Explaining developmental dyslexia : Orthographic processing difficulties

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The present paper reviews an on-going series of studies researching the representation of word knowledge by dyslexic readers. The studies examine the orthographic knowledge that dyslexic readers construct about words and teaching strategies for helping them to improve this knowledge.

Fluent readers process text at a number of levels; at the word, the sentence, the conceptual and the topic levels (Munro & Munro, 1991, 1994). The outputs from each process are retained for varying durations in short-term working memory. Depending in part on their purposes for reading at any time, readers perceive the outputs of some levels to be more useful than those at other levels. As they read, they move between the various levels in ways that would be difficult to map in a general sense They may, for example, begin by processing a few words in a text to gain an initial impression of its likely topic, making use of their existing knowledge. They may then return to modify this initial topic level impression after working at the word and sentence levels. Sentence level processing can facilitate word level processing by assisting readers to anticipate words within a sentence, thus contributing to word level processes within the sentence.

The representation of the text constructed by the reader at any time is determined in part by the efficiency of the processing at each level. One aspect of this efficiency is the extent to which the processing make demands on attention. The more any one of these processes uses up the limited attentional resources available to the reader, the less attention there is available for processing at the other levels and for building a continually-updated integrated model of the text. This use of attention has implications for understanding reading disabilities.

Those who have difficulty reading display processing difficulties at one or more of these levels. In particular, they may need to invest an excessive amount attention at one level. Some readers have difficulty recognizing automatically most of the words in a text. They may invest most of their attention in sounding out the words in order to decide what they are and have little attention left for processing at the sentence, conceptual or topic levels. Other readers may recognize most of the words in the text relatively automatically but

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[1] Munro, J. (1995c). Explaining developmental dyslexia: Orthographic processing difficulties. *Australian Journal of Remedial Education*, 27,1, 5-15.

have difficulty integrating the meanings of groups of words at the sentence level. They may need to invest excessive attention in using their knowledge of grammar and sentence structure to integrate the word meanings. Their difficulty at the sentence level will impact on their text comprehension. Still others may not use their knowledge of the topic automatically as they read and they not relate ideas in a meaningful network. Each sentence is read in isolation of the others and the readers don't use their knowledge of the topic to predict likely ideas and events.

In my work over the last decade I have examined aspects of processing at each of these levels and what we can do as teachers to facilitate processing at each level by reading disabled students. Processing at the sentence, conceptual and topic levels has been discussed in Munro and Munro (1992) . Teaching and diagnostic implications and strategies are detailed in Munro (1991a). The present article reviews our recent research with dyslexic readers at the word level.

There has been a tendency over the past two decades to move away from the study of word level processes in literacy education and yet, for those who find reading difficult, these can be critical. Many of these readers can operate effectively in oral language contexts. They have great difficulty, however, in drawing on this knowledge when they read. A major cause of reading disability is poor word recognition (Jorm, Share, MacLean & Matthews, 1984). Word recognition difficulties are in turn attributed to these readers having comparatively impoverished orthographic knowledge about written words (Adams, 1990; Szeszulski & Manis, 1987). It is critical then, if we are to understand more about reading disabilities and to assist those who find reading difficult, that we examine word level processes.

Dyslexic readers have less orthographic knowledge of words

The word recognition difficulties of developmental dyslexic[2] readers in particular and others who display reading disabilities have been in turn attributed to a comparatively impoverished orthographic knowledge about written words (Adams, 1990; Szeszulski &

[2]The term 'developmental dyslexic' rather than more diffuse terms such as 'reading underachiever' is used in the present paper because the readers involved in the investigations displayed behaviours consistent with commonly accepted criteria for developmental dyslexia; they read at a grade level at least 1.5 years below their expected level, lay within an average general reasoning span and the nature of their reading disability was not attributable to sensory, environmental, cultural, emotional or socio-economic causes. In particular it should be noted that their verbal and nonverbal reasoning was not impaired.

Manis, 1987). The purpose of the present set of studies is to examine further various aspects of the orthographic learning of these readers.

How skilled readers read words In order to understand the nature of these orthographic difficulties, it is useful to examine first how skilled readers process words. Word recognition models propose that skilled readers represent the orthographic properties of written words at several levels of complexity; individual letters, letter clusters, morphemes, word stems and words (Adams, 1990; Taft ,1991). This knowledge allows them to recognize whole words efficiently and to segment unfamiliar strings of letters into familiar letter clusters. Readers who have represented graphic information largely at the single letter level may be expected to to be less efficient in word recognition that those who can recognize multi-letter clusters.

The orthographic units are linked with corresponding phonological units for meeting sound-based demands of reading (representations of phonemes and sound groups). Readers may convert groups of letters to sound patterns in order either to identify the words (this is called pre-lexical phonological recoding) or subsequent to word recognition, in order to say the word (this is called post-lexical phonological recoding). Both sets of units are linked with a 'word meaning bank, referred to as a set of "meaning processors" (Adams, 1990) or as a "master lexicon" (Taft, 1991). Readers access the meanings of written words either by using their orthographic knowledge directly and retrieving the linked semantic information or by converting the orthographic information to a sound-based code first. Relatively little is known about the developmental acquisition of orthographic knowledge by readers generally (Adams, 1990). What research there is supports the following order; an awareness of (1) the 3-letter consonant-vowel-consonant form, (2) initial consonant blends and final vowel-consonant blends and the relevance of the vowel for letter string segmentation, (3) syllables and (4) longer word forms.

