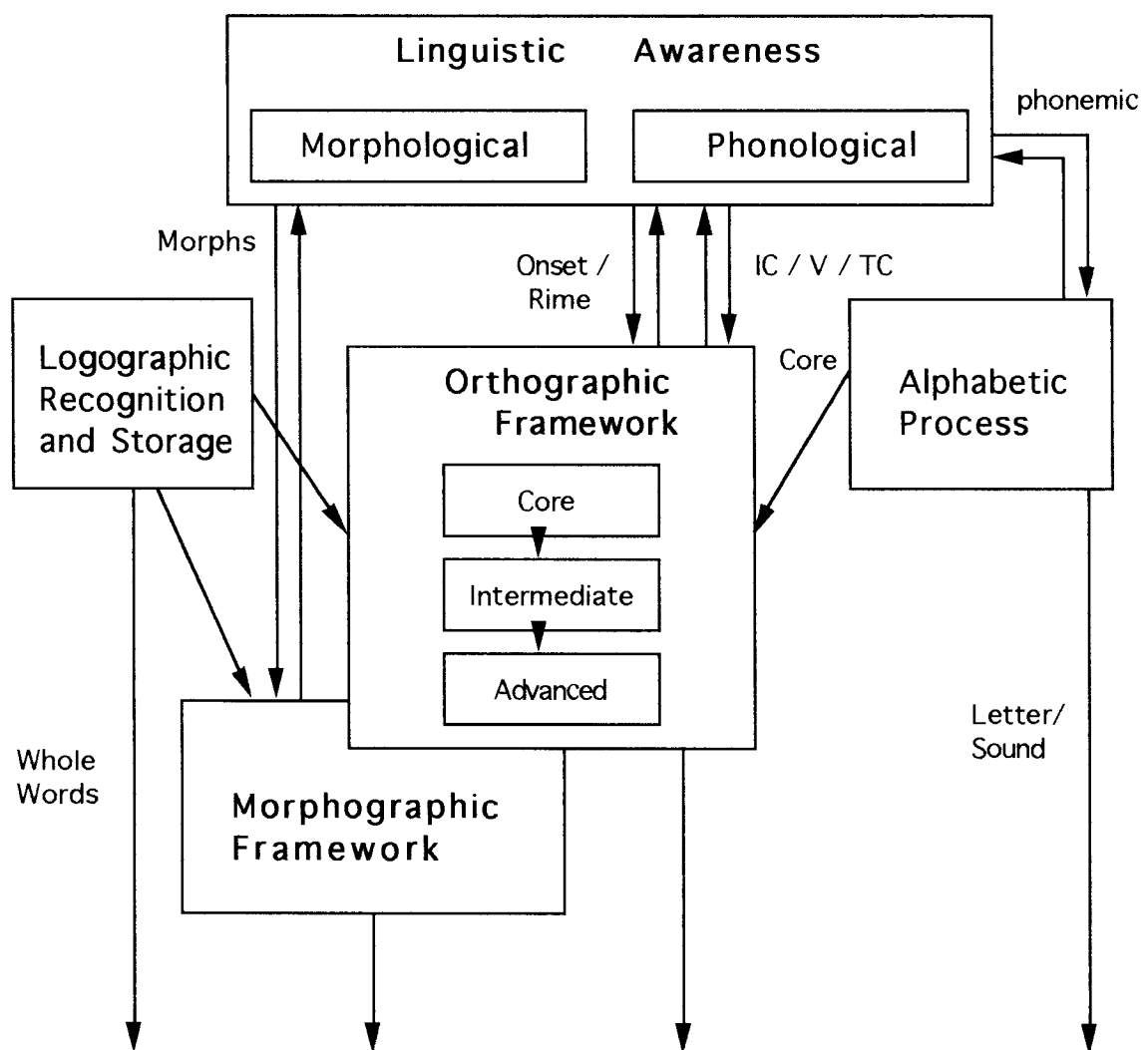
Foundation stages of the model

For Seymour the early stages of reading commence with the development of three elements. These are shown in diagram form in Figure 2.4. Two of these elements play a foundation role, in that they provide a basis for further developments. The first of these foundations is a logographic store. The logographic store is concerned with the direct storage and recognition of words. This store is not however equivalent to Frith's logographic stage. While the early stages of this foundation can be characterised by the storage of partial or incomplete representations of orthographic knowledge (Seymour & MacGregor, 1984), many representations will be accurately specified. Equally while the store requires no explicit phonological awareness beyond the capacity to segment sentences into words in order to develop, letter-sound cues help to represent words. Thus Seymour's logographic stage is equivalent to both the 'visual cue' and 'phonetic cue' stages of Ehri's model. Letter-sound knowledge will help to form increasingly accurately specified representations of word knowledge.

In Seymour's account the alphabetic foundation is held to refer to a set of letter-sound associations, systematically applied in a sequential left to right manner, with the product of this analysis organised into a spoken response. This alphabetic approach is

associated with the overt sounding out of words. Consistent with much of the research discussed in chapter one, the alphabetic process in Seymour's model shares a close and interactive relationship with explicit phonemic awareness. Explicit awareness of the sound structure of speech is seen to play an enabling role in that it interacts with existing foundation structures to aid reading development. Unlike Frith's model, both the alphabetic and logographic stages continue to make contributions to reading in later stages of development and do not follow a sequential structure in their emergence.

Figure 2.4. Seymour's (1997) dual-foundation model of reading development.



The orthographic and morphographic stages

At the heart of this theory of literacy acquisition is an orthographic store which is held to develop from the basis of the dual foundation of logographic and alphabetic resources. This store codes generalised knowledge of the orthographic system as well as word-specific information. This stage emerges when the lexicon undergoes a 'representational redescription' through the application of sublexical phonology to the logographic lexicon.

This application of phonological knowledge is based on a reinterpretation of the hierarchical view of the structure of the syllable discussed in chapter 1. Seymour accepts that there is a developmental sequence in the emergence of implicit subsyllabic awareness, characterised by implicit awareness of onset and rime structures and with the emergence of peak and coda and phonemic units within a rime emerging gradually during development (Maclean et al, 1987; Treiman & Zukowski, 1991, 1996). Seymour assumes however that explicit awareness of sound structures is crucial in reading acquisition. Explicit phonological awareness is influenced by 'external' factors such as instruction (Gombert, 1992; Seymour & Evans, 1994). Thus it is small units such as onset, peak and coda which are crucial in early reading. The explicit use of orthographic onset and rime units is held to develop only later in reading acquisition (Seymour & Evans, 1994; Duncan et al, 1997).

In its earliest form the orthographic network is a core 'three dimensional' structure based upon initial consonant, medial vowel and final consonant elements. During reorganisation, an internal search of the lexicon is made for words which have an appropriate CVC phonological structure. At this point of reorganisation words and nonwords sharing this CVC structure can be read accurately. Thus at this point, the capacity for generalisation, which is not available in the logographic stage, first emerges. In subsequent stages this '3D' structure is expanded to take in more complex initial and final consonant clusters and vowel digraphs. Explicit teaching of complex

digraphs may aid this process, though other units such as onset clusters may be acquired 'more or less naturally' (Seymour, 1997). Once fully internalised the orthographic system should be able to decode and represent a full range of English monosyllables.

In the final stage of development, children incorporate their morphemic knowledge to develop multisyllabic representations involving bound and root morphemes such as prefix + stem and stem + suffix words. This stage is dependent upon the development of the orthographic network and also interacts with earlier established linguistic awareness in establishing the status of word segments such as stems or affixes. This system also interacts with the logographic system in which, Seymour argues, word forms provide exemplars to establish morphemic features.

Evaluation of Seymour's model

Seymour's model has the twin strengths of being worked out in detail and based upon current theorising. The model shares with Frith (1985) a concern to explain development from pre-literacy through to skilled reading and spelling. Seymour provides a more comprehensive account of reading development than Frith as his account makes explicit reference to the role of morphemic structure and the nature of multi-syllabic representations in more skilled reading. Another attractive aspect of the model is that it explicitly considers the cognitive effects of external factors such as literacy instruction which probably influence reading development (Morton & Frith, 1993, Seymour & Evans, 1994). The cognitive effects of schooling have not been given great consideration in some alternative models.

Seymour has also developed a framework for orthographic assessment that can be used for the purpose of targeting interventions (Seymour, Bunce, & Evans, 1992). Remedial instruction can thus be based on careful qualitative assessment of the developmental stage that a child has reached. Seymour has described several cases of

developmental dyslexia in this manner using the single case methodology (Seymour & Evans, 1988; Seymour & Bunce, 1994). One dyslexic, DK, who suffered a specific nonword processing deficit showed improvements in phonetic spelling but still suffered in terms of decoding ability after targeted instruction. Another patient, RC, described as a 'morphemic dyslexic', had particular difficulty reading and spelling exception words, and showed some modest improvements in this domain after targeted remediation. While potentially important, this sort of work is still in its infancy and the status of module-specific teaching remains unclear. One problem is that the research does not yet provide strong evidence on the differential effects of various teaching methods, and it may be difficult to ascertain the cause of improvements made (Snowling, 1996).

One aspect of the model that may be problematic is the description of the logographic foundation stage as a relatively sophisticated representation of orthographic knowledge. This description may bypass some of the problems associated with a logographic stage discussed earlier in the chapter where evidence indicated that much 'logographic' reading entails learning very little or nothing about the orthography (Masonheimer et al, 1984; Gough & Juel, 1991). Seymour argues that the logographic store is not associated with exclusively visual cues or the recognition of logos, but is more akin to an accurate 'sight vocabulary'. However at the onset of logographic reading one problem may be in distinguishing between the poor 'pre-logographic' associate learning described by Gough and Juel, and the logographic reading Seymour describes.

In the later stages of logographic reading, another problem may be the claim that accurate representations of sight vocabulary can exist in the absence of sublexical phonological awareness. There is substantial evidence that phonological skills are associated with even the very earliest stages of single word reading (Maclean et al, 1987; Perfetti, Beck, Bell, & Hughes, 1987; Vellutino & Scanlon, 1987). Furthermore

purported observations of logographic reading have often been made without assessment of phonological skills (Seymour & MacGregor, 1984) or alternatively are based on the observation of individuals who can read a few words in the absence of ability to read nonwords. Seymour and Evans, (1988) for example describe a child A.T. who suffered from Klinefelter's syndrome. He suffered a range of linguistic and motor difficulties and had a measured I.Q. of 56. A.T. could read around 40 % of words shown to him but only between 1 and 5 percent of nonwords. They conclude that A.T.'s reading has been arrested at the logographic stage. However the observed 'lexicality effect' in A.T.'s reading performance is open to several interpretations. It may be for example that the limited lexicon provided too few exemplars to read nonwords by analogy. Furthermore phonological skills, while severely impaired were still evident, suggesting that the modest levels of reading skill shown by A.T. were associated with modest analytic phonological abilities.

Another potentially problematic aspect of Seymour's conceptualisation of the logographic stage concerns the extent to which it is possible to distinguish qualitatively between the logographic and orthographic stages. If the logographic store has greater precision than theorists have previously assumed, and accepting that the developing application of letter-sound cues increases the quality of the specification of word representations in the logographic store, then it is not clear why the logographic stage cannot provide a basis for orthographic generalisation. From this view it may be that the logographic stage differs from the orthographic stage in degree rather than in kind.

The main reason that Seymour attempts to separate logographic and orthographic stages appears to be driven by the assumption that theoretical accounts should include mechanisms that allow for differential impairments and contrasting patterns of disability. This view has been strongly influenced by the observation of apparent dissociation between nonword and exception word reading abilities in certain classes of dyslexic patients discussed earlier in this chapter (Coltheart et al, 1983;

Funnell, 1983). However as discussed earlier, a double dissociation between lexical and sublexical reading skills has not yet been demonstrated in the developmental literature, as dyslexics' reading performance appears to be qualitatively similar to that of reading age matched controls in all aspects of word but not nonword reading (Bryant & Impey, 1986; Stanovich et al, 1997).

Turning to Seymour's orthographic stage of development, several aspects of the orthographic stage have received empirical support. As was first mentioned in chapter 1, the characterisation of the development of phonological awareness where explicit onset peak and coda awareness emerges prior to explicit onset and rime awareness has been supported by some studies (Seymour & Evans, 1994; Duncan et al, 1997). This view also predicts that the use of orthographic inferences on the basis of small units may precede that of large rime inferences. Empirical work on the early and late use of rime inferences by children is discussed in detail in the third chapter. While much of this evidence supports Seymour's theory, one objection to Seymour's theory of orthographic generalisation is that it considers explicit rather than implicit skills as of central importance. There is some evidence that implicit phonological skills may be more important in early reading than explicit phonological skills. The potential role of implicit onset and rime phonological skills is therefore discussed below.

The role of onsets and rimes

A further problem with some of the interactive models and the dual foundation model outlined above is that they assume, as did the stage models before them, that the most important source of phonological information that children could use to analyse or underpin words is small unit information. In Perfetti, Ehri, and Stuart and Coltheart's models children learn the association between letters or letter clusters and phonemes, in Seymour's model explicit onset, peak, and coda knowledge is crucial. However as mentioned in chapter 1, an alternative way to conceptualise the process of early reading is that children associate larger letter strings with supraphonemic sound segments. In

this way children might be able to use phonological onset and rime categorisation skills which are present before they learn to read. As was noted in the first chapter, young children are quite adept at manipulating phonological onsets and rimes and often show some rime awareness before the ability to carry out explicit phoneme manipulation tasks has developed, (Goswami & Bryant, 1990). There was at least some evidence that onset and rime manipulation skill predicts early reading ability (Bradley & Bryant, 1983; Lundberg, Olofsson, & Wall, 1980).

One possible use for onset-rime awareness is to allow children to form categories of words based upon similarity at the orthographic or phonological level (Adams, 1990; Bryant & Bradley, 1985; Goswami & Bryant, 1990). The use of large letter unit representations would be effective in capturing the redundancy of English orthography, (Adams, 1990). One way that knowledge about the pronunciation of large letter units may be applied to reading is by the use of an analogy process, (Glushko, 1979; Goswami, 1986). Alternatively children may infer large letter unit or Orthography-to-Phonology (OPC) correspondence rules (Patterson & Morton, 1985). A third possibility is that large unit representations emerge as a consequence of monitoring the covariant properties of phonology and orthography in English (Adams, 1990; Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990). Such notions have been implemented in some computational models with the aim of simulating aspects of human reading performance. Rival computational simulations have suggested that grapheme to phoneme correspondence rules or onset peak and coda correspondences are sufficient to explain reading acquisition. Computational simulations are therefore considered in the next section.

Computational models of reading development

Computational implementations of connectionist learning networks represent a further way of evaluating competing accounts of reading acquisition. The comparison of the performance of models against behavioural data provides a potentially powerful

tool to evaluate general cognitive accounts of reading behaviour. Two classes of models are considered below - single route distributed models which have attempted to simulate the acquisition of a range of letter to sound relationships including those of rime body units and dual route connectionist models which simulate the acquisition of grapheme to phoneme correspondence rules and lexical representations.

Single route models

One class of formal computational implementations of connectionist learning networks (Seidenberg & McClelland, 1989; Seidenberg, Plaut, Petersen, McClelland, & McRae, 1994, Plaut, McClelland, Seidenberg, and Patterson, 1996) has generally sought to exploit the 'covariant learning principle' (Van Orden, Pennington & Stone, 1990) whereby the statistical consistencies of orthographic and phonological relationships across the written language are captured by a series of weighted connections rather than by a system of abstract rules. In such accounts, rule-like reading behaviour is seen as an emergent property arising from the development of multiple weighted connections between orthographic and phonological representations of letter strings.

Seidenberg and McClelland's 1989 model reads by virtue of 400 triples of graphemes or 'wickelgraphs' (following Wickelgren, 1969) which are connected to 460 phonological representations or 'wickelphones'. Between these two unit types, there are 200 hidden units which are themselves interconnected, but which receive activation only indirectly from input units. Hidden units serve to enhance the computational power of the system. For any letter string, wickelgraphs map every possible position of letters, for example for the word 'make', the wickelgraphs [_ma, mak, ake, ke_] are connected to corresponding phonemic representations or 'wickelphones' (where _ signals a word boundary). Repeated exposure to a corpus of 2897 monosyllabic words influences the 'weights' in the connections between these units via a learning rule (the backpropagation of error algorithm). The feedback from hidden units influences the orthographic units. This pattern of activation can then be compared against the original

pattern and any discrepancy between the two is termed the orthographic error. Activation from the hidden units also flows to the phonological units, and the discrepancy between actual and desired phonological activation can also be compared. Any resultant discrepancy is termed the phonological error. These two forms of 'error' are then used to modify or evaluate performance of the system.

The implemented model can simulate a number of important effects observed in normal reading, such as word regularity and word frequency interaction effects (Andrews, 1982; Seidenberg et al, 1984; Taraban & McClelland, 1987), and can mimic individual differences in reading exposure (Seidenberg, 1985). The model also has a reasonable ability to read both nonwords and exception words using a single associative mechanism. Despite having no lexicon, Seidenberg & McClelland have also argued that their model can account for lexical decision data. In their model, lexical decision is assessed by comparing the orthographic error rates for different classes of words, though a phonological component to lexical decision is assumed to be required when evaluating unique words like 'aisle' presented amongst highly 'wordlike' nonwords such as 'bink'.

Attempts have also been made to lesion the model in order to simulate the effects of acquired reading disorder (Patterson, Seidenberg, & McClelland, 1989). Patterson et al sought to simulate the pattern of regularity effects, and the preservation of nonword reading and the presence of regularisation errors to exception words that is characteristic of surface dyslexia. Lesions to the system produced variable impacts upon reading performance. The model was able to simulate some of the standard impairments found in surface dyslexia, such as regularisation errors.

Evaluation of single route models

Some controversy surrounds the ability of Seidenberg and McClelland's model to simulate normal adult single word reading performance (Besner, Twilley, McCann,

& Seergobin, 1990; Castles & Coltheart, 1993; Coltheart, Curtis, Haller, & Atkins, 1993; Seidenberg & McClelland, 1990; Quinlan, 1991). The ability of the model to simulate nonword reading performance, pseudohomophone effects, and to accurately simulate lexical decision, amongst other effects, has been seriously questioned (Besner et al, 1990). In some cases the debate on these issues has shifted back to questioning the robustness of the empirical data, (e.g. for the pseudohomophone effect, Seidenberg & McClelland, 1990). The other criticisms remain to be explained. Other critics have commented upon the difficulty in understanding aspects of the process of backpropagation of error in psychological terms. While phonological error could be readily interpreted as the effect of expert feedback on pronunciation accuracy, it is not clear what the psychological equivalent of feedback to the orthographic units might be (Quinlan, 1991).

Another more fundamental problem surrounds evaluation of the extent to which the model's failures to simulate human performance derive from the relatively limited implementations run to date, or from more fundamental flaws in the model's theoretical conception. Seidenberg and McClelland (1990), for example, suggest that the relatively small learning set, the absence of an implemented semantic system, and the relatively poor quality of phonological representations limits direct comparisons of their model with human performance. While these objections may be entirely valid, the problem of falsifying the model's claims inevitably have to be raised (Quinlan, 1991).

From a developmental perspective, another central concern lies with the relatively unstructured nature of the initial state of the phonological system in Seidenberg and McClelland's connectionist model. In their account, phonological units are set randomly to intermediate strengths of activation, which are then adjusted through experience of print. In contrast, children begin reading with some highly developed phonological skills. It is demonstrably false therefore to equate the *tabula rasa* of the connectionist learning system prior to exposure to the training word corpus with the

phonological skills of the preliterate child. A psychologically plausible model of reading development would need to incorporate both children's pre-existing and developing phonological skill (Hulme, Snowling, & Quinlan, 1991) and to include the influence of other concurrent knowledge sources such as from spelling (Brown & Watson, 1991).

More recent connectionist models have attempted to incorporate more sophisticated initial phonological representations in their simulations. Seidenberg et al, (1994) and Plaut et al, (1996) have presented a connectionist model of reading that incorporates positional phonological representations of syllabic onsets, nuclei, and codas in input phonology. Justification for this system was drawn from its theoretical appeal as an account of syllabic structure (Selkirk, 1982) and from its demonstrable influence in children's conception of the internal structure of the syllable, (Treiman, 1992). Unlike their previous simulations, this simulation, utilising a complex but 'flat' representation of the syllabic phonology (Fowler, Treiman, & Gross, 1993) was able to simulate the performance of adults on nonword reading tasks equally as effectively as a system which inferred grapheme to phoneme rules (Coltheart et al, 1993).

Dual route connectionist models

An alternative dual route connectionist model has been advanced (Coltheart, Curtis, Atkins & Haller, 1993). In this model one mechanism serves as a sublexical route to reading acquisition. This procedure translates letter strings into strings of phonemes using grapheme to phoneme rules. These rules are not preset but are acquired by exposure to a corpus of words and extracting positional letter-sound relationships (for the sake of comparisons the same 2897 words as used by Seidenberg & McClelland, 1989 were used). Thus rules assign beginning, middle, and end classifications to letter sound relationships. Rules for pronouncing multi letter graphemes (e.g. 'igh' in 'light') are learned by applying single letter rules to such words and computing the mismatch between known whole word pronunciation and pronunciations derived from letter to sound rules. Multi-letter rules are assigned to

whatever parts of a word are not accounted for by single letter rules. Thus for the word 'light', single letter rules will yield pronunciations for the beginning and end letters of the word, and the learning algorithm derives the rule that 'igh' -> / I /. This inferential rule system is highly efficient: it can infer rules in two passes through the database, wherein single letter rules are learned in the first pass and multi-letter rules in the second pass. Once learned the rules can be applied to unfamiliar letter strings. The system for example reads 98% of a corpus of nonwords correctly. For comparison the Seidenberg and McClelland (1989) distributed model is capable of learning only 68% of the same nonword set. The second mechanism in Coltheart et al's model is a lexical procedure for reading exception words. The lexical route is the Interactive Activation (IA) cascade model advanced by Rumelhart and McClelland and discussed when considering Perfetti's theory earlier. To date only the rule based system has been implemented.

Evaluation of the dual route connectionist model

In many regards the lexical routine is the weakest part of the system. Given the explicit aim of explaining the acquisition of word knowledge, the IA model provides no clear explanation of exactly how exception words are acquired, and in the absence of formal simulations, it is unclear how effective such a mechanism might be in simulating acquisition of word specific knowledge. As was discussed earlier, IA models represent static accounts of relatively skilled reading behaviour, and explanations of how such a system might simulate the acquisition of word knowledge is lacking.

A second problem concerns the sublexical routine. As currently instantiated, the dual route model provides no explanation of the emergence of the rime body effects in pronunciation amongst skilled readers described in chapter 1 (Glushko, 1979; Kay & Marcel, 1981) as the sublexical system only infers grapheme to phoneme conversion rules. Equally the model ignores the possibility that in reading acquisition, other kinds of phonological processing such as onset-rime segmentation may affect the rule induction process.

Another problem with the model is more philosophical in nature. This issue concerns the epistemological question of the origin of knowledge about the orthography. In the implemented part of the dual route connectionist system, mechanisms for acquiring rules are built into the sublexical routine. No explanation of the origin of these mechanisms is offered. One of the attractive aspects of the alternative distributed connectionist models such as Seidenberg and McClelland (1989) is that they are more justifiable from an epistemological view, in that they reflect the associations developed through experience of print. Brown has argued (G. D. A. Brown, 1993, personal communication), that the resort to 'rules' should only be sought when a purely associationist learning approach fails, as the epistemological origin of rules is far harder to explain. Together then there may be reasons for preferring the single procedure parallel distributed connectionist models over dual route models.

The relationship between computational models and developmental theory

Irrespective of whether single or dual route connectionist models are preferred, the extent to which computational models of reading acquisition inform developmental theories also needs consideration. One problem is that connectionist models have not sought to incorporate developmental theorising, and have generally sought to simulate adult rather than developmental data on reading performance. While there have been attempts to understand developmental dyslexic reading and spelling performance in terms of connectionist architectures (Brown & Watson, 1991; Loosemore, Brown & Watson, 1991; Seidenberg & McClelland, 1989), relatively little attention has been given to modelling normal reading development. The one exception to this is Seidenberg & McClelland's simulation of developmental changes in the influence of regularity on children's word reading errors, originally demonstrated by Backman, Bruck, Hebert and Seidenberg (1984). One future aim must be to attempt to simulate qualitative patterns of novice and intermediate reading performance and patterns of reading paralexias in more detail. It seems likely that the quality of representational units that has been suggested by empirical research (Ehri, 1992; Perfetti, 1992; Stuart &

Coltheart, 1988) would need to be implemented as partial recognition units in future simulations.

The precision of phonological representations

Despite these problems developmental and computational models both appear to share the assumption that there is a close relationship between the quality of phonological representations of orthographic knowledge and the ability to read novel words. Some developmental theorists have recently considered models of reading that share assumptions with the connectionist account. Rack, Hulme, Snowling, and Wightman's (1994) 'direct mapping' hypothesis sets out the view that the role of phonological skills is to help children to learn the relationships between the written forms of words and their spoken forms. Unlike explicit GPC rule procedures, the direct mapping hypothesis characterises the role of phonology as the activation of often only partially defined pronunciation information from cues in the printed words. This model clearly has much in common with the covariant learning principle of connectionist models, as well as with aspects of Ehri's account of 'partial cues' in a direct route to reading. This is a promising theory, but to date the working of the model has not been described in detail.

The extent to which connectionist models fully reflect the phonological skills of children is nevertheless debatable. Arguably connectionist models have demonstrated that precise representations of phonology appear to be necessary in order to compute the relationship between orthography and phonology. On the other hand, while some more recent parallel distributed models (e.g. Plaut et al, 1996) have gone some way towards implementing a more structured model of phonological skills based upon a hierarchical view of the syllable, no connectionist accounts have entirely represented the fact that very young children have the ability to recognise and manipulate onset and rime units, but not necessarily to manipulate smaller grapheme or even peak and coda units.

The role of orthographic inferences

A second assumption shared by developmental and both single and dual route connectionist models is that inductive mechanisms are central to reading acquisition. All models place a central emphasis upon the ability to infer the pronunciations of sublexical letter strings after exposure to words embodying those representations. The dual route connectionist model assumes the inference of grapheme to phoneme rules while the parallel distributed connectionist model emphasises the inference of large unit correspondences. Until fairly recently there has been relatively little research on the use of orthographic inferences in early reading. There is now a body of behavioural data against which such models can be compared. The evidence for inference and particularly rime inference in reading acquisition is therefore discussed in the next chapter.

Conclusion

The present chapter has evaluated some of the more influential models of reading development. Early stage models of reading development based upon dual route theories did not fully represent the phonological skills of young children, nor did they provide causal explanations of the process of reading development. Current models of reading acquisition suggest that a more interactive relationship exists between letter and sound knowledge. Ehri's recent stage model of reading argues that children amalgamate their knowledge of letter names to aid in the representation of letter strings in a direct route to reading from the very earliest stages of reading. Perfetti and Stuart and Coltheart have also suggested that reading should be conceptualised as one of increasing specification of orthographic knowledge in a connected system from initially poorly specified representations of orthography.

While differing in terms of emphasis, these interactive models of reading have generally provided a more satisfactory account of the interaction of phonological skill

and word recognition than early stage models, though they do not always provide clear evidence about causal influences. An important aspect of children's phonological awareness, that neither stage models nor connected models fully consider, is children's early ability to categorise rime and onset sounds in words. These skills have been considered by some to be strong predictors of reading success. Traditional stage models, and more interactive models of reading have also assumed that while large unit representations are important, they emerge only later in reading. One possibility is that the ability to use large letter units represents the link between rime awareness and early reading development. Another line of evidence in support of early use of rime body units comes from some implemented connectionist learning models which can simulate aspects of human reading performance. The third chapter therefore seeks to review the behavioural evidence for the development of orthographic rime inferences.

Chapter 3

Children's use of rime bodies in learning to read

Summary

The present chapter reviews the evidence that young children infer large rime body units in learning to read. Two issues are central to this chapter. The first issue concerns the extent to which children can infer the relationship between phonological rimes and their orthographic counterparts without explicit tuition. The second issue concerns the age at which these rime body units are important in reading development. Many theorists suggest that only relatively experienced readers make use of rime body information. More recently the idea that children might use such units in the earliest stages of reading acquisition has become influential. The evidence from four experimental paradigms - conflict experiments, lexical neighbourhood and consistency experiments, and clue word transfer experiments is evaluated, along with some evidence from training studies and cross-linguistic comparisons. The clue word experiments have been seen to provide some support for the theory that young children can infer rime body relationships in order to learn to read. In the clue word paradigm substantial amounts of clue word information are provided during the posttest stage. An important issue is whether children show a similar facility in reading analogous target words in situations that are more similar to those encountered in naturalistic reading of single words. One way to investigate this is to contrast the effects of different forms of reminders of clue word information on the improvement in reading of analogous target words. This and other issues are discussed prior to an experimental investigation in the fourth chapter.

Inferring rime body relationships

Many models of reading development have suggested that a potentially useful strategy for reading is one that takes advantage of orthographic similarity between words, (Baron, 1977; Coltheart et al, 1993; Ehri, 1992; Frith, 1985; Goswami, 1986; Goswami & Bryant, 1990; Seidenberg & McClelland, 1989; Stuart & Coltheart, 1988;

Thompson, Cottrell, & Fletcher-Flinn, 1996). A central issue in the developmental literature in recent years is the extent to which children can infer large unit representations (Duncan, Seymour, & Hill, 1997; Goswami, 1993). A second related issue is whether strategies using large units or smaller grapheme units are preferred at particular points in reading acquisition (Baron, 1977; Goswami, 1993; Marsh, Friedman, Welch, & Desberg, 1980). As discussed in the previous chapter, most developmental models have assumed that children learn grapheme to phoneme relationships early in reading; the use of rime inferences is assumed to occur relatively late in reading acquisition (Marsh et al, 1980; Frith, 1985; Ehri, 1992; Duncan et al, 1997). In contrast some recent models (Goswami, 1993) suggest that children use orthographic rime inferences early in reading and only develop knowledge of graphemes relatively late in reading acquisition. These positions are considered below.

Evidence for rime body inference in children's reading

Conflict experiments

In order to evaluate the ability of children to infer sublexical relationships, the approach undertaken in a number of studies is to examine whether children can use information about strings of letters from familiar words in order to read nonwords that are by definition unfamiliar. In order to contrast the use of this strategy with the strategy of inferring or applying grapheme to phoneme correspondence rules to derive pronunciations, studies have used exception words.

An early study by Marsh, Desberg and Cooper (1977) used a 'conflict' technique to distinguish nonword pronunciations that were constructed from individual grapheme to phoneme (GPC) rules from responses made on the basis of orthographic analogies. The study investigated the ability of two groups of children aged 10 and 16 and a group of college students to read nonwords that were analogous to exception words. The nonwords differed from the real word analogues by one

phoneme, usually in the first position, creating stimuli such as 'biety' (piety), 'tepherd' (shepherd), and 'puscle' (muscle). Marsh et al reasoned that if the pronunciation of the nonword such as 'puscle' is derived by reference to the orthographic structure of the known word 'muscle', then the nonword pronunciation would rhyme with that word. If, however, subjects were applying grapheme to phoneme correspondence rules to read the nonword, they would pronounce it 'puskle'.

The results of the study showed that the 10 year olds were more likely to pronounce the nonwords in a free choice paradigm as if they were using GPC rules than by using the exception words as the basis for an analogy. In contrast, for the two older groups, analogies were more frequent, though a significant advantage for analogy pronunciations over grapheme to phoneme pronunciations was not evident until college age. However, in a forced choice paradigm in which both pronunciations were given, an 'analogy' pronunciation was preferred even by the younger children. A very similar pattern of results was found in a variation of the task when the nonwords were embedded in prose (Marsh, Friedman, Welch, & Desberg, 1980). The results of the two studies were interpreted as suggesting that the spontaneous use of lexical inference emerges only in relatively mature readers, consistent with their developmental model. A contingent comparison of nonword responses, contrasting performance when children either knew or did not know the real word analogue, revealed that analogic responses were generally associated with real word knowledge.

Knowledge of the real word did not guarantee that an analogy pronunciation was given. Around 20% of responses reflected grapheme to phoneme correspondences even when the real word analogue was known, suggesting that an analogy strategy may supplant, but not completely displace, a grapheme to phoneme strategy, again as their developmental model would predict. Marsh et al, (1977) conclude that younger children with a small reading vocabulary will tend to prefer a grapheme-phoneme decoding strategy.

In a further study, Marsh, Friedman, Desberg, and Saterdahl (1981) showed that children as young as 7 were very good at making analogies if they were given explicit instruction. Two groups of 7 and 9 year old children were given nonwords to read. In addition they were also shown the real word analogues and were told that the nonwords were made by changing one letter of the real words. Following this instruction, the seven year olds pronounced the nonwords by analogy to the exception words with 78% accuracy; the 9 year olds were near perfect, reading the nonwords with 92% accuracy. The use of analogies in spelling was less common in second grade children than a grapheme to phoneme strategy, and equal preference for analogy or graphemic strategies was shown in grade four children. Marsh et al were also able to compare use of analogies by normal readers and developmental dyslexics. Their results showed that poor readers, grade two normal reading children, and grade four normal readers who were the same age as the dyslexics did not differ in the use of analogies in reading, though an advantage was evident for spelling analogies for the older normal readers over the other two groups. However conclusions need to be drawn with caution as this study did not explicitly match the dyslexics and grade two children on reading performance. A study by Manis, Szeszulski, Howell and Horn (1986) using a similar testing technique, and which did match these two groups, found deficits in the use of analogies in reading for fifth and sixth grade developmental dyslexics compared to reading age controls.

Evaluation of the conflict studies

There are several problems with the conflict experiments which make it difficult to draw strong conclusions about the development of reading strategies. One problem concerns the stimulus set used in some of the studies. Ten words and their nonword analogues were used by Marsh et al, (1980). Most words had altered first letters, but one unexpectedly had two letters altered in the middle ('cetto' as an analogy for 'cello'). Another stimulus 'tworld', (for 'world') had an additional rather than a changed first letter and need not be read by analogy, but by adding the first letter to the pronunciation of the word 'world'. Goswami and Bryant (1990) argue

that both the 1977 and 1980 studies may be methodologically flawed because the developmental improvements may reflect younger children's lack of knowledge of the real word analogues. However, while knowledge of the real word is clearly important, the contingent analyses described in Marsh's 1977 study do not confirm the simple view that performance was determined solely by a lack of lexical knowledge.

Another important problem with the studies is that the experiments involved children performing a rather artificial task using exception words. It is possible that children are aware that exception words do not provide a very good basis for lexical analogies to unknown words. The quality of young children's lexical representations of the words is another factor that may limit performance. As exception words do not share orthographic neighbours, the 'precision principle' (Perfetti, 1992) might predict that these words will be poorly specified. More recent approaches have considered that the number of similar representations of rime orthography may be an important contributor to children's use of rime units. These lexical neighbourhood and consistency studies are considered below.

Neighbourhood experiments

Many theorists have assumed that stored orthographic knowledge will have an impact upon the processing of other subsequently encountered words. One approach has been to investigate the effects of orthographic neighbourhoods on reading accuracy. Lexical neighbourhood is usually measured using M. Coltheart's 'N' - the number of other words created from a string of letters by iteratively varying one target letter and by holding all other letters constant (Coltheart, Davelaar, Jonassen, & Besner, 1977). 'High N' words, which share neighbourhoods with many other words, are read more accurately than 'low N' words which share few neighbours, by 9-12 year old normal reading children, (Laxon, Coltheart & Keating, 1988; Laxon, Masterson, Pool, & Keating, 1992), and even by seven year old normal readers (Laxon, Masterson, & Moran, 1994; Laxon, Smith, & Masterson, 1995).

The neighbourhood measure gives equal weighting to words with shared letters in any position. An idea that has gained wide currency is that shared letters in certain word positions may be more important than other letter positions in determining pronunciations. This view is implicit in many models of adult reading which consider rime bodies to be important (Baron, 1977; Glushko, 1979; Kay & Marcel, 1981; Patterson & Coltheart, 1987; Patterson & Morton, 1985; Seidenberg & McClelland, 1989) though other subsyllabic units have been suggested (Marcel, 1980; Taraban & McClelland, 1987). One possibility is that reported 'N' effects may in fact reflect rime neighbourhood effects. In Laxon's studies for example, 'high N' words also share more rime neighbours than 'low N' words (Leslie & Calhoun, 1995).

Rime neighbourhood studies

Rime neighbourhood studies have investigated children's pronunciations of nonwords. Such studies provide a test of contrasting predictions from theories emphasising rime body or grapheme to phoneme rules. Traditionally it has been assumed that the use of grapheme to phoneme rules are necessary to derive nonword pronunciations (Coltheart, 1978). Thus nonword reading performance will reflect the level of children's knowledge of such rules. However if children apply rime body inferences to nonwords then they may read nonwords which have many real word neighbours better than nonwords with few real word neighbours.

Evidence that rime bodies may play a large part in neighbourhood effects in children was reported by Treiman, Goswami and Bruck, (1990). They found that 'friendly' nonwords, that is words that share similar spelling and pronunciation of the vowel and terminal consonant units with real words e.g. 'tain' ('main', 'rain', 'lain', 'gain', 'plain') or 'goach' ('coach', 'roach', 'poach', 'loach') are more likely to be read correctly than 'unfriendly' nonwords e.g. 'goan' ('moan', 'groan') or 'taich', which share few or no neighbours with the same orthographic rime.

This pattern of results was found for a group of first grade children aged seven years, but reading at the level of beginning second grade children, (where the proportions were .49 versus .41 respectively), and for poor readers, (.56 versus .39), and good readers, (.90 versus .79) in the third grade. Adults were also included in the study, and a small but nonsignificant naming latency advantage was evident for high versus low neighbourhood nonwords (552 versus 563 m/sec). Similar orthographic rime frequency effects have now been reported by a number of researchers (Bowey & Hansen, 1994; Bowey & Underwood, 1996; Leslie & Calhoun, 1995).

Evaluation of the rime neighbourhood studies

In Treiman et al's study the frequency of neighbours in the consonant-initial position was controlled. This suggests that rime body units are responsible for the pattern of results witnessed. The results of a series of partial correlations also supported this view. The rime neighbourhood frequency of nonwords which shared vowel and terminal consonant '-VC' units correlated with reading performance, whereas for nonwords sharing the initial consonant and vowel 'CV-' units, correlations between CV frequency and CV reading performance were not significant, even though the number of neighbours these words had varied substantially. While this finding is consistent with the idea that orthographic rimes have a particularly strong role in the development of reading skills, because overall neighbourhood size (as measured by Colheart's 'N') also varied between high and low rime neighbour words, it is difficult to conclude that it was specifically rime, or overall neighbourhood size which played the most important role in facilitating nonword reading.

The results of correlational analyses also indicated a strong relationship between performance on the nonword reading task and knowledge of grapheme to phoneme rules, which was particularly strong for the first grade children ($r = .61$ for the friendly nonwords, $r = .73$ for the unfriendly nonwords). Regression analyses confirmed that GPC knowledge accounted for a significant amount of the variance

even after VC frequency was controlled, forcing Treiman et al to concede that graphemic as well as rime units are used by children in nonword reading.

There are several other problems with the rime neighbourhood studies. Visual inspection of the results in the studies by Treiman et al and the studies by Bowey et al show that rime frequency effects are relatively modest. Furthermore, a careful investigation of the analyses provided by Treiman et al reveal that while the overall analysis of first grade reader's results was significant, analyses of the subset of 15 first grade children who were reading at a chronologically appropriate level showed a far more modest pattern of performance. The analysis by subjects was just significant ($p < .05$, two tailed), but the analysis by items failed to reach conventional significance. Only when the better or older readers were included in analyses were results strongly significant. Therefore clear evidence for a role for rime bodies is only evident in this study in children reading at least at the second and third grade level.

Similar evidence comes from a study by Bowey and Hansen (1994). They compared four groups of children on their ability to read a set of nonwords based upon those used by Treiman et al. The two youngest groups had reading ages of less than 5: 3; the older groups had reading ages of 5: 11 and 7: 8. The results showed that only the latter two groups showed the rime frequency effect. The effect was strong in the older group ($p < .001$), but rather modest in the younger group ($p < .05$). No item analyses were presented so it is not clear how reliable the results are across items. In a second experiment, comparisons of normal reading grade 2 and grade 4, and poor reading grade 4 children was undertaken on the same tasks. Rime frequency effects were evident, but these did not interact with reading age. The poorer readers showed a nonword reading deficit, reading both sets of words less well than their reading age matched controls. Bowey and Hansen concluded that rime frequency effects were dependent upon the development of a substantial reading vocabulary.

In a subsequent study of the rime frequency effect Bowey and Underwood, (1996, experiment 1) compared normal reading second, fourth, and sixth grade readers on the same word set used in their previous study. Subject analyses revealed a main effect of rime frequency, with more frequent rimes being read more often. This effect did not interact with reader group. However an item analysis revealed a significant reader group by rime frequency effect, with reliable advantages for frequent over infrequent rimes evident only for the fourth and sixth grade children. These studies by Bowey confirm the evidence from Treiman et al (1990) that the rime frequency effect is only reliably found in relatively experienced readers.

A study by Leslie and Calhoun (1995) compared rime frequency effects for forty first and second grade children who varied in their reading ability. The effect of large, medium and small rime neighbourhoods was investigated. Unlike previous studies, a strong rime frequency effect was reported in even these young children in subject analyses ($p < .01$), though no item analyses were presented. However, unlike the previous studies, words with large, small and medium rime neighbourhoods were not balanced in terms of the same grapheme to phoneme correspondences across frequent and infrequent rime stimuli sets. No other attempts were made to balance the words on other relevant variables such as positional bigram frequency (Mayzner & Tresselt, 1967). In the absence of such control little can be concluded from this study.

Another problem in the rime frequency experiments is that, for nonwords, relatively unfamiliar orthographic rime patterns necessarily require the construction of less familiar articulation programmes, and these programmes may also be executed less easily than for their high-neighbourhood counterparts (e.g. consider the 'friendly' nonwords 'jub' and 'veed' versus the 'unfriendly' words 'jud' and 'veeb'). There is evidence to support this view from the analyses of adult performance. Despite there being no significant differences in naming latency, adults made more pronunciation errors to low neighbour nonwords.

The differences between friendly and unfriendly rimes found by Treiman et al are difficult to explain through the use of abstract grapheme to phoneme correspondence rules, though the use of an additional set of rime body rules (Patterson & Morton, 1985) could accommodate such results (Treiman et al, 1990). The rime frequency effect may also be difficult for more recent models such as that of Thompson, Cottrell and Fletcher-Flinn (1996) which have suggested that children take advantage of positional graphemic knowledge in the early stages of learning to read. Thompson et al argue that children may abstract positional specific information about the identity of letters, e.g. inferring the identity of the letter '-t' and the phonological unit /t/ from the experience of words such as 'not', 'get', 'cat', 'went' and 'got', which could then be used to read unfamiliar words.

Thompson et al assessed the positional frequency of printed words in books available to 24 beginning readers with a mean age of 5 years 10 months. For these children, words with letters 'b' and 'th' at the beginnings of words were frequent, whereas the same letters were infrequent at the ends of words. Nonwords were created which comprised consonant and vowel (CV-) units (e.g. 'ba', 'bo', and 'tho', 'tha') or vowel and consonant (-VC) units (e.g. 'ab', 'ob', and 'ith', 'uth') which contained similar letters. The CV- nonwords with high positional frequency were read better than the -VC nonwords which had lower frequencies, though with a small item set the effect was not strong ($p < .05$).

In another experiment, children were shown nonwords which were either CV- or -VC units (e.g. 'ub', 'ob' or 'bu' and 'bo'). They were then taught eight words which all ended in 'b' (e.g. 'crab' 'jab', 'rob' and 'bob'). Finally the nonwords were re-shown. Improvements in reading were only found for the -VC nonwords. Furthermore no additional improvements were found for nonwords which shared vowels and final consonants (e.g. 'ab' or 'ob') over nonwords which shared only final consonants (e.g. '-eb', or '-ub') suggesting that children had inferred final consonant graphemes rather

than orthographic rime pronunciations. This result does not therefore support the model of early rime unit use advanced by Treiman et al (1990).

Thompson et al suggested that results supported a view of early reading in which boundary consonants are inferred early on but where medial vowel representations are insufficiently established as a basis for the inference of sublexical relations. However this result conflicts with the results of the study by Treiman et al where reading of nonwords varied, despite the fact that initial and final consonant units were the same for the high and low neighbourhood words. The two studies can be reconciled by assuming that the results reflect performance at different levels of competence. Very young children may develop partial representations of initial and final consonant positions in words from print experience (Thompson & Fletcher-Flinn, 1993; Thompson et al, 1996), whereas in the second and third years of reading tuition, these representations start to become amalgamated into rime units which children can use to read unfamiliar letter strings.

Consistency experiments

As well as considering the number of neighbours that a word has, many researchers have considered the consistency of rime neighbourhoods to be important. One of the first developmental studies of consistency of word pronunciations on reading performance was carried out by Backman, Bruck, Hebert, and Seidenberg, (1984). They contrasted the ability of children between the second and fourth year of school to read regular words and nonwords sharing similar patterns with consistent pronunciations such as 'UST' (e.g. 'must', 'bust'), and homographic exception words sharing rimes such as 'OSE' ('nose', 'lose'). Developmental effects of consistency were evident, with regular consistent words read comparatively well even in the early school grades, whereas the inconsistent words gradually improved with reading experience, in many cases matching performance on consistent words by grade 4. Backman et al interpreted these results in terms of developing lexical and sublexical routes, though as was noted in chapter 2, these results could be understood as the

activation of connected letter to sound relationships, reaching asymptote with greater experience (Seidenberg & McClelland, 1989; Van Orden, Pennington & Stone, 1990).

Zinna, Liberman, & Shankweiler, (1986) also looked at the effects of word consistency on vowel reading performance in first, third, and fifth grade readers. They found that frequency effects were evident for first grader's vowel reading, whereas consistency by frequency interaction effects were found for third and fifth graders, indicating a developing awareness of rime neighbourhood with greater reading ability. Only low frequency inconsistent words were a problem for the older readers. This view was supported by an analysis of nonword reading in a second experiment. The influence of final consonants upon reading of vowel digraphs was assessed by contrasting pronunciations of vowel and rime units with consistent rime neighbourhoods (e.g. '-oom' and '-oon') with words with inconsistent neighbours (e.g. '-ool' and '-ook'). Nonwords with consistent neighbourhoods produced less variable vowel responses. They concluded that the relatively small reading vocabularies in first grade children effectively limit the amount of lexical information that they can use to read new words, whereas by the third grade, children are able to take advantage of rime neighbourhoods in order to infer letter sound relationships in unfamiliar words. Results again support the view that the use of rime bodies develops gradually in young children.

A number of more recent studies have also investigated the effects of different classes of rime bodies upon reading accuracy. Laxon, Masterson and Coltheart (1991) compiled a list of 70 words, and derived 70 nonwords from these by changing their first letters. The words were of five types based upon the rime unit or word 'body' taxonomy first outlined by Patterson and Morton (1985). Nonwords were defined by the real word category shared by their rimes. The first set of fourteen words contained only consistent rime bodies. These words were regular and entirely consistent in their pronunciation in all real words (e.g. 'ink' in 'wink', 'pink'). The

second set of words were 'consensus' words - similar to the consistent words but sharing one 'heretic' word that provides an inconsistent pronunciation (e.g. 'ave' in 'gave' 'save' and 'have'). The third and fourth sets were regular or irregular, and were 'ambiguous' words - the rime units provided thoroughly unreliable pronunciations (e.g. 'ove' in 'cove' 'move' and 'dove'). The final word set were 'gang' words that were irregular but generally consistent (e.g. 'alm' in 'calm' 'palm').

The real and nonsense words were given to two groups of children, one of average readers aged 7: 11, and a group of very good readers aged 8: 08, but with a reading age nearly two years in advance of their chronological age. Regular and irregular pronunciations were considered for the real and nonwords. If children are sensitive to the pronunciation of orthographic rime neighbours, then more regular responses should be given to the consistent and the consensus words than to the ambiguous words, and very few regular pronunciations should be assigned to the gang words. If even young children use a rime body strategy, then this pattern should be repeated across both age groups.

Considering first the real words, in the subject analyses consistency effects only approached significance for the older readers. Here fewer ambiguous words were read correctly than regular consensus and consistent words, for both groups. There were no differences between the irregular words for the younger children, though the gang words were read better than the ambiguous words by the older children. In an analysis by items however, body consistency effects were found across both age groups, but no differences between gang and ambiguous words were evident.

There was a more reliable effect of reading ability on the pattern of nonword reading. Only the very good readers showed a tendency to offer fewer regular pronunciations to the ambiguous words. Results indicated that the younger children were less discriminating, offering regular pronunciations regardless of word

consistency. Results also indicated some evidence of a developing awareness of inconsistency, as children tended to offer more irregular pronunciations to ambiguous words. However differences in the number of irregular pronunciations between gang and consensus words were evident only for the older children. There was a significant trend for the younger children to make more irregular pronunciations to the ambiguous words than the gang words, suggesting that they knew relatively little about irregular rime neighbourhoods.

In a similar study, Coltheart and Leahy (1992) gave regular consistent, irregular consistent, and ambiguous nonwords to three groups of children with average ages of 6: 10, 8: 01, and 8: 11. The two groups of older children made significantly more regular pronunciations to the regular consistent words than to the ambiguous or irregular words. The younger children again showed less selectivity, making as many regular pronunciations to ambiguous words as to the regular consistent words but fewer regular pronunciations to the irregular words. Furthermore, the younger children showed a smaller tendency to make irregular pronunciations to ambiguous and irregular nonwords, compared to the two older reader groups. A further analysis that took knowledge of one real word analogue of nonsense words into account still found that the youngest children made fewer irregular responses (12.7%) than both year two (19.2%) and year three children (20.4%).

Coltheart and Leahy concluded from these findings that, while there exists some tendency for children to be aware of rime units before fully mastering pronunciation rules (for example even the youngest children were less likely to offer a regular pronunciation to the irregular consistent words than to the ambiguous words) the results of this study and that of Laxon et al (1991) are consistent with the notion that grade 1 children read by applying grapheme to phoneme correspondence rules, whereas the use of rime body rules or rime analogies represents a later stage of reading increasingly adopted by children in grades two and three.

Bowey and Underwood (1996) have also found evidence for age-related changes in the use of rime versus grapheme to phoneme correspondences in the reading of Coltheart and Leahy's ambiguous nonwords. Regular responses dominate in the early years of reading, but by grade six consistent and inconsistent responses are given equally often for these words. Bowey and Underwood have also found that rime responses can be influenced by the phonetic quality of the onset of words in such tasks. Nonwords such as 'zaid' are described as phonetically 'closer' to their underlying real word neighbours (said) than a 'distant' nonword like 'gaid', as the former nonwords differ only in terms of one phonetic feature (in this case the voicing). Close ambiguous nonwords are given more rime pronunciations than distant ambiguous nonwords by second, fourth, and sixth grade children. Bowey and Underwood argue that such a result would not fit very well with the rime body rule system proposed by Patterson & Morton (1985). However the finding could be readily incorporated in Seidenberg and McClelland's connectionist model, by assuming that it reflects the feedback from activated phonology. An alternative explanation is that as some of the close phonetic words are also visually very similar to real word analogues, the close ambiguous words simply make the real word analogue more salient to the reader than the distant ambiguous word.

Evaluation of consistency experiments

There are a number of problems associated with the consistency experiments. A theoretical error that affects many studies is the assumption that regular consistent pronunciations for nonwords reflect the use of grapheme to phoneme correspondences. These pronunciations can equally reflect the use of rime bodies. The regular consistent words in the Coltheart & Leahy study such as 'dack' could, for example, be read by analogy to the real word 'back'. The second problem concerns the legitimacy of drawing conclusions from comparisons across word types. In Coltheart & Leahy and Laxon et al's studies, the crucial comparison is that between the regular consistent and the irregular consistent words. As the comparison is of a

between groups nature, it is important to be absolutely certain that these words are matched on all other extraneous variables.

The list of psycholinguistic factors which may affect single word reading is formidably long. At the very least word sets should be matched for positional bigram frequency (Mayzner & Tresselt, 1967) and possibly for the influence of a single high frequency neighbour (Grainger, O' Regan, Jacobs, & Segui, 1989; Segui & Grainger, 1990). Age of word acquisition is another factor that is known to affect reading ability (Laxon et al, 1988). A related problem is the use of rather dated norms (e.g. those of Carroll, Davies, & Richman, 1971; Edwards & Gibbon, 1964) as an index of children's word frequency. In some cases adult measures of word frequency have been used. However, one particularly important neglected variable in at least one study (Coltheart & Leahy, 1992) was an explicit match in terms of the total number of rime neighbours. Goswami (1998) notes that the regular inconsistent words share 140 rime neighbours, whereas the irregular inconsistent words share only 68 rime neighbours. Thus differences in reading performance for these word types may reflect rime body use rather than regularity.

One study that may overcome some of these problems is described by Laxon, Masterson, and Moran, (1994). This experiment investigated the effects of the number of body neighbours on the word reading accuracy of two groups of children aged 7: 05 and 9: 04, as well as investigating the effects of rime body class on reading. Words were carefully matched for rime neighbourhood size and positional bigram frequency. Results showed that neighbourhood effects were evident for both the younger and older children, whereas rime body effects were evident only in the older children. While this result is interesting, caution still needs to be maintained, as the neighbourhood and rime neighbourhood measures were general dictionary count measures which do not necessarily reflect the knowledge base that children may have generated from their reading experience.

This criticism highlights a more general problem with all of the experiments of this type. It is not clear to what extent differences in the pattern of word reading represent information about the network or rule system itself or differences in the effects of experience upon the number and type of word representations or rules. The developmental effects of orthographic consistency are difficult to assess because consistency effects reflect the accumulated and perhaps idiosyncratic experiences of children. It is particularly important to know about the rime body units that children have actually experienced before drawing conclusions about whether children use rime bodies.

An unpublished study by Stuart, Masterson, and Dixon demonstrates one possible way to overcome this problem. In this study, the number of rime body neighbours in children's lexicons was assessed by counting types and tokens in individual children's reading records. Stuart et al were able to demonstrate that despite having fewer rime neighbours, both by type (19.2 versus 22.3) or token (1004.5 versus 1422) children with a reading age of 8: 5 were able to offer more irregular pronunciations to irregular consistent words than to ambiguous inconsistent words, whereas children with reading age of 6: 7 were unaffected by rime body class. The study thus suggests that the better readers are influenced by rime body inconsistency whereas the poorer readers were not. However even here caution is required in interpretation, as it is not possible to be certain that children actually read or internalised the spellings of words that they have met in texts.

Well controlled factorial comparisons of regularity and consistency effects in reading are very hard to carry out properly. Therefore rather than try to describe the nature of the reading system by attempting to measure previous print experience, another approach is to investigate the results of learning upon the subsequent ability to read, and to relate improvements to other skills considered important to the reading process. This developmental approach has the advantage of providing an indication of improvement which can be measured in even the least experienced

readers. Results of such studies may also be more readily interpretable in terms of either rime or smaller grapheme unit use. This methodology is evident in studies of transfer of learning.

Transfer of learning experiments

The first studies of transfer of orthographic rime learning were carried out by Baron (1977). He taught five year old children to read words such as 'bat' 'at' and 'red', as well as letter segments 'b' and 'ed'. In a second phase the children were shown words which Baron describes as 'analogous', (e.g. 'bed') and words which he felt required the use of grapheme to phoneme correspondences, (e.g. 'bet'). Children read many more of the first word types than the second (90% versus 15%). Baron suggested that even young children used lexical analogies to start reading. However the results may have reflected the specific tuition on the onset and rime units used in the study (e.g. 'b' and 'ed'), rather than an analogy process. Pick, Unze, Brownell, Drozdal, and Hopmann (1978) also showed children words such as 'bug', and then showed them nonwords which shared the CV unit (e.g. 'bup') or the VC unit (e.g. 'sug'). Children were significantly better on the former than the latter nonwords, suggesting that they can make analogies but that these need not be based upon rime bodies. Goswami & Bryant (1990) argue that a stronger case may be made if children are able to use analogies to read words which contain more complex units than the simple letter sound relationships used by Pick et al, which may simply have served to activate the appropriate letter to sound rules that children may already know.

Goswami's clue word studies

In clue word studies children are told the pronunciation of one printed word and then asked to read other words which share letter strings with the clue word. The experiments investigate whether children can make an inference about the pronunciation of other words based upon the lexical information they have just been given. The first study by Goswami (1986) sought to investigate the development of

this skill in children between the ages of 5 and 7. The sample also included one set of children who were 'prereaders'.

The children were first given all of the experimental test words to read as a pretest measure of word reading ability. They were then shown a 'clue' word which could provide the basis to make analogies about new words. In each trial of the analogy test, children were first shown a card with a 'clue' word written upon it, such as 'beak', and were told what it said. Children were then asked to read other words - the 'target' words. These were the words that children had seen previously in the pretest reading phase. In the first study there were three types of target words which shared different sorts of similarity with the clue words. Some target words shared a letter string which represented the rime (e.g. 'beak' - 'peak'). Other words shared the 'head' - the onset and vowel(s) (e.g. 'beak' - 'bean'). The third set of words shared three letters with the clue word (e.g. 'beak' - 'bask').

If differences in target word reading were evident between the pretest and the second reading of the words at the posttest specifically for the analogous words, then this could reflect generalisation from learned clue words to unfamiliar words that shared orthographic and phonological sub-word units. The improvement in reading would be a measure of 'transfer' of clue word learning. For the children who could read some words at the start of the study, there was significant improvement in the ability to read previously unknown words if the words shared a common letter string. Furthermore, systematic differences in improvement were observed depending upon the sub-word unit of transfer. Greater transfer effects were observed for different parts of mono-syllabic words. Where familiar and unfamiliar words shared a rime (e.g. 'beak' - 'peak') greater transfer was found than to words that shared heads (e.g. 'beak' - 'bean'). Moreover, transfer to rime units appeared developmentally to precede head analogy transfer, as even the pre-readers showed a small but significant tendency to read analogous words that shared rimes, but did not show any tendency to read words that shared common head units. Similar

results have been found using a very similar procedure for assessing the use of rime induction in spelling (Goswami, 1988a).

These results are consistent with the idea that rime bodies play an important part in the development of reading ability. Transfer effects emerge earliest, and are strongest for words which share rime bodies with known words. One reason for the poorer performance for the head analogous words may be that these words do not respect the natural boundary of the rime unit. This suggests some interesting hypotheses about the pattern of transfer to other word segments. One prediction is that where the initial letter or letter cluster respects the onset segment of a word, transfer effects may be evident, but where the end of the word does not respect the rime body then little or no transfer may be witnessed. This idea was investigated in a study by Goswami (1991).

The experiment used a very similar design to the previous study and sought to contrast the improvement in reading where the clue word shares an initial consonant cluster with an unknown word (e.g. 'trim' - 'trot') and words where the letter cluster represents part of the rime of that word (e.g. 'wink' - 'tank'). The study also included two common letter control words (e.g. 'trim' - 'tint'). The transfer skills of a group of children who had reading ages of between seven and eight years were investigated. Results showed that significant transfer was found only when the unit of transfer was the onset.

This pattern of development, giving early pre-eminence to onset and rime awareness has recently been partially replicated in a study by Goswami (1993, Experiment 3). Prereaders and beginning readers performed transfer tasks where the unit of transfer was either the rime body (e.g. 'wink' - 'pink') the onset (e.g. 'trim' - 'trot'), the head (e.g. 'trim' - 'trip') or a vowel (e.g. 'trim' - 'slip'). Equivalent transfer effects were found from the heads and rimes for older readers, though no transfer to the single vowel were evident. Goswami failed to replicate the results of the 1991

experiment by finding nonsignificant transfer for onset analogous words. Goswami (1993, experiment 2) has also compared transfer to vowel digraph analogous words (e.g. 'meat' - 'heap') as well as rime analogous ('beak' - 'peak') and head analogous words ('beak' - 'bean'). Results showed strong improvements in reading both head and rime analogous words ($p < .01$) which did not differ from each other statistically, and modest but significant improvement for vowel digraph analogous words ($p < .05$).

Despite some failures to replicate previous findings, Goswami interpreted the results of her studies as suggesting that analogy transfer emerges earliest, and is greatest when the common orthographic units between the known and the unknown word map onto the phonological subsyllabic unit of the rime. This suggests that the facility witnessed in rime transfer may be related to children's ability to detect rimes in phonological awareness tasks. As was noted in the first chapter, some studies have found a strong relationship between early rime awareness and subsequent reading development (Bradley & Bryant, 1985; Maclean et al, 1987). Goswami (1990) has argued that as children are able to categorise sounds on the basis of onsets and rimes, then they may use this information to generate expectancies about the consistency of the letter strings used to represent those sounds. One possibility then is that the ability to perform rime analogies represents a link between early rime awareness and the development of reading skill. This has been investigated by considering the relationship between phonological awareness and the ability to perform orthographic analogies in the clue word task.

Goswami (1990a) gave 35 children with a mean age of 7 years a standard reading test, a test of receptive oral vocabulary, the Bradley test of auditory organisation (Bradley, 1980) and a phonemic awareness task (phoneme deletion), as well as assessing children's ability to perform analogies in the clue word task. Results were analysed in fixed order multiple regression analyses with vocabulary as the first step and with analogy transfer skill as the dependent variable. Goswami found a

strong and significant relationship between ability to categorise rimes in both the medial and final oddity tasks considered as separate measures of rime awareness and the number of orthographic analogies that children made, even after verbal ability was entered as the first step and phoneme deletion skill was entered as the second step in regressions. The relationship between the phoneme deletion task and rime analogy transfer was less strong when entered as the last step in analyses. These results were confirmed in a study by Goswami and Mead (1992), and have also been reported in subsequent studies (Peterson & Haines, 1992; Muter, Snowling, & Taylor, 1994). These findings are consistent with the notion that phonological rime skills and orthographic rime generalisation skills are closely related, and provide supportive evidence for a causal interactive model of reading development.

Goswami (1993) argues that early reading can be characterised by the establishment and use of phonologically underpinned direct orthographic recognition units, in an interactive analogy model. The privileged phonological status of onset and rime units is reflected in the stronger phonological underpinning of orthographic units corresponding to onsets and rimes in early word learning. As these recognition units are thus well specified, they then enable children to recognise the common segments in analogous words and to read new words by analogy. This has been called the 'Phonological Status' hypothesis (Goswami, 1993).

Evaluation of the interactive analogy model

Theoretical issues

The interactive analogy model characterises reading as a strategy based upon the phonological skills and expectancies that children bring to reading print. The account has strengths in being an explicit causal model of reading development that is consistent with models of skilled reading which emphasise the role of rime bodies (Kay & Marcel, 1981; Patterson & Morton, 1985). It also provides a model of early self-teaching, as, in contrast to the awareness of phonemic information which may require explicit tuition (Morais, 1991; Seymour & Evans, 1994) knowledge of

subsyllabic rimes is available to children prior to formal instruction (Bradley & Bryant, 1983; Maclean et al, 1987). Despite these strengths, the model suffers some weaknesses in terms of the generality, validity and theoretical interpretation of findings. These issues are considered below.

The generality of findings

The rime analogy model addresses the use of analogies from monosyllabic words that share rime neighbours. The model will not provide an explanation of how children read 'unique' words such as 'soap' which share no rime neighbours. Analogies to bisyllabic words have also not been considered to date despite the fact that such words are common even early on in children's reading vocabularies (Coltheart & Leahy, 1992). The model also appears to describe early reading development best in 'opaque' alphabetic orthographies. Cross linguistic comparisons, e.g. with German, (Wimmer & Goswami, 1994; Wimmer, Landerl, & Schneider, 1994), have suggested that grapheme level units rather than rimes are used early in reading by German children because the orthography is more regular, or 'transparent' than English. Wimmer et al assume that onset-rime representations may be used later in reading to map more complex units (e.g. 'str-').

Wimmer et al (1994) report that a German version of the oddity task correlated only weakly with reading and spelling in the first year of reading instruction, though it was strongly correlated with reading ability at grade three and with spelling ability at grade four. This is consistent with a view that orthographic onset and rime representations develop as a result of substantial experience of the statistical properties of the orthography rather than, or as well as, through the early use of phonological skills developed prior to reading instruction. Interpretation of this result must be undertaken with some caution as no measures of phonemic awareness or more general measures of ability, such as verbal intelligence were taken, so it is not yet clear whether the link between rime awareness and reading is as specific in German as in English.

Interpreting improvements in target word reading

Another theoretical problem for the analogy model concerns the developmental improvement in rime word reading in the clue word task. While improvements for the rime words in grades 1 and 2 are equally strong (children read on average two extra words at posttest, which represents nearly a 40% improvement), rime use by prereaders is rather modest, with an average of less than one word read correctly at posttest, reflecting only a 7% improvement. If preschool rime awareness determines reading ability, then the interactive analogy model does not explain why this developmental improvement in rime reading occurs. Equally a detailed explanation of why transfer occurs to other non-status units later in development is also lacking. It is not clear whether this represents the use of grapheme to phoneme correspondence rules, or whether other large letter unit analogies, e.g. head analogies emerge. In either case, the finding of equivalent transfer to head and rime analogous units reported by Goswami (1988b, 1993) suggests that the advantage for rimes is rather short lived in young children.

Sometimes transfer effects are confounded by the size of the shared units in clue and target words and hence the informativeness of clue words as a guide to target word pronunciation. In Goswami's 1993 study for example, while head and rime units share similar sized letter strings, (e.g. 'beak' - 'peak' and 'beak' - 'bean'), this is not the case for vowel transfer (e.g. 'beak' - 'heap') so the role of vowel induction has not been properly assessed. It is important in these cases to be aware that other ways of analysing transfer should be considered. One approach is to take the number of analogies made, irrespective of whether the rest of the word was pronounced correctly, rather than the number of correct pronunciations of whole words as the dependent variable, (Goswami, 1988b; Savage, 1997).

These measures can often produce very different results to those of the traditional measure and probably provide a better index of children's ability to apply sublexical inferences. A recent study of analogy use in early spelling development

(Nation & Hulme, 1996) compared transfer to target words sharing heads (e.g. 'corn' - 'cord'), rimes (e.g. 'corn' - 'horn') and vowel digraphs (e.g. 'corn' - 'lord'), as well as unrelated control words. The dependent variable was the number of analogies made. Results showed significant and equivalent transfer in all three analogous conditions, suggesting that early spelling ability does not take advantage of rime units over other subsyllabic units. Savage (1997, experiment 2) was only able to replicate Goswami's 1991 finding of privileged onset transfer when the total number of analogies made rather than the number of correct responses was the dependent variable in analyses.

Another problem with the interactive analogy model is the finding that improvement in the use of prompted rime analogies is not correlated with reading ability (Bruck & Treiman, 1992; Goswami, 1986; 1990a; Muter, Snowling, & Taylor, 1994). This could leave the model open to the criticism that the results are artefactual, whereby analogy transfer represents a 'natural but infelicitous strategy' (Bruck & Treiman, 1992). A final problem concerns the extent to which the model can explain the relationship between phonological awareness and reading. As was noted in the first chapter, one problem for the view that early rime awareness underpins later reading performance is that the ability to detect rimes cannot be equated with the conscious ability to manipulate such units (Morais, 1991; Seymour & Evans, 1994). Chapter 1 also revealed that while the evidence supported a link between phonemic awareness and reading, there have been some notable failures to replicate links between onset-rime awareness and reading ability (Lundberg et al, 1988; Muter et al, 1997). It was concluded that models based upon rime awareness may be less well underpinned than has previously been assumed.

Empirical evaluations of the interactive analogy model

The analogy model has also been subject to empirical scrutiny. Three issues in particular have been considered by researchers: 1) the role of grapheme to phoneme knowledge in inference use; 2) the short-term nature of learning involved in

the clue word studies; 3) the ecological validity of the clue word task. These issues are therefore considered in detail here.

The role of grapheme to phoneme knowledge in inference use

The results of a recent study (Ehri & Robbins, 1992) appear to question the assumption that children can use rime analogies without some prior understanding of a phonemic code. In their study, six year old children were divided into two reading ability groups based upon their performance in reading five simple nonwords. This nonword task was designed to assess children's ability to use a recoding strategy. Children who performed reasonably well on this task were labeled 'decoders', and the second group who could read few or none of the nonwords were labeled 'non - decoders'. Both groups of children were then taught to read words in an artificial orthography such as 'KĀĀV' (pronounced 'cave'). Children were then shown similar words which shared orthographic rimes with the taught words (e.g. 'SĀĀV') or shared vowel digraphs (e.g. 'RĀĀN') and asked to read them. Results showed that only the decoders showed significant improvement in their ability to read the analogous words. Ehri and Robbins concluded from this that children need some rudimentary decoding skills before they can use a process of lexical analogy.

There are a number of problems with drawing this conclusion. One important problem is that the task used to categorise the children as decoders and non-decoders is ambiguous. One problem is that some of the stimuli are real words. Secondly, of the five stimuli that children were asked to read - 'kin', 'fop', 'rut', 'mal', and 'bev', all but the last two share many rime body neighbours with many other simple CVC real words. Some of the stimuli could therefore have been read through a process of analogy rather than through a letter by letter decoding strategy as implied by Ehri and Robbins. A further distinct problem with the study is that the pattern of transfer effects may have been due to differences in the extent to which children adjusted to the use of an artificial orthography, rather than to differences in the ability to perform analogy.

Others have also found that phoneme awareness is associated with the induction of orthographic onsets and rimes. The study by Byrne and Fielding-Barnsley (1989) discussed in chapter 2 described the ability of very young children to perform onset analogies. Children were taught the words 'Mat' and 'Sat', and then asked which word of two words presented ('Mow' and 'Sow') said 'sow'. Only children with letter-sound knowledge and phonemic awareness were able to perform the task. A recent study by Walton (1996) also suggests that phonemic awareness is implicated in analogy transfer. In this study, rime awareness, letter-sound knowledge, and phonemic awareness, as assessed by a phoneme identity task (Yopp, 1988) were correlated with analogy test performance on a version of Baron's (1977) transfer task. The strongest correlate of transfer was performance on the phoneme identity task. After this measure was entered into a fixed order multiple regression analysis, the rime awareness measure did not explain a significant proportion of the variability in rime transfer.

The short term nature of the learning task

Another criticism of Goswami's analogy model is that the learning required to derive pronunciations may be of a rather superficial nature. Bruck and Treiman (1992) trained children to read analogous pairs of words in two 10-15 minute sessions presented over two days by highlighting their phonological and orthographic similarities. These words were either rime analogous words (e.g. 'PIG' - 'BIG'), head analogous words (e.g. 'PIG' - 'PIN'), or vowel analogous words (e.g. 'PIG' - 'RIB'). The experimenters took two measures of word learning, one was a measure of the speed of learning, and another was a measure of retention of learning presented the day after the learning phase was completed.

Results showed that while the group taught to read the rime words learned the pronunciations of the 10 training words faster than the other groups learned head and vowel analogous words, children who were taught the rime analogous words were significantly worse at retaining the knowledge of word pronunciations than both of

the other taught groups. One potential problem with the study is that differences in the retention of word knowledge could simply reflect differences in the amount of training (Goswami, 1993). However the pattern of results remained even when differences in the number of training trials taken to learn the words was adjusted by covariance of the number of learning trials. The results of the study by Bruck and Treiman therefore suggest that caution may be necessary in interpreting the short-term improvements in word learning studies.

The results of another study (Wise, Olson, & Treiman, 1990) have also suggested that the short term advantages for rime analogous words are not reflected in sustained improvements in reading performance. Wise et al taught children to pronounce single words using a computer feedback 'teacher'. Early learning advantages were found for words segmented at the onset-rime boundary, (e.g. CL-AP) over words with post-vowel segmentation (e.g. CLA-P). They found however that these advantages were not found in a posttest delivered thirty minutes later, again suggesting that short-term improvements in the use of rime units are not reflected in long term improvements in reading performance.

The ecological validity of the learning task

A related criticism of the analogy model concerns the nature of the tasks used to study transfer effects. As previously noted, Goswami and Bryant (1990) argue that an analogy strategy is a spontaneous strategy which may make an important contribution to the development of reading in naturalistic settings from the earliest age. One of the most interesting aspects of this theory is that the transfer effects reflect the 'natural' phonological propensities of the child rather than the result of explicit tuition. They argue that children learn to associate onsets and rimes with strings of letters with very little explicit instruction to do so. However the amount of training required to perform analogies is an important practical and theoretical issue. Early research (Baron, 1977, 1979; Marsh et al, 1981) appeared to show that explicit teaching of an analogy strategy was necessary in order for young children to use it.

More recently some have criticised Goswami's model on educational grounds for its very lack of focus on explicit teaching (Chew, 1994; though see also Goswami, 1995).

Irrespective of such educational implications, it is clear that the empirical evidence for the use of a rime analogy strategy comes from experimental clue word tasks in which either explicit emphasis is placed upon the subsyllabic unit of transfer in the clue word teaching phase (Goswami, 1988b) or where very specific concurrent clue word information is provided (Muter, Snowling & Taylor, 1994; Savage, 1997). It is clear therefore that the extent to which the positive pattern of analogy transfer witnessed in the clue word tasks is independent of purely procedural and situational factors particular to the test is an important issue which is investigated in the next section.

One exception to this description of the analogy literature is a recent study by Duncan, Seymour and Hill, (1997). They compared performance in reading nonwords based upon known words in sight vocabulary for young children with high and low rime awareness. Duncan et al. found that children with well developed onset-rime phonological skills showed no advantage in reading rime analogous nonwords presented to them in isolation compared to children with poor phonological skills. Duncan et al. interpret this finding as suggesting that young children do not spontaneously perform lexical analogies from their sight vocabularies. As Duncan et al did not check how many rime analogous real words the children knew, it is not clear whether young children are limited in performing transfer because they have a limited number of analogous words in their sight vocabulary (Bowey & Hansen, 1994; Muter, Snowling & Taylor, 1994; Savage, 1997) or because the children lack the ability to perform spontaneous analogies at this age. Nevertheless the study does show that children do not appear to make spontaneous rime inferences on the basis of one known clue word in naturalistic circumstances. This is an important observation.

The role of the clue word in the clue word task

In the clue word studies several variations of a transfer procedure have been used to investigate orthographic analogy. In some studies of transfer, (Goswami, 1988b, 1990b, 1991; Muter, Snowling, & Taylor, 1994) a methodology was employed in which the clue words were pretaught, and the target words were subsequently presented. These studies are discussed later. A majority of the clue word studies to date (Goswami, 1986, 1988a, 1988b, 1990a, 1990b, 1993; Goswami & Mead, 1992) have used a testing procedure whereby both clue word and target word are simultaneously presented to the child. In these studies the target word is placed beside the clue word and the children are told - "this word says (e.g. 'beak'), what does this word say?". In one sense this procedure could be described as a 'clean test' of a developmental skill (Calfree, 1977) as few additional task demands are imposed. Performance is therefore unlikely to be affected by attentional, cognitive or other task factors that might otherwise obscure task performance in very young children. Nevertheless, if it is maintained that children can use a process of lexical analogy in the classroom environment (Goswami & Bryant, 1990; Goswami, 1991, 1995), then it is important to demonstrate that children can perform lexical analogies despite more taxing task demands, if these demands are likely to be made in naturalistic reading.

An assumption that is often implicitly made in the literature is that the results of clue word studies, including those using a contiguous clue word procedure, are comparable to reading in more naturalistic situations. However there are a number of differences between the use of analogy in a clue word task and the use of an analogy strategy in naturalistic reading tasks that may render the assumption of equivalence between the two tasks invalid. Two problems with the concurrent clue word procedure outlined above lie in the possibility that it allows children to take advantage of strategic expectancies particular to the clue word task, and in the substantial differences that exist in terms of the precision of stored phonological and

orthographic knowledge required to perform the task. These issues are discussed below.

Strategic effects

Concern that the use of strategies in experimental reading tasks may be unrepresentative of normal reading abilities has a long pedigree, and can be traced back at least as far as Huey's seminal work on reading (1908). In the clue word task there are a number of ways that children might be able to use a strategy that may allow them to 'read' analogous words, but which does not mean that they are retaining any permanent representation of orthographic rimes in the mental lexicon. One possibility is that children use some form of rime generation heuristic. That is to say, children may realise that rimes are often required in the clue word task and therefore simply generate rime pronunciations irrespective of the orthography, or perhaps in conjunction with a cursory analysis of the first letter of a target word. This could be a problem given that rimes appear to be so salient for young children. Arguably the clue word tasks do provide some protection against this possibility as, in the majority of studies, rime responses would only be correct on a third of the words.

Goswami (1993) argues that there is no evidence that children use this indiscriminate riming strategy despite the fact that in one study (Goswami, 1990b) she found significant priming from orthographically dissimilar words which shared rime phonology (e.g. 'head'-'said'). This finding suggests that children are using a purely phonological strategy, possibly akin to the phonological priming effects reported in the adult literature (Tanenhaus, Flanigan, & Seidenberg, 1980). Since the largest transfer effect in this experiment was for words with shared orthography and phonology (e.g. 'head'-'bread'). Goswami suggests that a phonological priming effect contributes to, rather than explains the pattern of transfer witnessed in her task. While this study shows that children at least consult orthographic sources during the transfer task, it is not clear that the transfer effect can be partitioned into discrete

phonological and orthographic components. Alternatively, it may be that the effects of phonological prompts and clue or target word orthography may exert a combined, rather than a distinct influence on target word reading. Furthermore, if Goswami assumes that part of the rime transfer effect reflects a purely phonological strategy then this leaves open the possibility that the advantages for rime over other units such as heads may reflect phonological activation rather than superior ability in using orthographic rime analogies (Bowey & Hansen, 1994; Bowey & Underwood, 1996; Savage, 1994).

Another kind of problem is that the temporal contiguity of the clue and target words during the analogy task emphasises the similarity between the known and the unknown words. In this case orthographic knowledge may be central to transfer, but the nature of the task may induce the child to consider a strategy that would not be considered, or is not helpful in other situations, such as when reading continuous text. This problem was noted by Goswami (1988b) -

" It could be argued that the word game used [in experiment 1] artificially promoted the use of analogy, as the only two words that the child saw in a given trial were the clue word (e.g. beak) and the test word (e.g. peak or bean). This might have enhanced any tendency that children have to make analogies in reading new words, or could even have encouraged them to use a strategy they would not normally employ".

The particular concern about the use of strategic expectancies in the analogy task is an important one given the theoretical and educational implications drawn from the studies. Other researchers have also drawn attention to this problem. Hansen and Bowey (1992) distinguished between the use of an automatic orthographic analogy system, and the use of a merely task-specific attentional strategy to derive pronunciations. They argue that while rimes are salient for young children, this does

not imply their automatic use in reading. They also suggest that the greater time constraints imposed by reading connected prose might render a conscious rime strategy less effective.

Hansen and Bowey reason that one way to discern whether children are merely using an attentionally based rime strategy or an efficient orthographic system is to investigate the effects on naming speed of blocking pairs of rime words together. They point out that, for adults, blocking rime words produces no naming latency advantage over unblocked trials (Bowey, 1990). The subjects in their study were nine year old readers of average reading ability. Results showed that, unlike skilled readers, the latency advantage for rime words over non-rime words was dependent upon whether the words were blocked together rather than randomly presented during the experimental trials. No significant facilitation in naming speed was found for rime analogous words in the randomised condition. Hansen and Bowey interpret their finding as suggesting that children use strategic expectancies in reading rime analogous words. They argue that the automatic use of an orthographic analogy strategy emerges only in relatively mature readers.

This finding does not rule out the possibility that children can develop an automatic rime reading skill with repeated learning sessions. Lemoine, Levy, and Hutchinson (1993) found that even poor readers were uninfluenced by blocked versus random presentation of words on transfer of learning if sufficient practice was given. In the training phase of the schedule, children were shown 10 sets of 12 rime analogous words (e.g. 'rain', 'brain', 'gain', 'main') in a total of 34 learning trials presented cumulatively over 4 days. In the retention phase given four and seven days later, no advantage was found for presentation method upon naming latency though early gains in accuracy were evident in the blocked presentation group.

A recent study of rime use has also attempted to take advantage of comparisons between blocked and unblocked learning trials to evaluate rime and

vowel unit use. Greaney and Tunmer, (1997) presented 30 normal readers with a reading age of 7: 5 and a reading age matched group of older poorer readers with lists of words containing a high frequency word designed to be familiar to the children, along with four analogous words sharing either the rime (e.g. 'ball', - 'tall', 'wall', 'hall', 'fall') or the medial vowel (e.g. 'farm' - 'hard', 'start', 'card', 'part'). Children were shown word lists either in a blocked or unblocked form. An assumption was made that children would use the most familiar word (e.g. 'farm') to make analogies to unfamiliar words in the list without the need to draw attention to a specific clue word. However the design of the study, where no pretest - posttest element was incorporated provides no protection against the possibility that children simply knew different numbers of words in each experimental category. Furthermore the experimental word lists, which contained many analogous words may well have encouraged children to use inductive strategies that they would not have used in reading connected prose.

Training Studies

One way to evaluate the effects of rime knowledge on reading independent of particular prompted strategies may be to look at the effects of training children to identify rimes. However, as was noted in chapter 1, training studies do not provide particularly clear evidence that children learn to read by using rime analogies. Even when those studies focus clearly upon rimes (Bradley & Bryant, 1983; White & Cunningham, 1990), it is very difficult to know which aspect of training improved children's reading performance, or what aspect of performance has in fact improved. However, one study by Peterson and Haines, (1992) may be informative about the effects of transfer because it incorporated a more specific measure of outcome than training studies typically use.

Peterson and Haines first evaluated transfer from words that share rimes (e.g. 'cold' - 'bold') heads (e.g. 'cold' - 'colt') or common letters (e.g. cold' - 'cone') in a very similar way to that in Goswami's studies. Children's onset-rime, word, and

phoneme awareness, as well as letter-sound knowledge were also assessed. Children were then trained on 10 different sets of 6 rime analogous words, mainly containing short vowels (e.g. 'dad', 'mad', 'lad', 'gad', 'tad', 'fad') over a period of one month. In the final phase children recompleted the analogy transfer task and the measures of phonological awareness and letter-sound knowledge. Results showed that children made greater improvements in rime word reading than in reading other word types following training suggesting that they can take advantage of rime training in their subsequent spontaneous transfer.

One problem with this study is that it uses the same prompted transfer task as Goswami has used for its outcome measure. The study does not indicate whether children can go on to perform spontaneous and unassisted transfer following training on rime bodies. Furthermore, as training consisted of an exclusive focus on rimes, it does not indicate whether attention to rimes or other units such as heads is equally effective in promoting reading transfer. Another problem in evaluation of transfer is that the head analogous words included several poorly selected items on orthographic (e.g. 'lamp' - 'lamb'), phonological (e.g. 'coat' - 'coal'), and morphemic (e.g. 'band' - 'bans') grounds which may have affected head transfer. Finally it is worth noting that the results of training were to improve phonemic as well as onset-rime awareness and letter sound knowledge. Transfer improvements may therefore have reflected children's development of the ability to abstract and use graphemic level information.

Representations of orthographic knowledge

A second type of concern with the clue word task is that the information presented during transfer allows children to perform a task that they would not be able to do in other situations, due to the imprecise nature of their early representations of the orthography. In naturalistic reading tasks an analogy strategy will nearly always require the use of stored information about similar words rather than fully specified and concurrently available information from 'clue' words. The cognitive abilities required to perform transfer in the clue word task and in

naturalistic reading are not therefore equivalent. An important skill in reading by analogy is the ability to detect that known and unknown words share an orthographic sequence. As noted in chapter 2, a number of theorists suggest that the initial stages of learning to read are characterised by very poor stored representations of the orthographic and phonological structure of known words. In Frith's logographic stage (Frith, 1985) the initial processing of a word is based upon rather sparse information such as a word's distinctive features. Similarly Ehri, (1992); Perfetti (1992); and Stuart and Coltheart, (1988) have characterised the earliest stages of a functional lexical representation system as lacking both quantity and precision, and in particular have noted that vowels are poorly represented in early reading. The results of some transfer studies are also consistent with this view (Thompson et al, 1996).

If children's stored orthographic and phonological representations for known words are initially this under-specified then the information they contain would be insufficient to sustain analogical transfer to unfamiliar words. Savage (1997) argued that one way that the clue word prompts may aid transfer is by temporarily supporting poor representations of orthographic and phonological word information. Caution may therefore be required in suggesting that children can take advantage of an analogy strategy until the skill is demonstrated in situations where the task demands match those required in naturalistic conditions. Clearly, a stronger case could be made for the use of analogy in early reading if transfer were demonstrable under conditions where the clue word is not present to provide prompts to aid performance (Muter, Snowling, & Taylor, 1994; Savage, 1994, 1997). If the teaching and transfer stages of the clue word task were separated it may be possible to answer concerns about the role of the clue word in supporting orthographic processing. Such a separation would also go some way towards addressing the issue of strategic expectancies in the clue word task. Studies that have attempted to do this are considered below.

Studies of transfer without contiguous clue word prompts.

To date five studies have investigated transfer in the absence of concurrent prompts. Goswami (1988b, experiment two) pretaught children two clue words and then presented them with target words to read in isolation. The main focus of this study concerned the effects of consistency of clue word pronunciation on transfer, so children were taught pairs of clue words such as 'peak' and 'weak' or 'peak' and 'steak'. Transfer effects were only investigated for rime analogous words. Results showed improvements in target word reading which were stronger for consistent than inconsistent pairs, suggesting that children develop an awareness of inconsistency which influences the probability of transfer. Specific tuition in segmentation and blending of rime units in both clue words was given during the teaching phase. It is extremely likely that this explicit emphasis on the rime unit facilitated transfer when the clue word was not present. A similar problem exists in Goswami's (1991) study in which specific tuition at the subsyllabic level was given. While greater transfer was found following specific tuition at the onset level than to non-onset units it is not possible to draw any strong conclusions from this study about transfer in naturalistic reading which may require a more spontaneous transfer skill.

There is evidence (Walton, 1996) that rime transfer is indeed facilitated by explicit segmentation of clue words into onset and rime units while learning them at pretest. In this study, transfer from clue words which were segmented into onset and rime units was compared to the transfer from clue words which were taught as unanalysed whole units. In both cases, clue pairs were pretaught and one word of the pair remained present during transfer. Transfer was significantly greater in the segmented condition. Walton concluded that this preteaching had helped to make the rime units particularly salient to the children.