Our research has focussed on the reading of words at the first two levels of Adams' (1990) developmental acquisition sequence; those words having either the 3-letter consonant-vowel-consonant form (for example, cat, hit) or single syllable words with consonant and vowel blends (for example, cart, ship). For these words, the present investigations have assumed that, in terms of processing complexity, the orthographic structure varies on two dimensions; the number of letters in the word and the nature of the orthographic - phonemic mapping, varying from one in which each letter maps into a phoneme, to one in which a group of letters, such as consonant cluster, a vowel-consonant or vowel-vowel cluster, maps into a phoneme. An additional influence on the learning of orthographic representations was the consistency of the orthographic -

phonological match; whether the letter cluster consistently maps into one sound pattern (in regular words) or displays an inconsistent mapping, mapping into two or more sound patterns (as in irregular words). Within each category, words are grouped on the basis of shared rime.

Our research : the guiding questions Earlier analyses of the word recognition performance of dyslexic readers suggests that they recognize individual letters in words rather than multi-letter units such as letter clusters or whole words. As a result, they attempt to read words either by converting individual letters to sounds letter by letter in a systematic way (this is consistent with the 'Chinese' word reading pattern reported by Freebody and Byrne (1989) for beginning readers and the 'surface dyslexic' reading pattern reported by Castles & Coltheart (1993) or by using some of the letters in a non systematic way (for example they use the first and last letters of words to identify them); this is consistent with the 'Phonecian' word reading pattern reported by Freebody and Byrne (1989) for beginning readers and the 'phonological dyslexic' pattern reported by Castles and Coltheart. These behaviours suggest that dyslexic readers haven't built up knowledge of more complex letter patterns.

We have been interested in examining two related questions:

(1) How is orthographic knowledge represented by dyslexic readers ? How are their representations of written words similar to and different from those of more able readers ? Do their representations, for example, contain less information ?

(2) How is orthographic knowledge changed or increased most effectively ? Here we need to distinguish between temporary change in a reader's knowledge base and more permanent storage and use of orthographic knowledge. Which, of the various types of teaching strategy works most effectively for any particular level of word knowledge ? Do different orthographic / phonological profiles of word knowledge respond better to some forms of teaching rather than others ?

Procedures for examining orthographic knowledge. Children display their orthographic knowledge in how they read and spell words. The focus of the present series of studies was on the use of orthographic knowledge when reading. Using patterns in how readers vocalize written words to infer orthographic knowledge for words is supported by Adams (1990). In our research we examined how readers read words

presented one at a time[3]. The words used were single syllable words that varied orthographically in two ways; in the number of letters in the word (from 3 to 6 letters) and in the orthographic - phonemic complexity, varying from those in which each letter mapped into a sound (for example, dog, strip), to those in which two letters mapped into a sound, for example, a consonant cluster (thin, trash) , a vowel-consonant cluster (turn, bowl, car) or vowel-vowel cluster (train, pale).

Each reader's response, the time taken for correct reading (whether the word was read rapidly or slowly) and behavioural indicators of the strategy used (for example, whether the reader said part of the word first, for example, for strip, said "st", "str" and then "strip") or used letter by letter sounding were recorded. Readers were assumed to have learnt a particular orthographic unit when they could recognize it rapidly in all of the test words in which it appeared. This criterion is supported by Adams (1990). In this way we distinguished between those words that could be read automatically, those that demanded attention to be read and those that needed to be converted to sounds to be read. As well, for words that were read incorrectly, the nature of the error was noted, for example, whether the response (1) involved juxtaposing, deleting from or adding letters to the target word , (2) was a word known by the reader and shared letters with the target word, (3) was made after the reader vocalised part of the stimulus correctly or (4) was a word read accurately by the reader but has no orthographic similarity to the target word. From these responses the types of words that each dyslexic reader had represented orthographically were identified and patterns in reading responses were used to compile an orthographic knowledge profile. The procedures used for making sense of the errors and for developing the profile are described more fully in Munro (1994).

This analysis showed that the dyslexic readers had a much lower level of orthographic knowledge than their peers. Their word reading suggest that they represented the written forms of most words at the single letter or two-letter cluster levels. This was shown in several ways;

(1) for a particular regular letter group such as 'and' they could read shorter words such as 'and' and 'hand' more rapidly and accurately than longer words such as 'brand' or 'strand', even when we controlled for word frequency. The criterion

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[3] Studying the orthographic knowledge of readers should not be interpreted as a lack of interest in comprehension-based processes. Studying individual word recognition allows the examination of orthographic knowledge in the absence of semantically-based contextual processes. This in turn permits consideration of the extent of automatized orthographic processing.

for having the orthographic representation of a type of words was being able to read the words correctly and rapidly. More generally, the word reading performance for the dyslexic readers was much more sensitive to variation in the two dimensions of orthographic structure noted earlier. In terms of orthographic - phonemic mapping, ease of reading ranged from the 1:1 letter - phoneme mapping, through the consonant cluster and vowel-vowel cluster mappings to the vowel-consonant mapping. For each type of mapping the number of letters in the word (ranging from 3 to 6 letters) influenced word reading accuracy. Matched able readers displayed less sensitivity in variation in letter length and in mapping.

(2) they were more likely to use single letters in words to identify them, either by sequential letter by letter sounding or by selecting individual letters nonsystematically.

(3) analysis of their errors suggested that they were focusing on individual letters rather than on letter groups; for example, a dyslexic reader may be able to read 'farm' correctly but read 'cart' as 'crat' and 'part' as 'prat'. Learning to recognize multi-letter units such as letter clusters, (for example, 'spl') or digraphs (for example, 'ar') in written words allows readers to 'hold' individual letters in place. A reader might be said to have learnt the 'ar' unit when the reader expects that 'a' has a reasonable chance to be followed by 'r' in a word. Readers who haven't developed representations of units such as 'ar' or 'spl' are more likely to see each letter as separate from the others in a word and are more likely to reverse letters, omit or insert them. They were more likely, for example, to read 'cart' as "crat" or 'perm' as "prem". The dyslexic readers were more likely than their able-reading peers to make these types of errors and these errors became more likely as the letter length of words increased. They also had much greater difficulty recognizing frequently occurring letter groups such as 'ar' in words and seeing smaller words within longer words.

How can we explain these orthographic processing difficulties ?

Why do some children have greater difficulty building orthographic knowledge ? To examine these questions we need to look at how this knowledge is usually acquired. To build orthographic knowledge readers need to link letter and individual sound knowledge in a systematic way (Stanovich, 1986; Vellutino & Scanlon, 1987). It should be noted at the outset that it is not individual letter-sound knowledge that these children need, because many of them already know this. While letter-sound or phonic

knowledge is a start, it is insufficient. Rather, it is the developing ability to represent and use automatically increasingly more complex multi-letter clusters. These representations can be in turn mapped onto the prose that readers read in a way that makes minimal demands on attentional resources.

Two processes in orthographic learning Two processes are believed to be involved in orthographic learning; phonemic segmentation (Catts, 1989; Magnusson & Naucler, 1990) and recognizing orthographic patterns between words by analogy (Goswami, 1991). The first process allows readers to make links between individual words that they use in their speech and the groups of letters that they read. To learn a match between the written set of letters 'cat' and a spoken word that the reader knows, the reader needs to segment the spoken form into three separate sounds and link each sound with the corresponding letter, or at least have the capacity to do this. Over time, this allows the reader to 'attach' the written form of the word to its spoken form, that is, to recode the sound-based form orthographically. Segmenting spoken words into parts is a major predictor of later reading ability (Catts, 1989; Magnusson & Naucler, 1990; Vellutino & Scanlon, 1987). Children who can't do this and who don't make these links are compelled to use the word recognition strategies noted earlier; either to convert individual letters to sounds in order to recognize the word or to use one or two letters in a 'distinctive features' manner to decide the word. Using sounding out all the time demands excessive attention. Using one or two letters in a word on the other hand, may be sufficient if there is no other word with a similar written form. However, where there are orthographically similar words, such as 'cart' or 'chat', using one or two letters in a nonsystematic way may not be enough. Readers who use this strategy consistently cannot progress beyond the partial visual representation of words using distinctive features (Freebody & Byrne, 1988; Stuart & Coltheart , 1988) and are more likely to display reading disabilities (Byrne, Freebody & Gates, 1992).

We also need to keep in mind that for many words the link between letters and sounds is more complex that a one-to-one letter-sound mapping. In some words, two or more letters may be linked with one sound, for example, 'car' or 'action', while in others the link between the letter group and sound parts may not be predictable; the mapping may be exceptional, as in 'yacht' or inconsistent as for the 'ost' letter group in 'lost' or 'cost' versus 'host' or 'most' and for the ough letter group in 'through', 'cough', 'ought', 'rough' or 'thorough'. Readers learn to deal with this by building larger and more complex links between letter groups and sounds; the simpler links are not sufficient here.

Children learn these 'multiletter' units by matching the letter group with its sound pattern when they are reading words. They still need to be able to segment spoken words into parts but to do this in more complex ways. They need to handle more difficult, complex sound patterns and letter groups. If they can't use the less complex letter-sound knowledge automatically, they will find building this more complex orthographic knowledge more difficult.

Our research supports that of other investigators in showing that difficulties segmenting spoken words into sounds is a characteristic of some dyslexic readers (Catts, 1989; Vellutino & Scanlon, 1987). The types of sound segmentation patterns that these readers frequently show, their diagnosis and recommended teaching strategies are described in Munro (1991, 1994). Our research added to earlier knowledge by showing that the ability to demonstrate skills associated with phonemic awareness, for example, segmentation, phonemic awareness or deletion, is a function of the sound length of the word for these readers.

It should be noted, however, not all dyslexic readers show phonemic awareness difficulties. Other dyslexic readers who show the same word reading patterns as these readers have adequate sound segmentation abilities; their word reading difficulties are attributed to other sources, more closely linked with orthographic processing.