Goswami (1988b, Experiment 3) also investigated transfer effects when children were given target words embedded in prose passages. In this study the words used were a subset of those used in previous clue word tasks requiring single

word reading. The clue words were either taught as part of the title of the story, or as part of the title and repeated on the first page, or not taught at all. No information on segmenting the clue word was provided. The study investigated transfer to rime, head, and common letter control words. Results showed that transfer occurred to analogous words only when the title was taught. No additional transfer was found when clue words were repeated. Interestingly, unlike the single word reading task, equivalent transfer was witnessed for head and rime analogous words. Thus, although they used the same word sets, the prose studies did not mirror the findings of single word transfer studies. This could suggest that different processes (such as phonological priming) are involved in single word reading in clue word studies, compared to reading continuous prose (Bowey & Hansen 1994; Bowey & Underwood, 1996).

In the study by Goswami (1990b) in which transfer was investigated to rime analogous words that either shared phonology and orthography with taught clue words (e.g. 'most' - 'post'), or shared orthographically inconsistent but phonologically consistent rimes (e.g. 'most' - 'toast') or phonologically inconsistent but orthographically consistent rimes (e.g. 'most' - 'lost'), there were also differences in the extent to which children would transfer clue word knowledge to create a nonword pronunciation in the 'most'-'lost' condition. In the clue word task children sometimes produced the pronunciation of 'lost' so that it rhymed with the word 'toast', whereas in a prose reading task they rarely responded in this manner. This has been interpreted as suggesting that children use a nonword check procedure in reading connected prose. However other interpretations of this finding are possible.

Hansen and Bowey (1992) have interpreted the differences in performance between the two single word and prose reading studies as suggestive of two very different strategies in the two tasks. They argue that the equivalent transfer to head analogous and rime analogous words in the prose task in the 1988 study means that performance can be accounted for equally well by the activation of grapheme-to-

phoneme correspondence rules as by an analogy strategy. Hansen and Bowey argue that as most of the control words in the clue word studies are not controls for grapheme-phoneme correspondence because the vowel digraphs are split (e.g. 'beak' - 'lake') little or no transfer would therefore be expected on the basis of these words. One additional problem with the prose studies is that extra contextual facilitation is provided by the story title, so the results could at least partly reflect the effect of the role of prose context upon word reading. Performance in the clue word task, where rime transfer advantages are evident over beginning analogous words could reflect the strategic use of phonological rimes.

The literature on early analogy considered to this point does not therefore provide any clear evidence that young children can make spontaneous use of lexical analogies. In order to provide evidence on this important point, Muter, Snowling, and Taylor (1994) taught six year old children isolated clue words (e.g. 'ring') until they could name them reliably. No information on segmentation was given during the teaching session. In a subsequent transfer phase that followed immediately after learning the clue word, children were shown rime analogous target words (e.g. 'sing' or 'king') and common letter control words, (e.g. 'gain' or 'sign'). For one group of children the clue word remained present during the analogy task, for a second group it was removed.

Significant transfer was evident from pretest to posttest for rime analogous words in both conditions, suggesting that the children had used orthographic analogies to read the previously unfamiliar words. However, only modest rime transfer effects were found when the clue word was absent during the posttest ($p < .05$). This suggests that the contiguity of the clue and target word does have an effect in enhancing analogy transfer. Further analysis revealed that when the clue was absent, transfer was correlated with measured reading ability, whereas when the clue was present there was no such association with reading skill. Muter et al argue that the clue word plays an important role by providing an orthographic referent, and they

interpret the finding that the analogy transfer effect is much reduced in the absence of the clue word as evidence that children will not perform analogies in naturalistic situations with any degree of frequency.

The study by Muter et al is informative, but also raises a number of important questions (Savage, 1994, 1997). One potential problem is that the rime analogous words are present on half of all transfer trials, and are in families of four words. This may increase the chance that children may take advantage of a rime heuristic or a task-specific strategy, even in the absence of concurrent prompts. Secondly, the effects of concurrent prompts upon transfer from letter strings such as heads has not yet been investigated. Goswami (1993) argues that the advantage for rime over head analogous words reflects the phonological underpinning of orthographic rime representations. The model therefore predicts an advantage for 'status' units such as rime analogous words over 'non-status' units such as head analogous words in spontaneous transfer, as well as in situations where transfer is supported by contiguous clue word information.

Thirdly, it is not clear whether different forms of contiguous clue word information play a particular role in promoting analogy transfer. In most of the clue word analogy tasks, both phonological and orthographic information about the clue word is presented, and according to the interactive analogy model both sources of information play a part in facilitating transfer. In the study by Muter et al, only orthographic information was presented and yet significant additional transfer was found when the clue word was present. As Muter et al themselves state, it is not possible to decide whether the presence of the clue word facilitated transfer by providing an orthographic prompt or by facilitating access to a phonological representation of the clue word. One question of interest therefore is whether other aspects of clue word information foster transfer in the clue word task. Finally, it is important to know whether older readers performing analogy tasks are also affected by the concurrent prompts provided by the clue word task.

Savage (1997) investigated these issues by evaluating the conditions under which transfer occurs. The sample were 48 normal reading children with a mean age of six years and five months. In the first experiment the effects of purely phonological prompts, purely orthographic prompts, and combined (phonological and orthographic) prompts, were compared to a no prompt baseline condition. All children were pretaught the clue words to a criterion of three successful pronunciations in a row. The phonological prompt group then received a spoken reminder of a previously taught clue word at posttest. The orthographic group received a visual reminder of the clue word at posttest. The combined prompt group received both spoken and visual reminders of the clue word. The no prompt group were taught the clue words prior to the posttest but received no prompts during the transfer phase. Rime transfer was found to be equally strong for groups given either combined or phonological prompts, suggesting that phonological prompts play a key role in facilitating transfer. No transfer was evident when a purely orthographic prompt was presented at posttest. No advantage was found for rimes over heads in the no prompt condition, though a small but significant advantage for rimes over control words was found ($p < .05$).

Experiment 2 investigated transfer to onset analogous words (e.g. 'stilt' - 'stem'), medial vowel analogous words (e.g. 'stilt' - 'milk'), and grapheme to phoneme correspondence controls, (e.g. 'stilt' - 'sent'), in an older group of children with a mean reading age of seven years and six months. The prompt groups were the same as those in experiment 1. In addition, an untaught control group were included as a baseline to measure transfer in the unprompted transfer group. No transfer effects were found at all, suggesting that even these relatively mature readers were not adept at using onsets to accurately pronounce analogous target words. However an analysis of the number of analogies made, which considered the number of correct applications of analogous units even if the word was not correctly pronounced (e.g. 'steam' as a response to 'stem', after being shown the clue word 'stilt'), revealed significant transfer effects. These transfer advantages were

only evident in the two groups that received phonological prompts. No significant transfer was found at all in the absence of such prompts.

Finally the analysis compared transfer to different classes of medial vowels. According to Treiman (1984b) adults performing oral language tasks more readily associate fricatives with the coda (end of the rime) whereas liquids are associated with the peak (beginning of the rime). For rime units such as /ilk/, the natural parsing would be il + k, whereas for /isk/ it would be i + sk. Treiman (1992) has speculated that similar effects may be found in children's reading. If this were true then it may have affected transfer from medial vowel analogous words sharing vowel-liquid units, (e.g. 'stilt' - 'milk'), which may be easier to perform than words sharing vowel-fricative units, (e.g. 'frisk' - 'mist'). The analysis of transfer to medial vowel digraphs allowed investigation of this possibility. The medial vowel analogy words were coded into liquid (e.g. 'il' in 'stilt' - 'milk'), nasal (e.g. 'un' in 'blunt' - 'fund') and fricative (e.g. 'is' in 'frisk' - 'mist'). Analysis of transfer revealed no effects of vowel cohesiveness. In fact the units deemed most difficult in transfer (fricatives) showed a modest advantage over other units. Similar results have been found by Goswami (1991) suggesting that sub-rime analysis does not influence transfer in the clue word task.

The present studies

The first stage of the present work seeks to extend work by Savage (1997) upon improvements in target word reading in the clue word task to clarify two important questions left open in the previous transfer studies.

1) The role of the concurrent phonological prompt

The role of the phonological prompt given during the clue word task remains unclear. Since Savage (1997) taught children a clue word immediately before the purely phonological reminder was given, it is not clear whether improvements in target word reading in this condition reflects the activation of previously stored

orthographic information, or is a more direct effect of the concurrent phonological prompt on target word reading.

Evidence that phonological clue word prompts can activate orthographic information has been provided by a recent study by Nation and Hulme (1996). Nation and Hulme demonstrated that a phonological prompt can facilitate transfer to analogous nonwords in spelling. In their study no teaching of clue words was given at pretest, though clue words were selected so as to be familiar to children. Transfer was investigated to rime (e.g. 'green' - /trin/), head (e.g. 'green' - /grin/) and vowel analogous nonwords (e.g. 'green' /pim/). Equivalent transfer was found for all analogous nonwords. Nation and Hulme suggest that the phonological prompt can activate orthographic representations of word knowledge for prompted and analogous words within a distributed lexical system. The present study seeks to clarify the role of concurrent prompts by not exposing children in the phonological prompt condition to an orthographic representation of the clue word at pretest.

2) Transfer in the absence of concurrent prompts

Savage (1997) showed that in the no prompt condition no advantage was found for target words sharing onsets and rime with previously taught clue words (which were not present as prompts during the transfer phase) casting doubt on children's ability to spontaneously apply an analogy process to reading novel words. However since no measurement was made of children's ability to read the clue word at posttest, it is impossible to be certain that they had available the relevant orthographic analogue from which rime units could be spontaneously retrieved. Experiment 1 therefore seeks to clarify this issue by measuring clue word knowledge at posttest.

In the second phase of research the ability of children to make spontaneous inferences in the absence of concurrent prompts is further explored. Exposure to several words exemplifying letter-sound patterns is considered in these studies.

Several lines of evidence suggest that spontaneous rime inferences are more frequent if children know many words which embody orthographic rimes. Rime neighbourhood studies (Treiman et al, 1990; Bowey & Hansen, 1994) appear to indicate that a relationship exists between rime body use in nonword reading and the level of reading expertise. Furthermore, transfer in clue word studies in the absence of concurrent prompts is associated with the size of children's sight vocabulary (Muter et al, 1994; Walton, 1996). Experiments 3 and 4 therefore extend research on spontaneous lexical inference from rime and vowel digraph analogous words taught prior to the posttest phase. Finally Experiment 5 seeks to evaluate the nature of individual differences in reading transfer in this revised version of the analogy task, and their association with reading ability and other reading-related phonological skills.

Orthographic representations in inference tasks

Another important question surrounding orthographic inference tasks concerns the quality of children's representations of word knowledge at pretest. The interactive analogy model has generally investigated only the number of correct responses given for target words. However much research reviewed in the previous two chapters suggests that children are able to form partial word recognition units based upon early phoneme manipulation skills (Rack et al, 1994; Stuart & Coltheart, 1988). These theorists suggest that children often form representations of words at pretest which accurately represent boundary letters but where vowels may be inaccurately specified. Thus the word 'peak' may be misread as 'park' at pretest. However as discussed in chapter 2, a stronger test of the view that early partial representations are phonologically underpinned would be if boundary phonemes rather than letters were considered in error taxonomies. The first phase of error analysis in the present study seeks to extend the work of Stuart and Coltheart (1988) to examine the pattern of correlations between errors categorised on the basis of the phonemes shared with the word presented, reading ability and measures of phonological awareness.

A second issue concerns the possible role of partial representations of target words in facilitating transfer in the clue word task. Analyses of this type have not been undertaken to date, yet the relationship between transfer patterns and such pretest representations of target word orthography is potentially highly informative. One possibility is that target words given incorrect but partly accurate pronunciations at pretest are more likely to be read correctly at posttest than target words with pronunciations that are either unrelated or only distantly related to the correct target word pronunciation. For example, if the target word 'peak' was read as 'park' at pretest, where the boundary consonants are correctly pronounced, then this word may be more likely to be read than a word such as 'leak' misread as 'car', in which the boundary consonants were not accurately pronounced in the pretest paralexia. Importantly such analyses could also potentially reveal the size of the unit involved in transfer tasks. For pretest target word paralexias such as 'peak' misread as 'park', the subsequent presentation of a clue word 'beak' at posttest may allow children to derive the pronunciation of the medial vowel digraph rather than larger rime units in the target word because the boundary consonants of targets are already correctly represented. If transfer in the present analogy studies is associated with such word reading paralexias, then this could suggest that vowel digraphs rather than rimes are the functional units of transfer in the clue word task. An exploratory approach is then taken across the five studies presented here to investigate any links between transfer in the clue word task and target word paralexias at pretest.

Conclusions

Conflict and neighbourhood studies have suggested that children learn to read by applying letter sound knowledge, but use rime bodies relatively late in reading development. However, conflict studies have evaluated transfer on the basis of a single exception word, which may limit their relevance to reading other words. Some consistency studies have underestimated the complexity of investigating rime neighbourhood effects in young children. In contrast, clue word analogy studies

appear to provide evidence that even very young children perform analogies when it is based upon shared rime or onset. There is also reason to believe that children's phonological awareness plays an important part in the transfer process. This has been interpreted as supporting an interactive analogy model in which analytic orthographic skills are based upon children's early categorial phonological skills (Goswami, 1993). However interpretation of the transfer effects evident in a number of these studies is complicated by the provision of concurrent prompts. These prompts may assist the process of transfer in a way that is unavailable in naturalistic reading situations. The first study seeks to investigate the effects of different forms of prompts upon the pattern of transfer effects in the clue word task.

Chapter 4

The role of clue word information in the analogy task

Experiment 1

The review of the literature on children's use of inferences in early reading in chapter 3 suggested that one appropriate way to find out about children's inferential skills is through the use of transfer of learning studies such as the clue word analogy task (e.g. Goswami, 1986, 1993). Discussion of the clue word analogy paradigm has highlighted one major problem with the interpretation of findings: most studies use a testing procedure in which concurrent clue word prompts are present at posttest. Subsequent research (Muter et al, 1994; Savage, 1997) has shown that the absence or presence of these prompts significantly affects the level of inference use, suggesting that children may be less adept at using inferences in naturalistic reading settings than the interactive analogy model implies. However the mechanism by which concurrent clue word prompts act and their precise impact on the level and nature of inference use remains unclear. The main purpose of Experiment 1 therefore is to clarify three important as yet unresolved issues about the nature of inference use, namely (a) the function of phonological prompts, (b) spontaneous use of rime units to read novel words, and (c) the size of units involved in spontaneous inference use.

A further aim was to investigate the nature of paralexias in target word reading and their relationship to reading ability, phonological awareness, and patterns of improvement in target word reading in the clue word task. Work here sought to extend research carried out by Stuart and Coltheart (1988) by examining correlations between word reading paralexias and other reading measures when the error taxonomy is based on phonemic rather than letter overlap with the correct target word pronunciation. Together these investigations should clarify the nature and use of lexical inferences made on the basis of a single taught clue word.

Method

Participants

Sixty children (mean age 6 years 3 months, range 5 years 3 months to 7 years) from the infant classes of two West London primary schools took part in the study. Children were selected from a total of 91 children screened on the basis of reading ability prior to the study. In the screening sessions, ability to read was assessed using the British Ability Scales (BAS) single word reading test (Elliott, Murray & Pearson, 1983). Twenty three children who failed to achieve a reading age were excluded from the study; mean reading age for the remaining children was 6 years 3 months, (range 5 years 3 months to 7 years 7 months). Children were also shown the six clue words to be taught in the next phase of the study and eight children who could already read at least 5 of the 6 clue words were also excluded. Analysis of the BAS reading scores of the selected sample revealed that the distribution did not deviate markedly from normal: kurtosis ($k = 0.39$) and skew, ($s = 0.27$) were both non-significant. In addition to reading measures, children were also given the short form of the British Picture Vocabulary Scales (BPVS) to assess receptive vocabulary knowledge (Dunn, Dunn, Whetton & Pintilie, 1982). This test provides an age-normalised vocabulary score which is highly correlated with verbal I.Q. The mean BPVS score was 95.30, $SD = 13.82$.

Children were split into four 'prompt condition' groups matched for reading ability, clue word knowledge, and vocabulary ability on the BPVS. Equal proportions of children from each school were included in each group, thus controlling for possible effects of different teaching methods across schools. Each group contained equal proportions of girls (60%) and boys (40%). The mean scores on screening measures are presented in Table 4.1 (chronological and reading ages are expressed in months).

Table 4.1. Scores on screening measures across four prompt conditions.

Prompt condition	Age (months)	Reading age (months)	BPVS (standard scores)	Sex (m)	Clues
Combined	74.7 (7.89)	75.4 (6.65)	94.5 (12.4)	6	0.93 (1.33)
Phonological	75.3 (7.72)	75.9 (6.99)	95.5 (15.9)	6	0.93 (0.96)
No prompt	72.9 (5.96)	74.7 (8.59)	95.1 (13.8)	6	0.93 (1.28)
Untaught	74.9 (5.22)	75.1 (7.29)	96.3 (14.4)	6	0.93 (1.33)
Mean score	74.5 (6.69)	75.3 (7.24)	95.3 (13.82)	6	0.93 (1.21)

A 4 (prompt condition: combined versus phonological versus no prompt versus untaught) x 4 (measure: chronological age versus BAS versus BPVS versus clues known) Anova confirmed that matching was achieved on the measured variables. The prompt condition factor and the prompt condition by measure interactions were both non-significant ($F < 1$ in both cases). The observed BPVS scores in Table 4.1 are slightly lower than the expected mean scores. There was also some variation in mean scores of children on this measure between the two schools used, ($\bar{X} = 94.1$ and 97.2 respectively) with lower scores in one school reflecting the perceived lower socio-economic status of the catchment area. Since reading ability was age appropriate, and the differences between observed and expected BPVS scores were not large, the sample was deemed acceptable for present purposes.

Design and Materials

The experiment was run in two sessions (A and B), each consisting of pretest, training and posttest phases. At each session, half of the experimental stimuli were presented (i.e. three clue word sets). Presentation of each half was counterbalanced across subjects, with orders of presentation for each of the three clue word sets rotated using a latin square design within prompt groups. During the pretest phase, children

were asked to read all novel target words to be presented in that session, to give a baseline measure of their knowledge of these targets. Occasionally children offered accurate word segmentations without offering a blended articulation of the target word. In the pretest only, the child was told “tell me the whole word - put the letters together”. The response was accepted if the word was then read successfully, otherwise these were counted as errors. Training was then carried out as specified under the 'Prompt conditions' below. During the posttest phase, children were again asked to read all the novel target words.

Stimuli

A set of six clue words was compiled. Each clue word had a set of six corresponding target words. Two target words in each set were Rime clued words (e.g. clue word "rail" - rime target "sail"). Two in each set were Head clued words (e.g. clue word "rail" - head target "rain"). Two were unrelated Control words (e.g. clue word "rail" - control target "yawn"). These could not be read by making inferences based upon intra-syllabic letter clusters, and shared no grapheme-phoneme correspondences. They provide a control for general improvements in word reading ability that are unrelated to clue word orthography.

These words were based upon the word set originally used by Goswami (1986) but differed in two important respects. Firstly, the Control words differed from those in Goswami's original study. Goswami sometimes argues that her control words are a control for 'orthographic overlap' (Goswami, 1986), and sometimes inaccurately states that they are a control for shared grapheme to phoneme correspondences (GPCs), although they often share unpredictable levels of overlap with the clue words. Only in some cases do words share two graphemes (e.g. 'beak' to 'bank') thus providing a control for both the number of shared GPCs and the extent of orthographic overlap. As Hanson and Bowey (1992) point out, 25% of the control words split the shared vowel digraph ('beak' - 'lake', 'hark' - 'hair', 'seen' - 'nose') so words share

common letters but not common graphemes (i.e. the orthographic representation of phonemes). The final set of word pairs suffer the additional problem of the changing pronunciation of the /s/ from unvoiced to voiced form. Of the remaining control words, a positional rotation is required in order to synthesise pronunciations (e.g. 'rail'- 'lain'). Furthermore in many cases the shared graphemes are not consistent across exemplars (e.g. 'skin' - 'silk', 'skin' - 'pink'). The existing control words are therefore rather unsatisfactory. Initial attempts were made to create a true grapheme to phoneme correspondence control condition, but this proved to be impossible with the present word set. It was decided therefore to substitute an alternative unrelated control condition. These words were designed so as to share no graphemes with the clue words, and so provide a control for general improvements in word reading ability unrelated to clue word orthography.

Secondly, in an attempt to avoid pretest advantages for rime analogous words which have been reported previously in the literature (Goswami, 1988b; Savage, 1997), words were matched for mean frequency across clue word type. A preliminary investigation of the target word sets was undertaken in order to attempt to balance words on this potentially important confounding variable. The original words were, according to Goswami (1986), roughly matched for frequency of occurrence in childrens print, using the Carroll, Davies and Richman (1971) norms. These rather dated norms may be inaccurate as a measure of current print frequencies in children's experience. Words were therefore screened using a current and extensive measure of printed word frequency developed by Morag Stuart. Analyses revealed that the means for the rime analogous words ($\bar{X} = 31.83$) were larger than those for the head analogous words ($\bar{X} = 15.25$) and the control words, ($\bar{X} = 18.67$). While Oneway analysis of variance (words: head clued versus rime clued versus control words) revealed that differences were non-significant, the effects upon target word reading with large numbers of subjects may magnify the effects of word frequency. Therefore three of the high frequency rime analogous words, 'green' (93) 'boat' (94) and 'tail'

(75) were replaced with lower frequency alternatives 'preen' (0) 'goat' (58) and 'sail' (15), where figures in brackets represent the number of occurrences of words per million in children's print using Stuart's database. The resulting mean word type frequencies are - Heads $\bar{X} = 15.25$ (SD = 19.11), Rimes $\bar{X} = 16.08$ (SD = 21.26), Controls $\bar{X} = 18.67$ (SD = 36.46). Clue words and their associated targets can be seen in Table 4. 2.

Table 4. 2. Full word set used in Experiment 1.

Clue words	Target words		
	Head clued	Rime clued	Controls
<u>Session A</u>			
beak	bean	peak	herd
	bead	weak	coin
hark	harp	lark	ford
	harm	bark	doom
rail	rain	sail	firm
	raid	hail	yawn
<u>Session B</u>			
seen	seed	queen	bird
	seem	preen	howl
coat	coach	float	food
	coast	goat	boil
skin	skip	chin	loud
	skim	pin	pork

Prompt Conditions and Procedure

Children in each experimental group participated in one of four prompt conditions: combined (orthographic and phonological) prompt; phonological prompt; no prompt; or untaught condition. All children were asked to read all the clue words as part

of the pre-experimental screening procedure. At pretest children were given the appropriate prompt treatment instructions as detailed below.

In the combined (orthographic and phonological) prompt condition clue words were shown to the children who were told "These words here are called clue words, they are a clue to the mystery of how to read some new words". No more precise information on how to use the clue words was given. Throughout the training phase the clue word was visible, and the target word was placed next to it. The experimenter pointed to the clue word saying "This word says (e.g. 'beak'); what does this word say?". The block of six target words for each clue word was then presented with words randomised, and with the clue words indicated and pronounced after every second target word. This condition is comparable to that used in previous studies of analogy use by Goswami.

In the phonological prompt condition, clue words were not shown at pretest. During the training phase children were told "your clue word says...(e.g. 'beak'); what does this word say?". The block of six target words for each clue word was then presented with words randomised, and with the clue word pronounced after every second target word.

In the no prompt condition, clue words were shown to the children who were told "These words here are called clue words, they are a clue to the mystery of how to read some new words". No more precise information on how to use the clue words was given. The training phase began with children being taught three relevant clue words (one for each target word set) by repeated presentation of the whole word on a flashcard, to a criterion of three consecutive correct responses. Once this criterion was reached, clue word cards were hidden from sight, and the six target words for each clue word were presented with words randomised, and with no further assistance.

In the untaught condition, children were not taught relevant clue words. The posttest phase was identical to the pretest phase, in that children were simply shown the six target words associated with each clue word, and invited to read them, without further assistance. Children were given general praise and encouragement in all four prompt conditions.

Measures of clue word knowledge

For the combined prompt group and for the no prompt groups a measure of pretest knowledge of the clue words was taken, by asking the children "Do you know what this word says?" immediately prior to being instructed in the pretest phase. The same measure of clue word knowledge was also taken immediately after the posttest phase of the task for all prompt groups in the experiment.

Letter-sound knowledge

A limited measure of childrens knowledge of grapheme to phoneme relationships was taken at the end of the posttest phase. The letter set comprised 14 letters from the word set in the clue word task, but which were not part of rime or head clue word segments. These included consonant singletons such as 'p' (in 'beak' - 'peak') and digraphs such as the 'ch' (in 'skin' - 'chin'). Children were shown 10 x 7.5 cm cards each with one of the 14 graphemes in a random order. Letters were presented to the child to read one by one, and children were asked "can you tell me what sounds these make?". No more precise instructions were given.

Phonological awareness measures

In a final session two measures of phonological awareness were taken, the Bradley Test of Auditory Organisation (Bradley, 1980), a measure of implicit awareness of phonological structure¹, and a test of explicit phonemic segmentation skill

¹ The Traditional Bradley test of auditory organisation was used here in preference to alternative pictorial versions of the oddity task to allow comparisons to be made of the effects of different prompt conditions on correlations between improvement in target word reading and phonological skills against previous reported findings.

used by Goswami (1990a) to measure phonemic awareness. For half of the children the segmentation was the first task they were given, for the other half it was presented after the oddity tasks.

The Bradley Test of Auditory Organisation

The auditory organisation task requires a child to judge which of four verbally presented words is dissimilar, when three of these words share phonological segments in common. The task was administered in three sections-

1. First sound oddity - children were asked to judge the 'odd one out' where three words share common heads, (e.g. bud bun bus rug).
2. Middle sound oddity - children were asked to judge the 'odd one out' where three words share common rimes and the odd word differs in terms of the medial vowel (e.g. lot cot pot hat)
3. Last sound oddity - children were asked to judge the 'odd one out' where three words share common rimes, and the odd item differs in terms of the terminal consonant, (e.g. pin win sit fin).

The position of the odd word within the set of four words was varied across trials. The children were told " We are going to play a game about spotting the odd one out. I am going to say four words. One of them will differ at the beginning (in the middle / at the end). Listen carefully, and see if you can spot the odd word out, the one that sounds different at the beginning (in the middle / at the end). Lets have a practice first". For each condition there were two practice trials in which feedback about the correct answer was given, followed by 12 experimental trials where no corrective feedback was given. The order of presentation of the oddity tasks was rotated using a

latin square design. Children were given general praise and encouragement throughout the trials.

Phonemic segmentation task

In this task a simple consonant - vowel - consonant (CVC) word was presented verbally. The task was to segment the word into its constituent phonemes. Children were told - "Now we are going to play a game about chopping up words. We can chop words up into the sounds hidden inside them can't we? [a chopping movement of the hand emphasised this idea]. We can chop up the word 'bat' into 'b'-'a'-'t'. So if I say 'bat' you can say [most children repeated the phonemes associated with 'b'-'a'-'t' at this point, if not the previous information was repeated]. Good. What about the word 'rod' can you chop up this word?". If children offered no answer, the correct answer was given by the experimenter, and the next training word was presented. Otherwise children were either praised or corrected as appropriate before the next trial. There were sixteen experimental words and five training words. The order of the presentation of this task was balanced approximately. A full list of materials used in both phonological awareness tasks is presented in Appendix 1.

Results

Analysis of target word reading

Two forms of analyses were undertaken upon the main experimental data. In the first set of analyses the number of correct responses across wordtype made by each subject was the dependent variable. In the second set of analyses, the number of words read correctly for each item was the dependent variable.

Subject analyses

The mean scores for the pre- to posttest are shown in Table 4.3. An inspection of section 5 of Table 4.3 shows that with data from all prompt conditions combined, pre- to posttest increases are found for the rime clued words and to a lesser extent for

the head clued words but there is no evidence of improvement for the control words. Considering the effects of prompt condition, (sections 1-4 of Table 4.3) children in both the combined prompt and the phonological prompt conditions show a substantial and apparently equivalent improvement in reading rime clued words, compared to the no prompt and the untaught conditions. There is also substantial improvement in reading head clued words in both prompted conditions, which is stronger and apparently equivalent to rime improvements in the phonological prompt condition. Results show that there is little or no improvement in reading of the clued words between pre- and posttest for children in the untaught and no prompt conditions.

Preliminary investigations revealed that pretest differences in word reading remained despite attempts to prevent this by matching word sets for word frequency. This complicates the interpretation of findings at posttest. In order to confirm that the improvement for rime clued words was due to improvements between pre- and posttest, the data were submitted to a 4 (prompt condition: combined versus phonological versus no prompt versus untaught) X 3 (clue word type: rime clued versus head clued versus controls) analysis of covariance with pretest scores as the covariate, and with repeated measures on clue word type ². Results showed that there was a main effect of prompt condition, $F(3, 111) = 7.47, p < .001$. There was also a main effect of clue word type, $F(2, 111) = 15.19, p < .001$.

² Data in this and all following experiments were screened for possible violations of assumptions of the normality required for multivariate analyses, using the methods recommended by Tabachnik and Fidell (1989). Investigations of kurtosis, skew, and the presence of outliers proved satisfactory. Tabachnik and Fidell also note that analysis of covariance additionally assumes homogeneity of regression between dependent variables and covariates. In mixed designs, however, there is no simple way of assessing the null hypothesis of homogeneity of regression lines. Tabachnik and Fidell advise that it is probably safe to proceed with covariance analyses for robust models if no interaction between dependent variables and covariates is expected. A robust design is characterised by the authors by two tailed tests with equal sized samples and twenty or more degrees of freedom for error. The present design satisfies these constraints so assumptions were assumed to have been met.

Table 4.3. Mean number of target words read across prompt conditions (subjects).

Prompt condition	Testing session	
	Pretest	Posttest
1. Combined prompt		
Head clued	2.00 (2.85)	3.20 (3.28)
Rime clued	2.40 (2.72)	4.40 (4.44)
Control	1.40 (1.60)	1.07 (1.39)
2. Phonological prompt		
Head clued	2.07 (1.67)	4.53 (2.77)
Rime clued	3.20 (2.76)	5.47 (3.16)
Control	2.27 (1.91)	2.53 (2.36)
3. No prompt		
Head clued	2.60 (3.33)	2.80 (3.39)
Rime clued	3.00 (3.09)	3.33 (3.74)
Control	2.20 (2.83)	2.40 (2.95)
4. Untaught		
Head clued	1.87 (2.42)	2.07 (2.55)
Rime clued	2.73 (2.94)	3.13 (3.23)
Control	2.60 (3.33)	2.67 (3.60)
5. Totals across groups		
Head clued	2.13 (2.59)	3.15 (3.07)
Rime clued	2.83 (2.82)	4.08 (3.70)
Control	2.12 (2.49)	2.17 (2.71)
(Standard deviations are shown in parentheses)		

Note: Max n=12.

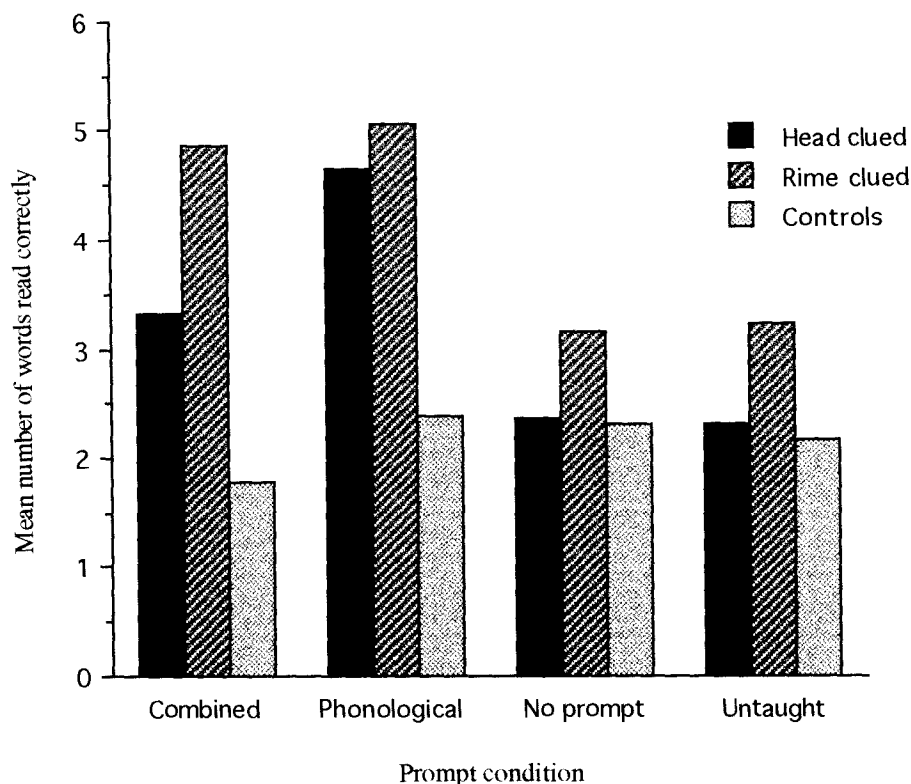
The interaction between prompt condition and clue word type was also significant, $F(6, 111) = 3.47$, $p = .004$. Newman-Keuls post hoc tests carried out on the adjusted means show that within the combined prompt condition, significant differences were evident for rime clued words over both head clued words, ($p < .05$) and control words, ($p < .01$). Between prompt group conditions, significant differences were evident for rime clued words in the combined prompt condition over rime clued words in the no prompt and control conditions ($p < .01$ in both cases). Within the phonological prompt condition, significant differences were also evident for both rime and head clued words over control words ($p < .01$ in both cases) but there was no significant difference between rime and head clued word improvements. Between prompt conditions, rime clued words in the phonological prompt condition were significantly different from rime clued words in both no prompt and untaught conditions ($p < .01$ in both cases), and head clued words were significantly different from head clued words in all other conditions ($p < .01$ in every case).

The mean scores for the prompt condition by clue word type interaction adjusted by the effect of the covariate means were calculated and are shown in Table 4.4. Scores are also presented graphically in Figure 4. 1.

Table 4.4. Adjusted means: prompt condition by clue word type interaction (subjects).

Prompt condition	Head clued	Rime clued	Controls
Combined	3.33	4.87	1.79
Phonological	4.60	5.07	2.38
No prompt	2.35	3.16	2.32
Untaught	2.32	3.24	2.18

Figure 4. 1: Words read correctly in experiment 1 (adjusted means)



Item analyses

The mean scores for the analysis by item are shown in Table 4.5. These mean scores show a very similar pattern of improvements to that found in the analysis by subjects. An inspection of section 5 of the table shows that, with data from all prompt conditions combined, pre- to posttest increases are found for the rime clued words, and to a lesser extent for the head clued words, with no evidence of improvement for the control words. Considering sections 1-4 of the table which shows improvements across prompt conditions, considerable improvements are found for the rime clued words at posttest in both the combined prompt and phonological prompt groups. There is also some improvement in the reading of head clued words in the phonological prompt group, with improvements for head clued words apparently equivalent to that of rime clued words. Again there appears to be little improvement in target word reading evident in the no prompt groups and the untaught groups.

Table 4.5. Mean number of target words read across prompt condition (items).

Prompt condition	Testing session	
	Pretest	Posttest
1. Combined prompt		
Head clued	2.50 (1.51)	4.00 (2.30)
Rime clued	3.00 (2.34)	5.50 (1.78)
Control	1.75 (1.22)	1.33 (1.67)
2. Phonological prompt		
Head clued	2.58 (2.54)	5.67 (2.77)
Rime clued	4.00 (3.13)	6.83 (3.33)
Control	2.83 (2.72)	3.17 (2.48)
3. No prompt		
Head clued	3.25 (1.76)	3.50 (1.24)
Rime clued	3.75 (2.67)	4.17 (2.48)
Control	2.75 (2.30)	3.00 (2.63)
4. Untaught		
Head clued	2.33 (1.61)	2.58 (2.07)
Rime clued	3.42 (3.06)	3.92 (2.94)
Control	3.25 (2.01)	3.33 (2.06)
5. Totals across groups		
Head clued	2.67 (1.87)	3.94 (2.38)
Rime clued	3.54 (2.75)	5.10 (2.86)
Control	2.65 (2.14)	2.71 (2.32)

(Standard deviations are shown in parentheses)

Note: Max n=15.

Preliminary analyses again indicated that there were pretest differences in word reading. In order to confirm that the improvements for rime clued words were genuine, the data were submitted to a 4 (prompt condition: combined versus phonological versus no prompt versus untaught) X 3 (clue word type: rime clued versus head clued versus controls) analysis of covariance with pretest scores as the covariate, and with repeated measures on clue word type. Results showed that there was a main effect of prompt condition, $F(3, 43) = 9.22, p < .001$. There was also a main effect of clue word type, $F(2, 87) = 16.78, p < .001$.

The interaction between prompt condition and clue word type was also significant, $F(6, 87) = 4.06, p = .001$. Newman-Keuls post hoc tests carried out on the adjusted means revealed that, within the combined prompt condition, significant differences were evident for rime clued words over both head clued words and control words, ($p < .01$ in both cases), and between prompt conditions significant differences were evident for rimes in the combined prompt condition over rimes in the no prompt and control rimes ($p < .05$ in both cases). Within the phonological prompt condition, significant differences were also evident for both rime and head clued words over control words, ($p < .01$ in both cases) but there were no significant differences between rime and head clued word improvements. Between prompt conditions, rime clued words in the phonological prompt condition were significantly different from rime clued words in both the no prompt and untaught conditions ($p < .01$ in both cases), and head clued words were significantly different from heads in all other conditions ($p < .01$ in all cases). These results are very similar to those reported from the analysis by subjects. Adjusted means are shown in Table 4.6.

Table 4.6. Adjusted means: prompt condition by clue word type interaction (items).

Prompt condition	Head clued	Rime clued	Controls
Combined	4.12	5.90	2.20
Phonological	5.72	6.50	2.99
No prompt	3.10	4.02	2.90
Untaught	2.81	4.01	2.75

The number of inferences made

In order further to investigate the performance of children under different testing conditions, a second set of analyses was carried out on the main experimental data. In these analyses, the total number of analogous word segments correctly read were included. This analysis counts as correct any accurate pronunciation of an analogous word segment, irrespective of whether the whole word is read correctly. For example, if a child offers 'kin' or 'sin' to the rime analogous target word 'chin' this is counted as a correct rime clued pronunciation, equally the paralexia 'coat' for the head analogous target word 'coach' would be counted as a correct head clued pronunciation. However scoring in this way replicated the results reported already and so is not detailed here.

Analysis of control word paralexias

If control words which do not share common orthographic or phonological segments with clue words are assigned pronunciations at posttest which are analogous to target word pronunciations then this would suggest that improvements witnessed have a purely phonological basis. In order to evaluate the possibility that rime strategies are unrelated to orthographic target word information, analyses of control word pronunciation errors were undertaken for the combined and phonological prompt control words. Analyses were based upon the number of pronunciations which shared either the rime or vowel of the clue word. An example of this form of rime paralexia is

the response of one subject, who after being taught the clue word 'skin' pronounced the control word 'loud' as 'lin'. The mean number of such errors is shown in Table 4.7.

Table 4.7. Mean number of control words sharing clue word pronunciations by prompt condition.

Prompt condition	Testing session	
	Pretest	Posttest
1. Combined prompt	0.00	0.66 (0.99)
2. Phonological prompt	0.00	1.53 (2.39)

For the combined prompt condition, all of the errors displayed in Table 4.7 involved rime generalisation. For the phonological prompt condition, 61% of errors made involved rime generalisation, and 39 % were vowel generalisations. Inspection of the mean scores in Table 4.7 indicates that increases in the number of target-related pronunciations are evident for control words in both conditions at posttest. The pattern of improvement is substantially greater in the phonological prompt condition. In order to confirm this pattern of observations, the data were submitted to two separate Wilcoxon non-parametric z tests for related samples (parametric tests were not used as the variables were not normally distributed), giving for the combined prompt condition $Z = -2.02$, $p = .043$ and for the phonological prompt condition $Z = -2.67$, $p = .008$. These analyses confirm that in both prompt conditions, after being taught the clue words, children made a significant number of erroneous rime or vowel analogous pronunciations to control words despite the fact that these did not share common orthographic or phonological sequences with the clue words.

Analysis of clue word knowledge

Improvement in clue word knowledge from screening test to posttest was also evaluated in the present study. As well as being asked to read the six clue words in the

screening test, children were asked to read the clue words immediately after the posttest was completed. Data were submitted to a 4 (prompt condition: combined versus phonological versus no prompt versus untaught) X 2 (test: screening test versus posttest) Anova with repeated measures on test. The dependent variable was the number of clue words correctly articulated out of six. There was a main effect of prompt condition, $F(3, 56) = 6.56$, $p < .001$, a main effect of test, $F(1, 56) = 138.97$, $p < .001$, and an interaction between prompt condition and test, $F(3, 56) = 21.27$, $p < .001$. The means are presented in Table 4.8.

Table 4.8. Mean number of clue words read: prompt condition by test interaction.

Prompt condition	Screening test	Posttest
Combined	0.93 (1.33)	3.33 (1.95)
Phonological	0.93 (0.96)	2.40 (1.88)
No prompt	0.93 (1.28)	5.47 (0.83)
Untaught	0.93 (1.33)	1.40 (1.96)

(Standard deviations in parentheses)

Note: Max n= 6.

Post hoc tests (Newman-Keuls) indicated that there were significant improvements for all prompt conditions ($p < .01$) at posttest except for the untaught group where the comparison was non-significant ($p > .05$). Considering the scores at posttest, significantly more clue words were read in the phonological prompt condition than in the untaught condition ($p < .05$). In the combined prompt condition, clue words were read correctly significantly more often than in the phonological prompt condition, ($p < .05$) and in the untaught condition, ($p < .01$). The number of clue words read correctly in the no prompt condition was significantly greater than in all of the other conditions ($p < .01$).

Analysis of improvements in clue word reading between screening test and pretest

It is possible that children improved in their reading of clue words in the delay between screening sessions and the pretest session (a period of several weeks). If improvements were evident here, this could complicate the interpretation of previous findings. A further analysis was therefore undertaken in order to evaluate this possibility. For the two prompt conditions where clue words were taught or shown at pretest (the no prompt and the combined prompt conditions), children were asked to read the six clue words at the start of the session before they were taught the pronunciation of the clue words. Analysis of these scores against the appropriate screening test scores would reveal whether any improvement in clue word reading occurred in the period between the screening session and the start of the pretest session. The means for these conditions are presented in Table 4.9.

Table 4.9. Mean number of clue words read in experiment 1: Screening test to pretest.

Prompt condition	Screening test	Pretest
Combined	0.93 (1.33)	0.93 (1.44)
No prompt	0.93 (1.28)	1.33 (1.84)

(Standard deviations in parentheses)

Note: Max n= 6.

Visual inspection of these mean scores reveal few improvements in the reading of clue words between the two testing sessions. In order to confirm these impressions, data were submitted to a 2 (Prompt condition: combined versus no prompt) X 2 (test: screening test versus pretest) Anova with repeated measures on test. The dependent variable was the number of clue words correctly read out of six. Analyses confirmed that there were no main effects of prompt condition, $F(1, 28) < 1$, or test, $F(1, 28) = 1.42$, $p > .05$, and no interaction between prompt condition and test, $F(1, 28) = 1.42$,

$p > .05$. This analysis confirms that improvements in clue word reading were made as a result of the clue word teaching between the pre- and posttest sessions, rather than as a result of general improvements in word reading between the screening test and the pretest.

Correlational analyses

Analyses were also undertaken to evaluate further the relationship between reading measures and other classes of reading-related skills. The first set of correlations considered the pattern of relations between measured reading ability and a range of reading-related measures. These are presented in Table 4. 10 alongside the mean scores, standard deviations and maximum possible scores for each of the phonological and letter tests. By the time phonological skills were tested, two children from the sample were unavailable, having left the area. Correlations involving phonological measures are therefore based upon a sample size of $n = 58$. All other correlations are based upon a sample size of $n = 60$. The relationship between the two measures of phonological awareness and measures of reading ability was of particular interest.

Table 4. 10. Correlations between reading ability and phonological measures ³.

Measure	first odd	Mid odd	Last odd	Cd odd	Phon seg	Cd Phon	L.S. Know	L.S + Phon
BAS	.25	.26	.11	.25	.24	.32*	.35**	.34**
Mean	5.55	6.10	5.62	17.28	6.86	23.95	9.67	16.31
SD	2.50	3.14	2.60	6.83	4.99	9.24	2.63	6.30
Max	12	12	12	36	16	52	14	30
BAS	BAS single word reading				Cd phon	Cd odd and phon seg combined		
First odd	Bradley first sound				L.S. know	letter-sound knowledge		
Mid odd	Bradley middle sound				L.S. + Phon	L.S know and Phon seg		
Last odd	Bradley last sound							
Cd odd	Combined Bradley score							
Phon seg	Phonemic segmentation							

3 * $p < .05$, ** $p < .01$.

Table 4.10 indicates that of the present set of measures, the only significant individual associate of reading ability is letter-sound knowledge. Neither of the individual measures of phonological awareness was significantly associated with measured reading ability, though an additive combined measure of phonemic awareness and the Bradley oddity test was significant, and the phonemic awareness measure reached significance when combined with letter-sound knowledge. The combined letter-sound and phonemic awareness measure did not add to significance beyond that achieved by the simple measure of letter-sound knowledge. Further analyses showed that the two phonological awareness measures were not significantly correlated with each other ($r = .23$ n.s.). Letter-sound knowledge and phonemic segmentation skill were, however, significantly associated with each other ($r = .40$, $p < .01$). Finally, neither the combined scores, nor the individual measures of oddity from the Bradley Test of Auditory Organisation were significantly associated with letter-sound knowledge. This result suggests that there is a close and quite specific relationship between phonological awareness at the level of explicit awareness of phonemes and the acquisition of knowledge about single grapheme to phoneme rules.

The second set of correlations evaluated improvement scores between pretest and posttest in the analogy task and their association with other reading-related skills. The improvement in target word reading from pretest to posttest was calculated separately for rime and head clued words in both the combined and phonological prompt conditions. Following Goswami (1990a) and Savage (1994), gain scores were calculated using the formula (posttest score - pretest score) / (maximum possible score - pretest score). This formula for calculating improvement scores has the advantage over simple gain scores of taking into account the possible amount of improvement. All correlations are based upon $n = 15$, apart from correlations involving the phonological measures for the combined prompt condition which are based upon $n = 14$, as one child in this condition was

excluded as they were at ceiling on target word reading at pretest. These correlations are presented in Table 4.11.

Table 4. 11. Correlations between reading, phonological measures, and improvements in target word reading.⁴

Measure	Combined rime	Combined head	Phon. rime	Phon. head
BAS	.75**	.19	.41	.49
First Odd	.16	.08	-.02	.06
Mid odd	.65*	-.17	-.18	.41
Final odd	.73**	.01	.15	.33
Cd Odd	.66**	.05	.03	.31
Phon Seg	.68**	.25	.48	.26
Cd phon	.80**	.14	.30	.38
L.S. Know	.37	.35	.04	.08
L.S. + phon	.45	.68**	.41	.25

Key:

Combined rime	Combined prompt condition - rime clued words
Combined head	Combined prompt condition -head clued words
Phon. rime	Phonological prompt condition - rime clued words
Phon. head	Phonological prompt condition - head clued words

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Final odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined
L.S. know	letter-sound knowledge
L.S. + phon	L.S know and phon seg combined

The correlations between improvement in target word reading from pretest to posttest in Table 4. 11 appear to show some differences in the patterns of significant associations across word and prompt condition. Improvements in reading for rime clued words in the combined prompt condition is strongly associated with reading ability, phoneme segmentation, and with the middle and final sound oddity sub-tasks of the Bradley test. This therefore replicates the pattern of correlations between pre- to posttest scores in the clue word task and phonological skills observed by Goswami (Goswami

4 * p < .05, ** p < .01.

1990a; Goswami & Mead 1992). Correlations with letter-sound knowledge do not reach significance for this condition. By contrast, there are very few significant correlations with improvements in target word reading for words in the other conditions. The combined measure of letter-sound knowledge and phonemic skills is associated with improvement in reading head clued words, but there are no significant correlations with any measures either for head or for rime clued words in the phonological prompt condition, possibly suggesting that individual differences in phonological awareness or reading ability do not determine variation in the improvements shown in target word reading in the phonological prompt condition, but are important when clue word orthography is provided at posttest. However the r values in many cases while not reaching significance are quite large and the number of observations in each cell may mitigate against drawing strong conclusions from these data.

A third set of correlations investigated the relationship between classes of pretest errors and reading ability. At the pretest, of the 2160 possible responses, 425 (19.7 %) were read correctly, and 1735 (80.3 %) were read incorrectly. A further analysis was undertaken of the pretest target word reading errors made in Experiment 1 to evaluate Stuart and Colthearts' (1988) observation that word reading paralexias are systematically related to target word orthography. They reported that errors which preserve both the initial and final letters of target words were strongly correlated with reading ability. The present analysis sought to extend investigations of this relationship between these partial representations of target words and reading ability and phonological skills by categorising words on the basis of shared phonemes rather than shared letters as Stuart and Coltheart have previously done. As was first argued when discussing Stuart and Coltheart's model in chapter 2, this analysis provides a stronger test of the view that phonological skills are used to underpin partial representations of the orthography in early stages of reading development. The pretest word reading errors

for experiment 1 were therefore categorised only broadly following the taxonomy used by Stuart and Coltheart (1988)⁵. The categories were -

1. Unrelated errors

Words were classified as unrelated errors if they shared no orthographic overlap whatsoever with any letters of the target word. Examples of unrelated errors include misreading the target word 'bean' as 'doom' or the target word 'harm' as 'slot'.

2. Errors sharing orthographic overlap

Error pronunciations in this category retained at least one letter from target words but did not necessarily share common pronunciations. Target and error pronunciations did not share initial or terminal position phonemes. Examples include reading the target word 'goat' as 'log' or the target word 'chin' as 'can't'.

3. Errors preserving the initial phoneme

These error pronunciations preserved the initial phoneme only of the target words. Examples of such errors included misreading the target word 'rain' as 'road', or misreading the target word 'lark' as 'leaf'.

4. Errors preserving the final phoneme

These error pronunciations preserved only the final phoneme of a target word. Examples of errors in this class include misreading the target word 'lark' as 'bike', or misreading the target word 'bird' as 'did'.

⁵ In addition to categorising paralexias on the basis of shared phonemes rather than shared letters, the present taxonomy also differs from that used by Stuart and Coltheart (1988) in three other ways. Firstly, the smallest category of errors in their large data set (3.12 % of errors) were 'morphemic' in nature, representing the target morpheme within the erroneous response. An example of which is the mis-reading of the word 'boy' as 'boys', or the word 'coming' as 'comes'. No errors of this form were recorded in the present smaller data base. A second difference between the present and original taxonomy lies in the inclusion of refusals as an error response category. Finally any errors that preserved the head or rime of the target word were recorded as a separate category.

5. Errors preserving both the initial and final phoneme

These words preserved both the initial and final boundary phonemes of the target word, but the vowel digraphs which made up the middle phoneme of the target words were inaccurately pronounced. Examples of such errors include misreading the target word 'harp' as 'hope', and misreading the target word 'bead' as 'bed'.

6. Errors preserving rimes.

Errors in this category preserved the medial vowel and terminal consonant of the target word. Examples of errors in this category include misreading 'chin' as 'kin' or misreading 'howl' as 'owl'.

7. Errors preserving heads.

Errors in this category preserved the medial vowel and initial consonant of the target word. Examples of errors in this category include misreading the target word 'coach' as 'coat', or misreading the target word 'skin' as 'skip'.

8. Refusals

Errors in this category were either non-responses or the response 'I don't know'.

The total number and percentage of errors made at pretest in each error category is shown in Table 4.12 for the combined and phonological prompt conditions. The paralexias are broken down for rime clued and head clued target words separately, with the pretest errors for combined prompt rime clued words presented in section 1 of the table and for head clued words in section 2 of the table. Paralexias for the rime and head clued words in the phonological prompt condition are presented in sections 3 and 4 of the table.

An investigation of the percentage of total errors in section 1 to 4 of Table 4.12 reveals that the largest two error categories are 'refusals' and errors which preserve

A substantial numbers of observations occurred only amongst initial and final and refusal paralexia classes so only these two error categories were analysed further. The proportion of errors made at pretest for these error categories was calculated for each subject and correlated with reading ability and other reading-related measures ⁶. These sets of correlations are presented in Table 4.13, along with means, standard deviations and maximum possible scores for the proportion of errors made in the two error categories.

Table 4.13. Correlation of error proportions with reading and phonological measures ⁷.

Measure	I & F	Refusal
BAS	.67***	-.32**
First odd	-.07	.17
Mid odd	.01	.05
Last odd	.04	.03
CdOdd	.02	.07
Phon seg	.22*	-.04
Cd phon	.11	.07
L.S. know	.35**	-.14
L.S+ phon	.27*	-.06
Mean	.37	.35
SD	.25	.29
Max	1	1

Key:

Pretest errors

I & F initial and final phoneme shared with target
 Refusal refusal to answer

Reading-related variables

BAS BAS single word reading
 First odd Bradley first sound
 Mid odd Bradley middle sound
 Last odd Bradley last sound
 Cd odd Combined Bradley score
 Phon seg Phonemic segmentation
 Cd phon Cd odd and phon seg combined
 L.S. know letter-sound knowledge
 L.S.+ phon L.S know and phon seg combined

⁶ These errors were based upon all 36 responses made at pre-test.

⁷ * p < .05, ** p < .01, *** p < .001.

An inspection of Table 4.13 reveals that there is a specific pattern of associations between pretest error types and reading ability. A strong positive correlation is evident between errors preserving both the initial and final consonants and reading ability. Refusals are strongly negatively correlated with reading ability. This therefore supports the findings reported by Stuart and Coltheart (1988).

An investigation of the association between other reading related skills and error types revealed that errors preserving initial and final consonants were positively correlated with both phonemic segmentation skill and letter-sound knowledge, but not with any of the Bradley oddity tests. Patterns of associations for refusals appear generally to be non-significant. These results suggest that the development of partial representations of target words which preserves boundary consonants are closely and specifically associated with knowledge of small orthographic and phonological units: letters and their pronunciations and the explicit ability to segment syllables into phonemes.

A final set of correlations investigated the relationship between the proportion of pretest errors made in each of the error categories and subsequent improvement in reading of rime and head clued words. These correlations can reveal whether the quality of representations of target words at pretest influences is associated with improvement in target word reading. This analysis may allow comparison of two views of the role of phonological awareness in developing initial orthographic representations of target words. Goswami (1993) assumes that children's sensitivity to rhyme allows them to form phonologically underpinned orthographic rime units. By contrast Ehri (1992) assumes that the early phonological underpinning is initially of single letter graphemes. If the proportion of pretest word reading errors preserving both boundary consonants are correlated with the level of rime inference use, then this may suggest that such inferences are based upon smaller vowel digraph units rather than larger units such as shared rimes. From this view, if a child's representation of the target 'peak' preserves

both boundary consonants at pretest, a clue word such as 'beak' could serve to inform children of the correct pronunciation of only the medial vowel digraph of the target word. In order to investigate this, correlations are presented separately for the combined prompt and phonological prompt conditions below in Table 4.14.

Table 4. 14. Correlations between error proportions and improvement in target word reading.⁸

Measure	Combined rime	Combined head	Phon. rime	Phon. head
I & F	.74**	.43*	.20	.39
Refusal	-.64**	-.43*	-.01	-.39

Key:

Prompt condition

Combined rime	Combined prompt condition - rime clued words
Combined head	Combined prompt condition - head clued words
Phon. rime	Phonological prompt condition - rime clued words
Phon. head	Phonological prompt condition - head clued words

Pretest errors

I & F	initial and final phoneme shared with target
Refusal	refusal to answer

The data in Table 4. 14 reveal that there is a significant pattern of associations between improvements in target word reading and certain kinds of pretest errors. Considering the pattern of performance for the combined prompt condition, there is a strong positive correlation between improvements made between pretest and posttest in the analogy task and errors preserving the initial and final consonants of words at pretest: this relationship holds for head and rime clued words. Equally there is a strong negative correlation between improvements in target word reading at posttest and refusals to answer at pretest. Again this pattern is evident for rime and head clued words.

⁸ * p < .05, ** p < .01.

For the phonological prompt condition, there is a similar pattern of associations, with a positive correlation evident between rime and head clued words and errors preserving initial and final consonants. Negative correlations between rime and head clued words and refusals were also evident. In neither case however did these correlations reach significance. The results presented here appear to suggest that the quality of pretest representations of target word orthography do appear to be associated with improvements in target word reading at posttest in the combined prompt condition of the present study. As the correlations are based upon $n = 14$ observations, all interpretation needs to be made with some caution.

Discussion

The pattern of results in experiment 1 is considered in four sections. The first three reflect the three main questions addressed in Experiment 1 - (a) the function of phonological prompts, (b) spontaneous use of rime units to read novel words, and (c) the size of units involved. The final section considers other evidence from correlational analyses.

The function of phonological prompts

The main aim of the present experiment was to evaluate the ability of children to demonstrate improvement in target word reading from a single clue word across a range of testing conditions. The main analysis of improvements in the number of target words read correctly before and after learning the clue word revealed that there were substantial differences in the level of improvement depending upon the availability of different kinds of concurrent clue word information. Significant improvements were evident for both rime and head clued words but not for controls in the combined prompt condition. Improvement was significantly greater for rime clued words than head clued words. This pattern of results replicates the findings of previous analogy tasks

(Goswami, 1986, 1988b, 1993) that have investigated target word reading under the same testing conditions.

An important new finding was that pre- to posttest improvements in target word reading were as strong for rime clued words in a condition where only phonological information about a clue word was given at posttest, as when the clue word was presented to the child whilst phonological information was given. For head clued words, improvements were significantly greater under this condition than when both orthographic and phonological prompts were given. These results strongly suggest that the phonological prompt acts in a more complex manner than the rime analogy model implies. What kind of a model could explain the pattern of improvement in reading witnessed in this experiment?

As the presence of the clue word at posttest does not appear necessary for improvements in target word reading, one explanation of improvements may be that they represent purely phonological activation of related words, rather than the use of phonologically underpinned orthographic units in the early stages of reading acquisition. Some forms of purely phonological activation of related words have been reported previously in the analogy literature. Goswami (1990b) investigated analogy use from clue and target word pairs which shared common letters and sounds in rime strings, (e.g. "most" - "post"), words which shared only phonology (e.g. "most" - "toast"), and words which shared only orthography (e.g. "most" - "lost"). Results showed that improvements in reading did occur from orthographically dissimilar words, (e.g. "most" - "toast"), and this may reflect a phonological priming mechanism. Numerically, the amount of improvement thus explained was small but significant. However improvements in reading for words sharing both rime orthography and phonology (e.g. "most" - "post"), was significantly greater than to words sharing only phonology. Goswami thus argued that a pure priming effect contributes to, rather than explains, the pattern of improvements witnessed in her task.

While at least part of the improvement in target word reading in the present analogy task may reflect the activation of pronunciations without the consultation of orthographic knowledge, there are some limitations to an explanation of all improvements observed in Experiment 1 of the present study purely in terms of phonological priming. Phonological priming is an unlikely explanation of the significant improvement in clue word reading witnessed at the posttest for children in the phonological prompt condition. While it could be argued that a residual prime effect influenced the pronunciation even of these words, this view is weakened in the light of the observation that the repeated pronunciation of clue words at pretest in the no prompt condition of this experiment did not appear to 'prime' the pronunciation of target words at all at posttest immediately afterwards, suggesting that any purported priming effects would have to be of a relatively short duration.

An alternative view is that the phonological prompt serves directly to activate previously stored orthographic clue word knowledge which, once activated, can then facilitate the pronunciation of orthographically related target words. Nation and Hulme (1996) have recently offered such an explanation of improvements in target word reading witnessed in their study of inference in spelling development. In their study children were primed by the pronunciation of a nonsense word clue but no orthographic clue word information was provided. Primes shared various phonological relations to clue words. One set of primes shared a head with clue words (e.g. '/grib/' - 'green'), another set shared a vowel (e.g. '/pim/' - 'green') and the third set shared a rime (e.g. '/trin/' - 'green'). Equivalent improvement was witnessed in all cases. They argued that their results offered no support for models of spelling such as Goswami's in which onset and rime units have privileged status in transfer tasks but could best be explained by the activation of orthographic information within a lexicon conceptualised as a connectionist network (Seidenberg & McClelland, 1989) wherein a range of letter-sound relations are abstracted through the experience of reading.

Poor levels of pretest performance on clue word reading make this an unlikely explanation in the present study. Children in Nation and Hulme's study were selected only if they could spell around 50% of clue words. This selection procedure ensured that children already had an orthographic referent which a phonological prompt might activate. In experiment 1 of the present study, children were able to read very few of the clue words at pretest. It is unlikely that such little reading ability as the children displayed at this point would be sufficient to explain the extent of improvement in reading subsequently witnessed in the prompted transfer conditions, even if all previously seen clue words were activated by the phonological prompt in the manner envisaged by Nation and Hulme.

There is an alternative explanation of the patterns of improvement in target word reading witnessed in the present experiment, which is consistent with the view that a phonological prompt serves in a more direct manner in the construction of a response to target words in the clue word task. This explanation centres on the very particular context of the clue word learning task. In this situation children are offered the repeated pronunciation of a 'clue' word during the posttest phase. Furthermore children are told that the word is, albeit in some undisclosed manner, a 'clue'. It seems plausible to assume that at least some children are able to infer that the pronunciation is a direct guide to the target word that they are attempting to read. As children have difficulty in reading the medial vowel digraphs of such words (Stuart & Coltheart, 1988), children with well developed phonological skills who are able to segment monosyllabic words are able to apply this pronunciation information directly to the orthographic units that correspond to the medial vowel, and/or the orthographic rime unit of target words. Children may then apply this insight that they have gained about the pronunciation of vowels and rime units to similar words that they meet subsequently. This account is therefore able to explain the modest pattern of improvement in clue word reading witnessed at posttest in the two prompted conditions. While such an explanation must

necessarily remain rather speculative, it potentially offers a coherent explanation of the role of phonological prompts in the clue word task.

Spontaneous use of rime units

Given the theoretical problems associated with interpreting improvements in target word reading in the presence of concurrent prompts, it is particularly important to evaluate the ability of children to perform inferences in the absence of such prompts. At a theoretical level, this condition can be seen as a pure test of the nature of links between stored lexical knowledge and output phonology. Furthermore, at a practical level, improvement in the no prompt condition is also closest to the task demands of reading by analogy in naturalistic settings. If children are able to perform lexical analogy as an entry strategy to reading in classroom situations, then they should be able to demonstrate analogy use in this condition. The present results found no sign of improvement in target word reading whatsoever in the no prompt condition of experiment 1. Previous research findings have either reported some small but significant improvement in some cases, (Muter et al, 1994; Savage 1997, Experiment 1), or no improvements whatsoever in others (Savage, 1997, Experiment 2). The present result therefore provides further support for the view that children find orthographic inference from a single taught clue word either very difficult or impossible when attempted in the absence of concurrent prompts.

This interpretation of results is strengthened by the finding that children in the no prompt condition are nearly at ceiling on their ability to read clue words after the posttest stage has been completed. This very strongly suggests that the children remember the taught clue word, but nevertheless are unwilling or unable to use the shared orthographic and phonological rime and head units to derive the pronunciations of target words. Knowledge of a single stored clue word is not sufficient to produce improvement in the reading of words sharing common orthographic and phonological strings. It seems important to reiterate that these are exactly the conditions under which children should be

able to demonstrate analogy use if they use this strategy spontaneously outside of prompted experimental conditions. The finding of no increase in target word reading whatsoever despite the relatively close temporal proximity of clue learning and posttest stages and despite the fact that children are also told at pretest that the taught words are 'clues' only strengthens the view that the use of orthographic inferences from a single stored source of lexical knowledge is not a spontaneous acquisition strategy available to children in the earliest stages of learning to read ⁹.

The size of orthographic units in the prompted clue word task

The results of Experiment 1 may also suggest that vowels as well as rime units are involved in improvements witnessed. This view is suggested by the finding of a systematic relationship between the quality of pretest phonologically underpinned orthographic representations of target word knowledge and the subsequent use children are able to make of clue word prompts at posttest. Paralexias which preserved both initial and final consonants, but where the medial vowel digraphs were inaccurately pronounced, were strongly correlated with the number of words read correctly at the posttest phase in the combined prompt condition. Equally, refusals to answer were negatively associated with subsequent improvements in target word reading. These findings may suggest that pretest representations of target word orthography play an important part in analogy use in the traditional form of the analogy task. One theoretical implication of the association between errors preserving initial and final consonants at pretest and subsequent target word reading at posttest may be that children use the

⁹ The analysis of the number of analogies made has also reinforced the main findings concerning the patterns of analogy use in the present experiment. Improvements in target word reading only occurred in the presence of clue word prompts. This general pattern of results supports the claim made by Savage (1997) that one factor which limits analogy use is the ability to synthesise the pronunciation of non-analogous segments in the clue word task. Where those non-analogous segments are complex, such as in onset analogy tasks requiring analogies from words such as 'stilt' to 'stem' (Savage, 1997), then ability to read target words correctly may be limited. However, measures which include the number of analogies made, rather than the pronunciation of whole words, pick up on significant transfer of orthographic knowledge. Where the pronunciation of the target involves a relatively simple non-analogous segment, (such as single letter onsets - the 'p' in 'beak' - 'peak' in the present task) which children of this age have no difficulty in synthesising, then this will not limit analogical abilities and the measure of analogies made will not differ markedly from measures of the number of correct responses.

concurrent clue word information to synthesise vowel digraph pronunciations, and combine them with the consonant representations that they already know.

An explanation of analogy use in terms of vowel digraphs would not of itself be able to account for the additional improvement witnessed for rimes over head units in the combined prompt condition. However the advantage for rimes over heads could be due to the additional contribution of a distinct phonological priming effect reported in clue word tasks (Bowey & Underwood, 1996; Goswami, 1990b). Alternatively, the number of words sharing such initial and final consonants may be an important predictor of analogy use. Thus an explanation of the advantage for rimes may lie not in the privileged phonological status of such units but rather in the greater proportion of rime words in which initial and final consonants are specified at pretest. Such an advantage was evident in the present results: in the combined prompt condition there were more initial and final errors amongst rimes than heads at pretest (32 versus 25 percent of totals respectively). In contrast in the phonological prompt condition, pretest paralexias which preserved initial and final consonant representations were equally numerous in the head and the rime category, possibly explaining the equivalent improvement witnessed in this condition. Clearly this view remains rather speculative on the basis of the present data with only 14 items in each correlation analysis: further work with larger numbers of children in the combined prompt correlation sample is required to clarify the role of pretest representations of target words in the clue word task.

Finally there is another potential explanation of the advantage evident for rime over head clued words in the combined prompt condition. This argument centres upon Goswami's word set which was also used in a modified form in this study. The main issue is that there is differential complexity in the clue-target word relations. While some word pairs (e.g. 'beak' - 'peak' or 'beak' - 'bean') have an equivalent CVC structure, there are a number of head and rime target words (e.g. 'coat' 'coach' or 'seen' - 'queen') which violate this pattern. The overall number of these is equated across both groups.

However in the rime target word list there is also one word ('pin') with a simple three letter CVC structure, which may be particularly easy for children to synthesise. A clearer test of the view that children are inferring rimes or vowel digraphs might be possible if all words used in the target word sets had the same consonant - vowel digraph - consonant structure. This sort of consistent word set would also allow a clearer test of the view discussed above that pretest representations of boundary consonants in target words is influential in facilitating target word reading at posttest via learning the pronunciation of complex vowel digraphs, and would therefore also inform debate about the size of the unit involved in transfer studies. This issue is pursued in experiment 2.

Correlational analyses

Finally the pattern of other correlations in the present study between reading ability and word reading paralexias at pretest lends support to the notion that good and poor readers differ in the quality of representations of orthographic knowledge. Good readers tend to make more correct responses to words read to them at pretest, but they also make more inaccurate responses which nevertheless retain initial and final phonemes, and fewer unrelated, or only distantly orthographically related responses. This extends the evidence presented by Stuart and Coltheart (1988) by suggesting that partial awareness of the phonemic structure of syllables is involved in developing partial orthographic representations early in reading.

A further set of correlations between error types and other reading-related abilities, such as phonological awareness, did not produce such strong patterns of association as the reading measure. The best correlate of word reading ability, and a correlate of initial and final representations, was the measure of letter-sound knowledge. Phonemic but not onset-rime awareness also correlated with the number of initial and final consonant representations made at pretest. There were also significant interrelations between the phonemic awareness measure and letter-sound knowledge. Letter-sound knowledge and the combined measure of letter-sound knowledge and phonemic

awareness were also the only strongly significant associates of measured reading ability in the present study. Together, this pattern of interrelations also provide some modest support for the notion that phonemic rather than larger phonological units are associated with the formation of partial representations of words in the earliest stages of reading acquisition. These correlation results may fit rather well with models of early reading such as Ehri's, (1992, 1995) in which young children are considered adept at using letters as symbols for sounds in words, and in which early representations of word are partially correct, and dependent upon the level of letter sound knowledge.

Conclusions

The present study has sought to evaluate the pattern of improvement in target word reading from clue word information across a range of test conditions in which either phonological and orthographic, phonological, or no concurrent clue word information is presented during the posttest stage. Results showed that concurrent clue word information was necessary in order for improvement in target word reading to take place. Orthographic information was not necessary to produce significant patterns of improvement. Phonological information appeared to be sufficient to produce an increase in the number of accurate pronunciations of analogous rime and head clued words. Together these results suggest that there are a number of problems in interpreting the nature of target word reading improvements in the traditional form of the clue word task. An alternative explanation of improvement in target word reading is possible, with a strong contribution from purely phonological information implicated in the task. There was also some evidence to suggest that information derived from partial representations of the target word influences improvements. This aspect of Experiment 1 is further investigated in Experiment 2.

Finally, results have also confirmed that in those situations which most closely approximate naturalistic reading, 6 year old readers do not appear to be able to take

advantage of prior exposure to a single clue word to derive pronunciations of analogous but unfamiliar words. The present results are limited to the ability of children to use a single clue word as the basis for analogy use. A theoretically interesting and practically important issue is whether children can perform sublexical inferences from exposure to several words sharing orthographic and phonological overlap. This question is addressed in Experiment 3.

Chapter 5

The relationship between pretest errors and posttest improvements in target word reading in Goswami's clue word task

Experiment 2

One result of experiment 1 was to confirm that children are able to take advantage of concurrently presented clue word information to read rime analogous target words (e.g. 'beak' - 'peak'). Performance was greater for these words than for words sharing heads (e.g. 'beak' - 'bean'), as predicted by the interactive analogy model of early reading (Goswami, 1986, 1993). However, a potential problem in interpreting this advantage evident for rime over head clued words in the combined prompt condition concerns Goswami's word set. Discussion at the end of experiment 1 highlighted the fact that there is differential complexity in many of the clue-target word relations. Some word pairs (e.g. 'beak' - 'peak' or 'beak' - 'bean') have an equivalent CVC structure. However there are a number of head and rime target words (e.g. 'coat' 'coach' or 'seen' - 'queen') which violate this pattern and there is also one word that appears in the rime target word set ('pin') with a simple three letter CVC structure. It was argued that a stronger case could be made for the view that children infer rimes rather than other orthographic units if all words used in the target word sets had the same consonant - vowel digraph - consonant structure. The first aim of Experiment 2 is further to investigate the pattern of target word reading between pre- and posttest using a word set with a uniform CVC structure. This analysis should therefore provide a clear evaluation of whether shared rime units provide an advantage over head units in the clue word task.

A further implication of the use of this sort of consistent word set is that it also allows a clearer evaluation of the role of pretest representations of boundary consonants in target words in facilitating target word reading at posttest. This analysis can potentially

also inform debate about the size of the unit involved in transfer studies. If pretest paralexias preserving boundary consonants are crucial to transfer at posttest, then this could suggest that improvements reflect the inferential learning of the pronunciation of complex vowel digraphs from the clue word presentation. Therefore a main aim in experiment 2 is to further investigate the relationship between word reading improvements in Goswami's form of the clue word task and the pattern of pretest word reading errors.

Experiment 1 provided some preliminary evidence from correlational analyses that the number of incorrect target word pronunciations made at pretest which share initial and final phonemes with the target word was a significant predictor of the likelihood of making correct pronunciations of target words at posttest. As the error taxonomy was based upon shared phonemes rather than shared letters this analysis provides support for the view that phonemically underpinned partial representations of words which preserve boundary letters rather than phonologically underpinned orthographic rime units are a feature of early reading of monosyllabic words (Ehri, 1992, 1995).

There were only 14 items in the correlation analysis in experiment 1, so further work with larger numbers of children in the combined prompt correlation sample is required to clarify the role of pretest representations of target words in the clue word task. This is achieved in experiment 2 by using more participants in a single condition that is comparable to the combined prompt condition used in experiment 1, thus improving the power of this particular analysis. The results of this study should therefore be able to elucidate the role of pretest target word representations in concurrently prompted transfer, and further investigations of the correlations between improvements in target word reading, measured reading ability, and two distinct measures of phonological awareness will further elucidate the correlates of individual differences in concurrently prompted transfer in Goswami's clue word task.

Method

Unless otherwise stated the method was the same as that used in the combined prompt condition of Experiment 1.

Participants

Twenty six children (mean age 6 years 6 months, range 5 years 9 months to 7 years 3 months) from two London primary schools took part in the study. For the convenience of quickly identifying a group of children reading at the appropriate level for this study, the children in experiment 2 were a subset of those participating in the previous study. Children were drawn equally from the 'no prompt' and 'untaught' conditions used in Experiment 1 (four of the original 30 children in these conditions were unavailable for this study). In the screening stage of the present experiment, reading ability was measured again, using the BAS single word reading test. The mean reading age for the sample of children was 6 years 8 months (range 5 years 6 months to 7 years 8 months). Analysis of the sample BAS reading scores revealed that the distribution did not deviate markedly from normal: kurtosis, ($k = -0.61$), and skew, ($s = 0.34$) were both non-significant. There were 14 girls and 12 boys in the sample. Equal proportions of children from each school and from each sex were still present in the sample.

Design and materials

There is only one prompt condition so the design is fully within-subjects. This prompt condition was the same as the combined prompt condition in experiment 1. Children were shown all target word at the pretest. At posttest children were shown the target words in each set individually, with a clue word present next to the target. The experimenter pointed to the word and said: "this word says (e.g. 'beak'); what does this word say?". The pronunciation of the clue word was provided after every second target word was presented and the appropriate clue word remained present throughout the

posttest phase of the study. Three clue-target sets were presented in each testing session.

Stimuli

Types of target word were the same as in experiment 1, but a new set of six clue words and corresponding targets was compiled. The previous study had revealed the need to carry out analyses of covariance to adjust for pretest advantages in rime clued target word reading, despite attempts to control for pretest differences by controlling word frequency. One potential problem with the target words used in the previous study is that they contained a mix of simple CVC words such as 'pin' and CVC words such as 'coach' with more complex orthographic structures. One possible explanation of differences in pretest word reading therefore lies in the differences in the complexity of stimuli across word types. This difference in the complexity of stimuli could also influence pre- to posttest improvements.

The new stimulus set consisted entirely of words with the same single consonant-vowel digraph- single consonant (CVC) structures. The frequency of these words was balanced across target word types using the same word frequency database as in Experiment 1. For rime clued words the mean frequency was 5.42 (SD = 8.05); for head clued words, 7.00, (SD =15.12); and for the unrelated control words, 6.08, (SD = 8.92). Oneway Anova confirmed that a mean frequency match was achieved, ($F(2, 22) < 1$). The mean frequency of the combined target word set, at 6.17, was also lower than in the first experiment, where the frequency was 16.67 overall. The full word set used in Experiment 2 is presented in Table 5.1.

Table 5.1. Full word set used in Experiment 2.

Clue words	Target words		
	Head clued	Rime clued	Controls
<u>Session A</u>			
fork	ford	cork	hurl
	fort	pork	gown
beat	bean	seat	soil
	beam	heat	moan
card	cart	lard	soap
	carp	yard	loin
<u>Session B</u>			
turk	turn	lurk	heap
	turf	murk	word
main	mail	gain	soup
	maid	pain	reap
loam	loan	foam	deaf
	loaf	roam	barb

Letter-sound knowledge.

A more comprehensive measure of letter-sound knowledge was included in Experiment 2. Knowledge of all letter-sounds was assessed except that the letter 'x' was omitted and the letter 'q' was presented with 'u' as a digraph unit for the letter-sound assessment.

Phonological awareness measures

As phonological skills had been measured around 8-10 weeks previously these measures were not re-administered but the existing scores were re-used.

Results

Analysis of target word reading

Subject analyses

The mean scores for the target word between pre- and posttest are shown in Table 5.2 ¹. An inspection of these data show that there were improvements for rime and head clued words between pretest and posttest, but little or no improvement in reading of the control words. Preliminary analyses again showed significant differences between words at pretest. As the design was fully within subjects, it was not possible to use analysis of covariance to adjust means for pretest differences in word reading. Analyses of gain scores can be considered as an alternative in such circumstances, if there is a very strong correlation between scores at both times of measurement (Neter, Wasserman, & Kutner, 1990; Tabachnik & Fidell, 1989) ². In this case, correlations of $r = .8$ and $r = .9$ were present in each of the variable-covariate regression analyses for rime and head clued words.

Simple gain scores when used as an index of response can be influenced by floor or ceiling effects. In order to avoid this problem adjusted gain scores were computed. Following Goswami (1990a), adjusted mean improvements scores were calculated following the formula: (posttest score - pretest score) / (maximum possible

¹ The data were initially analysed with a 'previous prompt condition' between subjects factor. This sought to evaluate whether membership of the untaught or no prompt conditions in experiment 1 had any impact upon the pattern of improvements in the present study. None of the main effects of prompt condition or interactions with prompt condition approached significance, so re-analyses were undertaken ignoring the prompt condition factor. Only these main analyses are reported here.

² Neter et al demonstrate (page 897) that where the slope of treatment regression lines approach 1, analyses of covariance and analyses of variance on $y - x$ scores produce essentially equivalent mean square error terms, and thus are comparable analyses.

score - pretest score). The mean adjusted scores were - for head clued words .24 (SD = .21); for rime clued words .35 (SD = .28); for control words -.03 (SD = .01). These data were submitted to a Oneway Anova with 3 levels (clue word type: head clued versus rime clued versus control words). Results showed that there was a main effect of clue word type, $F(2, 50) = 28.97$, $p < .001$. Newman-Keuls post hoc tests confirmed that the head and rime clued words both differed from the control words at $p < .01$, confirming that the advantage for rime and head clued words over controls was robust when pretest scores were controlled. A modest advantage for rime over head clued words was also evident, ($p < .05$). The mean scores are also presented in Figure 5. 1.

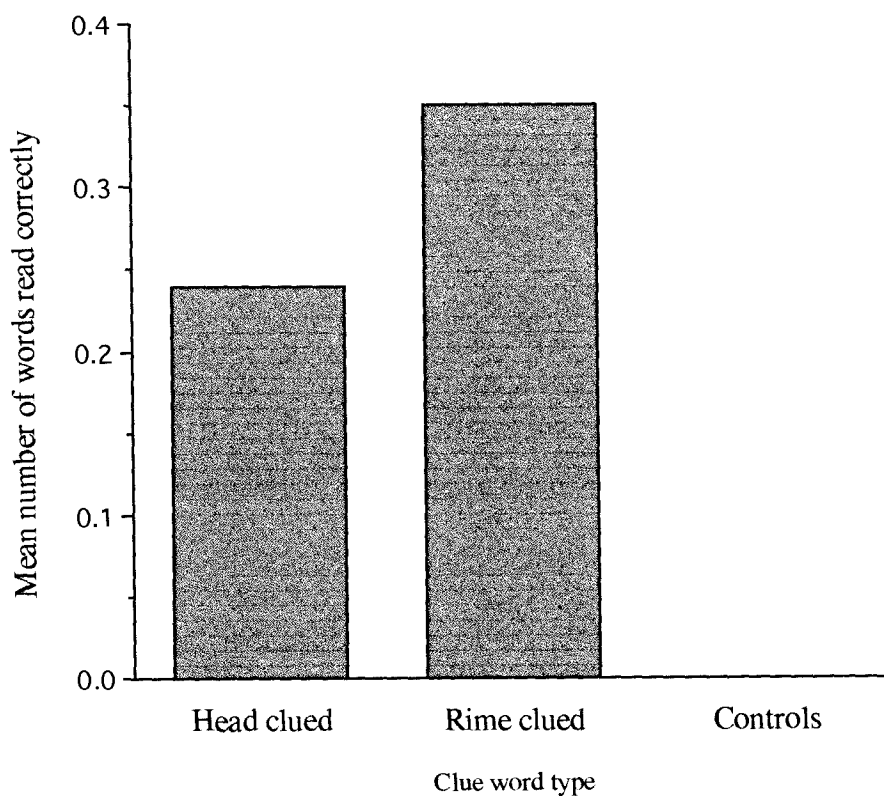
Table 5. 2. Mean number of target words read in experiment 2 (subjects).

Clue word type	Testing session	
	Pretest	Posttest
Head clued	3.12 (3.12)	5.12 (3.28)
Rime clued	2.31 (2.94)	5.27 (3.57)
Controls	2.58 (2.56)	2.35 (2.45)

(Standard deviations are shown in parentheses)

Note: Max n=12.

Figure 5. 1: Words read correctly in Experiment 2 (adjusted scores)



Item analyses

A further analysis on the main experimental data was carried out analysing the target word reading scores by item. The means are shown in Table 5. 3.

Table 5. 3. Mean number of target words read correctly in experiment 2 (items)

Clue word type	Testing session	
	Pretest	Posttest
Head clued	6.75 (2.70)	11.08 (3.48)
Rime clued	5.00 (3.94)	11.42 (2.50)
Controls	5.58 (3.82)	5.08 (3.82)

(Standard deviations are shown in parentheses)

Note: Max n=26.

Preliminary analyses showed that there were again significant differences between clue word types at pretest. Data were transformed into gain scores in the same manner as in the subject analyses. The mean adjusted gain scores were - for head clued words .23 (SD = .20); for rime clued words .30 (SD = .28); for control words -.03 (SD = .01). Data were submitted to a Oneway Anova with 3 levels (clue word type: head clued versus rime clued versus control words). Results showed that there was a main effect of clue word type, $F(2, 22) = 48.55$, $p < .001$. Newman-Keuls post hoc tests again confirmed that the head and rime clued words both differed from the control words ($p < .01$ in both cases). Rime and head clued words did not differ from each other significantly ($p > .05$).

Analysis of the number of inferences made

A second set of analyses was undertaken on the number of inferences made irrespective of whether the whole word was read correctly. Again the differences between these analyses and the main analyses reported previously were negligible.

Analysis of control word paralexias

The number of control word pronunciation errors which shared pronunciations with clue words was 0.038 (SD = 0.2) at pretest, and 0.42 (SD = 0.81), at posttest. Errors made divided equally between rime and vowel units shared. An example of a rime-based error was when the control word 'barb' was misread as 'boam' by one child following presentation of the clue word 'loam'. An example of a vowel-based error was when the control word 'heap' was mispronounced as 'hurl' by another child following presentation of the clue word 'turk'. Data were submitted to a Wilcoxon test, as the data showed significant kurtosis and skew. The analysis was significant ($Z = -2.11$, $p = .035$), showing that there was some significant tendency for clue word knowledge to be inappropriately extended to control words. The effect was however relatively modest in size in comparison to the overall level of improvement witnessed for rime and head clued words between pretest and posttest.

Analysis of clue word knowledge

Improvement in clue word knowledge from pretest to posttest was evaluated. The mean at pretest was 1.54 (SD. = 1.58), and at posttest, 3.92 (SD = 1.50) out of a maximum possible of 6. Data were submitted to a related t-test which revealed that this difference was significant, $t(25) = 7.59, p < .001$.

Correlational analyses

The first set of correlational analyses investigated the relationship between reading ability and other classes of reading-related skills. These are presented in the first part of table 5.4. Also presented for the sake of comparisons below these figures are the same analysis from experiment 1. Means, standard deviations, and maximum possible scores are also presented for all the tests used in experiment 2 in the third part of the table.

Table 5. 4. Correlations between reading ability and phonological measures ³.

Measure	first odd	Mid odd	Last odd	Cd odd	Phon seg	Cd Phon	L.S. Know	L.S + Phon
Expt 2								
BAS	.20	-.08	-.18	-.04	.24	.10	.11	.22
Expt 1								
BAS	.25	.26	.11	.25	.24	.32*	.35**	.34**
Expt 2								
Mean	5.89	5.27	5.04	16.19	7.19	23.39	19.65	26.89
SD	2.54	3.21	2.86	7.24	4.86	9.21	2.21	6.36
Max	12	12	12	36	16	52	25	41
BAS	BAS single word reading				Cd phon	Cd odd and phon seg combined		
First odd	Bradley first sound				L.S. know	letter-sound knowledge		
Mid odd	Bradley middle sound				L.S. + Phon	L.S know and Phon seg		
Last odd	Bradley last sound							
Cd odd	Combined Bradley score							
Phon seg	Phonemic segmentation							

³ * $p < .05$, ** $p < .01$.

Analysis of the associations between reading ability and the measures of letter-sound, as well as between the onset-rime oddity and phonemic awareness measures, revealed no significant correlations. These results differed to an extent from those in experiment 1 where letter-sound knowledge correlated significantly with reading ability. A likely explanation for this difference in the pattern of associations may lie in the statistical power of analyses in the two studies. In experiment 1, correlations included scores from all 60 participants in the experiment, whereas in experiment 2 there were only 26 participants. The nature of the letter-sound knowledge tested was also different in the two experiments. In Experiment 2 the tests mainly assessed knowledge of simple letter-sound correspondences whereas in experiment 1 knowledge of relatively complex digraphs such as 'ch' and onsets such as 'sk' were also assessed. The tests in experiment 1 may therefore tap a more complex knowledge of English orthography and therefore be more closely associated with reading ability than simple letter-sound correspondences are in children at this point in reading acquisition. Support for this view comes from investigation of the mean score for letter-sound knowledge in table 5.4, where the average score was 19.65 out of a possible score of 25. This suggests that most children knew most of the simple letter-sound rules used here.