The second process involves recognizing what is common or shared between two or more written words. Readers learn to use what they know about some words to read unfamiliar words, for example, if they can read 'care' and 'mare', they may be able to use this to read unfamiliar words like 'flare' or 'stare'. Dyslexic readers display difficulties using visual analogy processes (Treiman, Goswami & Bruck, 1990). Whereas normal readers seem to use analogies spontaneously (Peterson & Haines, 1992), dyslexic readers are less likely to use what they know about some words to recognize others, particularly through analogy processes (Lovett, Ransley, Hardwick, Johns & Donaldson, 1990; Treiman, et al., 1990). In one investigation we examined how well these readers could use what they knew about one word to read other words that had the same 'word body' or 'rime'. One child, for example, could read 'train' and 'main' rapidly and accurately but not 'rain' or 'stain' and we monitored the number of trials[4] it took him to transfer his knowledge. It took this child nine trials. Some of the

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[4] Each trial involved the child seeing both the written known word ('train') and the written unfamiliar words ('main', 'rain' and 'stain'), each written in a separate card, saying the known word and then being asked to say the unfamiliar words. Trials were repeated with these words until the child could read the four words correctly when the four word cards were mixed with four words already known by the reader. The number of trials it took for him to achieve 100 % was counted.

dyslexic readers needed up to 16 trials to learn to recognize the letter cluster correctly, particularly when the words containing it were mixed with other words that they knew.

The question of whether readers need a level of sequential phonemic decoding in order to use orthographic analogy is currently debated (Ehri & Robbins, 1992; Goswami, 1991). Our research with dyslexic readers (Munro, 1994) suggests that there is a link. In order to use 'train' and 'main' to read 'rain ' or 'stain' the readers needed to be able to recognise the shared sound group in 'train', 'main', 'rain ' and 'stain'; they need to be able to obtain or isolate the shared sounds from the words. They also need to be aware that there is a link between the letter clusters and sounds. Readers who can't analyse what they know in these ways are less likely to make orthographic links between words and are less able to recognize groups of letters efficiently in words. Difficulties making analogies between words can be attributed to difficulties segmenting phonological representations of known words. Orthographic change seems to require a particular level of phonemic knowledge.

It would seem, then, that some readers, either through inate or learnt abilities, can make the links between written and spoken words in such a way that they represent the orthography comparatively easily and become fluent readers. Others do not make these links. Approaches to literacy education that have not targeted either the acquisition of phonemic knowledge or the gradual transfer of orthographic patterns have helped some children to develop as readers; those who have already had in place the necessary capacities for making orthographic-phonological links. Other potential readers have been inadvertently disadvantaged. They have not come to the literacy learning situation with the specific capacities for doing this, although they have frequently had high levels of verbal-linguistic knowledge in other areas.

Helping dyslexic readers improve their orthographic knowledge.

So far we have drawn attention to the importance of orthographic learning for effective reading, the difficulties that dyslexic readers have in building this and possible reasons for this difficulty. It is now useful to ask how we can help these readers to improve their orthographic knowledge. What should be the features of a teaching programme ?

Any teaching programme needs to take account of what learners already know and how they go about learning. Readers make the links between sound and letter data in different ways (Stuart & Coltheart , 1988). In order to use teaching resources most efficiently and to minimize student frustration, it is important that any teaching programme takes account of what has already been shown to work. Interestingly, earlier teaching

programmes focussing on how dyslexic readers can be taught these links has attracted little research. Studies have trained abilities in two areas; (1) phonemic and letter sound knowledge and (2) visual word patterns. Phonemic awareness training, when combined with letter-sound knowledge training has been shown improve word reading ability (for example, see Ball & Blachman, 1991). These studies have not, however, reported the specific influence of this training on individual reader's orthographic knowledge. They have not shown, for example, which aspects of the teaching at any time were associated with orthographic change. Further, they have not shown whether change in phonemic segmentation ability or an increased comprehension of phonemic identity is more likely to be associated with change in orthographic knowledge (as suggested by Byrne and Fielding-Barnsley (1990).

The question of whether either letter-sound or whole word teaching procedures help dyslexic readers more was examined by Lovett, Warren-Chaplin, Ransley and Borden (1990). Both procedures were linked with an improvement in word recognition accuracy and spelling, with neither emerging as superior for words taught directly. The whole-word format led to better transfer. The results of this study are limited, however, in their usefulness for looking at orthographic learning, for several reasons.

First, neither teaching procedure directed readers' attention to multiletter subword units. One condition taught letter by letter sounding and the other taught whole word processing. This is surprising, given the current debate on the use of multiletter knowledge in reading, the use of onset and rime by able readers for analogies (Ehri & Robbins, 1992; Goswami, 1991; Peterson & Haines, 1992) and the finding that dyslexic readers are less able to use what they know about some words to recognize others (Szeszulski & Manis, 1987). Our research compared the three teaching conditions and showed that teaching dyslexic readers to segment regular single syllable words into onset and rime (for example, the word 'stamp' into 'st' and 'amp' , the word 'bend' into 'b' and 'end' and the word 'clip' into 'cl' and 'ip') facilitated orthographic learning most. One aspect of our teaching procedure involved encouraging the reader to visualize each letter sequence (such as 'st' or 'amp') while saying it to themselves as a sound pattern. This facilitated both initial learning and transfer.