Further analysis showed that the two sorts of phonological awareness measure (phoneme segmentation and rime oddity) did not correlate with each other, replicating the results of experiment 1. Phoneme segmentation skill did correlate strongly with letter-sound knowledge ($r = .57$, $p < .01$) but there was no significant association between any of the Bradley tasks and letter-sound knowledge. Both of these results replicate significant patterns of correlation reported in experiment 1, where phoneme segmentation skill and letter-sound knowledge were strongly associated ($r = .40$, $p < .01$), but where the Bradley tests of auditory organisation were not significantly associated with letter-sound knowledge.

A second set of correlations considered the improvements in target word reading between pretest and posttest. These score are presented in the first part of table 5.5. For comparison the same correlations from the combined prompt condition of experiment 1 are presented on the right side of the same table.

Table 5.5. Correlations between reading, phonological measures, and improvements in target word reading.⁴

Measure	Rime Expt 2	Head Expt 2	Rime Expt 1	Head Expt 1
BAS	.56**	.16	.75**	.19
First Odd	.29	.17	.16	.08
Mid odd	.22	.11	.65*	-.17
Final odd	.07	.23	.73**	.01
Cd Odd	.23	.20	.66**	.05
Phon Seg	.35	.15	.68**	.25
Cd phon	.36	.23	.80**	.14
L.S. Know	.16	.01	.37	.35
L.S. + phon	.31	.11	.45	.68**

Key:

Rime	rime clued words
Head	head clued words
BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Final odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined
L.S. know	letter-sound knowledge
L.S. + phon	L.S know and phon seg combined

As in experiment 1, improvement in reading rime clued words was correlated with measured reading ability, suggesting that inference use is associated with increasing knowledge of English orthography. However, unlike experiment 1, no other correlations were significant, although associations between improvements in reading rime clued words and both phoneme segmentation skill and a combined measure of phonemic

⁴ * p < .05, ** p < .01.

segmentation skill and the Bradley tests of phonological awareness approached significance. Improvements in reading head analogous words were not associated with any of the phonological awareness tests. The reason for this difference is not entirely clear. One possibility may be that as the same phonological tests were used for the same participants in experiments 1 and 2, experiment 1 therefore reflects a test of the concurrent association between transfer and various sorts of phonological awareness, whereas in experiment 2, as transfer in the analogy task was assessed around 8-10 weeks after the measurement of phonological skills, the study may be addressing a longitudinal relationship between the two variables. If true, then this suggests that the link between inference use and phonological awareness described by Goswami (Goswami, 1990a; Goswami & Mead, 1992) is fairly fragile and evident only in concurrent studies of phonological skills and inference use.

The third set of correlations investigated the associations between pretest error scores and reading ability. Errors were categorised as in experiment 1: the proportion of total errors in each category is shown in Table 5. 6. Errors for rime clued words are shown in part 1 and errors for head clued words are shown in part 2 of the table.

Table 5.6. Error category analysis: experiment 2

	Unr	Orth	Init ph	Final ph	I and F	Rime	Head	Refusal
1. Rime errors								
N	4	7	33	6	155	1	6	40
%	1.6	2.78	13.1	2.38	61.5	0.4	1.67	15.9
2. Head errors								
N	3	5	52	4	110	1	8	48
%	1.30	2.16	22.5	1.73	47.6	0.43	3.46	20.8

Key:

Unr	errors sharing no orthographic relationship with target
Orth	errors sharing orthographic overlap with target
Init ph	errors sharing initial phoneme with target
Final ph	errors sharing final phoneme with target
I and F	errors sharing initial and final phoneme with target
Rime	errors sharing common rimes with targets
Head	errors sharing common heads with targets
Refusal	refusal to answer

Visual inspection of the percentage of errors in sections 1 and 2 of the table reveal that errors preserving initial and final consonants represent the largest single error category. Refusals were the second largest error category overall. Correlational analysis of these target error categories against reading and phonological variables are presented in Table 5.7, against the results of the same analyses carried out in experiment 1.

Table 5.7. Correlation of error proportions with reading and phonological measures ⁵.

Measure	Expt 2		Expt 1	
	I &F	Refusal	I &F	Refusal
BAS	.61***	-.35*	.67***	-.32**
First odd	-.06	.12	-.07	.17
Mid odd	-.33*	.36*	.01	.05
Last odd	.16	.17	.04	.03
CdOdd	-.23	.29	.02	.07
Phon seg	.23	-.18	.22*	-.04
Cd phon	-.05	.13	.11	.07
L.S. know	.20	-.24	.35**	-.14
L.S+ phon	.20	-.18	.27*	-.06
Mean	.58	.16	.37	.35
SD	.25	.26	.25	.29
Max	1	1	1	1

Key:

Pretest errors

I & F initial and final phoneme shared with target
 Refusal refusal to answer

Reading-related variables

BAS BAS single word reading
 First odd Bradley first sound
 Mid odd Bradley middle sound
 Last odd Bradley last sound
 Cd odd Combined Bradley score
 Phon seg Phonemic segmentation
 Cd phon Cd odd and phon seg combined
 L.S. know letter-sound knowledge
 L.S.+ phon L.S know and phon seg combined

⁵ * p < .05, ** p < .01, *** p < .001.

Inspection of table 5.7 reveals that reading ability was negatively correlated with the proportion of refusal errors, though positively correlated with the proportion of word reading errors preserving initial and final consonants at pretest. This replicates the pattern of results reported in Experiment 1, and extends the pattern of results first reported by Stuart and Coltheart, (1988). This analysis confirms that word reading errors which preserve initial and final phonemes are a significant associate of early reading ability.

Other patterns of correlation were not as consistent with those reported in experiment 1. The association between errors preserving initial and final consonants and phoneme segmentation ability reported in experiment 1 was of the same magnitude as in the previous study ($r = .23$ in experiment 2, $r = .22$ in experiment 1), but escaped significance in the second smaller scale experiment. The explanation for this probably lies in differences in the statistical power of analyses. This correlation in Experiment 1 was based upon $n=60$ observations, whereas the present correlation is based upon $n=26$ observations. The significant correlations reported in experiment 1 between letter-sound knowledge and the number of pretest paralexias preserving boundary consonants also escaped significance in experiment 2. The reason for this may lie in the difference in the nature of the two tests of letter-sound knowledge used in experiments 1 and 2 which was discussed earlier when considering a similar failure to find a significant correlation between letter-sound knowledge and reading in experiment 2 as reported in experiment 1.

The correlations reported in experiment 2 that were not reported in experiment 1 were in all cases modest. The Bradley middle sound oddity task was positively correlated with refusals to answer, but negatively correlated with errors preserving boundary consonants. This may suggest that rime awareness abilities are not involved in developing partial representations of target words which preserve initial and final consonants. No other correlations reached significance.

The final set of correlations considered one of the main aims of experiment 2: to investigate further the relationship between the proportion of pretest errors made in each of the pretest target word error categories and subsequent improvement in reading of rime and head clued words at posttest. The relationship between improvements made and the proportion of errors made at pretest which preserve boundary consonants was of particular interest. Correlations are presented separately for the rime and head clued words in Table 5. 8, and the same correlations carried out in the combined prompt condition of experiment 1 are also presented for the purposes of comparison.

Table 5. 8. Correlations between errors and improvements in target word reading.⁶

Measure/ Errors	Expt 2 Rimes	Expt 2 Heads	Expt 1 Rimes	Expt 1 Heads
I and F	.51**	.51**	.74**	.43*
Refusal	-.38*	-.42*	-.64**	-.43*

Key:

Pretest errors

Rimes	rime clued words
Heads	head clued words
I and F	initial and final phoneme shared with target
Refusal	refusal to answer

The data in Table 5.8 reveal that there is a significant pattern of associations between improvements in target word reading between pre- and posttest and certain kinds of pretest errors. There is a strong positive correlation between improvements made between pretest and posttest and errors preserving the initial and final consonants of words at pretest: this relationship holds for head and rime clued words. Equally there is a strong negative correlation between pre- to posttest improvements and refusals to answer at pretest. Again this pattern is evident for rime and head clued words. This replicates the pattern of associations reported in experiment 1. Improvements in target word reading appear to be strongly associated with word reading errors at pretest which

6 * p < .05, ** p < .01.

represent boundary consonants accurately but where medial vowel digraphs are inaccurately specified.

In a final set of analyses, partial correlations were undertaken to establish whether the correlation between individual differences in reading of rime clued words at posttest and pretest proportions of errors preserving boundary consonants survived when measured reading ability was first controlled statistically. When reading ability was controlled, there was no significant association between error proportions and improvements in target word reading though a trend towards significance was clearly discernible ($r = .28$, $p = .09$), however when error proportions were first controlled there was a reduced but still significant association between reading ability and improvements in target word reading ($r = .36$, $p < .05$). One interpretation of this finding is that the association between improvement in target word reading and pretest errors is primarily explained by measured reading ability. However, while a larger sample of $n=26$ participants was used in the present study than in experiment 1, the size of the sample in this study is still relatively modest, and it remains quite possible that the partial correlation between inference use and errors preserving initial and final phonemes controlling for reading ability would reach significance in a larger sample of children.

Discussion

One of the aims of experiment 2 was to investigate the pattern of inferences made by young children to words sharing heads (e.g. 'main' - 'mail') or rimes (e.g. 'main' - 'gain') when given concurrent clue word prompts. The contribution of the present study to existing knowledge was to investigate inferences when all words in target sets shared a common consonant - vowel digraph - consonant structure. Significant pre- to posttest improvements were found in two analyses of target word reading for rime and head clued words over unrelated controls. There was also a modest additional advantage for rime over head clued words in an analysis by subjects. However in a second analysis by

items the small advantage for rimes did not reach significance. The analysis tends to suggest that the advantage for clue-target words sharing rimes over other subsyllabic units is not as great as has been previously found by Goswami.

However one possible argument against the present interpretation of the pattern of transfer is that some of the target words may be flawed. A potential problem is that there are words within the present word set for which the subsyllabic unit is itself a real word. An example is the clue-target pair 'fork' - 'ford' in which the head unit shared is itself a word - 'for'. These items may thus have artificially stimulated the use of subsyllabic inferences in a manner not available for the other target words. This word set problem was not considered when the word set was designed and could make interpretation of results more difficult. This issue is therefore considered here. While the problem of real words influencing subsyllabic transfer is potentially an important confounding variable, inspection of words in table 5.1 reveals that there are two word sets for which the head analogous words may be advantaged (the 'fork' set and the 'card' set) but there is also one rime analogous word set (the 'beat' set) which would be differentially advantaged by this mechanism, so the overall contribution of this factor to differences observed between rime and head word types may be small.

More importantly, inspection of means scores for these items provide little evidence that these items are contributing additionally to scores achieved beyond that of words that do not have real words as the the rime or head. One way to look at this is to inspect item mean scores for pre- to posttest transfer in the clue word task. The adjusted mean improvement for all head items between pre- and posttest is .23. For the items 'ford' and 'fort', sharing 'for' with clue word 'fork', the mean item improvements were .22 and .18 respectively. For the other head items which are potentially advantaged in this manner- 'cart' and 'carp', which share 'car' with clue word 'card', the mean improvements were .27 and .10 respectively. Similar analyses for the rime set 'seat' and 'heat' which share 'eat' with clue word 'beat' reveal that while the overall mean

improvement for rimes was .30, for 'seat' and 'heat', the mean item scores were .40 and .18 respectively. There is little evidence here therefore that any of these items are contributing additionally to overall scores achieved.

The present results therefore are consistent with the view that with a carefully selected word set, advantages for rimes over heads are not statistically reliable across subject and item analyses. It may be that too much theoretical weight has been given to the relatively modest rime advantage witnessed in clue word tasks. The present findings are consistent with a view that suggests that children show fairly equal facility in using shared rime or head units in the clue word task. One reason for this may be that as improvements are associated with the number of errors preserving initial and final consonants at pretest, in fact in both cases children are not using large rime or head units at all but rather are adopting a common strategy of inferring complex vowel digraph pronunciations. Support for this view comes from the correlational evidence considered below.

The other main aim of experiment 2 was to investigate further the relationship between reading improvement in the clue word analogy task and the pattern of representation of word knowledge at the pretest reported in experiment 1. Correlational analysis confirmed the finding reported in experiment 1 that there was a significant association between individual differences in improvements in target word reading in the clue word analogy task, and the proportion of errors which preserve both the initial and final consonants of the target words at pretest. Children who refused to offer any answer were unlikely to show signs of improvement in target word reading at posttest. Indeed in the present study, as demonstrated in tables 5.5 and 5.8, of all of the associates of improvements in target word reading, the proportion of errors which preserve initial and final consonants was second only behind reading ability as a significant predictor of rime target word reading at posttest, and was the only significant correlate of improvements in head target word reading between pre- and posttest.

Previous studies (Goswami 1990a; Goswami & Mead, 1992) which have sought to investigate individual differences in the level of pre- to posttest improvements have reported that phonological tests, and particularly the rime oddity sub-test of the Bradley test of auditory organisation are strong predictors of improvements in the clue word task. Here the correlation between pre- to posttest improvements in target word reading and all measures of phonological skills escaped conventional significance. The relatively small sample size ($n = 26$) meant that even relatively strong r values failed to reach conventional significance for two tailed tests. Previous studies by Goswami (1990a) and Goswami and Mead (1992) have used sample sizes of $n=35$ and $n=44$ participants respectively and thus have greater statistical power in correlational analyses. In the present study, the phonological tests which involved phonemic awareness explained a near significant 12% of the variance in reading for rime clued words but the correlation of $r = .35$ was not significant on a two tail test. In contrast, rime awareness measured by the Bradley rime oddity test explained less than 1% of variability in improvement. Results therefore provide some modest support for the view that small phonemically underpinned units, rather than larger rime underpinned units, may be involved in improvements witnessed in target word reading in the clue word task. As reviewed in chapter 3, while some researchers have replicated Goswami's finding of a specific link between rime awareness and pre- to posttest improvements in the reading of rime clued targets (Peterson & Haines, 1992), others have found stronger associations between phonemic than onset-rime awareness and improvements in target word reading (Walton, 1996). It appears that there is a relatively mixed pattern of findings in this area.

One possible explanation of this failure to find the same significant pattern of correlation between rime transfer and phonological rime awareness in experiment 2 as reported by Goswami, and found in experiment 1, may be that these latter studies reflect a test of the concurrent association between transfer and various sorts of phonological awareness, whereas experiment 2 may have addressed a longitudinal relationship between the two variables. Transfer in the analogy task in experiment 2 was assessed

around 8-10 weeks after the measurement of phonological skills. This could suggest that the link between inference use and phonological awareness described by Goswami (Goswami, 1990a; Goswami & Mead, 1992), and reported in experiment 1 is only evident in studies of the concurrent association between phonological skills and inference use. Other evidence also supports this view. Muter et al, (1994) report a concurrent association between rime awareness and improvement in reading rime analogous words, but the same significant correlation was not evident in their longitudinal study of reading development.

In two other regards the present results differed from those of experiment 1. In the present study the proportion of errors preserving initial and final errors were not correlated with either individual differences in letter-sound knowledge or phonemic awareness. In experiment 1 both of these variables were correlated with errors preserving initial and final consonants. The reasons for this different pattern of results are unclear. One possible explanation of the differing patterns of association between phoneme segmentation and error types preserving boundary consonants may reflect differences in the power of statistical analyses in the two studies, as the r values in both studies (.22 in experiment 1, and .23 in experiment 2) were comparable. Further studies in this thesis may further elucidate the nature of this relationship.

The other area of difference between the two studies is in terms of the contribution of letter-sound knowledge to partially specified representations of target words. One plausible explanation lies in the differences in the complexity of orthographic knowledge in the two studies. In Experiment 2 the tests mainly assess knowledge of simple letter-sound knowledge, whereas in experiment 1 knowledge of relatively complex digraphs such as 'ch' and onsets such as 'sk' were also assessed. Investigation of the mean score for letter-sound knowledge in table 5.4 revealed that the average score was 19.65 out of a possible score of 25. This suggests that most children

knew most of the simple letter-sound rules used here, and also suggests that such measures may produce limited returns in future studies with children of this age.

Conclusions

Together therefore, the present results provide several converging lines of evidence to suggest that the use of small orthographic units (graphemes) rather than the use of large units (orthographic rimes) may be sufficient to explain improvements in target word reading in the traditional form of the clue word analogy task. As was noted in discussing experiment 1, it cannot be concluded that improvements between pre- and posttest in studies of transfer in which analogy use is supported by concurrently presented clue words do reflect the use of orthographic vowel analogies, as there are at least two alternative explanations of improvements in word reading in the traditional form of the clue word tasks. One view is that concurrent clue word prompts serve as phonological primes to backwardly activate stored orthographic representations of sublexical information shared by clue and target words (Nation & Hulme, 1996). As clue word knowledge at pretest was greater in experiment 2 than in experiment 1, and improvement appeared to be equivalent across a range of shared units (heads and rimes) such an explanation could be sufficient to explain the improvements in target word reading witnessed here.

Alternatively as mooted in experiment 1, children may use concurrent prompts to directly infer pronunciations for target words. From this view children may show no preference for rime or head units so equivalent improvements would be expected, especially if it is assumed that children are inferring vowel digraphs and synthesising these with consonants in word-initial and word-final positions. As discussed earlier in experiment 1, the present form of the clue word task provides no method for distinguishing between these alternative models of performance in the clue word task. An alternative approach to evaluating analogy theory is to evaluate the use of sublexical

inferences in the absence of concurrent prompts. This approach may reduce the possibility of priming of target word pronunciations by concurrent clue word pronunciations, and should also reduce the salience of the clue word. This approach would also allow an evaluation of children's ability to perform sublexical inferences in situations more similar to those met in naturalistic reading tasks.

Further work is therefore required in the second phase of research to demonstrate whether children can make orthographic inferences in the absence of concurrent prompts. Experiment 1 has already confirmed that children are unable or unwilling to use a single stored clue word to read target words sharing letter-sound strings in common. It remains possible that greater exposure to words with shared orthographic patterns may allow children to infer letter-sound relationships. If children can demonstrate inference use under these more demanding yet more ecologically valid conditions, a second important issue is the size of the units involved, and the role of partial representations of target orthography, reading ability and phonological skills in facilitating sublexical inferences. These issues are investigated in experiments 3, 4, and 5 of this thesis.

Chapter 6

The spontaneous use of sublexical inferences in early reading

Experiment 3

Experiment 3 sought to further investigate some of the questions surrounding the nature and use of sublexical inferences posed by the results of the main transfer of learning task in Experiment 1. The research described in Experiment 1 confirmed that children show transfer to analogous target words following presentation of a clue word knowledge when concurrently prompted with clue word pronunciations at posttest, as first reported by Goswami (1986, 1993). Experiment 1 also however revealed that concurrent phonological clue word prompts facilitate equal levels of improvement in pre- to posttest target word reading, even in the absence of any orthographic clue word information. This finding could suggest that children are not using an orthographic analogy strategy in the clue word task.

Experiment 1 also sought to investigate the spontaneous use of rime inferences in the absence of concurrent clue word prompts but where a single clue word was pretaught minutes before the posttest. This particular condition has not been investigated previously by Goswami, but nevertheless reflects an important test of the spontaneous use of inferences in early reading, as in natural reading situations children must make inferences from stored rather than concurrently presented clue words. Experiment 1 revealed that children are unable to infer sublexical relationships on the basis of a single taught clue word, despite the fact that this ability to use inferences without concurrent prompts is required in naturalistic reading situations.

The results of experiment 1 are illuminating but Experiment 1 is limited to considering the use of inferences on the basis of a single taught clue word. The main

aim of this study is to evaluate the ability of young children to infer sublexical relations when given prior exposure to word families sharing common orthographic patterns. An alternative method of studying spontaneous inferences is developed to investigate the effects of greater levels of teaching involving several clue words exemplifying orthographic patterns in a distinct pretest phase, thereby avoiding the use of concurrent clue word prompts in the posttest phase of the present study. To this end the present study used a new version of the basic transfer of learning paradigm utilised by Goswami (1986) in which children in the experimental conditions were pretaught three analogous 'clue' words minutes before the posttest stage. The results of this study should reveal whether young children can make spontaneous orthographic inferences after prior exposure to several words embodying letter strings shared with untaught words.

A second aim was to investigate whether words sharing orthographic rimes (e.g. 'leak' - 'peak'), which according to Goswami's model have 'phonological status' in early reading, enjoy privileged transfer in these new conditions over words sharing only the medial vowel digraph (e.g. 'leak' - 'bean'), which do not have phonological status in Goswami's model. These provide a test of the view that smaller vowel digraph units are inferred as well as the rime units considered in Goswami's model. Experiments 1 and 2 had provided some support for an alternative to Goswami's model. From this alternative view, children who are aware of the pronunciation of the boundary consonants of CVC target words at pretest may therefore use the clue words in Goswami's analogy task to synthesise vowel pronunciations rather than rime body units.

The present study provides an experimental test of these contrasting theories by comparing inferences from three pretaught clue words sharing rimes with targets (e.g. clues 'corn', 'torn' and 'horn' to target 'worn') to inferences from three pretaught clue words sharing only vowel digraphs with targets (e.g. clues 'corn', 'torn' and 'horn' to

target 'form') against unrelated control words (e.g. clues 'corn', 'torn' and 'horn' to target 'boil'). These comparison should reveal whether the advantage for rime inferences over other subsyllabic units reported by Goswami (e.g. 1986, 1993), in inference tasks using concurrent clue word prompts at posttest is also evident in spontaneous inference use, or whether children use clue word information to spontaneously derive vowel digraph pronunciations as suggested by correlational analyses presented in experiments 1 and 2 of the present thesis.

Children's ability to read clue words before and after the posttest stage was also measured in order to evaluate the extent of available clue word knowledge during the posttest phase of the experiment. Two measures of phonological awareness were taken to measure the correlation between improvements in target word reading and phonological skills, and to further investigate the correlation between pretest target word reading paralexias and reading-related measures.

Method

Participants

A new sample of forty five children (mean age 6 years 3 months, range 5 years 9 months to 6 years 9 months) from two London primary schools were included in the study. These children had not taken part in any previous studies of analogy and inference use. The mean reading age on the BAS was 6 years 4 months (range from 5 years 3 months to 7 years 9 months). Two children had reading ages more than two standard deviations above the mean reading age and were excluded from the sample. Analysis of the sample ($n=45$) BAS reading scores revealed that the distribution did not deviate markedly from normal. Kurtosis ($k = 2.18$), and skew, ($s = 0.19$) were both non-significant. The mean BPVS score was 94.73 ($SD = 15.84$).

Children were randomly allocated to one of three groups of 15 subjects. These groups were matched for reading ability, clue word knowledge, and vocabulary ability on the BPVS. Equal proportions of children from each school were present in each group, thus controlling for possible effects of different teaching methods across schools. Each group contained approximately equal proportions of girls and boys. The mean scores on screening test measures are presented in Table 6.1.

Table 6. 1. Scores on screening measures across three teaching groups.

Teaching group	Age (months)	Reading age (months)	BPVS (standard scores)	Sex (m)
Taught-vowel	74.8 (3.49)	76.1 (5.29)	94.5 (16.0)	8
Taught-vowel-and-rime	75.3 (3.94)	75.5 (7.35)	94.9 (18.0)	7
Untaught	74.7 (3.70)	75.6 (3.11)	94.7 (14.5)	8
Mean	74.93 (3.62)	75.73 (5.41)	94.73 (15.84)	

A 3 (teaching group: taught-vowel versus taught-vowel-and-rime versus untaught) X 3 (measure: chronological age versus BAS reading age versus BPVS vocabulary) Anova confirmed that matching was achieved on the measured variables. The teaching group, and teaching group by measure interactions were both non-significant ($F < 1$ in both cases). Children were also shown four cards, each denoting one of four vowel digraphs used in the experiment ('ea', 'or', 'oo', 'ar') and asked to pronounce them. No other measures of letter-sound knowledge were included in this or subsequent experiments as experiment 2 had revealed that most children at this point in reading acquisition already knew most simple letter-sound pronunciation rules and measures may therefore show significant ceiling effects.

Design and materials

Each group of 15 children participated in one of the three clue word teaching conditions in a between subjects design. All groups saw the same target words at pretest and posttest. The groups differed only in terms of the clue word information they were given prior to the posttest. Children in the 'taught vowel-and-rime' condition were pretaught clue words which share rimes with the rime words (e.g. clue word 'leak', targets 'peak' and 'weak') and medial vowel digraphs with the vowel words (e.g. clue word 'leak', targets 'bean', and 'bead'). Children in the 'taught vowel' condition were pretaught clue words which shared medial vowel digraphs with both target word sets (e.g. clue word 'meat', targets 'peak', 'weak', 'bean', 'bead'). Control target words shared neither rime nor medial vowel digraph with rime or vowel clue words. Pretest target word reading errors were classified using the same taxonomy described in experiment 1.

Stimuli

A new set of target words was needed to compare spontaneous inference use from three pretaught clue words and in order to compare the level of rime and vowel digraph inference use under these conditions of spontaneous transfer. As far as possible, all target words were CVC monosyllables; where this was not possible (due to the size of the word families required) words with consonant cluster onsets (e.g. 'freak') were included. The number of consonant cluster onsets was equated across the taught-vowel and taught-vowel-and-rime clue word sets. The clue and target word chosen were generally low frequency words. However, as matching word sets using formal frequency counts had not succeeded in equating the number of words read at pretest in previous experiments, words were not systematically matched on standard counts of frequency in the present study. A full list of words used in experiment 3 is presented in Table 6.2.

Phonological awareness measures

Two types of phonological awareness measure (the Bradley oddity tests and phonemic segmentation) were administered in the same manner as described in experiment 1.

Table 6.2. Full word set used in Experiment 3.

Clue words		Target words		
taught vowel-and-rime	taught-vowel	vowel share	vowel-and-rime share	controls
<u>Session A</u>				
leak	meat	bean	peak	herd
speak	seat	bead	weak	coin
teak	treat			
corn	stork	form	worn	loud
torn	cork	ford	born	boil
horn	pork			
<u>Session B</u>				
spoon	loop	moon	goof	bait
roof	scoop	moot	hoof	gout
proof	coop			
bark	darn	harp	park	soap
dark	yarn	hart	lark	surf
mark	barn			

Conditions and Procedure

Children in each experimental group participated in one of the following three teaching conditions: taught-vowel group, taught-vowel-and-rime group, or an untaught control condition.

1. The taught-vowel group were taught only the vowel share clue words. These words shared only vowels with two sets of target words, vowel share targets (e.g. 'meat' -

'bean'), and vowel-and-rime share targets (e.g. 'meat' - 'peak') and shared no graphemic relation with the control words (e.g. 'meat' - 'herd').

2. The taught-vowel-and-rime group were taught only the vowel-and-rime share clue words. These words shared vowels with the vowel share target words (e.g. 'leak' - 'bean'), rimes with the vowel-and-rime target words (e.g. 'leak' - 'peak') and shared no graphemic relation with the control words, (e.g. 'leak'-'herd'). This group therefore provided a within-subjects comparison of improvements after exposure to rime and vowel clued words.

3. The Untaught group were taught no clue words. For this group, the posttest was the same as the pretest. They provided a baseline against which to measure improvements in taught groups.

There were four clue-target word sets. Children were either taught vowel or rime clues or were not taught any clue words. In each experimental session the child was shown a total of two clue and corresponding target word sets. Sets 1 and 2 were presented in one session, sets 3 and 4 in the other session. The three clue words were taught to a criterion of three successful pronunciations in a row. During the teaching phase no information on rime or other word segments was given. Children were told - "this word says... (e.g. 'corn'). Corn Flakes are made of corn. What does the word say ?" [the child says 'corn']. "Can you remember that word?". If the child said "yes", the next word was then presented. If not it was repeated, with the injunction "look carefully at the word". Only one word was therefore present at any one time during the training phase. After all three words had been read to criterion they were placed next to each other, and the experimenter said "we know these three words don't we? ... corn ...torn... and ...horn".

Clue words were then hidden from sight and children were given a brief intervening visual search task which required them to count a series of items presented on a card and respond verbally with a correct answer. This took around two minutes to complete. The purpose of the intervening task was to dissipate any temporary activation of the phonological or orthographic system caused by the repeated reading of similar words. Children were shown the corresponding target word set immediately after completing the visual search task. Children in all conditions were asked to read all target words, rime, vowel, and control. Children were also asked to read the four vowel digraphs first shown in the screening test ('ea', 'or', 'oo', 'ar') after the posttest to evaluate whether children had been able to learn these digraphs after exposure to clue words containing them.

Results

Analysis of targets read correctly

Subject analyses

The mean scores for the target word reading between pre- and posttest are shown in Table 6.3¹. Children in the taught-vowel-and-rime group made improvements for vowel share and vowel-and-rime share words. Children in the taught-vowel group also showed improvement with both these sets of target words. Children in the untaught group showed little or no improvement in reading either set of targets. No children showed any improvement in reading control words.

¹ At this point a word set error was noticed. The word 'peak' shares more than the rime unit alone with the clue word 'speak'. At the post-test, this word was read better than all of the other words. Improvement scores for this stimulus word were therefore excluded. The scores for the other seven target words were multiplied up to make them comparable to the other word sets.

Table 6. 3. Mean number of target words read across teaching group (subjects).

Teaching group	Pretest	Posttest
1. Taught-vowel		
vowel share	2.07 (1.67)	3.47 (1.55)
vowel-and-rime share	2.27 (2.28)	4.00 (1.96)
controls	0.73 (1.16)	0.80 (1.27)
2. Taught-vowel-and-rime		
vowel share	1.73 (1.75)	3.20 (2.27)
vowel-and-rime share	1.67 (1.95)	4.14 (2.32)
controls	0.53 (1.30)	0.47 (1.30)
3. Untaught group		
vowel share	1.87 (1.41)	1.67 (1.40)
vowel-and-rime share	1.53 (1.60)	1.80 (1.93)
controls	0.20 (0.56)	0.27 (0.59)
(Standard deviations are shown in parentheses)		

Note: Max n=8.

Preliminary analyses confirmed that there were pretest differences between word types. The data were therefore submitted to a 3 (teaching group: taught vowel versus taught vowel-and-rime versus untaught) X 3 (word: vowel share versus vowel-and-rime share versus controls) analysis of covariance with pretest scores as the covariate, and with repeated measures on word ². The dependent variable was the number of words read correctly out of 8. Results showed that there was a main effect of

² The control word distributions differed markedly from normal. There may be a case for transforming these variables prior to analysis. However scores are at floor, and showed kurtosis as well as skew: this makes it difficult to transform variables to achieve normality. Tabachnik and Fidell (1989), argue that covariance can proceed with non-normally distributed variables if transfer is not possible, so analysis proceeded using the raw scores.

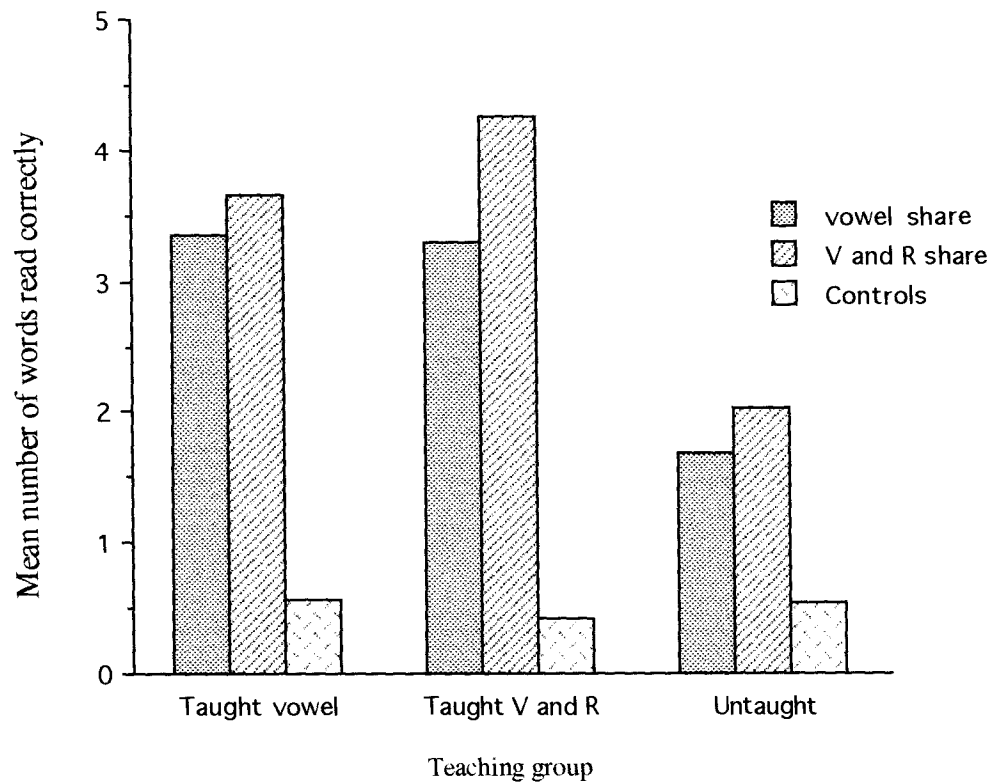
teaching group, $F(2, 41) = 9.52$, $p < .001$, and a main effect of word $F(2, 83) = 32.91$, $p < .001$. There was also a significant teaching group by word interaction $F(4, 83) = 4.91$, $p = .001$. Newman-Keuls post hoc test carried out on the adjusted means revealed that the interaction was due to a greater number of vowel share and vowel-and-rime share words being read correctly in both the taught vowel and taught vowel-and-rime groups compared to the control words ($p < .01$ in all cases). Importantly there was no advantage for vowel and rime share words over the vowel share words within either the taught-vowel-and-rime group or the taught-vowel group. In the taught-vowel-and-rime group and the taught-vowel group these comparisons with the same words in the untaught group were also significant ($p < .01$ in all cases). The adjusted mean scores are presented in Table 6.4, and in Figure 6. 1.

Table 6.4. Adjusted means: group by word interaction (subjects).

Teaching group	Words		
	vowel share	vowel-and-rime share	controls
1. Taught-vowel	3.36	3.66	0.57
2. Taught- vowel-and-rime	3.30	4.26	0.42
3. Untaught	1.68	2.02	0.54

Note: Max n = 8.

Figure 6. 1: Words read correctly in experiment 3 (adjusted scores)

Key:

Taught vowel: Taught-vowel group
 Taught V and R: Taught-vowel-and-rime group
 Untaught: Untaught group

Item analyses

The mean scores for target word reading between pre- and posttest are shown in Table 6.5. Children in the taught-vowel-and-rime group made improvements for vowel share and vowel-and-rime share words. Children in the taught-vowel group also show improvement with both these sets of target words. Children in the untaught group showed little or no improvement in reading either set of targets. No group of children showed any improvement in reading control words.

Table 6.5. Mean number of target words read across teaching group (items).

Teaching group	Pretest	Posttest
1. Taught-vowel		
vowel share	3.88 (3.14)	6.50 (3.82)
vowel-and-rime share	4.25 (1.98)	7.50 (3.16)
controls	1.38 (0.92)	1.50 (0.93)
2. Taught-vowel-and-rime		
vowel share	3.25 (2.49)	6.00 (2.33)
vowel-and-rime share	3.14 (1.73)	8.00 (1.51)
controls	1.00 (0.93)	0.88 (0.83)
3. Untaught		
vowel share	3.50 (3.78)	3.13 (3.04)
vowel-and-rime share	2.88 (2.70)	3.34 (2.77)
controls	0.38 (0.52)	0.50 (0.53)
(Standard deviations are shown in parentheses)		

Note: Max n=15.

Preliminary analyses confirmed that there were pretest differences between word types. The data were therefore submitted to a 3 (teaching group: taught vowel versus taught vowel-and rime versus untaught) X 3 (word: vowel-share versus vowel-and-rime share versus controls) analysis of covariance with pretest scores as the covariate, and with repeated measures on word. The dependent variable was the number of words read correctly out of 8. Results showed that there was a main effect of teaching group, $F(2, 20) = 31.84$, $p < .001$. There was a main effect of word, $F(2, 41) = 23.12$, $p < .001$. There was also a significant teaching group by word interaction $F(4, 41) = 7.21$, $p = .001$. Newman-Keuls post hoc test carried out on the adjusted

means revealed that the interaction was due to a greater number of vowel share and vowel-and-rime share words being read correctly in both the taught vowel and taught vowel-and-rime groups compared to the control words ($p < .01$ in all cases). In the taught-vowel-and-rime group and the taught-vowel group these comparisons with the same words in the untaught group were also significant ($p < .01$ in all cases). There was also an advantage for vowel-and-rime share words over the vowel share words within the taught-vowel-and-rime group ($p < .01$) and over the vowel-and-rime share words in the taught-vowel group ($p < .05$), suggesting that there was an advantage for inferences from shared rimes over inferences from shared vowels in these data. The adjusted mean scores are presented in Table 6.6.

Table 6.6. Adjusted means Group by Word interaction (items).

<u>Teaching group</u>	<u>Words</u>		
	vowel-share	vowel-and-rime share	controls
1. Taught-vowel	6.25	8.29	0.82
2. Taught-vowel-and-rime	6.22	6.66	1.20
3. Untaught	3.16	3.93	0.86

Note: Max $n=15$.

Analysis of the number of inferences made

A further analysis on the main experimental data using the more sensitive measure of the 'total number of inferences made' was undertaken. However there were almost no changes to the totals using this analysis (one extra pronunciation for each of the taught-vowel and taught vowel-and-rime groups). These did not alter any of the means or the main analyses appreciably and so these data are not presented here.

Analysis of control word paralexias

The means for all of the erroneous control word responses that share analogous pronunciation with their clue words are presented in Table 6.7.

Table 6.7. Mean number of control words read sharing clue word pronunciations in Experiment 3.

Teaching group	Pretest	Posttest
1. Taught-vowel	0.27 (0.59)	1.00 (1.25)
2. Taught-vowel-and-rime	0.07 (0.26)	0.93 (1.10)
3. Untaught	0.40 (0.51)	0.40 (0.83)

Note: Max $n=8$.

For the taught vowel-and-rime group, 60 % of these clue word-analogous responses shared vowels with the clue word, and 40% shared rimes. For the taught-vowel group, 11 % of analogous responses shared rimes, the rest shared vowels. The data were submitted to a 3 (teaching group: taught-vowel versus taught-vowel-and rime versus untaught) X 2 (test: pretest versus posttest) Anova with repeated measures on test. The dependent variable was the number of over-extensions made out of 8. Analyses revealed a significant main effect of test $F(1, 42) = 11.52, p < .02$. This shows that there was some tendency for children to give clue-word analogous pronunciations for words which do not share orthographic units with the clue word. However the main effect of teaching group and the teaching group by test interactions were both non-significant ($p > .05$ in both cases), so these overextensions do not appear to be specific to children taught analogous clue words. Furthermore these overextensions are not of the same magnitude as the patterns of inference use in table 6.3, suggesting that inference use in the main experimental task reflects children's awareness that clue and targets share orthographic strings.

Analysis of vowel digraph reading

The mean scores are presented in Table 6.8 by test and teaching group. Investigation of the means show few improvements in the reading of vowel digraphs between the pretest and the posttest. Data were submitted to a 3 (teaching group: taught-vowel versus taught-vowel-and-rime versus untaught) x 2 (test: screening test versus posttest) Anova with repeated measures on test. The dependent variable was the number of vowels pronounced correctly out of 4. This revealed no significant effects whatsoever (all $F_s < 1$).

Table 6.8. Mean number of vowels read at screening test and posttest in experiment 3.

Teaching group	Pretest	Posttest
1. Taught-vowel	1.53 (0.74)	1.60 (1.40)
1. Taught-vowel-and-rime	1.60 (0.91)	1.67 (0.98)
3. Untaught group	1.53 (1.36)	1.73 (1.53)

(Standard deviations are shown in parentheses)

Note: Max $n = 4$.

This analysis indicates that, despite showing some signs of improvement in reading target words which share vowel analogous segments in common with clue words, children show no improvement in reading the vowel digraphs in isolation.

Analysis of clue word knowledge

The improvements in the number of clue words read between pretest and posttest were analysed for the taught vowel and taught vowel-and-rime groups. Data were submitted to a 2 (teaching group: taught vowel versus taught vowel-and-rime) X 2 (test: pretest versus posttest) Anova with repeated measures on test. The dependent

variable was the number of clue words correctly read out of 12. Results showed that there was a main effect of test, $F(1, 28) = 253.55$, $p < .001$, but neither the main effect of teaching group, nor the teaching group by test interaction approached significance, (both $F_s < 1$). The means are presented in Table 6.9.

Table 6.9. Mean number of clue words read at pretest and posttest. Experiment 3.

Teaching group	Pretest	Posttest
1. Taught vowel group	3.00 (2.83)	10.67 (2.09)
2. Taught-vowel-and-rime	2.20 (2.43)	10.47 (1.85)

(Standard deviations are shown in parentheses)

Note: Max $n = 12$.

This analysis shows that the children had learned the clue words very effectively and could articulate them at the posttest. Furthermore, the level of word learning was equivalently high across the two teaching group conditions. This is important as it confirms that the patterns of improvement in target word reading in the main task cannot be explained by any differences in the level of word learning across the two groups.

Analysis of speed of clue word learning

Analysis of the speed with which children learned the clue words was also undertaken. As the number of trials to criterion was three correct articulations of the clue word in a row, the minimum possible score was therefore 36. The data are presented in Table 6.10.

Table 6.10. Speed of clue word learning: Experiment 3.

Teaching group	Mean number of trials to criterion
1. Taught-vowel	47.90 (4.04)
2. Taught-vowel-and-rime	50.40 (6.95)
(Standard deviations are shown in parentheses)	

An unrelated t-test confirmed that there was no significant difference between the two taught groups in terms of the number of learning trials required to reach criterion, $t(28) = 1.19$, n.s. This analysis confirms that children in the taught-vowel and taught vowel-and-rime groups had equivalent numbers of clue word learning trials. As these words were taught in a distinct pretest phase no advantage for rime analogous over vowel analogous clue words would be expected in terms of the number of learning trials needed.

Correlational analyses

The first set of correlations considered the pattern of relations between measured reading ability and other classes of reading-related measures. These results are presented in table 6.11 alongside the same analyses from experiments 1 and 2 for the purposes of comparison.

Inspection of the results in table 6.11 reveals a very similar pattern of non-significant results reported in previous studies. Notably the oddity scores did not correlate with reading ability. However unlike experiments 1 and 2, reading ability was significantly positively correlated with phoneme segmentation ability. Reading ability was also less strongly correlated with the combined phonological measure in which the scores for all phonological tests are combined. The reason for this varying pattern of

correlation results for phoneme segmentation is unclear, though in previous studies the r values have indicated a modest positive correlation between phonemic segmentation and reading ability, and a trend toward significance may be evident in these results. Further analysis revealed that the Bradley oddity task and the phonemic segmentation task scores were not correlated with each other. This aspect of these results is therefore very similar to those reported in experiments 1 and 2.

Table 6. 11. Correlations between reading ability and phonological measures ³.

Measure	first odd	Mid odd	Last odd	Cd odd	Phon seg	Cd Phon	L.S. Know	L.S + Phon
Expt 3								
BAS	.01	.08	.13	.10	.39**	.32*		
Expt 2								
BAS	.20	-.08	-.18	-.04	.24	.10	.11	.22
Expt 1								
BAS	.25	.26	.11	.25	.24	.32*	.35**	.34**
Expt 3								
Mean	5.00	6.12	5.21	16.33	7.10	22.83		
SD	2.20	2.73	2.56	5.53	5.26	9.62		
Max	12	12	12	36	16	52		

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Last odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined

The second set of correlations evaluated the improvement in target word reading between pre- and posttest in the main experimental task for the 30 children who were taught clue words, and the association with reading ability and other reading-related skills. As there were unequal proportions of target words sharing vowel digraphs

³ * $p < .05$, ** $p < .01$.

compared to words sharing orthographic rimes, an overall measure of improvement was taken by combining the improvement scores for each subject on the vowel share and vowel-and-rime share words. Analysis was based upon 27 subjects as three children were unavailable for the final testing session measuring phonological skills. The correlations are presented in table 6.12 and for the sake of comparison, scores in similar analyses in the previous two experiments are presented on the right hand side of the table.

Table 6.12. Correlations between reading, phonological measures, and improvements in target word reading.⁴

Measure	Imp 3	Rime	Head	Rime	Head
		Expt 2	Expt 2	Expt 1	Expt 1
BAS	.26	.56**	.16	.75**	.19
First Odd	.28	.29	.17	.16	.08
Mid odd	-.01	.22	.11	.65*	-.17
Final odd	.14	.07	.23	.73**	.01
Cd Odd	.18	.23	.20	.66**	.05
Phon Seg	.34	.35	.15	.68**	.25
Cd phon	.34	.36	.23	.80**	.14
L.S. Know	—	.16	.01	.37	.35
L.S. + phon	—	.31	.11	.45	.68**

Key:

Imp 3 combined improvement for vowel and rime words in experiment 3
 Rime rime clued words
 Head head clued words

BAS BAS single word reading
 First odd Bradley first sound
 Mid odd Bradley middle sound
 Final odd Bradley last sound
 Cd odd Combined Bradley score
 Phon seg Phonemic segmentation
 Cd phon Cd odd and phon seg combined
 L.S. know letter-sound knowledge
 L.S. + phon L.S know and phon seg combined

4 * p < .05, ** p < .01.

Inspection of table 6.12 revealed that, unlike the results of previous studies, no correlations reached conventional significance. A consistent finding in previous experiments was that inference use was correlated with reading ability. While there was a modest positive correlation in the present experiment, this escaped conventional significance. The reason for this is not clear. One possibility may be that spontaneous inference use, unlike the concurrently prompted transfer investigated in experiments 1 and 2 is not strongly correlated with reading ability, though further studies will be needed to confirm this hypothesis. It may also be of importance to note that, in the present study of spontaneous inference use a trend towards significance was evident in the associations between improvements in target word reading and phonemic segmentation ($r = .34, p < .1$) and the combined phonological measures ($r = .34, p < .1$) on two tail tests. With a larger sample this correlation may have reached conventional significance.

The third set of correlations investigated the association between pretest error proportions and reading ability. The proportions of the total number of errors in each category at pretest are shown in Table 6.13. Errors preserving both initial and final consonants are the largest single category of errors at pretest. Refusals also constituted a substantial proportion of the errors. Correlations between reading and reading-related measures and the category of error types are presented in Table 6.14.

Table 6.13. Error category analysis experiment 3.

	Unr	Orth	Init phon	Final phon	I and F	Rime	Head	Refusal
Pretest errors								
N	1	7	42	5	210	4	5	90
%	0.27	1.92	11.54	1.37	57.69	1.10	1.37	24.73

Key:

Unr	errors sharing no orthographic relationship with target
Orth	errors sharing orthographic overlap with target
Init ph	errors sharing initial phoneme with target
Final ph	errors sharing final phoneme with target
I and F	errors sharing initial and final phoneme with target
Rime	errors sharing common rimes with targets
Head	errors sharing common heads with targets
Refusal	refusal to answer

Table 6.14. Correlation of error proportions with reading and phonological measures ⁵.

Measure	Expt 3		Expt 2		Expt 1	
	I and F	Refusal	I & F	Refusal	I & F	Refusal
BAS	.39**	-.14	.61***	-.35*	.67***	-.32**
First odd	.33*	-.19	-.06	.12	-.07	.17
Mid odd	.14	-.12	-.33*	.36*	.01	.05
Last odd	.19	-.19	.16	.17	.04	.03
CdOdd	.28	-.22	-.23	.29	.02	.07
Phon seg	.09	.12	.23	-.18	.22*	-.04
Cd phon	.33*	-.21	-.05	.13	.11	.07
L.S. know	—	—	.20	-.24	.35**	-.14
L.S+ phon	—	—	.20	-.18	.27*	-.06
Mean	.54	.28	.58	.16	.37	.35
SD	.28	.30	.25	.26	.25	.29
Max	1	1	1	1	1	1

⁵ * p < .05, ** p < .01, *** p < .001.

Key:Pretest errors

I & F initial and final phoneme shared with target
 Refusal refusal to answer

Reading-related variables

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Last odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined
L.S. know	letter-sound knowledge
L.S.+ phon	L.S know and phon seg combined

Inspection of this table reveals that in experiment 3, as in experiments 1 and 2, the proportion of pretest target word reading errors preserving boundary consonants is strongly positively correlated with reading ability. The negative correlation between the proportion of pretest refusals and reading ability reported in experiments 1 and 2 was also evident in experiment 3, but escaped significance. This analysis again confirms that partial representations of words preserving boundary phonemes are a common feature of early reading and are associated with developing reading ability.

Correlations between phonological skills and categories of pretest target word reading errors were not numerous. The proportion of partial representations of target words preserving initial and final phonemes was correlated with the first sound oddity task of the Bradley test and with the combined phonological measure, but not with either of the rime oddity tasks. This could suggest that the Bradley beginning oddity subtask is measuring phonemic sensitivity and for this reason is correlated with the number of errors preserving initial and final phonemes with target words. This analysis needs however to be considered against the failure to find a similar positive correlation between explicit phoneme segmentation and the proportion of errors in this category, which has been reported previously in experiment 1.

The final set of correlations investigated the association between the proportion of pretest errors made in each of the error categories and subsequent improvements in target word reading. Correlations are presented in Table 6. 15.

Table 6.15. Correlation between pretest error scores and improvements in target word reading.⁶

Measure/ Errors	Expt 3 Imp	Expt 2 Rimes	Expt 2 Heads	Expt 1 Rimes	Expt 1 Heads
I and F	.45*	.51**	.51**	.74**	.43*
Refusal	-.19	-.38*	-.42*	-.64**	-.43*

Key:

Imp Improvement in target word reading between pre- and posttest experiment 3

Pretest errors

I and F initial and final phoneme shared with target

Refusal refusal to answer

The data in Table 6.15 reveal that there is a significant pattern of associations between improvements in target word reading at posttest and certain kinds of pretest errors. As in experiments 1 and 2, errors preserving the initial and final consonants at pretest were strongly and positively correlated with improvement in target word reading at posttest. However unlike experiments 1 and 2, the negative correlation between refusals and improvements in target word reading escapes conventional significance. This analysis provides further support for the robust association between errors preserving boundary consonants and improvements in target word reading reported in experiments 1 and 2, and is consistent with results reported in the main experimental study of inference use which suggested that children make spontaneous inferences from vowel digraphs of clue words in analogy tasks rather than using orthographic rime inferences as Goswami's interactive analogy model suggests.

Discussion

The main aim of Experiment 3 was to investigate whether children can perform spontaneous inference of orthographic knowledge following prior exposure to examples of clue words sharing sublexical segments with targets. The second aim of

⁶* $p < .05$, ** $p < .01$.

the experiment was to compare the levels of improvement in the reading of target words sharing common rimes or common vowels with clue words, in order to investigate Goswami's (1986, 1993) claim that rime units have a privileged status in transfer of learning tasks. The results of the main inference task showed that significant and reliable improvements in reading of target words sharing vowel digraphs and rimes was evident over untaught control conditions. Unlike previous investigations of analogy use which have used concurrent prompts (Goswami, 1993) strong evidence for vowel inference use was found ($p < .01$ in both subject and item analyses). This study suggests therefore that even six year old children are able to use sublexical inferences without requiring concurrent prompts to support them. This is the first demonstration of such an ability in very young children. The findings suggest that spontaneous inference use is a strategy available to young children - if they have sufficient orthographic and phonological knowledge of neighbouring words from which to make the orthographic inference.

There was rather mixed evidence of additional advantages for rime analogous over vowel analogous targets after the pretest scores were covaried out. The two sets of words were statistically indistinguishable in subject analyses but significant advantages were evident for words sharing rimes over targets sharing only vowels with clues in the item analyses. The present results stand in some contrast to the strong rime analogy use and relatively weak but significant vowel digraph analogy use reported in the traditional clue word task (Goswami, 1993). The interpretation of the present results was however complicated by imprecision in the word set used. As one of the target words 'speak' was flawed, this necessitated rejecting all scores attributable to this item and multiplying up the scores of the other items to make them comparable with the means of the taught-vowel and control word types. This approach is not ideal and further work with an improved word set is clearly necessary to provide more definitive evidence about the efficacy of different sized sublexical units in orthographic inference tasks.

Analyses of errors also provided some support for the view that vowel digraph units are central to improvements in target word reading. The proportion of pretest target word reading errors which preserved initial and final consonants was again strongly correlated with subsequent improvements in target word reading. This relationship between improvements and pretest target word representations was also found in experiments 1 and 2, and suggests that errors preserving initial and final consonants are implicated in sublexical inferences across a range of conditions. It is worth noting that these errors were the best predictors of subsequent inference use from taught clue words. Table 6.15 reveals that the r values for this relationship are larger than any other correlation reported in tables 6.12 to 6.15 and are significant predictors of inference use despite the fact that measured reading ability did not correlate with improvements in target word reading in this study.

Analyses of clue word knowledge showed that children were able to learn about and retain clue word knowledge. Indeed the children were near ceiling in their ability to read clue words after the posttest, suggesting that pre- to posttest improvement in the task is not limited simply by lack of knowledge of clue words needed to perform the inference task. There are many times when children know three relevant clue words but still do not perform sublexical inferences. In contrast to this ability to read clue and target words, children in this study did not show any increase in knowledge of the four vowel digraphs embedded in the clue-target relationships between pretest and posttest, possibly suggesting that the learning involved in the present task is not sufficient for children to infer vowel digraph information.

One possible explanation of the failure to find improvements in vowel digraph reading between pre- and posttest despite finding improvements in target word reading might be that improvements in target word reading in the main experiment reflect a purely strategic use of clues from the previously taught words, which then leaves children unable to read the appropriate vowel digraphs in isolation. However this view

would not be able to explain why improvements in target word reading were great when target words shared digraphs or rimes with previously taught clues (i.e. in the vowel-share and vowel-and-rime share conditions) whereas the number of inappropriate overextensions of clue word pronunciations to the control words which did not share digraphs with clue words was much lower. This finding suggests an alternative view of pre- to posttest improvements: children are able to infer vowel digraph pronunciations from taught clue words. It may however be that such inferred vowel information is fragile or dependent upon word context. One possibility is that the presentation of vowel digraphs in isolation encourages children to revert back to a commonly occurring but inappropriate pretest strategy of attempting to sound out the the two letters separately and then blend them together. Alternatively the fact that there were only four exemplars of vowel digraphs may mean that numbers were insufficient to allow genuine improvements in vowel digraph knowledge to be demonstrated.

Improvements in reading analogous words were not associated with reading ability or measures of phonological awareness. A trend towards significance was evident for phonological tasks involving phonemic segmentation with a correlation of $r = .34$ which therefore explained around 12% of the variance in inference use. In contrast, the Bradley rime awareness task explained less than 1 percent of the variance in inference use. Measured reading ability was more strongly correlated with phonemic segmentation than in experiments 1 and 2 and the association was strongly significant, but as in the previous two studies was not correlated with any of the individual subtests of the Bradley measure of onset and rime awareness. These results again provide some modest support for the view that phonemic awareness rather than rime awareness is related to reading ability.

Finally, Experiment 3 found a similar pattern of associations between classes of pretest word reading errors, reading, phonological skills and letter-sound knowledge to that found in the previous two studies. Experiments 1 and 2 found that refusals to

respond were negatively associated with reading ability, whereas errors preserving both initial and final consonants were positively associated with reading ability. In the present study there was no negative association between refusals at pretest and reading ability. There was a positive correlation between errors preserving initial and final consonants and reading ability. These latter errors were also associated with the first sound oddity task, and the combined phonological awareness tasks but not with the phonemic segmentation task. This confirms that these error types are associated with phonological skills, though also suggests that the kinds of task which capture this relationship (oddity versus phoneme segmentation) appear to vary, as phonemic awareness not oddity tasks were the best predictor of the number of these error types made at pretest in experiments 1 and 2. One possible explanation of this present result may be that the Bradley beginning oddity subtest is providing a measure of sensitivity to phonemes that is associated with the development of partial representations of target words in early reading.

Conclusions

The main aim of the present study was to investigate whether 6 year old children were able to show the use of orthographic inferences from previously taught clue words sharing common letter-sound relationships with target words in the absence of concurrent clue word prompts. The present results suggest that children can indeed make inferences under these conditions. This is the first time this skill has been demonstrated and, if reliable represents an important finding. A second aspect of the present work was to evaluate the relative use of inferences from shared vowel digraphs and inferences from shared rimes in order to test Goswami's interactive analogy model wherein rimes, but not medial vowel digraphs have privileged status in early reading. The present study provided a rather mixed pattern of findings, with strong and significant improvements in the reading of words sharing vowel digraphs with pretaught clue words, and with some additional advantage for target words sharing

rimes in one analysis by items, but not in an analysis of scores by subjects. This evidence does not provide strong support for Goswami's model.

The extent to which firm conclusions can be drawn from the present results were however limited by an error in the target word set making one item redundant. In order to evaluate the reliability of these potentially interesting results, a second similar study is undertaken which attempts to rectify the methodological problems evident in the present experiment.

Chapter 7

The spontaneous use of sublexical inferences in early reading

Experiment 4

The main aim of Experiment 4 was to further investigate two questions first addressed in Experiment 3. These were: a) whether children can make spontaneous orthographic inferences when given prior exposure to examples of words sharing common letter-sound relationships with target words, and b) whether words sharing orthographic rimes enjoy greater levels of pre- to posttest improvement than words sharing only medial vowel digraphs. Experiment 3 reported some evidence in support of the view that children can make spontaneous sublexical inferences when pretaught several clue words. The same experiment also produced some rather mixed evidence of advantages for rime analogous over vowel digraph analogous target words in spontaneous inference use. Advantages for rimes were evident in item but not in subject analyses. Reliable advantages for rime analogous target words over vowel analogous target words in spontaneous inference use is predicted by the Interactive Analogy model (Goswami, 1993). The results of experiment 3 may therefore suggest that clear advantages are not evident for rimes across subject and item analyses, and instead may provide support for the alternative view that children make vowel digraph inferences. However interpretation of the results of experiment 3 was complicated by problems with the word set used. Experiment 4 therefore seeks to address the same two questions as the previous study but with an improved word set. Experiment 4 should therefore clarify the nature of spontaneous inference use.

Method

Unless otherwise stated the method was the same as in Experiment 3.

Participants

A new set of forty two children (mean age 6 years 5 months, range 5 years 6 months to 7 years 8 months) from two London primary schools were included in the study. These children had not taken part in a study of analogy or inference use previously. The mean reading age on the BAS was 6 years 7 months (range from 5 years 5 months to 7 years). Eight children were excluded from the sample at the screening test. Six children read too few words to be given a reading age on the BAS single word reading test. Two children had reading ages two standard deviations beyond that of the mean reading age, and were therefore excluded from the study. Analysis of the sample ($n=42$) BAS reading scores revealed that the distribution did not deviate markedly from normal: kurtosis, ($k = -0.9$), and skew ($s = 0.39$) were both non-significant. The mean BPVS score was 101.98 ($SD=13.59$).

Children were matched across three experimental groups for reading ability, clue word knowledge, age, sex, and vocabulary, on the BPVS. The mean scores on screening test measures are presented in Table 7. 1.

Table 7. 1. Scores on screening measures across three teaching groups.

Teaching group	Age (months)	Reading age (months)	BPVS (standard score)	Sex (m)
Taught-vowel	77.1 (6.15)	78.9 (5.77)	101.9 (12.49)	7
Taught-vowel-and-rime	76.1 (6.89)	78.5 (6.10)	103.1 (14.47)	7
Untaught	76.9 (6.44)	78.9 (8.75)	100.9 (14.66)	7
Mean	76.71 (6.36)	78.76 (6.83)	101.98 (13.59)	

A 3 (teaching group: taught-vowel versus taught-vowel-and-rime versus untaught) X 3 (measure: chronological age versus BAS reading age versus BPVS vocabulary) Anova confirmed that matching was achieved on the measured variables. The teaching group, and teaching group by measure interactions were both non-significant, ($F < 1$ in both cases).

Stimuli

The clue and target words were essentially the same as those used in Experiment 3, with two improvements. The problematic clue word 'speak' was replaced by 'freak'. The control words were selected from a larger pool of candidate words administered during the screening phase of the study, to provide an equivalent level of correct word reading at pretest as the vowel-share and vowel-and-rime-share target words. To achieve this, the control word 'boil' was replaced by 'girl', 'bait' by 'boat', and 'gout' by 'howl'. Knowledge of the four vowel digraphs in the words in the target set was measured at pre- and posttest to measure gains in digraph knowledge, and two phonological awareness measures (phoneme segmentation and the Bradley oddity tasks) were administered in an identical fashion to that in experiment 3 to measure the association between these measures and inference use.

Results

Analysis of targets read correctly

Subject analyses

The mean scores for target word reading between pre- and posttest are shown in Table 7.2. Inspection of the scores in this table reveal that there are some improvements for vowel-and-rime share words and vowel-share words in the taught-vowel-and rime group. Importantly the level of improvement appears to be equivalent for both sets of words in this teaching group. There is also some sign of improvement for the same word types in the taught vowel group at the posttest. There is little or no improvement in reading of any words for the untaught group. There are no improvements in the reading of control words across teaching groups.

Table 7.2. Mean number of target words read across teaching group (subjects).

Teaching group	Pretest	Posttest
1. Taught vowel		
vowel share	2.71 (1.82)	3.79 (2.04)
vowel-and-rime share	3.50 (2.10)	4.57 (2.38)
controls	2.21 (1.72)	2.14 (1.70)
2. Taught vowel-and-rime		
vowel share	2.29 (2.33)	3.93 (2.52)
vowel-and-rime share	3.00 (2.74)	4.79 (2.46)
controls	2.50 (2.18)	2.36 (2.21)
3. Untaught		
vowel share	2.43 (2.03)	2.79 (2.19)
vowel-and-rime share	2.79 (2.08)	3.00 (2.32)
controls	2.86 (2.32)	2.93 (2.43)
(Standard deviations are shown in parentheses)		

Note: Max n=8.

Preliminary analyses revealed that despite attempts to match words, pretest differences between words were again evident. In order to clarify the improvement for rime and vowel analogous target words, the data were submitted to a 3 (teaching group: taught-vowel versus taught-vowel-and-rime versus untaught) x 3 (word: vowel-share versus vowel-and-rime-share versus controls) analysis of covariance with pretest scores as the covariate, and with repeated measures on word. The dependent variable was the number of words read correctly out of 8. Results showed that there was a main effect of teaching group, $F(2, 38) = 5.44$, $p < .01$, and a main effect of word, $F(2, 77) = 24.11$, $p < .001$.

There was also a significant teaching group by word interaction, $F(4, 77) = 5.21$, $p = .001$. Newman-Keuls post hoc tests carried out on the adjusted means revealed that the interaction was due to a greater number of vowel-share and vowel-and-rime share words being read correctly in both the taught vowel and taught vowel-and-rime groups compared to the control words ($p < .01$ in all cases). Importantly there was no advantage for vowel-and-rime share words over the vowel-share words within either the taught vowel-and-rime group or the taught-vowel group. In the taught-vowel -and-rime group, these comparisons with the vowel-share and vowel-and-rime share words in the untaught group were also significant ($p < .01$ in all cases). In the taught-vowel group, only vowel-and-rime share words were read significantly better than in the untaught group ($p < .05$). The adjusted means are presented in Table 7.3.

Table 7.3. Adjusted means: group by word interaction (subjects).

Teaching group	Words		
	vowel-share	vowel-and-rime-share	controls
1. Taught-vowel	3.56	4.21	2.44
2. Taught- vowel-and-rime	4.11	4.87	2.38
3. Untaught	2.83	3.28	2.61

Note: Max $n = 8$.

Analysis by items

The mean scores for the target words between pre- and posttest test are shown in Table 7.4. Inspection of the scores in this table reveal a very similar pattern to that reported in the subject analysis, with equivalent improvements evident for vowel-and-rime share words and vowel-share words in the taught-vowel-and rime group and the taught vowel group at the posttest. Again little or no improvement in reading of any words for the untaught group or control words across teaching groups is evident.

Table 7.4. Mean number of target words read across teaching group (items).

Teaching group	Pretest	Posttest
1. Taught-vowel		
vowel share	4.75 (4.20)	6.63 (4.14)
vowel-and-rime share	6.13 (3.04)	8.00 (2.33)
controls	3.88 (4.02)	3.75 (4.03)
2. Taught-vowel-and-rime		
vowel share	4.00 (2.56)	6.88 (3.04)
vowel-and-rime share	5.25 (2.19)	8.38 (2.07)
controls	4.50 (2.56)	4.13 (2.30)
3. Untaught		
vowel share	4.25 (2.82)	4.88 (2.47)
vowel-and-rime share	4.88 (2.59)	5.25 (1.83)
controls	4.88 (2.70)	5.13 (2.42)
(Standard deviations are shown in parentheses)		

Note: Max n=14.

Preliminary analyses again revealed pretest differences between word types. The data were therefore submitted to a 3 (teaching group: taught vowel versus taught vowel-and-rime versus untaught) x 3 (word: vowel share versus vowel-and-rime share versus controls) analysis of covariance with pretest scores as the covariate, and with repeated measures on word. The dependent variable was the number of words read correctly out of 14. Results showed that there was a main effect of teaching group $F(2, 20) = 7.93, p < .01$, and a main effect of word, $F(2, 41) = 20.94, p < .001$.

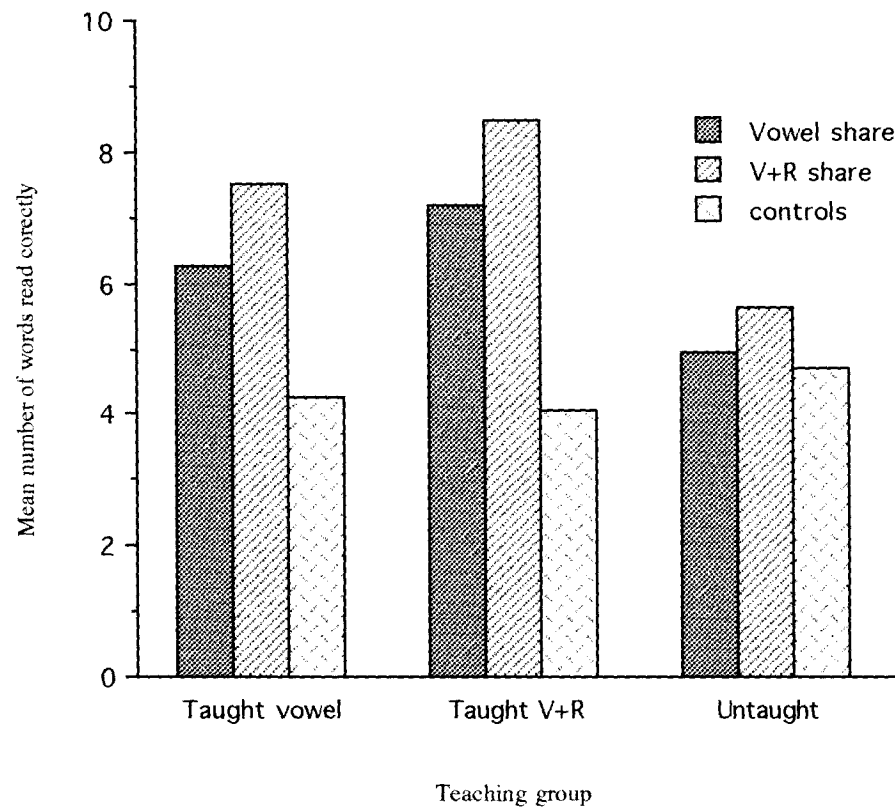
There was also a significant teaching group by word interaction $F(4, 41) = 4.96, p < .01$. Newman-Keuls post hoc tests carried out on the adjusted means confirmed that the interaction was due to a greater number of vowel-share and vowel-and-rime share words being read correctly in both the taught vowel and taught vowel-and-rime groups compared to the control words ($p < .01$ in all cases). Importantly there was no advantage for vowel-and-rime share words over the vowel-share words within either the taught vowel-and-rime group or the taught-vowel group. In the taught vowel-and-rime group, these comparisons with the vowel-share and vowel-and-rime share words in the untaught group were also significant ($p < .01$ in all cases). In the taught-vowel group, only vowel-and-rime share words were read significantly better than the untaught group ($p < .05$). The results for the by-subjects and the by-items analyses are therefore consistent in demonstrating the same kinds of improvement in target word reading: children show strong and statistically equivalent use of vowel digraphs and orthographic rimes in spontaneous inference use. The adjusted means are presented in Table 7.5 and in figure 7. 1.

Table 7.5. Adjusted means: group by word interaction (items).

<u>Teaching group</u>	<u>Words</u>		
	vowel-share	vowel-and-rime-share	controls
1. Taught-vowel	6.25	7.50	4.24
2. Taught- vowel-and-rime	7.17	8.49	4.05
3. Untaught	4.95	5.63	4.71

Note: Max n = 14.

Figure 7. 1: Words read correctly in experiment 4 (adjusted means)

**Key:**

Taught vowel: Taught-vowel group
 Taught V+R: Taught-vowel-and-rime group
 Untaught: Untaught group

Analysis of the number of inferences made

As in previous experiments, a further analysis was undertaken on the main experimental data using the more sensitive measure of the 'total number of inferences made'. Again there was almost no change to the total scores using this dependent variable, and no change to the pattern of significance reported for correct scores so the data are not presented here.

Analysis of control word paralexias

The means for all erroneous control word responses that share analogous pronunciations with the clue words are presented in Table 7. 6.

Table 7. 6. Mean number of control words read sharing clue word pronunciations.

Teaching group	Pretest	Posttest
1). Taught vowel	0.50 (0.65)	1.07 (1.00)
2). Taught vowel-and-rime	0.43 (0.51)	1.00 (1.04)
3). Untaught	0.36 (0.63)	0.43 (0.65)

Note: Max n=8.

For the rime group 86% of the analogous responses were vowel based, and 14% were rime based. For the vowel group all analogous responses were vowel based. Scores were submitted to a 3 (teaching group: taught vowel versus taught vowel-and-rime versus untaught) X 2 (test: pretest versus posttest) Anova, with repeated measures on test. Results showed that there was a main effect of test, $F(1, 39) = 10.41$, $p < .01$, but there was no effect of teaching group, $F(2, 39) = 1.42$, $p > .05$, and the teaching group by test effect was not significant either, $F(2, 39) = 1.76$, $p > .05$). This analysis shows that the tendency for children to give clue word-analogous pronunciations for words which do not share orthographic units with the clue word can not explain the pattern of improvements in target word reading witnessed in the main experimental task as the gains made in this condition are much smaller than those witnessed between the pre- and posttest in the main transfer task. As these gains in the number of paralexias read were no larger in the groups taught clue words than in untaught groups, this suggests that children cannot be inappropriately applying clue word knowledge to read unrelated control target words at posttest incorrectly.

Analysis of vowel digraph reading

The mean scores for the number of vowel digraphs read correctly at pretest and posttest are presented in Table 7.7. Investigation of the means show some modest improvements in the reading of vowel digraphs between the pretest and the posttest. Data were submitted to a 3 (teaching group: taught vowel versus taught vowel-and-rime versus untaught) x 2 (test: pretest versus posttest) Anova with repeated measures on test. This revealed no significant effects of teaching group, $F(2, 39) = 1.16$ n.s., and no interaction between teaching group and test, $F(2, 39) = < 1$. However the main effect of test just escaped conventional significance, $F(1, 39) = 3.99$, $p = .053$.

Table 7.7. Analysis of number of vowels read between pre- and posttest in Experiment 4.

Teaching group	Pretest	Posttest
1. Taught-vowel	2.14 (1.17)	2.50 (1.34)
2. Taught-vowel-and-rime	1.57 (1.45)	1.79 (1.42)
3). Untaught	2.14 (1.03)	2.29 (1.07)
(Standard deviations are shown in parentheses)		

Note: Max $n = 4$.

This analysis indicates that, despite showing some signs of improvement in reading target words which share vowel analogous segments in common with clue words, children show only a small improvement in reading the vowel digraphs in isolation. However this improvement is general to all three groups rather than specific to groups that were taught clue words. The results differed somewhat from those of experiment 3 where no effects reached significance.

Analysis of clue word knowledge

Means for improvement in clue word knowledge between pretest and posttest are presented in Table 7.8. Inspection of these scores show large and apparently equivalent improvements in clue word reading. In order to confirm this, data were submitted to a 2 (teaching group: taught-vowel versus taught-vowel and-rime) x 2 (test: pretest versus posttest) Anova with repeated measures on test. The dependent variable was the number of clue words correctly read out of 12. Results showed that there was a main effect of test, $F(1, 26) = 69.88$, $p < .001$, but no main effect of teaching group, or teaching group by test interaction (both $F_s < 1$).

Table 7. 8. Mean number of clue words read between pre- and posttest in Experiment 4.

Teaching group	Pretest	Posttest
1. Taught vowel	4.86 (3.63)	11.57 (0.94)
2. Taught vowel-and-rime	5.14 (4.59)	11.21 (0.97)
(Standard deviations are shown in parentheses)		

Note: Max $n = 12$.

This analysis shows that the children had learned the clue words effectively and could read a majority of them at the posttest. Furthermore the level of clue word learning was equivalently high across the two teaching groups, showing that the two groups did not differ in the number of clue word learning trials experienced before the posttest.

Analysis of speed of clue word learning

Analysis of the speed with which children learned the clue words was also undertaken. In this study, the number of trials to criterion (three correct articulations of the clue word in a row) was the dependent variable. The minimum possible score was therefore 36. The mean scores are presented in Table 7.9.

Table 7.9. Speed of clue word learning in Experiment 4.

Teaching group	Trials to criterion
1. Taught vowel	44.5 (4.90)
2. Taught vowel-and-rime	45.0 (5.63)
(Standard deviations are shown in parentheses)	

An unrelated t-test confirmed that there was no significant difference between these two scores, $t(26) < 1$, n.s. This analysis also provides evidence that children in the taught-vowel and taught-vowel-and-rime groups did not differ in their experiences of clue word learning. They both took as long to learn the clue words. This is unsurprising given the nature of the two words sets, and confirms that the preteaching of the two taught prompt groups did not differ in length.

Correlational analyses

The first set of analyses considered the pattern of associations between reading and phonological measures. The means are presented in Table 7.10 alongside the correlations reported in the same analyses in previous experiments for the sake of comparison. Unlike the results reported in experiments 1 and 3, measured reading ability was not correlated with phonemic segmentation ability in the present study. A very different pattern of correlations between reading and the combined and separate oddity measures was also evident. Previous studies in this thesis have reported no significant correlations between these two measures. In contrast, in experiment 4 reading ability was strongly correlated with the combined oddity measure, the medial oddity measure, and to a lesser extent, the final oddity measure. There were no other significant correlations.

Table 7. 10. Correlations between reading ability and phonological measures ¹.

Measure	first odd	Mid odd	Last odd	Cd odd	Phon seg	Cd Phon	L.S. Know	L.S + Phon
Expt 4								
BAS	.18	.42**	.31*	.47***	-.05	.30		
Expt 3								
BAS	.01	.08	.13	.10	.39**	.32*		
Expt 2								
BAS	.20	-.08	-.18	-.04	.24	.10	.11	.22
Expt 1								
BAS	.25	.26	.11	.25	.24	.32*	.35**	.34**
Expt 4								
Mean	6.10	6.42	5.39	17.91	12.15	30.05		
SD	1.20	2.76	2.42	4.78	4.73	6.62		
Max	12	12	12	36	16	52		

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Last odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined

The reason why these results differed from those in experiment 3 where strong correlations were evident between reading ability and phonemic awareness but not between reading ability and performance on the oddity task is unclear. One possible explanation of the failure to find a correlation between phonemic segmentation and reading is that all children in experiment 4 appeared to be very good at phonemic segmentation tasks. Comparison of means on this task in experiment 4 (12.15) with previous experiments show that it is substantially higher than in experiment 3 (7.10) and experiments 1 (6.86), and 2 (7.20). This theory does not, of course explain why medial and final oddity measures are strongly correlated in the present study, and not in

¹ * p < .05, ** p < .01 *** p < .001.

previous studies. One rather speculative possibility is that differences in the pattern of correlations may also reflect different emphases in teaching methods or differences in socio-economic status amongst the present children compared to those in experiments 1, 2, and 3. This theory is given some more plausibility by the fact that children in experiments 1 and 2, were drawn from a different London borough to those in experiment 3 who differed again from those in experiment 4 who were drawn from a third more prosperous London borough. Alternatively the results suggest that there is simply a great deal of variability in the way children approach reading and possibly provide a caution that a rather inaccurate picture of the correlates of reading could arise from single studies of reading using small samples.

The second set of correlations investigated the association between improvements in target word reading between pretest and posttest, measured reading ability and phonological awareness measures. The correlations are presented in table 7.11 alongside the same analyses from previous experiments to facilitate comparisons.

Table 7.11. Correlations between reading, phonological measures, and improvements in target word reading.²

Measure	Imp 4	Imp 3	Rime	Head	Rime	Head
			Expt 2	Expt 2	Expt 1	Expt 1
BAS	.55**	.26	.56**	.16	.75**	.19
First Odd	.10	.28	.29	.17	.16	.08
Mid odd	.18	-.01	.22	.11	.65*	-.17
Final odd	.14	.14	.07	.23	.73**	.01
Cd Odd	.23	.18	.23	.20	.66**	.05
Phon Seg	-.07	.34	.35	.15	.68**	.25
Cd phon	.08	.34	.36	.23	.80**	.14
L.S. Know	—	—	.16	.01	.37	.35
L.S. + phon	—	—	.31	.11	.45	.68**

Key:

Imp 4	combined improvement for vowel and rime words in experiment 4
Imp 3	combined improvement for vowel and rime words in experiment 3
Rime	rime clued words
Head	head clued words

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Final odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined
L.S. know	letter-sound knowledge
L.S. + phon	L.S know and phon seg combined

The analyses considered only the children who were taught clue words. The analyses are based upon $n=27$ scores. One child was at ceiling on target word reading at pretest and was therefore excluded.

The results of the analysis revealed that, unlike experiment 3, there was a strong association between measured reading ability and improvements made in target word reading. In discussing experiment 3, it was suggested that spontaneous inference use may not be correlated with reading ability. This argument does not appear to be supported by the results of experiment 4. Possibly a large scale study is needed to provide a definitive answer to the question of whether reading ability is significantly correlated with inference use in the light of these rather mixed findings. As in experiment 3, no other correlations approached significance. This suggests that spontaneous inference use is not correlated with phonological awareness skills, and stands in contrast to previous reported findings of strong correlations between phonological awareness and concurrently prompted transfer in the clue word task (e.g. Goswami & Mead, 1992), and which has also been reported in the replication of Goswami's study carried out in experiment 1.

Correlations with error categories

The proportions of pretest target word reading errors across categories are shown in Table 7.12. As in previous analyses, the largest error type was made up of paralexias preserving initial and final consonants. Refusals also made up a significant number of the errors made. Other errors did not contribute significantly to error totals.

Table 7.12. Error category analysis experiment 4.

	Unr	Orth	Init ph	Final ph	I & F	Rime	Head	Refusal
Pretest error proportions.								
N	0	4	24	4	178	1	4	72
%	0	1.4	8.4	1.4	62.0	0.3	1.4	25.1

Key:

Unr	errors sharing no orthographic relationship with target
Orth	errors sharing orthographic overlap with target
Init ph	errors sharing initial phoneme with target
Final ph	errors sharing final phoneme with target
I & F	errors sharing initial and final phoneme with target
Rime	errors sharing common rimes with targets
Head	errors sharing common heads with targets
Refusal	refusal to answer

Correlation between measured reading ability and pretest word representations are presented in Table 7.13 for the two largest error categories. The scores in table 7.13 reveal that the proportion of errors preserving initial and final consonants made at pretest are again positively correlated with reading ability, replicating the patterns reported in the first three experiments, and extending the findings first reported in the literature by Stuart and Coltheart (1988). Refusals to answer are also negatively correlated with reading ability, replicating the pattern reported in the first two experiments of this thesis. Correlations between these error types and phonological skills were also undertaken here. No correlations reached conventional significance. This pattern has been reported in previous experiments, and suggests that pretest target

word reading errors do not appear to be reliably associated with phonological awareness.

Table 7.13. Correlation of error proportions with reading and phonological measures ³.

Measure	Expt 4		Expt 3		Expt 2		Expt 1	
	I & F	Refusal	I & F	Refusal	I & F	Refusal	I & F	Refusal
BAS	.35*	-.35*	.39**	-.14	.61***	-.35*	.67***	-.32**
First odd	.08	-.04	.33*	-.19	-.06	.12	-.07	.17
Mid odd	.03	.03	.14	-.12	-.33*	.36*	.01	.05
Last odd	-.02	-.07	.19	-.19	.16	.17	.04	.03
CdOdd	.04	-.01	.28	-.22	-.23	.29	.02	.07
Phon seg	.02	.16	.09	.12	.23	-.18	.22*	-.04
Cd phon	-.02	.12	.33*	-.21	-.05	.13	.11	.07
L.S. know	—	—	—	—	.20	-.24	.35**	-.14
L.S+ phon	—	—	—	—	.20	-.18	.27*	-.06
Mean	.61	.24	.54	.28	.58	.16	.37	.35
SD	.28	.28	.28	.30	.25	.26	.25	.29
Max	1	1	1	1	1	1	1	1

Key:

Pretest errors

I & F initial and final phoneme shared with target
 Refusal refusal to answer

Reading-related variables

BAS BAS single word reading
 First odd Bradley first sound
 Mid odd Bradley middle sound
 Last odd Bradley last sound
 Cd odd Combined Bradley score
 Phon seg Phonemic segmentation
 Cd phon Cd odd and phon seg combined
 L.S. know letter-sound knowledge
 L.S.+ phon L.S know and phon seg combined

The final set of correlations investigated the association between the proportion of pretest errors made in each of the error categories and improvements in subsequent target word reading. Correlations are presented in Table 7.14. There were no

³ * p < .05, ** p < .01, *** p < .001.

statistically significant correlations between errors and pre- to posttest improvements in target word reading. The correlation between errors preserving both initial and final consonants and subsequent improvements in target word reading is in the same direction as that reported in previous experiments but just escaped conventional significance on a two tail test ($p = .057$). One possible reason for this failure of this correlation to reach significance is that, as shown in table 7.13, errors preserving both initial and final consonants are a relatively large proportion of the errors made at pretest. Nevertheless the pattern of results is broadly similar to that reported in the previous three studies.

Table 7.14. Correlation between pretest error scores and improvements in target word reading.⁴

Measure/ Errors	<u>Expt 4</u> Imp	<u>Expt 3</u> Imp	<u>Expt 2</u> Rimes	<u>Expt 2</u> Heads	<u>Expt 1</u> Rimes	<u>Expt 1</u> Heads
I and F	.31	.45*	.51**	.51**	.74**	.43*
Refusal	-.25	-.19	-.38*	-.42*	-.64**	-.43*

Key:

Imp Improvement in target word reading between pre- and posttest

Pretest errors

I and F initial and final phoneme shared with target

Refusal refusal to answer

Discussion

The main aim was to confirm whether a) children make inferences in absence of concurrent prompts and b) whether there is an advantage for rime over vowel digraph units in early spontaneous inference use. Significant improvements in reading target words sharing vowel digraphs and rimes was evident over control conditions between pretest and posttest. These results therefore confirm the findings of experiment 3 that

⁴ * $p < .05$ ** $p < .01$

six year old children are able to use sublexical inferences in the absence of concurrent prompts, provided they are given prior exposure to a number of words sharing letter-sound relationships from which to make orthographic inferences.

In contrast to the results reported in experiment 3, there was no evidence for additional advantages for targets sharing rimes with clue words over targets sharing vowels with clue words. The two sets of words were statistically indistinguishable in both subject and item analyses. The present results therefore provide strong evidence that vowel digraphs may be the functional units of sublexical inference when spontaneous rather than concurrently clued inference is considered. The present results do not provide support for the view that orthographic rime units have privileged status in early reading (Goswami, 1993). The present results suggest that Goswami's results do not generalise beyond the particular conditions of the traditional clue word task.

Analyses of the association between pretest target word reading errors and subsequent improvement in target word reading also provided some modest support for the view that vowel digraph units are central to inference. There was a strong trend for the proportion of pretest target word reading errors which preserved initial and final consonants to be correlated with subsequent improvements in target word reading. This is also somewhat inconsistent with the view that rime units are functional units in sublexical inference, as it suggests that children can arrive at the correct pronunciation of a target word if they use vowel digraph inferences from clue words to pronounce the medial vowel of a target word, alongside their existing knowledge of initial and final consonants rather than make rime inferences.

As in experiment 3, the improvement in reading analogous words was not associated with measures of phonological awareness. However, unlike experiment 3, there was a significant association between measured reading ability and improvements in target word reading. The pattern of associations between improvements in target

word reading and phonological awareness are therefore markedly different to those presented by Goswami (Goswami 1990a; Goswami & Mead, 1992) where a 'special link' has been reported between pre- to posttest improvements in reading target words sharing rimes with clue words, even after reading ability has first been controlled. This specific correlation is an important theoretical part of Goswami's model because it is claimed that this association reflects the developmental link between early onset-rime sensitivity and later reading success.

While the results of the correlation task in the present study and in the previous study have suggested that phonological skills may not be tied to improvements in target word reading the present results are limited in two ways. The first is that they have used samples that are relatively small in size ($n = 27$ in both experiments). The second problem is that combined scores for vowel and rime target words have been considered alongside scores for purely vowel analogous targets, so the present results are unable to address the issue of whether a specific link exists between improvement in the reading of targets sharing orthographic rimes with clue words and rime phonological awareness.