Second, Lovett, et al.'s (1990) study examined changes in the word knowledge of groups of students rather than changes in individual reader's orthographic knowledge. Pooling the reading scores for different children could mask the teaching condition that worked best for individual readers, obscuring individual trends similar to those noted by Freebody and Byrne (1988) or Stuart and Coltheart (1988).. It did not take account of individual readers' existing orthographic knowledge when commencing teaching at any

time. Nor did it link the teaching with changes in orthographic knowledge. Our research has focused on individual learner progress with teaching.

Third, Lovett, et al.'s (1990) study did not examine the relationship between a reader's level of phonemic knowledge and the ability to benefit from each form of teaching. As shown earlier, we have observed that a level of phonemic awareness knowledge is necessary for making orthographic analogies between written words. Dyslexic students who have a higher level of phonemic awareness knowledge are more able to benefit from orthographic analogy teaching.

Our investigations have investigated the issue of what is the most effective teaching procedure for changing a dyslexic reader's orthographic knowledge base at any point in time. Should the teacher be teaching phonemic awareness knowledge, letter cluster - sound knowledge or the use of orthographic analogy through word families ? The investigations have also recognized the need to distinguish between learning orthographic knowledge, encoding this knowledge in long term memory and transferring the knowledge to new situations.

Four major findings have emerged and these are summarized here. One is that dyslexic readers who have a higher level of phonemic awareness knowledge , that is, who can segment spoken spoken words into individual sounds more automatically are more able to make orthographic analogies between words. They are more able to recognize what is shared by members of a word family (for example, part, farm, car) and use this knowledge to read unfamiliar words. They can also learn to use a single prototype word (for example, come), to read other words (for example, none). The question then arises as to why they have not made these analogies spontaneously in their past and needed teaching for them to learn that they could do this. In summary, being taught to make analogies between words is not equally effective for all dyslexic readers; it is more useful for those children whose phonemic knowledge is better developed.

A second finding is that after initial letter-sound mastery, teaching dyslexic readers to link letter clusters rather than individual letters with their sounds is associated both with greater gain in orthographic knowledge for targeted words and with greater transfer to unfamiliar words than teaching at either the single letter or whole word levels. In other words, teaching children to read 'tram' by linking 'am' with a sound pattern first and then blending it with 'tr' is more likely to lead to the children recognizing the 'tr' and 'am' units than teaching the sequential letter by letter sounding 't' 'r' 'a' 'm'. A possible reason for this advantage is that teaching sequential letter-sound processing strategies seems to direct readers' attention to individual letters. Our findings show the

these readers can learn to recognize and use larger letter units when their attention is directed to them and when the procedures used for segmenting written words match 'natural' oral language segmenting strategies. Directing student attention to multiletter groups helps the children become aware that they can deal with two or more letters at once. It is important that the size of the letter group the child is required to process at any time take account of the child's information processing capacity.

A third finding has shown that building long-term memory strategies into the word recognition programme improves retrieval and transfer and use of word knowledge. This finding is consistent with the notion that dyslexic readers are more likely to display a spontaneous preference for using nonverbal representational codes for retaining verbal information. When letter-sound knowledge is taught embedded in visual imagery codes initially, for example, through letter pictographs or in a kinaesthetic code and then recoded verbally, their ability to transfer verbal information improves.

A fourth finding is that having students reflect on how they learn written properties of words and on what they know about words helps them to manage and direct their attention when reading unfamiliar words. Encouraging them to discuss the realization that in some words not every letter maps into a specific sound. This helps them to form the explicit concept of a digraph. Discussing their discovery that in some words 'ar' maps into one sound (as in car) and into another sound (as in care) predisposes them to looking for similar patterns in in other words. Having them describe how they went about reading an unfamiliar word such as 'traction' by noting how it was like a familiar word (tractor) helps them to generalize the strategy to other words. A focus on 'metareading' knowledge, (or , to be more precise, 'meta-orthographic knowledge') assists dyslexic readers to improve their word processing efficiency.

These findings have direct implications for how we assist dyslexic readers. They impact both on the diagnosis and teaching approaches that we implement.

Implications of this research for assisting dyslexic readers.

The research described in this article is seen as having several implications for teaching dyslexic readers. First, it adds to our understanding of why some readers find reading difficult. Teachers need to be informed about the nature of dyslexia. If we as teachers can be more informed, we are less likely to be perplexed by what often seems to us haphazard, incomprehensible behaviours. If we can understand why a child may be able to read or spell the word 'train' automatically but not 'main' or 'stain', because the child

used distinctive features, we can implement teaching that targets directly the child's needs.

Earlier studies of the orthographic knowledge of normal and dyslexic readers have been from the perspective of 'one-off snap-shots' of the reader's knowledge of words, using lexical decision, word naming or spelling tasks. One of our aims is to monitor the comparative effectiveness of different types of teaching on dyslexic readers' orthographic knowledge so that we could see what had the biggest impact in changing this knowledge.

We are more able to assess and diagnose the child's reading and identify the most effective teaching implications .