Another general problem with the results of the two spontaneous inference studies carried out to date (experiments 3 and 4) is the variability reported in the pattern of correlations. Measured reading ability for example is correlated strongly with the Bradley test of auditory organisation in the present study but not in experiment 3, where correlations with phonemic awareness but not rime awareness have been reported. Spontaneous inference use was correlated with reading ability in experiment 4 but not in experiment 3. The theoretically important correlation between inference use and pretest errors that preserve initial and final consonants, while in the predicted direction, escaped conventional significance in the present study, but has been consistently significant in the previous three experiments. Explanations of these differences may lie in variation in the teaching or in the sociological composition of these relatively small samples drawn from distinct geographical areas. It may equally be that there is simply a great deal of

variability in approach taken to reading acquisition by children. However, specification of the pattern of these correlations is theoretically important. Stronger evidence on the pattern of correlations with inference use, phonological skills and reading ability are required. Firmer conclusions could be drawn about the nature and use of spontaneous inferences use by comparing pre- to posttest improvements in target word reading amongst a larger group of children and where the use of spontaneous rime inferences was considered separately from the use of spontaneous vowel digraph inferences.

The final experiment therefore seeks to provide further information on the nature of individual differences in spontaneous inference use after children are given prior exposure to three clue words. The first aim of this study is to evaluate whether the specific link between improvements in orthographic rime target word reading and phonological rime awareness first reported by Goswami (1990a) is evident under these new testing conditions. A second aim was to evaluate the nature of vowel digraph inferences. Goswami (1990a) argues that vowel digraph inferences are associated with explicit phonemic awareness reflecting phonemic underpinning of graphemes, an ability which emerges later in reading development than orthographic rime inference use. The nature of the relationship between improvements in vowel digraph reading and phonemic awareness is also therefore evaluated. Finally the relationship between inference use and measured reading ability is also investigated in order to evaluate further the nature and developmental emergence of rime and vowel inferences in early reading.

Conclusions

The present study sought to replicate and clarify the pattern of results of a first study of spontaneous inference use reported in experiment 3. Experiment 4 has confirmed two important aspects of the results of experiment 3. Experiment 4 showed that children are able to make spontaneous inferences when pretaught three analogous clue words in a distinct pretest phase prior to the posttest. As no concurrent prompts

were given in this study this result suggests that children can make orthographic inferences in conditions similar to those met in naturalistic reading situations. Importantly experiment 4 also revealed that no advantage was evident for vowel over rime inferences in either in analysis where subject or by item score was the dependent variable. This result is not consistent with Goswami's interactive analogy model of reading acquisition (Goswami, 1993) which predicts an advantage for rimes in spontaneous inference use. However other aspects of the results of experiment 4 remain unclear. Experiment 4 sought to investigate the correlations between inference use, reading ability and phonological skills. There was substantial variation in the pattern of correlations reported in experiments 4 compared to those in experiment 3 and interpretations of these patterns are consequently unclear. The pattern of correlations between these variables is investigated in a fifth experiment which uses a larger sample in order to attempt to clarify these issues.

Chapter 8

The relationship between orthographic and phonological measures and individual differences in spontaneous inference use

Experiment 5

The main aim of experiment 5 was to investigate the relationship between individual variation in target word reading improvement after prior exposure to analogous clue words, measured reading ability and two measures of phonological awareness. The two phonological measures were - 1) the Bradley test of auditory organisation and 2) a measure of explicit phonemic segmentation ability. According to the interactive analogy model of reading acquisition (Goswami, 1993), the development of reading first proceeds by the establishment of phonologically underpinned orthographic rime units. Implicit onset/rime phonological awareness is held to underpin orthographic rime units and ensures they are accurately represented in the orthographic lexicon. These units can then be used as a basis for orthographic rime analogies. This view predicts that orthographic rime use and phonological rime awareness should be highly correlated. As discussed in chapter 3, some previous research by Goswami has provided support for this position. A specific link has been reported between phonological rime awareness (using the Bradley test of auditory organisation) and improvement in reading of rime analogous target words in Goswami's clue word task (Goswami, 1990a; Goswami & Mead, 1992).

Previous research in this thesis has reported a concurrent link between rime awareness and transfer in Goswami's version of the clue word analogy task (experiment 1) but has failed to find a strong correlation between spontaneous inference use and phonological awareness (experiments 3 and 4). However the previous studies are limited in two ways: 1) by the relatively small samples used ($n=27$), and 2) by the

fact that they have also combined measures from vowel-clued and rime-clued target words as the measure of inference. It may be that a clearer picture of inference use is evident when rime clued and vowel clued words are considered separately for correlational analyses. This is the sort of comparison that Goswami has investigated in her previous studies. The present research seeks to provide a further evaluation of the relationship between spontaneous use of rime inferences and phonological rime awareness in a larger sample of children where individual differences in inference after being taught vowels or rimes are considered separately. This experiment should therefore confirm the nature of the relationship between inference use from rimes and vowel digraphs and phonological rime awareness.

This experiment also provides a further opportunity to evaluate the role of vowel digraph inferences. One aspect of this evaluation was to further test the view that children perform sublexical inferences with equal facility on the basis of shared vowels as on the basis of shared rimes as reported in the previous two experiments. A second aim was to evaluate individual differences in vowel digraph inference use. The results of Goswami's studies (Goswami & Mead, 1992) support the view that head inferences (e.g. 'beak'-'bean') are correlated with explicit phonemic awareness. Goswami suggests that all inferences not solely involving rimes or onsets reflect phonemic underpinning of graphemes, an ability which emerges only later in reading development (Goswami, 1993). This position therefore also predicts that a correlation may exist between any improvements in vowel digraph reading and phonemic awareness when spontaneous inference use is considered, as such inferences would have to be underpinned by phonemic awareness in Goswami's view. The present study also seeks to test this prediction.

Another issue is the relationship between reading ability and inference use. Some previous research using the clue word paradigm has reported that inference use is associated with reading ability (Goswami & Mead, 1992), though other studies with

very similar methodologies have not reported a correlation (Goswami, 1990a). More recent research has suggested that rime and vowel inference use may be strongly associated with reading ability when spontaneous rather than concurrently prompted inference use is considered (Muter et al, 1994). There is therefore some reason to believe that inference use is associated with reading ability. The results of three studies in this thesis (experiments 1, 3 and 4), in which children appear to need to learn and remember several clue words in order to make spontaneous inferences in early reading, have provided some support for the view that children need some significant reading experience before spontaneous inference use can develop. However the correlation between spontaneous inference use and reading ability has been reported in experiment 4 but the same correlation was not found in experiment 3. The relationship between inference use and measured reading ability is therefore evaluated further here in a larger sample to provide a more conclusive answer to this issue.

This study also seeks to further explore the relationship between pretest target word paralexias and subsequent inference use reported in some previous experiments in this thesis. Inference use has been found to be strongly correlated with pretest errors preserving initial and final consonants in experiments 1, 2, and 3, though the positive correlation between these two variables reported in experiment 4 escaped conventional significance. The larger sample size in the present study compared to the previous studies should also confirm the nature of the relationship between pretest paralexias, reading ability, phonological skills, and in particular, inference use.

Method

The method was the same as in the taught-vowel-and-rime group in experiments 3 and 4. In this condition children were taught only vowel-and-rime share clue words. These words shared vowels with the vowel share target words (e.g. 'leak' - 'bean'), rimes with the vowel-and-rime target words (e.g. 'leak' - 'peak') and shared no

graphemic relation with the control words (e.g. 'leak' - 'herd'). Three clue words were pretaught minutes before the posttest phase and no concurrent clue word prompts were given at the posttest phase. The word set was the same as that used in experiment 4 and the two phonological awareness measures (Bradley oddity and explicit phoneme segmentation) were administered in the same manner as in experiments 3 and 4.

Participants

Fifty children from two London primary schools (mean age 6 years 5 months, range 5 years 5 months to 7 years 5 months) were included in the study. The mean reading age on the BAS was 6 years 5 months (range 5 years to 7 years 10 months). Thirteen of these children were from the taught-vowel-and-rime group in the previous experiment, whose scores were simply carried forward to the present study for the sake of convenience. One of the original 14 children included in that study was excluded from the present study as they were at ceiling on target word reading at pretest. The other 37 children were an entirely new sample who had not taken part in a study of analogy or inference use previously. Two additional children were screened but were excluded from the new sample as they read too few words to be given a reading age on the BAS single word reading test. BAS reading scores revealed that the distribution of the sample ($n = 50$) did not deviate markedly from normal: kurtosis ($k = 0.41$), and skew, ($s = 0.22$) were both non-significant. The mean BPVS score was 101.1, ($SD = 12.61$).

Results

Prior to considering the associations between individual differences in target word reading between pre- and posttest and reading and phonological abilities, analyses were undertaken to evaluate the overall patterns of inference use.

Analysis of targets read correctly

Subject analyses

The mean scores for target word reading between pre- and posttest are shown in Table 8.1. Inspection of these scores shows that children made improvements in reading vowel-share and vowel-and-rime-share words between pretest and posttest, but made no improvements in reading the control words. A modest advantage was evident for the vowel-and rime-share words over the vowel-share words.

Table 8.1. Mean number of target words read correctly in experiment 5 (subjects).

Word	Pretest	Posttest
Vowel-share	2.16 (1.89)	3.38 (2.15)
Vowel-and-rime -share	2.58 (2.16)	4.40 (2.14)
Controls	1.72 (1.85)	1.64 (1.74)

(standard deviations are shown in parentheses)

Note: max n = 8.

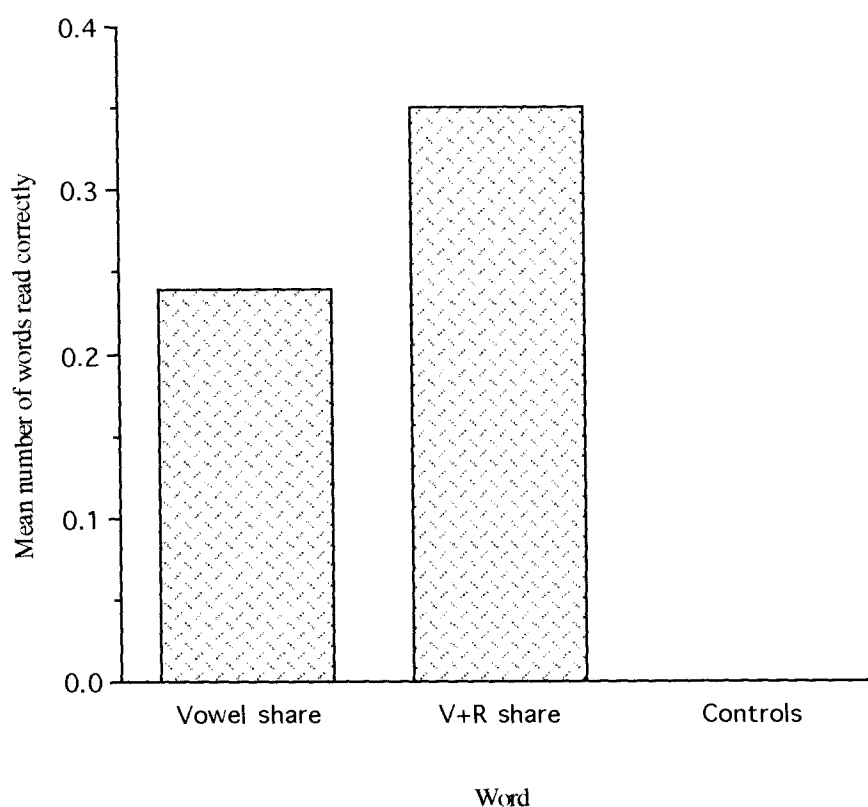
Preliminary analyses revealed pretest differences in target word reading, so adjusted improvement scores were calculated using the same (posttest - pretest) / (maximum possible - pretest) formula used in experiment 2, and which is also used in the main correlational analysis later. These scores were then submitted to a Oneway Anova with three levels (word: vowel-share versus vowel-and-rime share versus controls). The mean scores are shown in table 8.2 and in Figure 8. 1.

Table 8.2. Mean number of target words read (adjusted subject score).

Word	Mean score
Vowel-share	.24 (.22)
Vowel-and-rime-share	.35 (.27)
Controls	-.03 (.18)

(standard deviations are shown in parentheses)

Figure 8. 1: Words read correctly in experiment 5 (adjusted means)

**Key:**

Vowel share: vowel-share words
V+R share: vowel-and-rime-share words
Controls: control words

Analysis of these scores revealed a main effect of word, $F(2, 98) = 41.22$, $p < .001$. Post-hoc tests (Newman-Keuls) revealed that this effect was due to significant

differences between vowel-share and control words, and vowel-and-rime share and control words ($p < .01$ in both cases). Newman-Keuls tests also revealed that there was a significant additional advantage for vowel-and-rime-share words over vowel-share words ($p < .01$).

Item analysis

The means between pre- and posttest are shown in Table 8.3. As in the subject analysis, there were improvements in reading vowel-share and vowel-and-rime-share words between pretest and posttest, but no improvements in reading the control words. A modest advantage is again evident for the vowel-and-rime-share words over the vowel-share words.

Table 8.3. Mean number of target words read correctly in experiment 5(items).

Word	Pretest	Posttest
Vowel-share	13.50 (9.96)	21.13 (10.16)
Vowel-and-rime -share	16.13 (8.65)	27.50 (8.09)
Controls	10.75 (7.11)	10.25 (7.64)

(standard deviations are shown in parentheses)

Note: max n = 50

Preliminary analyses revealed pretest differences in target word reading, so adjusted improvement scores were submitted to a Oneway Anova with three levels (word: vowel-share versus vowel-and-rime-share versus controls). The mean scores by word are shown in Table 8.4.

Table 8.4. Mean number of target words read (adjusted item score).

Wordtype	Mean score
Vowel-share	.23 (.12)
Vowel-and-rime-share	.35 (.13)
Controls	-.03 (.08)

(standard deviations are shown in parentheses)

Analysis of these scores revealed a main effect of word, $F(2, 14) = 18.20$, $p < .001$. Newman-Keuls post hoc tests revealed that this effect was due to significant differences between vowel-share and controls, and between vowel-and-rime share words and controls ($p < .01$ in both cases). However there was no significant difference between vowel-share and vowel-and-rime share words ($p > .05$).

Analysis of the number of inferences made

A further set of analyses were undertaken using the more sensitive measure of the number of inferences made, which, as in previous studies counts as correct any mispronunciation of a target word where the clue word analogous segment is pronounced correctly. Thus for rimes the word 'born' mispronounced 'dorn' would be counted as correct; equally for vowel words the target word 'bean' mispronounced as 'peam' or 'pean' would be counted as correct. Unlike previous experiments these analyses using the number of inferences made as the dependent variable produced a significantly different pattern of results to the analysis considering the correct pronunciations only. The analyses are therefore presented below.

Subject analyses

The mean number of inferences made is presented in Table 8.5. Inspection of the means in this table reveal improvements in reading vowel-share and vowel-and-rime-share words between pretest and posttest, but no improvements in reading the control words. There is approximately equivalent improvement for the vowel-and rime-share words compared with the vowel-share words.

Table 8.5. Mean number of inferences made in experiment 5 (subjects).

Wordtype	Pretest	Posttest
Vowel-share	2.26 (1.90)	3.96 (2.13)
Vowel-and-rime -share	2.64 (2.19)	4.72 (2.07)
Controls	1.72 (1.85)	1.64 (1.74)

(standard deviations are shown in parentheses)

Note: max n = 8.

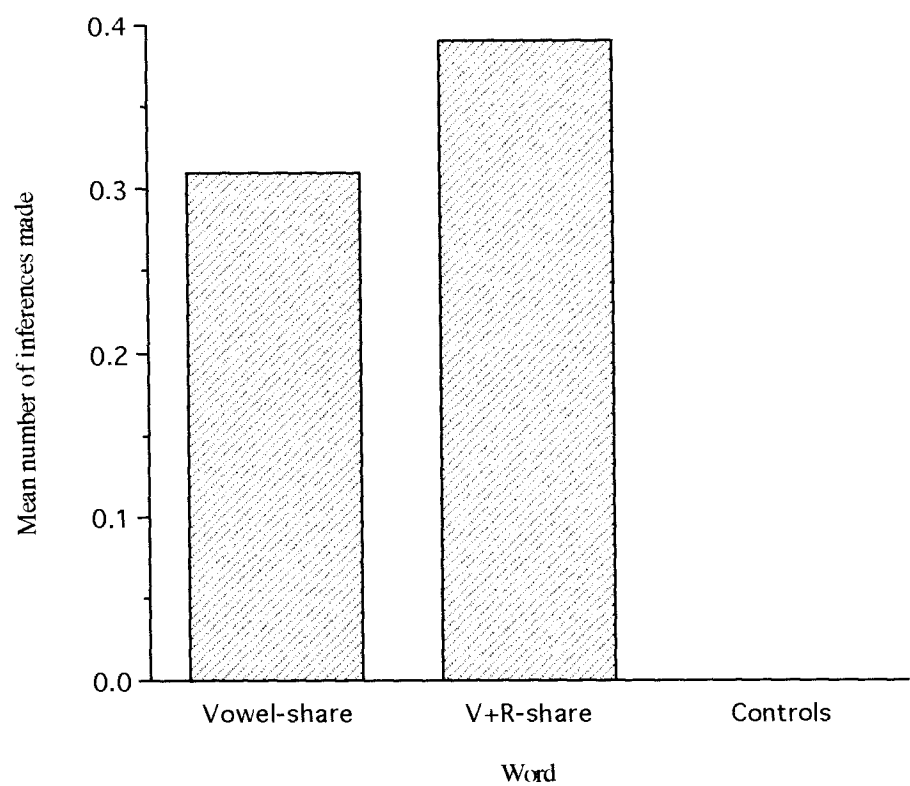
The adjusted improvement scores were submitted to a Oneway Anova with three levels (word: vowel-share versus vowel-and-rime-share versus controls). Analysis revealed a main effect of word, $F(2, 98) = 40.69$, $p < .001$. Newman-Keuls post hoc tests revealed that this effect was due to significant differences between vowel-share and control words, and vowel-and-rime share words and control words ($p < .01$ in both cases). However there was no significant difference between vowel-share and vowel-and-rime-share words ($p > .05$). The adjusted scores are shown in table 8.6 and Figure 8. 2.

Table 8.6. Mean number of target words read (adjusted subject score).

Word	Mean score
Vowel-share	.31 (.27)
Vowel-and-rime share	.39 (.31)
Controls	-.03 (.22)

(standard deviations are shown in parentheses)

Figure 8. 2: Inferences made in experiment 5 (adjusted means)



Key:
Vowel-share: vowel-share words
V+R-share: vowel-and-rime-share words
Controls: control words

Item analyses

The mean scores for the target words between pre- and posttest are shown in Table 8.7. As in the subject analysis, improvements in reading vowel-share and vowel-and-rime-share words were evident between pretest and posttest, but there are no improvements in reading the control words. A very modest advantage was evident for the vowel-and-rime-share words over the vowel-share words.

Table 8.7. Mean number of inferences made in experiment 5 (items).

Word	Pretest	Posttest
Vowel-share	14.13 (9.60)	24.75 (9.66)
Vowel-and-rime -share	16.50 (9.04)	29.50 (7.19)
Controls	10.75 (7.11)	10.25 (7.64)

(standard deviations are shown in parentheses)

The adjusted improvement scores were submitted to a Oneway Anova with three levels (word: vowel-share versus vowel-and-rime-share versus controls). The mean scores by word are shown in Table 8.8.

Table 8.8. Mean number of inferences made (adjusted item score).

Word	Mean score
Vowel-share	.33 (.17)
Vowel-and-rime-share	.40 (.13)
Controls	-.01 (.08)

(standard deviations are shown in parentheses)

Analysis of these scores revealed a main effect of word, $F(2, 14) = 21.37$, $p < .001$. Newman-Keuls post hoc tests revealed that this effect was due to significant differences between vowel-share words and control words, and between vowel-and-rime-share words and control words ($p < .01$ in both cases). However there was no significant difference between vowel-share and vowel-and-rime-share words ($p > .05$). There is therefore a consistent pattern of inference use across both subject and item analyses: both analyses show significant and equivalent vowel digraph and rime inference use.

Correlational analyses

The main aim of the present study was to investigate the pattern of associations between improvements in target word reading between pre- and posttest, reading ability and onset/rime awareness and phonemic segmentation skills ¹. The correlations are shown in table 8.9 alongside the same correlations from previous experiments for comparison. The only significant correlations were between improvement in target word reading for the vowel-share words and reading ability and improvement in target word reading for the vowel-and-rime-share words, and measured reading ability. This confirms the pattern of results reported in experiment 4, and reported for concurrently prompted rime transfer in experiments 1 and 2. Spontaneous inference use is one ability which appears to distinguish good from poor readers.

The correlations between pre- to posttest improvements and two measures of phonological awareness on the other hand, revealed no significant relationships, confirming the pattern reported for spontaneous inferences in experiments 3 and 4. This finding is particularly theoretically interesting as Goswami, (Goswami 1990a; Goswami & Mead, 1992) has reported a 'special link' between improvements in

¹ There was some evidence of ceiling effects for the phonemic awareness measure as the data showed modest negative skew. Two sets of correlations were therefore run, the first with the raw scores which are presented here. The second set of correlations was run with an inverse and then square root transformation of the phonemic awareness data as recommended by Tabachnik and Fidell (1989). This transformation of the data improved the distribution significantly but did not significantly alter the pattern of associations, so these are not reported separately.

reading rime analogous words and phonological rime awareness in the traditional version of the analogy task. The present findings add further support to the view that rime awareness is not correlated with target word reading when spontaneous inference use rather than concurrently prompted transfer in Goswami's task is considered.

Table 8.9. Correlations between reading, phonological measures, and improvements in target word reading.²

Measure	Rime Expt 5	Vowel Expt 5	Imp 4	Imp 3	Rime Expt 2	Head Expt 2	Rime Expt 1	Head Expt 1
BAS	.38**	.43**	.55**	.26	.56**	.16	.75**	.19
First Odd	.16	.06	.10	.28	.29	.17	.16	.08
Mid odd	.10	.04	.18	-.01	.22	.11	.65*	-.17
Final odd	.26	.19	.14	.14	.07	.23	.73**	.01
Cd Odd	.22	.12	.23	.18	.23	.20	.66**	.05
Phon Seg	-.10	-.10	-.07	.34	.35	.15	.68**	.25
Cd phon	.20	.13	.08	.34	.36	.23	.80**	.14
L.S. Know	—	—	—	—	.16	.01	.37	.35
L.S. + phon	—	—	—	—	.31	.11	.45	.68**

Key:

Rime Expt 5	vowel-and-rime-share words in experiment 5
Vowel Expt 5	vowel-share words in experiment 5
Imp 4	combined improvement for vowel and rime words in experiment 4
Imp 3	combined improvement for vowel and rime words in experiment 3
Rime	rime clued words
Head	head clued words

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Final odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined
L.S. know	letter-sound knowledge
L.S. + phon	L.S know and phon seg combined

A further set of correlations was run evaluating the role of pretest representations of target words but with the number of inferences made, rather than the

² * p < .05, ** p < .01.

number of correct pronunciations of the target word as the dependent measure of inference use. Considering first the association between the number of inferences made and phonological skills, there was no change to the previous pattern of non-significant correlations. The correlations between inference use and reading ability were however altered in this subsequent analysis. For vowels, the correlation was no longer significant, ($r = .24$, n.s.), while for the rime analogous words it was still significant but the r value was reduced, ($r = .29$, $p < .05$). One interpretation of this result could be that it suggests that rime inference use depends upon some existing reading ability whereas vowel inference use does not depend upon existing reading ability to emerge in early reading acquisition.

A second distinct set of correlations considered the relationship between improvements in target word reading between pre- and posttest and pretest target word reading paralexias. The proportion of pretest errors in each error category is presented in Table 8.10. The correlations between these errors and improvements in target word reading are presented below in Table 8.11.

Table 8.10. Error category analysis experiment 5.

	Unr	Orth	Init ph	Final ph	I & F	Rime	Head	Refusal
Pretest error proportions.								
N	1	18	95	24	477	2	6	249
%	0.1	2.06	10.9	2.75	54.7	0.2	0.7	28.6

Key:

Unr	errors sharing no orthographic relationship with target
Orth	errors sharing orthographic overlap with target
Init ph	errors sharing initial phoneme with target
Final ph	errors sharing final phoneme with target
I & F	errors sharing initial and final phoneme with target
Rime	errors sharing common rimes with targets
Head	errors sharing common heads with targets
Refusal	refusal to answer

Table 8.11. Correlation between pretest error scores and improvements in target word reading.³

Measure/ Errors	Expt 5 Rimes	Expt 5 Vowels	Expt 4 Imp	Expt 3 Imp	Expt 2 Rimes	Expt 2 Heads	Expt 1 Rimes	Expt 1 Heads
I and F	.18	.33*	.31	.45*	.51**	.51**	.74**	.43*
Refusal	.13	-.28*	-.25	-.19	-.38*	-.42*	-.64**	-.43*

Key:

Rimes vowel-and-rime share words

Vowels vowel -share words

Pretest errors

I and F initial and final phoneme shared with target

Refusal refusal to answer

The correlations in table 8.11 provide further evidence of a relationship between pretest error categories and subsequent inference use. The correlation analyses also revealed that the pattern of significant correlations appears to be rather different for vowel-share and vowel-and-rime share words. Vowel inference use appears to be positively correlated with errors preserving both initial and final consonants of targets and negatively correlated with refusals to answer at pretest. This is the same pattern reported in three of the four previous experiments (experiments, 1, 2, & 3), but which escaped significance in experiment 4. For vowel-and-rime share words, neither of these correlations reached conventional significance. This could suggest that rime inference is less closely tied to pretest word reading paralexias than vowel inference.

A further analysis was undertaken with the 'number of inferences made' rather than the number of correct target word pronunciations as the measure of inference use. When this measure was used, the relationship between inference use and pretest representations of target words showed essentially the same pattern of non-significant correlations for the rime words, but for the vowel-share words, the positive correlation between pre- to posttest improvement in target word reading and the proportion of

³

* p < .05, ** p < .01.

errors preserving both the initial and final consonants of targets, and the negative correlation with the proportion of pretest refusals was no longer evident. This finding is perhaps not surprising as the 'number of inferences made' reflects only the correct pronunciation of the analogous segment of a word and children do not need to have accurate representations of boundary consonants at pretest in order to achieve this.

A third set of correlations was undertaken to evaluate the relationship between reading ability, measures of phonological awareness, and partial representations of target words at pretest. These correlations are presented in Table 8.12 below. As in the previous four studies in this thesis, there is a significant positive correlation between measured reading ability and errors preserving both initial and final consonants at pretest. By contrast, refusals to answer show significant negative correlations with measured reading ability, as they have done in the majority of previous studies in this thesis. Table 8.12 also revealed that the proportion of pretest paralexias which preserved initial and final consonants were positively correlated with phonemic segmentation, the combined oddity measure, and the combined phonological measure. Refusals were also correlated negatively with rime oddity phoneme segmentation and the combined phonological awareness measure. These theoretically interesting correlations have not been reported before in experiments 3 and 4 and suggest that pretest errors preserving boundary consonants are made by children who have good phonological skills. One explanation for the presence of these correlations in experiment 5 but not in previous spontaneous inference experiments may be that the relatively large sample in the present study compared to that in experiments 3 and 4 allows these underlying associations to emerge more clearly.

Table 8.12. Correlation of error proportions with reading and phonological measures ⁴.

Measure	Expt 5		Expt 4		Expt 3		Expt 2		Expt 1	
	I & F	Refusal	I & F	Refusal	I & F	Refusal	I & F	Refusal	I & F	Refusal
BAS	.57**	-.33**	.35*	-.35*	.39**	-.14	.61***	-.35*	.67***	-.32**
First odd	.24	-.20	.08	-.04	.33*	-.19	-.06	.12	-.07	.17
Mid odd	.21	-.06	.03	.03	.14	-.12	-.33*	.36*	.01	.05
Last odd	.27	-.37**	-.02	-.07	.19	-.19	.16	.17	.04	.03
CdOdd	.32*	-.27	.04	-.01	.28	-.22	-.23	.29	.02	.07
Phon seg	.35*	-.30*	.02	.16	.09	.12	.23	-.18	.22*	-.04
Cd phon	.43**	-.39**	-.02	.12	.33*	-.21	-.05	.13	.11	.07
L.S. know	—	—	—	—	—	—	.20	-.24	.35**	-.14
L.S+ phon	—	—	—	—	—	—	.20	-.18	.27*	-.06
Mean	.59	.26	.61	.24	.54	.28	.58	.16	.37	.35
SD	.31	.29	.28	.28	.28	.30	.25	.26	.25	.29
Max	1	1	1	1	1	1	1	1	1	1

Key:Pretest errors

I & F initial and final phoneme shared with target
 Refusal refusal to answer

Reading-related variables

BAS BAS single word reading
 First odd Bradley first sound
 Mid odd Bradley middle sound
 Last odd Bradley last sound
 Cd odd Combined Bradley score
 Phon seg Phonemic segmentation
 Cd phon Cd odd and phon seg combined
 L.S. know letter-sound knowledge
 L.S.+ phon L.S know and phon seg combined

Correlations between reading-related measures

Another set of correlations investigated the relationship between phonological skills and reading ability. These are presented in table 8.13 alongside correlations in the same analyses in previous experiments for comparison. Reading ability was not correlated with phonemic segmentation ability in the present study even after transformation of the data to adjust for skew. Reading ability was strongly correlated with both the combined oddity measure, and the combined phonological awareness measure, as well as the beginning, medial and terminal oddity measures, suggesting

⁴ * p < .05, ** p < .01, *** p < .001.

that sound categorisation measured in the Bradley oddity tasks is an important skill associated with early reading ability. Similar correlations have been reported in experiment 4, though were not evident in experiments 1, 2, and 3. There appears to be some variability in results across studies. A larger scale analysis may be the best way to clarify whether rime awareness and reading are correlated, and this approach is considered below.

Table 8. 13. Correlations between reading ability and phonological measures ⁵.

Measure	first odd	Mid odd	Last odd	Cd odd	Phon seg	Cd Phon	L.S. Know	L.S + Phon
Expt 5								
BAS	.38**	.29*	.34*	.45**	.24	.43**		
Expt 4								
BAS	.18	.42**	.31*	.47***	-.05	.30		
Expt 3								
BAS	.01	.08	.13	.10	.39**	.32*		
Expt 2								
BAS	.20	-.08	-.18	-.04	.24	.10	.11	.22
Expt 1								
BAS	.25	.26	.11	.25	.24	.32*	.35**	.34**
Expt 5								
Mean	5.50	5.68	5.38	16.56	12.04	28.74		
SD	2.62	2.81	2.47	5.95	4.46	7.37		
Max	12	12	12	36	16	52		

BAS	BAS single word reading
First odd	Bradley first sound
Mid odd	Bradley middle sound
Last odd	Bradley last sound
Cd odd	Combined Bradley score
Phon seg	Phonemic segmentation
Cd phon	Cd odd and phon seg combined

⁵ * p < .05, ** p < .01, *** p < .001.

Meta analysis of the correlates of spontaneous inference use

In order to provide further evidence on the theoretically important question of the correlates of improvement in target word reading, a meta-analysis was undertaken combining the results for all children taught clue words in experiments 3, 4, and 5. As in experiments 3 and 4, a single improvement score was calculated by additively combining the adjusted pre- to posttest improvement scores for both the vowel-share and vowel-and-rime share target words read correctly. This single mean score was necessary as children in the taught-vowel groups in experiments 3 and 4 were not taught any rime analogous words, and thus separate comparisons of vowel and rime inferences were not possible in the meta-analysis. The sample size in the meta-analysis was $n=94$. Three sets of phonological awareness data were unavailable for reasons discussed in experiments 3 and 4. Correlations involving phonological measures are therefore based upon $n=91$ observations. This large data set should therefore allow a definitive evaluation of the relationship between pre- to posttest improvement in spontaneous inference tasks, pretest paralexias preserving initial and final phonemes, phonemic segmentation, the Bradley rime awareness measure and reading ability. The correlations between these variables are presented in table 8.14.

Table 8.14. Correlations between inference use, phonological awareness, reading and pretest paralexias ⁶

	Imp	I & F	Phon seg	Rime awareness	BAS
Imp		.36**	.14	.21*	.41**
I & F			.13	.18	.54**
Phon seg				.09	.23*
Rime awareness					.25*
Mean	.58	.60	10.52	5.45	77.04
SD	.44	.29	5.37	2.43	6.50
Max n	1	1	16	12	-

⁶ * $p < .05$, ** $p < .01$.

Key:

Imp	Pre- to posttest improvement in target word reading
I & F	Pretest errors preserving initial and final consonants
Phon seg	Phonemic segmentation
Rime awareness	Bradley last sound oddity
BAS	BAS single word reading score

The results of this meta-analysis reveal that there is a strong and significant correlation between improvements made in the spontaneous inference task and pretest paralexias preserving boundary consonants. There is also a strong correlation between spontaneous inference use and reading ability. These theoretically important correlations have been rather variable in experiments 3, 4 and 5. This analysis confirms that inference use is correlated both with reading ability and pretest paralexias which preserve boundary consonants. A set of partial correlations was undertaken to further evaluate the nature of these relationships. When the proportion of errors preserving initial and final consonants was first controlled, there was still a strong correlation between inference use and reading ability ($r = .27, p = .004$). However there was also a small but significant correlation between spontaneous inference use and pretest paralexias even when reading ability was first controlled ($r = .18, p < .04$). This correlation is modest but importantly does suggest that the relationship between inference use and pretest paralexias is not solely an artefact of reading ability.

A second important aspect of this meta-analysis was to investigate the relationship between phonological awareness measures and inference use and reading ability. Pretest paralexias were uncorrelated with either measure of phonological awareness in this analysis. This contrasts with the results of experiment 5, but is broadly in line with the results of the majority of the studies of spontaneous inference use reported in this thesis. Phonological rime awareness was weakly but significantly correlated with improvement in target word reading. This is theoretically important as this is the correlation reported by Goswami (e.g. Goswami & Mead, 1992) in her concurrently prompted transfer task, and which has been seen to strongly support the

interactive analogy model of early reading. This particular correlation between inference use and rime awareness has not been significant in experiments 3, 4, and 5. In the present spontaneous inference task the correlation is very modest, and stronger correlations between inference use and reading are evident. Partial correlations confirmed that once reading ability was controlled statistically, there was no correlation between inference use and rime awareness ($r = .13$, n.s), whereas the relationship between reading ability and inference use survived after controlling for rime awareness ($r = .38$, $p < .001$). This result differs from that reported by Goswami and Mead (1992) where a strong correlation between rime awareness and concurrently prompted rime transfer was evident even after first controlling for reading ability. Finally it is worth noting that reading ability is modestly correlated with both phonemic segmentation and rime awareness abilities, but neither of these two phonological awareness scores are correlated with each other, possibly suggesting that rime awareness and phonemic awareness make small but separate contributions to reading ability.

Further analysis of the clue word task

The final set of analyses evaluated aspects of inference use in the main experiment and clue word learning that have not yet been discussed in previous analyses. These analyses are therefore based upon $n = 50$ participants.

Analysis of control word paralexias

Analyses were undertaken on all control word responses that shared any pronunciation with the clue words (e.g. 'herd' read as 'heak' after learning 'leak'). Of these responses 69% were vowel analogous pronunciations, and the rest were rime analogous pronunciations. The mean for pretest was 0.54 ($SD = 0.79$) and at posttest was 1.38 ($SD = 1.40$). Scores were submitted to a related t-test. This revealed a significant increase in the number of control words which were misread as sharing vowel digraphs or rimes with taught clue words, $t, 49 = 19.94$, $p < .001$. This shows that there was some tendency for children to give analogous pronunciations for words

which do not share orthographic units with the clue word, but the numbers involved are relatively small compared to the main experimental task.

Further analyses were undertaken to explore the correlation between this tendency to overextend clue word knowledge, and other reading related variables. Correlations revealed a negative association between the number of overextensions that children made and measured reading ability ($r = -.29$, $p < .05$), and a negative correlation with middle sound oddity ($r = -.31$, $p < .05$). This suggests that poorer readers with poor phonological skills overextend clue word information inappropriately to words which do not share letter-sound relationships with clues.

Analysis of vowel digraph reading

The number of correct pronunciations for digraphs given at the pretest and the posttest was analysed. The mean score at pretest was 1.68, ($SD = 1.27$) and the mean at posttest was 1.94 ($SD = 1.35$). Data was submitted to a related t-test. This revealed a significant improvement in reading of vowel digraphs, $F(1, 49) = 5.24$, $p = .03$. This analysis indicates that children show a small improvement in reading the vowel digraphs in isolation.

Analysis of clue word knowledge

Substantial improvements were made in clue word reading from pretest to posttest. The pretest mean was 3.90 ($SD = 4.00$); the mean at posttest was 10.74 ($SD = 1.58$). Posttest data showed significant kurtosis and skew, so were analysed using the Wilcoxon test. The dependent variable was the number of clue words correctly articulated. There was a main effect of Test, $z = -6.01$, $p < .001$. This analysis shows that the children had learned the clue words effectively and could articulate them at the posttest. As noted in the discussion of experiment 4, there is a relatively high level of clue word knowledge displayed here. In contrast, spontaneous inferences from clue words to target words in the main experiment are comparatively rather weak. There are

many times then, when children know three clue words but do not articulate the target words sharing either orthographic rimes or vowel digraphs with known clue words.

Analysis of speed of clue word learning

Analysis of the speed with which children learned the clue words was also undertaken. In this study, the number of trials to criterion was three correct articulations of the clue word in a row. The minimum possible score was therefore 36. The mean was 46.0 (SD = 5.71).

Discussion

The main aim of experiment 5 was to evaluate the relationship between individual differences in target word reading improvement after prior exposure to analogous clue words, reading ability and two distinct measures of phonological awareness. Before these are discussed, the comparison of the relative levels of inference use for vowel-share and vowel-and-rime-share target words is considered.

Inference use in experiment 5

The first set of analyses undertaken were on the overall patterns of inference use. The aim was to confirm the findings of experiments 3 and 4 that have found equivalent inference use amongst target words sharing either orthographic rimes or vowel digraphs with taught clue words. Two forms of analysis were undertaken: in the first the dependent variable was the number of correct responses made and in the second the dependent variable was a measure of the number of inferences made. Together these analyses were consistent in finding significant improvement in the reading of rime and vowel analogous target words, and no improvement for control words after prior exposure to taught clue words. This pattern of significant findings was evident across both subject and item analyses.

There was some evidence of additional advantages for target words sharing rimes with previously taught clue words over words sharing only vowel digraphs with the pretaught clues. When the number of target words read correctly by subjects was considered as the dependent variable this advantage for rimes proved to be statistically significant. However the advantage for rimes over vowels was not statistically significant when considered across items. Furthermore when the dependent variable was the number of inferences made, rather than the number of targets read correctly, this comparison was not significant in either the subject or the item analyses. The present results are therefore consistent with previous findings from experiments 3 and 4 in providing robust evidence for the use of vowel inferences by 6 year old children when given sufficient exposure to analogous clue words, but where additional advantages for rime analogous words are either not found at all or are inconsistently found.

Individual differences in inference use

The central aim of experiment 5 was to further investigate the correlates of individual differences in the pattern of improvements made in target word reading between pre- and posttest for vowel and rime analogous words. Previous research (Goswami, 1990a; Goswami & Mead, 1992; Peterson & Haines, 1992) has suggested that improvements in reading of target words sharing orthographic rimes with concurrently presented clues is linked specifically to awareness of phonological rimes. In contrast, improvement for other sublexical orthographic units in Goswami's clue word task, which do not preserve onset-rime boundaries, is correlated with phonemic awareness. The results of experiment 5 provided no evidence of a link between spontaneous rime inference or vowel inference and awareness of either phonological onset-rime or phoneme units.

A meta-analysis of the combined results of experiments 3, 4, and 5 provided some modest evidence of a correlation between inference use and rime phonological awareness in a large sample of $n=91$ participants. However the correlation was very

modest and did not reach significance when reading ability was first controlled in partial correlations. These results therefore differ substantially from those presented previously in the literature. Goswami and Mead (1992) report that rime awareness accounts for a significant proportion of the variance in rime transfer in Goswami's clue word task even when reading ability is entered as the first step in multiple regressions. Failures to replicate previous findings need to be interpreted with caution, especially in the light of the observation that the phonemic awareness measure showed signs of ceiling effects. However the results of experiments 3 and 4, and those of the combined meta-analysis suggest that the present finding is consistent, and given the theoretical significance attached to the link between rime awareness and rime transfer, the reason for the discrepancy between Goswami's and the present results need to be carefully considered.

One issue may concern the combined score used in the meta-analysis. From one view the combined score may be seen as a blunter instrument for addressing correlations between rime and vowel inference use and phonological awareness as it combines scores and may blur underlying correlations such as that predicted between rime awareness and rime analogies. However there are good reasons for believing that a combined measure is helpful in addressing the correlates of inference use. One argument justifying combined scores follows from the assumptions behind Goswami's model. Goswami argues that words underpinned at levels other than the onset/rime level must develop as a result of first establishing orthographic rime representations. It follows that vowel digraph inferences are therefore dependent upon rime awareness. Thus a correlation would be predicted between vowel inference use and rime awareness. This is supported by the results of two reported studies of phonological awareness and analogy use (Goswami, 1990a; Goswami & Mead, 1992) where a strong correlation between head analogies ('beak' - 'bean') and rime awareness was evident. The combined score is therefore likely to provide a good measure of the correlates of spontaneous inference use.

At a general level, therefore, the explanation for this difference in the pattern of associates of improvements in target word reading between the present and previous studies may lie in the nature of the task used to measure orthographic inferences. In the traditional task, in which concurrent prompts are given, there is a strong association between improvements in reading rime analogous target words and phonological rime awareness. Goswami is therefore able to argue that the use of rime analogies may represent the developmental link reported between preschool rime awareness and later reading ability (Bradley & Bryant, 1985). However in the present task, where clue words are pretaught, inference use was not associated with phonological awareness, but was associated with measured reading ability. Furthermore, when the number of inferences made was considered, rime inference use was again correlated with reading ability whereas individual differences in vowel digraph inference use were not correlated with measured reading ability. Use of rime inferences is one ability that distinguishes good from poor readers. Alongside the observation that children require substantial exposure to words containing analogous letter-sound relationships in order to perform inferences, such results may be more consistent with models of reading in which the use of orthographic rimes emerges after some significant reading experience rather than as an entry strategy to reading (Ehri & Robbins, 1992; Duncan, Seymour, & Hill, 1997; Muter, Snowling, & Taylor, 1994).

Individual differences in vowel but not rime inference use were associated with pretest representations of target words. Vowel inferences at posttest were positively correlated with errors preserving initial and final consonants, and negatively associated with refusals to answer to target words at pretest. This replicates the pattern of significant results reported in experiment 3 but which just escaped significance in experiment 4. The results of a meta-analysis of the correlates of inference use in experiments 3, 4, and 5 with $n=94$ participants confirmed that there was a strongly significant link between the proportion of pretest paralexias which preserve boundary consonants and later reading ability. Furthermore there was a small but significant

correlation between inference use and the proportion of these pretest paralexias even when reading ability was first controlled statistically. Together these results suggest that the quality of representations of words misread at pretest is a significant predictor of correct target word reading at posttest. One possible interpretation of the partial correlation evidence presented above is that word reading errors preserving initial and final consonants represent a first stage of word recognition. These partial representations are combined with the use of vowel inferences to correctly specify the orthographic representation of CVC words. This may thus reflect the mechanism by which accurate reading development is achieved. However only a longitudinal study can answer these sorts of questions with certainty.

Experiment 5 also revealed that phonological awareness as measured by the Bradley test of auditory organisation, was strongly correlated with reading ability, despite not being correlated with inference use. While the correlation between rime phonological awareness and reading ability appears to be robust, rime oddity awareness does not appear to operate by facilitating orthographic rime inference use directly. This suggests that there may be a more indirect route through which implicit rime awareness aids reading acquisition, though at present it is unclear how this mechanism might work.

The correlation between pretest target word errors and phonological skills

Correlational analyses revealed that the proportion of errors preserving initial and final consonants at pretest was correlated with both phonemic segmentation skill and with two combined measures of phonological skill - the combined oddity scores and the combined phonological score. One interpretation of this finding is that phonological skills are used to establish such partial representations of the orthography early in reading (Stuart & Coltheart, 1988). This general pattern of associations between errors of this type and phonological skills has only occasionally been found in previous studies. The results of the meta-analysis of the results of experiments 3, 4, and 5 also found no evidence of a correlation between errors preserving initial and final consonants

and either measure of phonological skills, so the correlation reported in experiment 5 appears to be a rather unreliable one.

Three other important issues emerged from the present results. The first is that the present study found some evidence for the overextension of inferences from clue word pronunciations to non-analogous control words. While statistically significant, these findings were relatively modest in size so that they could not explain the pattern of inference use in the main experimental task. However they do demonstrate that a part of the improvement in target word reading witnessed between pre- and posttest may not be orthographic in nature. Further analysis revealed that individual differences in this overextension of pronunciation is negatively correlated with reading ability and phonological awareness. Thus there may be two distinct sources of improvements in target word reading: one that is orthographic in nature and positively associated with reading ability and another that is not tied to orthographic clue word knowledge and which is associated with poor reading ability and under-developed phonological awareness.

The present study also found some evidence for improvements in the reading of isolated vowel digraphs after exposure to clue words containing these vowel digraph units. Here, as in experiments 3 and 4, the improvements were very modest. Caution also needs to be maintained in interpreting these findings as there is no control condition to compare results against. It cannot be concluded from the present findings that improvements reflected children's ability to extract knowledge from clue words rather than more general improvements in digraph reading. One other aspect of results that deserves mentioning is that there was again very clear evidence of retention of ability to read clue words at posttest. In contrast to the pattern of inference use shown to target words this clue word learning was near ceiling, confirming that children are not just limited in performing inferences by their lack of knowledge of the orthography: even

when children know three analogous words they do not necessarily apply this knowledge to pronouncing targets which share letter strings with clues.

Conclusions

The main aim of experiment 5 was to investigate the correlation between individual differences in the application of spontaneous rime and vowel digraph inferences, measured reading ability and two measures of phonological skills - rime awareness and phonemic segmentation skill. Previous research from studies of concurrently prompted transfer suggested that individual variation in rime inference use should be correlated with rime awareness, whereas individual variation in vowel digraph inference use may be correlated with phonemic awareness. The results of the present study suggested that neither spontaneous vowel digraph nor spontaneous orthographic rime inference use were correlated with any measures of phonological awareness, but correlations between inference use and reading ability were evident. The correlations between rime inference use and reading ability were the most consistent of the correlations found, as they were evident both in analyses of the number of correct pronunciations of target words and in analyses where the total number of inferences made was the dependent variable. Meta-analyses showed that associations between inference use and reading ability were robust and also confirmed that inference use was correlated with errors preserving initial and final consonants. In one analysis this relationship held when reading ability was first controlled. These correlations provide further support for the idea that vowel digraph inferences are involved in early reading. The extent to which these results and the results of the previous four experiments can inform theoretical models of reading acquisition is considered in the final chapter.

Chapter 9

The nature and use of orthographic inferences in reading acquisition

Summary

The final chapter in this thesis seeks to draw together the results of the five experiments reported here, to consider how results have cast light on the questions set out at the beginning of the thesis, and the extent to which they inform models of reading acquisition. Results are discussed in four sections which serve to highlight the relationship between the present findings and the existing literature, with the aim of providing an integrated theoretical view of findings. The final sections of the chapter consider the limitations of the present work along with some suggestions for further work on children's use of inferences in early reading.

Aims of the present research

The present research sought to investigate the development of the capacity to infer the pronunciation of letter strings from prior exposure to words sharing similar letter strings. This skill is central to several current models of reading acquisition (Coltheart et al, 1993; Seidenberg & McClelland, 1989). The starting point for research pursued here was Goswami's explicit developmental model of the use of orthographic inferences (Goswami, 1993). Goswami has demonstrated that young children make improvements in reading of words sharing rimes after the concurrent presentation of a clue word (e.g. 'beak' - 'peak'), which is generally greater than for words sharing heads (e.g. 'beak' - 'bean'). She has also shown a strong and specific link between individual differences in improvements made in word reading and phonological rime awareness. These results have been interpreted as reflecting the use of a process of orthographic analogy based upon the use of phonologically underpinned orthographic rime units in early reading.

After an extensive review of research carried out in chapter 3, it was argued that Goswami's demonstration of 'analogy' use may be limited by the fact that the clue word and the target word are both presented concurrently. It is unclear both what role the concurrent reminders of clue word orthography and phonology play in facilitating target word reading and the extent to which children can perform spontaneous inferences in the absence of such concurrent prompts. Given that models of reading development must also be ecologically valid it is important to evaluate the ability of children to perform inferences across a range of clue word learning conditions before concluding that beginning readers can use such a strategy to learn to read.

Four specific issues were therefore identified at the beginning of the thesis. These were: a) the role of concurrent prompts in Goswami's clue word analogy task; b) the ability of young children to make spontaneous use of orthographic inferences in the absence of such concurrent prompts; c) the size of letter-sound units involved in spontaneous use of inferences; d) the correlates of individual differences in the use of orthographic inferences, either when spontaneous inferences were used, or when concurrent prompts were provided. The results of research on these four questions are considered in turn.

a) The role of concurrent prompts in facilitating target word reading

Existing research has already demonstrated that children are influenced by the presence or absence of concurrent prompts when making orthographic inferences. Children typically perform orthographic inferences more readily in the presence of clue word prompts than without them (Muter et al, 1994; Savage, 1997). The present studies sought to clarify and expand knowledge on this issue, by attempting to clarify the role of concurrent prompts. In particular the studies sought to evaluate the role of purely orthographic information on inference use by contrasting improvements when both clue word orthography and phonology were provided, compared to a condition where only clue word phonology was provided.

An important new finding from experiment 1 discussed in chapter 4, was that improvement in target word reading was as strong for rime analogous words in a condition where only phonological information about a clue word was given, as when the clue word was present in front of the child, and phonological information was given. For head analogous words, improvement was significantly greater under this condition than when both orthographic and phonological prompts were given. These results are not therefore consistent with Goswami's view that the improvements in target word reading represent the use of a lexical analogy process. Analogy theory assumes that the advantage for words sharing orthographic rimes with a given clue word arises because (a) children perceive the orthographic similarity between rimes of clue and target words; (b) the clue word is pronounced for them, (c) this gives them the pronunciation for the shared rime; (d) children's rime awareness enables them to conclude that word endings which look the same will sound the same. In the phonological prompt condition there was no external orthographic representation available to the child upon which this process of analogy might begin to work.

Three alternative explanations of the improvement for phonologically prompted target words were considered. None of these views require the assumption that children use orthographic inferences. The first view considered was that the improvements in word reading after being given a phonological clue word prompt may reflect a phonological priming strategy. However this explanation was rejected on the grounds that it would also predict priming under other test situations which was not evident. A second view was considered based upon that advanced for spelling development by Nation and Hulme (1996). They argue that the phonological prompt serves to activate orthographic representations of the clue and target words sharing orthography. This view too could be rejected for the results of experiment 1 because children knew too little clue word information to generate significant improvement between pre- and posttest, though it would be able to explain improvements in experiment 2.

A third potential explanation of improvements in target word reading with concurrent prompts is that children use the concurrent prompt along with particular contextual cues in the clue word task to directly infer the pronunciation of target words. From this view, children take advantage of the repeated reminder of the clue word pronunciation provided, alongside the information that the pronunciation is some form of a 'clue' to directly derive the pronunciation of unknown vowel digraphs or rimes of target words. That is to say, when presented with an unknown word such as 'peak' and provided with the pronunciation of a clue word 'beak', as well as being told that this information is a clue, children realise that part of the pronunciation provided may be meaningfully applied to letter strings in the unknown word 'peak'. Such a view has not been considered previously in the literature on inferences, but would be able to explain the pattern of results in prompted conditions witnessed in both experiments 1 and 2.

Conclusion

Irrespective of the particular explanation of the improvement in target word reading in the presence of concurrent clue word prompts, this discussion of the results of experiment 1 confirms that there are significant problems with the interpretation of improvements in target word reading in Goswami's clue word task. The improvements witnessed in the traditional version of the analogy task are open to more than one interpretation, so the underlying process being used in target word reading remains unclear. The most obvious way to obtain clearer evidence about the ability of young children to use orthographic inferences is to investigate whether children can spontaneously infer sublexical relationships in the absence of concurrent clue word prompts. Evidence for the use of inferences under these conditions is considered in the next section.

b) Spontaneous use of orthographic inferences

Spontaneous inference of sublexical relationships was investigated by preteaching clue words and avoiding the use of any concurrent clue word prompts at posttest. Studies of the use of spontaneous inferences produced a mixed pattern of results in the present series of experiments. Experiment 1 investigated inference use when children were taught a single clue word. Results showed that there were no improvements under these conditions. Some previous studies (Savage, 1997 experiment 1; Muter, 1994) report small but significant improvements, but other studies have reported no advantages whatsoever (Savage, 1997, experiment 2). The present findings provide a firmer test of hypotheses than some previous work because they included a relatively low ratio of clue to target words (unlike Muter et al, 1994) and were tested within the same session, thus eliminating other extraneous sources of improvement (unlike Savage 1997, experiment 1). Findings were also reinforced by the observation that children were near ceiling on the reading of clue words at posttest, showing that they had a stored clue word available but appeared unable to use it to read other words sharing letter-sound relations with it. Together then, the present results provide strong support for the view that children cannot perform spontaneous inferences after prior exposure to one analogous clue word.

Several studies have suggested that the number of words known which share letter strings with unfamiliar words influences the use of orthographic inferences. Studies of rime neighbourhood effects, for example, suggest that the number of words sharing common patterns influences the number of inferences made to words sharing letter-sound relationships. Nonwords which share letter strings with many real words (e.g. 'tain' and 'goach') are read better than nonwords which, while sharing the same letter-sound rules, do not share many rime neighbours (e.g. 'goan' and 'taich'). This suggests that the use of rime inferences develops as children develop sight vocabularies (Bowey & Hansen, 1994; Bowey & Underwood, 1996; Treiman, et al, 1990). Furthermore studies that have looked at inferences in the absence of concurrent prompts

(Muter et al, 1994; Walton, 1996) were able to demonstrate that inference use was significantly associated with reading ability, suggesting that reading experience is involved in inference use.

In the second phase of experimentation, studies were therefore carried out to evaluate inference use in the absence of concurrent prompts, but where children were given greater prior exposure to words embodying letter-sound relationships shared with unknown target words. Here three clue words were pretaught prior to the posttest phase of the study. A central new finding was that children could make orthographic inferences under these conditions where the clue word was not present to support inference use. Specific improvements in the reading of words sharing either rimes or vowel digraphs was found at posttests. This pattern of results was statistically robust and found consistently in experiments 3, 4, and 5.

Conclusion

Together the results suggest that young children are unable to perform lexical inferences on the basis of a single known clue word when no concurrent clue word prompts are available. The key problem for young children appears to be lack of orthographic experience rather than an inability to perform inferences at a young age, as children of a similar age to those taught a single clue word are able to use orthographic inferences even in the absence of concurrent clue word prompts, when given significant prior exposure to words sharing letter-sound relationships.

c) The size of units involved in inference use

An important part of the present work was to evaluate inferences from words that shared common rimes (e.g. 'peak' - 'leak') against words that shared common vowels (e.g. 'peak' - 'meat') in the absence of concurrent prompts. All three experiments involving spontaneous use of inferences (experiments 3, 4, and 5) provided support for the view that inference from shared vowel digraphs was as easy

as inference from shared rimes, if children were pretaught three examples of the orthography. This result is not consistent with the interactive analogy model, (Goswami, 1993). While strong and significant patterns of vowel inference were reported in all three experiments where clue words were pretaught, and no consistent statistically reliable additional advantage from rimes was evident, advantages in the number of inferences made from words sharing rimes over words sharing vowels have been found on two occasions in this thesis, even in the absence of concurrent prompts. These studies therefore merit careful consideration and are therefore discussed below.

Experiment 3 reported an advantage for targets sharing rimes over targets sharing vowels at posttest in the analysis by items but not in the subject analyses. The advantage for rimes is therefore unreliable. Furthermore problems with the word set suggest that the results of these analyses should be interpreted with particular caution. With an improved word set in experiment 4 no significant advantages were found for rimes. The second time that advantages for rimes have been reported was in experiment 5. Here significant advantages for target words sharing rimes over targets sharing vowel digraphs were reported in the analyses by subjects but not in the analysis by items. Again the advantages for rimes are not consistent across both subject and item analyses. Furthermore in experiment 5, when the 'number of inferences made', was considered rather than the number of clue words read correctly, the advantage for rimes disappeared even in the subject analyses. The number of inferences made provides a more sensitive measure of the use of inferences independent of knowledge of the pronunciation of other word segments (Savage, 1997). Together then the results confirm that while significant improvement in target word reading follows learning rime and vowel digraph analogous clue words, there is no reliable difference in the level of inference use between these two word types.

An important methodological point emerges from this discussion. The comparison of various statistical analyses reinforces the importance of using both

subject and item analyses to test the generality of findings in experimental studies. This approach is common in cognitive psychology, and results that are not consistent across subject and item analyses are often not reported. By contrast, analyses by items and by subjects have not been reported in many of the pivotal developmental studies of analogy (e.g. Goswami, 1986, 1988b, 1993), though they have been reported in some of the studies which have failed to find privileged use of rime inferences (e.g. Nation & Hulme, 1996).

The present results are also consistent with a number of recent studies of early word learning which have also come to the same conclusion that children are adept at using small units in reading (Bruck & Treiman 1992; Duncan, Seymour & Hill, 1997; Ehri & Robbins, 1992; Wise Olson & Treiman, 1990). In the review of literature in chapter 3 it was noted that some studies have shown that the rime advantages over other orthographic units reflect relatively short term gains that are relatively impermanent (Bruck & Treiman, 1992; Wise et al, 1990) whereas learning by the use of grapheme to phoneme correspondences, while slower, is more permanent. Other studies have demonstrated that rime inferences are only evident once children have some ability to decode (Ehri & Robbins, 1992).

Conclusion

The finding that children performed inferences as often when target words shared common vowels as they did when words shared common rimes does not support the "Phonological Status hypothesis" (Goswami, 1993). In that view, the use of vowel inferences represents a relatively late emerging skill, evident only after rime analogy ability has been established, (e.g. Goswami, 1993; Goswami & Bryant, 1990). The interactive analogy model developed by Goswami (1993) hypothesises that orthographic rimes are better underpinned by the application of phonological rime knowledge available to some children prior to school entry, than vowels which are only underpinned with reading experience. However the present results have shown that the

spontaneous use of inferences either to rimes or vowel digraphs requires significant prior exposure to words exemplifying particular orthographic patterns.

Abstracting vowel information after posttest

Across experiments 3, 4, and 5, an analysis was undertaken of the number of vowel digraph units children read between pretest and posttest, as a measure of the ability to extract abstract vowel digraph information. In contrast to the ability of children to use clue words to infer the pronunciation of analogous target words, a rather mixed pattern of results was evident in the pronunciation of abstract vowel digraph units. No significant vowel improvements were evident in experiments 3 and 4. Small but significant improvements were evident in experiment 5.

Conclusion

Clearly extraction of abstract vowel digraph rules on the basis of prior exposure to three clue words containing them is not a task readily performed well by children. One problem here may be the relatively limited scope for measuring improvements with only four vowel digraphs being measured in each case. Another problem may be that children may infer vowel digraph pronunciations in the inference task, but when presented with vowel digraphs in isolation revert back to the unhelpful strategy of attempting to blend together the two short letter sounds. This strategy was often evident in pre- and posttest assessments of vowel digraph knowledge. Clearly more work is needed to clarify the extent to which children can infer abstract grapheme to phoneme correspondences from words embodying such letter to sound relationships.

d) Individual differences in inference use

Prior work (Goswami, 1990a; Goswami & Mead 1992; Peterson & Haines, 1992) had shown that improvements in target word reading at posttest in the clue word analogy task were strongly correlated with phonological rime awareness. A similar pattern of correlation was also evident in the combined prompt condition of experiment

1. These results have lent support to the view that children use their early developing rime awareness to develop orthographic rime units in early reading (Goswami & Bryant, 1990). Two studies (experiments 2 & 5) set out to provide further information about individual differences in inference use. Experiment 2 sought to evaluate individual differences in the use of orthographic inferences under the same experimental test conditions as Goswami has used previously, but to investigate further the associates of target word improvements. Experiment 5 also sought to evaluate the correlates of spontaneous inference use in the absence of concurrent prompts.

Individual differences in prompted inference use

Experiment 2 sought to evaluate improvements in target word reading under the same conditions of transfer used by Goswami in which concurrent prompts were provided. As well as investigating the role of phonological rime and phonemic awareness, the study sought to investigate the role of partial representations of the orthography which children bring to the task. The role of pretest errors which preserved consonant pronunciations were of particular interest as these have been hypothesised to be influential in early reading (Stuart & Coltheart, 1988; Ehri, 1995). In this thesis the error taxonomy developed by Stuart and Coltheart (1988) was modified in order to extend their research. Stuart and Coltheart have developed a taxonomy in which errors are categorised by the extent to which such incorrect pronunciations share letters with target words. Thus errors preserving initial and final letters with target words include the response 'bike' for the target 'bone'. However if it is assumed that early reading is based upon letter-sound knowledge (e.g. Ehri, 1992, 1995; Stuart & Coltheart, 1988), then a stronger test of the idea that partial representations of target words represent partial knowledge of letter-sound rules would be evident if errors were categorised on the basis of shared sounds rather than shared letters. In this example 'bike' shares only the initial sound with the target but the response 'bean' shares both initial and final phonemes. Experiment 1 provided some preliminary evidence that errors preserving initial and final phonemes were correlated

with reading, thus replicating and extending Stuart and Coltheart's original findings. Experiment 1 also showed that improvements in target word reading were associated with the quality of pretest representations of the orthography, and particularly with those paralexias which preserved both initial and final consonants.

Experiment 2 sought to provide further evidence that paralexias preserving initial and final consonants are involved in improvements in target word reading. There were strong and significant positive associations between improvement in reading both head and rime analogous words at posttest and the number of errors children made at pretest which preserved the initial and final consonants of words. That is to say, the correct reading of a target word such as 'peak' at posttest, when provided with the clue 'beak', was more likely if that word was misread as e.g. 'park' at pretest, than if the pretest error did not preserve boundary consonants. Two important implications follow from this: the first is that it is not therefore necessary to assume that children are using large unit inferences even in the traditional form of the clue word task used by Goswami. The pattern of improvement witnessed could be explained by the derivation of vowel digraph pronunciations from clue words in conjunction with preexisting knowledge of boundary consonants. The second implication is that types of phonological awareness other than rime awareness may be important in producing improvements in target word reading.

Experiment 2 also revealed that improvements in target word reading were not significantly correlated with measures of phonological awareness. However of the two distinct measures of phonological awareness, the phonemic segmentation task explained a near significant 12 % of the variance in improvements whereas the rime oddity measure explained less than 1 % of the variance in improvements, suggesting that phonemic skills are stronger associates of improvements than rimes. In a slightly larger sample this former correlation ($r = .34$) may well have reached significance. It is not clear why the present results do not replicate the pattern of findings reported

previously by Goswami. One possibility is that as phonological skills were measured several weeks prior to the clue word task, the study provides a longitudinal rather than concurrent measure of the relationship. Evidence exists that the relationship between rime awareness and improvement in reading rime analogous words in the clue word task is only a concurrent one, and is not evident in longitudinal studies, (Muter et al, 1994). The present results could be seen to extend this finding by showing that the relationship is even more fragile than has been considered previously and does not hold even over relatively short time scales.

The view that small units play a significant role in pre- to posttest improvements in target word reading was also supported by the unexpected finding that improvements in reading rime analogous words were very modest compared to head analogous words in subject analyses, and were not present at all in the item analyses. Here again inconsistency in the advantage for improvements to words sharing common rimes compared to those sharing common vowel digraphs is evident even under the same conditions tested by Goswami. One possible explanation for the different results reported here may lie in improvements made in the word set, where CVC stimuli with consonant singletons were used throughout. In many of Goswami's studies word sets such as 'beak' - 'beach' have been included which may have complicated results.

Conclusion

Together these results provide little support for the interactive analogy model, (Goswami, 1993). The interactive analogy model assumes that children are better able to use rime inferences than inferences from other shared subsyllabic letter strings. Furthermore the interactive analogy model assumes that individual differences in rime inference use are strongly correlated with phonological rime awareness. Neither of these views were supported by the results of experiment 2. There was evidence that small units play an important role in facilitating improvements in target word reading. This was suggested by the association between improvements in target word reading

and the pretest representations of target word orthography in which consonants but not vowels were well represented. The use of small orthographic units was also suggested by the stronger link between phonemic awareness and improvements in target word reading than between rime awareness and target word improvements.

Individual differences in inference use in the absence of concurrent prompts

Experiments 3 and 4 had as their main aims the task of evaluating spontaneous inference use in the absence of concurrent prompts and the relative facility with which children make spontaneous inferences to vowel versus rime analogous words. These experiments also sought to evaluate the relationship between improvements made in target word reading in these two tasks and the pattern of reading ability, phonological skills and pretest target word reading errors in order to further evaluate the correlates of individual differences in inference use. Two important questions were considered. The first question was whether inference use is significantly associated with pretest target word reading errors which preserve initial and final phonemes. If true this would provide further support for the view suggested by experiments 3, and 4 that vowel digraphs are functional units of transfer. The second question was whether Goswami's claims about the association between different levels of phonological awareness and inference use are also evident when spontaneous inference use rather than concurrently prompted transfer is considered. If spontaneous inference use is associated with phonological rime awareness then this would provide strong support for Goswami's claim that use of rime analogies explains the link sometimes reported between preschool rime awareness and early reading ability (Bradley & Bryant, 1985).

The results of experiments 3 and 4 produced rather variable results on most of these questions. For example, a correlation between spontaneous inference use and reading ability was evident in experiment 4 but was not evident in experiment 3. Equally a correlation between inference use and pretest target word reading paralexias preserving initial and final consonants reached significance in experiment 3 but escaped

conventional significance in experiment 4. Furthermore the pattern of correlations between different sorts of phonological awareness and reading were extremely variable between the two studies. One problem with these two studies was that as experiments 3 and 4 were primarily experimental studies set up to study inference use in taught versus untaught control conditions, the correlational analyses using inferences were based upon only $n=27$ observations. Even where patterns of correlations were consistent across experiments 3 and 4 (for example the absence of a correlation between inference use and phonological awareness), it was not clear that strong conclusions could be drawn from these studies about individual differences in inference use. A final potential complication was that experiments 3 and 4 required the use of a combined improvement score for target words sharing vowels or rimes in the correlational analyses. A clearer picture was therefore required from a study which included a larger sample of $n=50$ participants, and which considered rime and vowel inferences separately in order to provide a more sensitive measure of inference use and its correlates.

Experiment 5 therefore investigated the skills associated with inference use, when inferential skills were tested in the absence of concurrent clue word prompts. The study sought to assess the generality of the associations between inference use and phonological rime awareness reported by Goswami, as well as to investigate further the role of classes of pretest paralexias on inference use. The results revealed that there was no association between improvements made in target word reading and either phoneme or rime awareness measures. In contrast, strong associations between inference use and reading ability were evident when the number of correct responses made was considered, though this was less strong when the number of inferences made was considered. There was a modest correlation between vowel inference use and the proportion of errors preserving initial and final consonants at pretest only when the number of correct responses was considered.

As the main correlational study in experiment 5 had produced few new significant correlations when rime and vowel words were considered separately, a combined score for the results in experiment 5 was amalgamated with the results for the taught conditions in experiments 3 and 4 in order to provide a meta-analysis of the correlates of spontaneous inferences use. The full sample contained $n=94$ participants and could therefore provide a more definitive answer to the theoretically important questions of the correlation between inference use, reading ability, phonological awareness and pretest target word paralexias.

The results of this study confirmed that there was a strongly significant correlation between inference use and the proportion of errors preserving initial and final consonants at pretest, and between inference use and reading ability. Furthermore the result of a partial correlation between inference use and pretest paralexias, where reading ability was first controlled, found that a small but significant correlation between inference and errors was still evident. This result is important as it may show that the relationship between inference use and partial representations of target words reported in this thesis is not simply an artefact of reading ability. One interpretation of this finding is that it shows that partial representations may represent an early but crucial stage in the development of full representations of word orthography early in reading (Ehri, 1992, 1995; Stuart & Coltheart, 1988). Furthermore it may also show that inference of vowel digraphs may be the mechanism by which these more precisely specified representations of digraphs in CVC words are achieved. While this is an intriguing idea, caution is of course required here as only a longitudinal design can answer these questions definitively.

The meta-analysis also sought to investigate the relationship between inference use and phonological awareness. No correlation with phonemic segmentation was evident, however there was a modest correlation between inference use and rime awareness. This finding is important as this is the 'special link' reported by Goswami

(e.g. Goswami & Mead, 1992) in her studies of concurrently prompted transfer in the clue word task. However unlike Goswami's study, the correlation did not survive once measured reading ability was controlled statistically, suggesting that when spontaneous inferences are considered there is no specific correlation between inference use and rime awareness. This finding is theoretically important as it suggests that inference use may not represent the link between preschool rime awareness and reading ability, contrary to the position advanced by Goswami (1993). Caution is again required here as it must be acknowledged that the best test of this purported causal relationship is through a longitudinal study. As discussed in chapter 3, such a study has been reported by Muter et al, (1994), and has not provided support for Goswami's position. Muter et al report no correlation between preschool rime awareness and later rime analogy use, though they did find a concurrent association between reading ability and rime awareness.

One possible explanation of the pattern of spontaneous inference in this thesis is that individual differences in inference use represent the use of an orthographic strategy in early reading. Several models of reading have considered the idea that children may use an automatic orthographic process that is independent of explicit knowledge of subsyllabic phonology (Ehri, 1992; Frith, 1985; Marsh et al, 1981). From such a view greater reading experience may be required to represent target words accurately in lexical memory in order to perform inferences (Duncan, Seymour & Hill, 1997; Ehri & Robbins, 1992; Muter, Snowling, & Taylor, 1994). However there are reasons to be cautious about this conclusion. Orthographic stages of theoretical models of reading development are rarely well specified (Bryant, 1995; Share, 1995). Furthermore, as noted in chapter 2, to assume the existence of an orthographic strategy simply from the absence of a correlation with phonological skills may be unwarranted.

There are also more direct reasons for assuming that inference use may involve phonological skills. Phonological skills are known to be associated with the proportion of errors preserving initial and final letters made by young children. Developmentally,

children start to make representations of the orthography which preserve initial and final letters at exactly the point where children start showing the use of phonological skills (Stuart & Coltheart, 1988). Other evidence is also consistent with this view. Byrne & Fielding-Barnsley (1989) have demonstrated with a younger group of children that both letter-sound knowledge and phonological skills are required to make inferences from the initial letter of a known word e.g. 'MOW' to unknown words with the same letter at the beginning of the word, e.g. 'MAT' versus 'SOW'. Furthermore simply giving children reading experience in the absence of well developed phonological skills is not sufficient for the children to infer letter to sound correspondences. Juel, Griffith, & Gough (1986) for example report that children with very low levels of phonological awareness were unable to read even a single nonword after having been given significant reading experience. Similar findings are evident in training studies looking at poor readers (Hatcher, Hulme, & Ellis, 1994). Improvements in reading do not take place when children are exposed to print in the absence of additional training in phonological skills.

In experiment 5, the problem of the ceiling effects on the phonemic segmentation task may have lead to the failure to detect a genuine underlying relationship between phonemic awareness and orthographic inference use. The relatively restricted range of phonemic awareness skill here, where 85% of children segmented a CVC word correctly on more than half of the trials, may not allow us to draw strong conclusions about the relationship between phonemic awareness skills and the use of inferences in reading. It is important to note that the same argument does not hold for the relationship between rime awareness and inference use. There was no ceiling effect on the rime awareness measure, nevertheless no significant association with inference use was evident.

Phonological awareness and reading ability

The results of the meta-analyses confirmed that there was a concurrent correlation between both rime awareness and reading ability and phonemic segmentation and reading ability. Both correlations were fairly modest, but each measure appeared to make separate contributions to reading ability as they were not correlated with each other. It may be that the analyses presented here provide something of a cautionary note on such correlational studies. Considering the results of each of the five experiments that have reported correlations between reading and phonological awareness (see table 8.13 on page 288 for full correlation data), there have been quite wide variations in the correlations reported between reading and the two phonological awareness measures in these small scale studies. The precise nature of the relationship between rime awareness, phoneme awareness and reading remains a focus of debate (e.g. Muter, Hulme, Snowling & Taylor, 1997). Arguably the meta-analysis shows that relatively large sample sizes may be required to provide stable results on this question, and suggests that drawing strong conclusions from studies with relatively small sample sizes is likely to be particularly hazardous.

Conclusion

Two studies have reported preliminary research on the relationship between the use of orthographic inferences, phonological skills and reading ability. Inference use was found to be associated with reading ability, but not with phonological skills. This result is not consistent with the predictions of the interactive analogy model (Goswami, 1993). Results are more consistent with the view that inference use emerges only after significant reading experience (Ehri, 1995). Caution is required here as further longitudinal work may be required before a stronger model of individual differences in inference use can be advanced.

Implications of results for models of reading development

Together, the present results are consistent with a view of reading in which children initially establish partial representations of the orthography, where, in the case of monosyllables, initial and final consonants may be well represented, but where vowel information is less well represented. Children were able to make inferences to unfamiliar words from rimes or vowel digraphs of familiar words, as long as they have had sufficient exposure to words sharing letter-sound patterns. The use of inferences appears to have a quite specific correlation with errors preserving initial and final consonants. The use of rime inferences does not appear to be associated with phonological rime awareness but is associated with reading experience, suggesting that inference use emerges after significant exposure to the orthography.

The present results may be generally consistent with Ehri's theoretical account of reading development (Ehri 1992, 1995). While Ehri does not explicitly deal with inference use within her model, she does assume that representations of orthographic knowledge become better specified through greater exposure to the orthography. From this view, children's use of inferences may serve to specify orthographic representations of words more accurately. Thus the use of orthographic inferences may help a child in moving from 'phonetic cue' to an orthographic 'cipher' stage of word representation, (Ehri, 1995). Individual differences in inference use, which appear to develop as a result of reading ability, may be consistent with Ehri's notion that children develop consolidated orthographic units to facilitate speeded word recognition. This would require the assumption that such a skill can begin to emerge in relatively skilled readers who, nevertheless, are comparatively young.

Results of the present studies may also be consistent with aspects of Seymour's dual foundation model of reading acquisition (Seymour, 1997). This account does not predict an advantage for the spontaneous use of rime inferences over other shared letter sequences as phonologically underpinned orthographic rime units do not have

privileged status in early reading. Seymour holds that rime units may however emerge later in reading development. Seymour argues that, in the early stages of reading acquisition, children with good phonological skills and some significant reading experience will start to develop abstract and generalisable orthographic knowledge that may allow them to make inferences on the basis of shared onset, peak and coda elements. Thus the present results can be accommodated within Seymour's model on the assumption that the present children who made spontaneous orthographic inferences had entered the orthographic stage of development, whereas the children who did not make use of orthographic inferences had not yet reached the orthographic stage of reading acquisition.

At a more general theoretical level, it seems that the present results can be well explained by both connectionist models of reading development (Rack et al, 1994; Seidenberg & McClelland, 1989) and the dual route cascaded (DRC) model of reading (Coltheart, Curtis, Atkins, & Haller, 1993). In these accounts, which are instantiated as computational simulations, the process of learning is conceptualised as the gradual development of associations between orthographic and phonological information as the result of feedback from reading experience. Such models come to map the statistical regularities of the written language that they experience. In the case of the DRC model, statistical regularities between graphemes and phonemes are then stored as a separate rule system for use in the sublexical route. The results of the present experiments fit models such as these readily as they will compute the more consistent consonant pronunciations earlier on and thus may form partial representations of consonants but not vowels. With greater experience of the orthography, letter string patterns evident in vowel and rime clue words will be represented. No advantage for rimes would be predicted under these conditions as, unlike Goswami's rime analogy model, the model contains no a priori assumptions about the activation of rime units in early reading.

In connectionist accounts, inference or 'analogy' effects are a by-product of the architecture of the system, reflecting the central tenet of such models that overlapping orthographic strings sharing pronunciations come to be represented by a common pattern of association between input and output representations, even if these representations are not themselves words. Associative learning networks can therefore account for the inferences evident when exemplars of orthographic and phonological associations were taught by learning several clue words (experiments 3, 4 and 5) and no improvements when only one clue word was taught (the no prompt condition of experiment 1). Connectionist models implement associative learning mechanisms in which the association between particular orthographic and phonological information is strengthened by exposure to exemplars of words which conform to the same letter-sound patterns. Inferences after repeated exposure to clue words are thus readily explained. Such models do not, however, readily cope with one trial learning, (Plunkett, Karmiloff-Smith, Bates, Elman, & Johnson, 1997), and possibly would not be able to infer letter-sound relationships on the basis of exposure to one word.

It is important to note that the present findings should not necessarily be taken as evidence against the idea that children might ultimately take advantage of rime units. The important point is that the present results are consistent with models of reading development in which the use of rime inferences emerges only after children have had some significant exposure to the orthography (Duncan, Seymour, & Hill, 1997; Frith, 1985; Muter et al, 1994). Such a position is also consistent with the findings of rime neighbourhood studies (e.g. Bowey & Hansen, 1994; Bowey & Underwood, 1996), which suggest that rime use emerges as a result of reading experience.

Limitations of present research

The present experiments have provided some clear evidence concerning the role of orthographic inferences in early reading development. There are nevertheless some

important limitations to the present work which should be addressed in any discussion of findings. These are considered below.

The experimental paradigm

The first limitation to drawing conclusions from the present results concerns the nature of the revised learning task used in experiments 3, 4, and 5. While more ecologically valid, the present methodology shares with its predecessor the necessity for children to learn many words which share letter strings over a very short time scale. It has proven impossible to entirely rule out the strategic use of rimes and vowel digraphs in this paradigm, despite strenuous attempts to limit their effects by avoiding concurrent verbal cues or segmentation training, and by separating clue word learning from posttests with an intervening task.

One way in which this problem may appear in both the original clue word task and the present revised task is in the misreading of control words at posttest which while sharing no orthographic relationship with clue words were read as if they were analogous. Such overextension errors, while substantially smaller than improvements in analogous target words, were nevertheless evident in the present studies. Improvements in the reading of target words cannot therefore be seen as entirely pure measures of children's awareness of orthographic commonalities shared between clue and target words. Possibly progress may be made in overcoming this problem if approaches were implemented that tested children's ability to use inference over even greater and more educationally relevant time scales.

The causal role of inference use

A second kind of limitation of the present results concerns uncertainty over the developmental significance of the use of orthographic inferences by young children. The results here demonstrate that children can make spontaneous orthographic inferences. In principle such a skill could be a powerful tool in developing a mental

lexicon. It is nevertheless unclear whether the use of orthographic inferences is an integral part of the process of reading acquisition. In particular it is not clear whether the use of inferences plays a causal role in reading development, or whether it simply represents an epiphenomenon of reading acquisition, in which the use of inferences may, as Bruck and Treiman, (1992), suggest be a 'natural but infelicitious strategy'. The causal link between inference use and reading ability has yet to be established. As was argued in chapter 1, the development of causal models of reading acquisition must remain a central aim of developmental research.

There is clearly a need for longitudinal studies looking at the predictive validity of measures of spontaneous inference use to establish whether inferences play a causal role in reading acquisition. The key question for these studies to address will be whether children who make inferences in the clue word task go on to become good readers even when powerful predictors of future performance such as current reading level are held constant. Longitudinal studies of the sort recently carried out by Muter et al, (1997) which trace the causal paths between different classes of phonological skills and reading could also be meaningfully expanded to consider the inter-relationship between inference use, reading ability and phonological skills, as well as looking at the role of partial representations of words preserving boundary consonants. Studies of this sort may start to shed light on how or if children's phonological and inferential skills exert a causal influence upon reading acquisition.

The mechanism by which inference use aids reading

A further related question is how inference use might work to develop later reading. Inference use might be an example of a skill where modest variations early on in reading acquisition have increasing importance later on in reading. Such 'Matthew effects' (Stanovich, 1986), may work by allowing children to profit from early exposure to the orthography which might lead to the establishment of an increasing large base of words. This knowledge could in turn then serve as a more complex base

from which to make a wider range of inferences in the future. For example, children who are able to gain from the exposure to words exemplifying '-ide' rules such as 'wide' and 'side' and from words such as '-ite' e.g. 'site' and 'bite' can generate the higher order rule '- i*e' which can then be generalised to a range of other orthographic strings such as 'wife' and 'life' (Goswami & Bryant, 1990). Further work is required however to establish whether this is indeed the case.

The significance of paralexias

Another kind of question concerns the role of partial representations of the orthography in reading acquisition. Here the role of errors preserving consonants but not vowel digraphs appeared to be important both in reading and in inference use. It would nevertheless be wrong to give the impression that such partial representations are static: there may be considerable variation in responses to the same word by the same child at different times. Evidence to support this comes from a further unreported study of inference use in twenty four 6 year old average readers. Responses to monosyllabic words which preserved boundary consonants, but not medial vowel digraphs were noted. When the same words were re-presented to children less than a week later the majority of words, while still misread, were assigned pronunciations that did not preserve boundary consonants. Deductions about the role of partial representations need to be weighed against the observation that there is considerable inconsistency in children's early reading responses.

Suggestions for further studies

As well as considering the implications of the observations above, future research could also usefully address a number of other important empirical questions concerning inference use.

Spelling

One important question is whether children can make spontaneous inferences in spelling development. It has often been assumed that grapheme-phoneme knowledge is crucial to spelling development (Ellis, 1984; Frith, 1985). Goswami (1988a) may have demonstrated that children make significant improvements in spelling rime analogous target words after the presentation of a clue word. As in the majority of her studies of reading by analogy, she used the version of task in which concurrent clue word prompts were provided. Whether children make spelling inferences in the absence of concurrent prompts remains unclear. Spelling then is an obvious area for applying the current spontaneous inference methodology.

Deavers and Brown (1997) have recently provided evidence from a cross-task comparison of rime analogy and phoneme to grapheme rule use, indicating that task context has a significant impact on the size of orthographic unit employed in spelling. They compared nonword spelling for irregular consistent and regular consistent nonwords in three conditions. The same nonword stimuli were used in each condition. The first condition was an unprompted condition in which knowledge of two real word analogues was assessed in a prior stage. In the second condition, a contiguous rime analogous clue word was provided for each nonword. The third condition was identical to that used by Goswami (1988a) in her study of spelling as a concurrent clue word prompt was provided but target words shared either common rime units, common heads or were controls.

The comparison of spelling performance by 22 children matched for chronological and spelling ages across all three tasks was of particular interest. A comparison of irregular consistent word spelling revealed significant differences in the use of analogies across tasks. Only 18% of the responses were irregular in the unprompted condition compared to 50% which were regular. In the prompted conditions the proportion of irregular responses rose to 82% and 51% (conditions 2

and 3 respectively) and the regular responses represented only 6% and 20% of the total respectively. These results suggest that the use of rime analogies in spelling is strongly dependent upon the presence of a concurrent clue word prompt. These results therefore indicate a very similar pattern of inference use in spelling to that demonstrated for reading in this thesis. The extension of the analogy task developed in this thesis for reading to measure inference use in spelling may provide another means to assess the size of the orthographic unit used in spelling.

Developmental dyslexia

A further direction for future work is to establish the significance of inferences in developmental dyslexia. If inference use is central to reading development then dyslexics may show specific deficits in this area of cognitive functioning. There is as yet very little clear experimental work on the use of inferences by dyslexic children. Lovett, Warren-Chaplin, Ransby and Borden (1990) taught children clue words such as 'cart' and then later showed them analogous words such as 'part'. Children showed no improvements in reading target words, leading Lovett et al, (1990) to conclude that dyslexics do not use orthographic inferences. However, as the present work has demonstrated, even young normal readers do not show inference use under these sorts of testing conditions, so the study does not conclusively show that dyslexic children have a deficit in inference use.

A study in Liverpool by Hanley, Reynolds and Thornton (1997) explicitly compared poor and normal readers on inference tasks, including one of spontaneous inference use. Their results appeared to show that dyslexics have deficits in their use of inferences. However the study of spontaneous inference use was based upon Muter's methodology in which there is exposure to only one clue word. Furthermore the study did not contrast rime and other forms of inference use specifically, so the conclusions the researchers drew about a deficit in rime inferences may be unfounded. Further work is clearly needed to clarify this issue.

The questions raised in this discussion chapter therefore suggest that there are a number of unresolved issues still to be addressed in assessing the significance of orthographic inferences in reading and spelling development. There is also a clear need for further experimental and longitudinal research. Research is also required into comparisons between normal readers and those who do not acquire orthographic knowledge at the normal rate. Although important questions remain to be resolved, the present thesis has both helped to clarify which questions now require further attention, and developed an improved methodology with which to investigate them. Work on the role of orthographic inferences in reading development seems set to remain a fertile one for researchers. The present studies represent a contribution to this ongoing development.

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Appendix 1. Stimuli used in phonological awareness tasks

1. Bradley first sound oddity

rot	rod	rock	box
lick	lid	miss	lip

bud	bun	bus	rug
pip	pin	hill	pig
ham	tap	had	hat
peg	pen	well	pet
kid	kick	kiss	fill
lot	mop	lock	log
leap	mean	meal	meat
crack	crab	crag	trap
slim	flip	slick	slip
roof	room	food	root
pan	tap	tag	tab
dug	duck	dull	gun

2. Bradley middle sound oddity

mop	hop	tap	lop
pat	fit	bat	cat

lot	cot	pot	hat
fun	pin	bun	gun
hug	dig	pig	wig
red	fed	lid	bed
wag	rag	bag	leg
fell	doll	bell	well
man	bin	pin	tin
fog	dog	mug	log
feed	need	wood	seed
fish	dish	wish	mash
sit	pat	bit	nit
bad	pad	lid	mad

3. Bradley last sound oddity

fan	cat	hat	mat
leg	peg	hen	beg

pin	win	sit	fin
doll	hop	top	pop
bun	hut	gun	sun
map	cap	gap	pal
men	red	bed	fed
wig	fig	pin	dig
weed	peel	need	deed
pack	lack	sad	back
sand	hand	land	bank
sink	mint	pink	wink
but	nut	cup	hut
sip	lit	rip	dip

4. Phoneme segmentation

bat	peg	cup
rod	fit	

bud
hop
dig
hat
fed
rag
sip
fog
pit
gun
wet
ban
pod
cut
pin
leg