Using word reading patterns to diagnose orthographic reading difficulties
The present investigations assume that a reader's orthographic knowledge will be reflected both in the words read correctly and in the errors made. The diagnostician can note patterns in the time taken to read words correctly; the time taken provides a measure of the relative automaticity of word reading. Those that can be read rapidly (in less than about 1 second) are the words the child may be reading orthographically. Those that are read correctly but more slowly may be demanding attentional resources for processing the orthographic information. Some words will need to be part-vocalized prior to accurate reading. Behavioural indications of the strategy used to read the word can be used to infer the partial orthographic knowledge learnt by the child; the reader may vocalizes part of the written form before saying it, (for example, the beginning letter cluster, or use letter-by-letter recoding strategies.

Error patterns in word reading also have implications for diagnosis and for teaching. Teachers frequently experience the word reading errors that these students make. Usually, however, these are ignored; it is believed that these errors indicate nothing about the child's orthographic knowledge. By comparing the way in which a child reads a word with the word itself a diagnostician can obtain an insight into what the child knows about the written word. The incorrect response may suggest (1) individual letter processing (for example, juxtaposing letters), (2) difficulty dealing with all of the orthographic information provided (for example, deleting letters from the written word, saying a word read accurately by the reader and that shares letters with the written word (3) difficulties dealing with all of the orthographic information without intermediate vocalization (for example, saying a word incorrectly after vocalizing part of it correctly.

Teaching strategies for building orthographic knowledge The focus of the teaching programme for any dyslexic reader needs to take account of the child's existing

orthographic knowledge, show a valuing of this and lead the child to see how it can be modified. When a sentence is read using the distinctive visual features of words, for example, the child who reads the sentence 'Peter fell off the horse' as "Peter fill up the house", the teacher can first work at the conceptual, topic and sentence levels, assisting the child to use knowledge of context to predict the intended meaning of the sentence. Once the child can read the words correctly, the teacher can the direct attention to the orthographic level to show how the orthographic information maps into words. For 'fell', the child can be told "Yes, this word looks like fill. It starts with 'f' and ends with 'l'." The teacher can momentarily obscure the f and ask the child to say the 'ell' cluster and then add the 'f'. Wherever possible throughout the teaching programme it is recommended that children be shown where they are correct in using the print information and how they can add to what they already know.

The research described earlier suggests that the building of particular orthographic knowledge requires as prerequisites (1) a level of phonemic knowledge (2) less complex orthographic knowledge (3) a sufficiently developed oral language repertoire and vocabulary and (4) a knowledge of how to operate orthographically (that is, 'meta-orthographic ' knowledge). In other words the support programme needs to target the acquisition of

(1) orthographic conceptual knowledge; categories of letter clusters, relationships between them, the characteristics of clusters, the types of clusters that are likely to occur in particular situations,

(2) orthographic procedural knowledge; knowing how to decode orthographic information, both in individual words and for words in the context of other words, knowing how to allocate attention when reading, knowing what to do when the orthography becomes too difficult to process,

(3) links with other areas of knowledge; with phonological and semantic knowledge

(4) positive beliefs and attitudes about one's ability to handle orthography.

It has already been noted that developmental dyslexic readers, by definition, have a sufficiently developed oral language repertoire and vocabulary (otherwise their reading disability would be attributable to severe generalized language disorders). Depending on the dyslexic reader's entry level knowledge, activities may need to be provided in several areas. Knowledge in the various areas will be developed at much the same time, with

the focus first on learning a new idea and then gradually automatizing it. These areas are described in greater detail in Munro (1991, 1994). They include the following.

1 Developing prerequisite phonemic knowledge As noted earlier, our research suggests that readers need a level of proficiency with phonemic awareness in order to construct orthographic knowledge. Phonemic awareness, in turn, is developed gradually, from the reader's implicit phonological knowledge. Types and examples of recommended phonological awareness activities include the following ;

(1) recognizing or producing rhyming words, for example, "Tell me words that rhyme with rat, fat, bat". Students can learn to categorize words according to rhyme or alliteration and in activities in which they see the pictures of four familiar objects, three of whose names shared a phoneme, (for example, a picture of a cat, a rat, a bat and a pig) and then selects the 'odd word out'.

(2) onset-rime segmentation activities, such as segmenting "rat" into "r - at" or "trim" into "tr- im".

(3) breaking off or 'stripping' the first consonant from a word, for example, segmenting "trim" into 't - rim" and deciding whether 'hat' and 'ham' begin with the same sound.

(4) segmenting a word into component sounds or syllables. The purpose here is for the child to segment the word into individual sounds, for example, segment 'clamp' into "c", "l", "a", "m" and "p".

(5) matching sounds in two or more words, (for example, "Do pat and pin start with the same sound ?", "Do pig and got have the same end sound ?" or " What sounds are the same in mat and cat ?") , recognizing a specified sound in a word, (for example, "What sound do you hear in camp but not in cat?").

(6) isolating a sound within a word, for example, "What is the last sound in cat ?"

(7) closing on a word by providing its remaining sounds, or auditory closure, for example, "I'm thinking of something that holds water; gl__ss" or ."What word am I saying; bo //le ?"

(8) modifying a sound sequence by moving sounds around, for example,

(1) deleting sounds from a word, for example, "What would be left if you take /m/ out of camp ?"

(2) recognizing a specified sound in a word, for example, "What sound do you hear in camp but not in cat ?" or

(3) substituting one consonant or vowel for another, for example "Say ' mate' but instead of m say l"

(4) reversing the order of sounds in a word, for example, "Put the sounds in pin in the opposite order t o make a word".

(9) categorizing sound groups , for example, categorizing long versus short sounds.

2 Learning individual letter-sound matches. Children may need to build and to automatize their recognition of some letters. This can be developed using letter pictographs, as long as the children can strip the initial sound from words. Suppose a child has difficulty learning the sound linked with the consonant h. The child is told the sound that goes with the letter and is asked to suggest words that begin with that sound. The child might suggest "hat" and "house". A picture of a hat or house is drawn within the letter either by the child or by the teacher with the child watching and the name of the object is used to cue its initial sound and the sound linked with the letter, for example,

h (a house)

Alternatively, an action that the child can perform may be linked with the letter, for example, the letter k can be linked with the child acting out kicking and the letter t with touching, as shown below;

k t

The orientation here is on individual letter-sound links being linked in turn both with the child's phonemic knowledge and with other, known letter-sound links. Looking for instances of the letter in prose and in signs, using their new knowledge in prose is important. As well, children can be asked to suggest what they might do to store the link in memory and how they might remember it in the future.

3 Working on two or three letters at once; recognizing letter clusters.

The student learns to work on reading letter clusters, beginning if necessary, with three and four letter words that have a 1:1 mapping between letters and sound vowels, for example, dim, ham or pan. The aim is for the student to learn to recognize groups of letters in words and to use them as automatically as possible to identify the words. The sequence of activities for learning any orthographic unit is as follows:

Child segments written word into onset and rime, links each with a sound pattern and blends	Child notes orthographic pattern within a word family, similarities within and between word families	Child uses orthographic pattern by analogy to read unfamiliar words

The letter patterns that a child needs to learn at any time will be indicated in reading assessments. For single syllable words that are reasonably predictable from their orthography, the following procedures are recommended:

(1) Students read the rime part first as a unit. You can begin by exposing only this part and having them say it and then show the first letter as well, for example,

im ------ > dim, an------ > van

For the word 'pen' they would say "en" and then "p-en".

(2) Once an orthographic pattern has been identified, words that have the letter-sound pattern are identified. The child can do this by suggesting other words that rhyme with each word. The teacher may write the first of these words, but gradually the child can predict their spelling and actually write the words, for example

dim	ham	can
rim	cam	fan
Tim	jam	man
him	ram	pan

The students read each word in each family and use it in a sentence that illustrates its meaning. These sentences can be written, words omitted from them and the students select the omitted words. They can suggest a story that contains several

list words that can be written and they read it. Again this can be restructured as a cloze activity.

(3) The students can talk about what they do to read these words, for example, which parts of a word they will look at first.

(4) The students talk about what the words in each family have in common or share both in letters and sounds. The focus here is on students recognizing shared orthographic features and using these to read words. Using one or two words here as prototype words is important here. They can, use a rime such as 'amp', for example, to read and to spell unfamiliar words such as cramp and dampen. They can discuss how they will remember each orthographic rime and onset. They can also practise visualizing each letter group. To form these mental images, they may need to remind themselves to

1. look at the letter group and decide how it matches the way it sounds,
2. close their eyes and try to see it 'in their heads'
3. write it from using the mental picture.

(5) The words can be written separately on cards, mixed up and have them read each, by focussing either on the whole word or the onset and rime parts of each word, not on individual letters. The aim here is for the child to automatize gradually the recognition of the unit, both in isolated words and in prose.

(6) Have them make up their own stories about these words, write these down and then read them.

As they automatize their processing of smaller letter-sound matches, they can gradually build orthographic representations of larger and more complex letter clusters. The attentional demands of the letter-sound matching process are critical to the amount of letter-sound knowledge that can be handled at any time. Within each type of words, the student work on reading each and then put them into categories.

4 Learning long vowels and the more complex letter clusters, for example, vowel digraph and blend patterns**.** Students learn more complex letter cluster - sound matches in much the same procedure as for simpler words. They learn that two letters or more can be associated with one sound and move to an understanding of digraphs, for example, oa, ai, ee and ea. They need to have in place the corresponding sound patterns before they can learn these links. Distinctions such as the

short versus long vowel sound patterns need to be learnt. Onset-rime segmentation is useful here as a first step; a child may first learn to recognize the 'ain' unit and then the 'ai' unit as follows

(1) the child learns to read the words main, pain, stain, etc and is led to generalize the 'ain' pattern as a unit

(2) the child is asked to read containing the 'ai' unit such as 'claim', sail', 'snail' and sees the need to segment the 'ain' unit into 'ai' and 'n'.

(3) the child uses this to read related word families such as

tail	maim	plain
mail	claim	train
trail		sprain

This gradual generalization avoids the teaching of phonic rules without a meaningful learner base. It seems to be even more important in reading words in which two letters map into a sound but are not next to each other, for example, in name or come.

Letter pictographs can be used to help students to build these links, to recognize and remember letter-sound patterns. The sound linked with the 'aw' or the 'oi ' clusters can be learnt by drawing around each letter cluster a characteristic picture of a word containing the sound, for example, for the 'aw' unit a picture of a hand saw and for the 'oi' unit a picture of an oil can;

aw o i

The words 'saw' and 'oi" can become prototypes for recognizing these orthographic clusters in other words. The prototype words can be written on cards and moved into the vicinity of other words (such as prawn, spawn, claw). They can, use a rime such as 'oil', for example, to read and to spell unfamiliar words such as foil and spoil. Students can discuss how they are using the prototype and how it can help them to read words they didn't know. They can work on making a mental picture of the prototype word. They can also discuss how their sound knowledge is growing.

Students need to learn that the same letter pattern can be linked with more than one sound, and the same sound with two or more letter groups. This can again be developed by

having students sort words with the same letter cluster them into categories based on shared sound patterns for example, the following 'ow' words:

frown	throw
town	thrown
clown	mow
trowel	slow
now	

As new sound alternatives for the letter clusters are learnt, students can show these on a chart that matches each letter pattern with prototypical words that are recognized by the student and that contain the sound, for example, :

print	sounds like	
oa	boat	boar
ai	train	fair
ee	feed	
ea	eat	bread

Many of the orthographic units that students need to learn do not appear in writing as separate entities for example, the letter clusters 'tion' or 'ance'.

Students can also draw pictures of their emerging letter-sound discoveries, for example, that the long "a" sound appears in different letter forms

long "a" sound

ay

ai

a-e

With polysyllabic words, as well, difficulties can occur with unstressed or silent sounds, the schwa sound, etc. The student's awareness of these may need to be developed as a prelude to orthographic representation in this case.

5. The need for a study of word structures. For many students a directed study of the structures of written words finishes halfway through their primary education. Further development is left to individual student interest and need. In this

situation students are more likely to add to their orthographic knowledge if they notice and are challenged by unfamiliar and unexpected structures.

Many students need to have access to directed assistance in this area. By themselves, they will not be challenged by unfamiliar orthographic knowledge to the extent that they actively pursue it. They need access to a directed teaching programme that assists then to add to and modify their orthographic knowledge as they move through primary and secondary education. They need to learn, for example, the relationship between orthography and morphology. In late primary and throughout secondary education, where there is an increased emphasis on reading and writing in order to learn, students need to build up a functional body of orthographic knowledge for the subject areas in which they are learning. They do not, for example, want their ability to learn science or geography to be impaired by word reading difficulties. With increased access to computer assisted learning, it should be possible to design individually implemented programmes that can be used to assist students to continue to develop their knowledge of word structures in these areas.

Other recommended word activities include the following: Students

(1) match words with the objects or pictures that they represent, using verbalizing as a bridge in contexts that interest them, for example, words to do with cars and trucks, a hobby or a favourite football team.

(2) produce messages by arranging words from print that they have read. After reading, they select words and write a story, or cut words out of newspapers and make up messages, posters, etc.

(3) match words that look the same or that mean the same in word card games, for example, Memory, Snap, Bingo.

(4) look for words within words, for example, make as many words as possible from the letters of a word, for example, 'carpenter', and build up words from smaller words, for example, carpet, manage. This can be introduced using words made up of two or more cards. They identify the same small word in two or three longer words, by tracing using highlighter or by drawing arcs under groups of letters. After doing this physically for a short while they can learn to do this mentally.

(5) collect words in the environment, for example, words in the street (Coca cola, milk bar signs, etc.), words in the kitchen or garage. Encourage them to anticipate words that might be expected in a situation, for example, the words on a notice at a railway station, the words in the for sale, weather forecasting or business sections of a newspaper and then check the predictions.

(6) build larger words from smaller words, for example, beginning with "an" and building words like 'pan', 'pant', or from letter clusters, for example, beginning with "oo" and building words like 'moon', 'loop', 'sloop'. This could be done initially using word parts and letters on cards.

(7) predict unfamiliar words by using context and partial graphophonic information (for example, the first few letters of the word) and then checking the guess by looking through the print to see if they can locate their suggested words. Students needs to learn gradually how to do this as letter- sound knowledge is automatized.

Conclusion

The study of word recognition processes and their relevance to the reading process, particularly for those who display specific reading disabilities has over the last three decades, been de-emphasised in literacy education circles. At the same time, however, the analysis of these processes from a cognitive -pyschological perspective have continued, and provide the contemporary special educator with a much broader and useful understanding of reading disabilities and strategies for teaching. As this review shows, contemporary approaches to word recognition differ markedly from the practices characterized this area in earlier decades.

Contemporary approaches locate word recognition processes and the knowledge base that allows them to operate effectively, that is, the reader's orthographic knowledge, within a broader model of reading. It is unrealistic to talk about word recognition and comprehension abilities as if they were separate, rather than inextricably linked and interacting processes such that the output of one influences directly output from the other.

It is obvious that the area of orthographic knowledge, both from the perspective of reading development generally and from the perspective of reading disabilities, will expand tremendously over the next few decades. The solution of current problems that face researchers in this area, such as mapping and monitoring orthographic growth on an individual basis, may be expected to contribute to our understanding of the reading lexicon and the ways in which its growth can be facilitated.

Reference notes

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Teachers and schools wishing to obtain copies of these can order them from EdAssist, PO Box 641 Hawthorn, Vic., 3122.

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