How to beat dyslexia

USHA GOSWAMI *gave this year's Broadbent Lecture at the Annual Conference, suggesting that the rhyme and rhythm of different languages holds the key to dyslexia.*

WHY do some children learn to read well, while others of similar intellectual ability struggle to become proficient? And why is a Finnish child reading with 90 per cent accuracy by the 10th week of schooling, while an English child is not?

Although reading and its development were never part of Donald Broadbent's wide and varied research interests, he liked research topics that were grounded in real-world problems. I hope to illustrate in this article that reading acquisition by children is a real-world problem that can be addressed by the rigorous psychological methods championed by Donald. I will argue that part of the answer to disparities in reading acquisition lies in the difficulty of the learning problem itself. Reading is a cultural activity, and reading does not develop without direct tuition. Successful learning depends on at least two key factors: possessing the precursor skills needed to benefit from this tuition, and the nature of the orthography being learnt.

The learning problem in reading

English is a very difficult language to learn to read. In fact, research suggests that English is the outlier among the world's languages in terms of learning difficulty. Children across Europe begin learning to read at a variety of ages, with children in England being taught relatively early (from age four) and children in Scandinavian countries being taught relatively late (at around age seven). Despite their early start, English-speaking children find the going tough. Cross-language comparisons of simple word reading (e.g. *boy*, *tree*, *boat*) and nonword reading (letter strings that lack meaning but which are decodable, such as *eb*, *dem*, *fip*) during the first year of schooling (Seymour *et al*., 2003) show that children learning to read Finnish, German, Spanish, Italian and Greek reach accuracy levels of 90 per cent or higher in both word and nonword reading very quickly indeed. Children learning to read Portuguese and Danish are less proficient, scoring at around 70 per cent accuracy for simple words and nonwords. But children learning to read English score at around 40 per cent accuracy, even when reading familiar and simple real words. After an extra year of tuition, English children scored at around the 70 per cent accuracy level. It usually takes three to four years of tuition in reading for the average English child to read nonwords with 90 per cent accuracy (Goswami *et al*., 1997). Why?

Popular answers have been that English children are poorly taught; that they are not taught enough 'phonics' (or the right kind of 'phonics': see box); and that they begin formal schooling too young, before the language system has developed sufficiently to enable the 'cognitive precursor skills' (discussed below) to develop properly. Only the third answer holds part of the explanation. The main reason that English children lag behind their European peers in acquiring proficient reading skills is that the English language presents them with a far more difficult learning problem. Learning phonics is certainly important for achieving proficiency, but simply giving an English child good phonic skills will not make them a proficient reader of their language (at least, not in 10 weeks). This is because there are many levels of inconsistency in the English spelling system. English has inconsistencies both when going from spelling to sound (*go*/*do*, *he*/*the*) and when going from sound to spelling (*Bert*/*hurt*/*dirt*). Most (although not all) of these inconsistencies derive from spellings or pronunciations for vowels.

An analysis of spelling–sound consistency by Treiman *et al*. (1995) showed that within English monosyllables, consonants are more consistent than vowels. For a child reading a simple word like *cot*, there is a strong likelihood – over 90 per cent – that the next word they encounter beginning with *c* or ending in *t* will share the pronunciation for the initial or final consonant of *cot*. For vowels, however, the likelihood is only 50 per cent (see Table 1).

Vowels become more predictable in their pronunciations when considered as a unit with the final consonants (called the 'rime' unit by linguists, e.g. *–ap*, *–ing*, *–ight*). Analysing rime units increases spelling–sound consistency to around 80 per cent. But this is still relatively distant from languages like Spanish and Greek, where comparable analyses give spelling–sound consistency figures close to 100 per cent for any letter in any word

TEACHING PHONICS

Most phonics teaching is based on direct instruction in letter–sound relationships. Choices can be made about whether single letter–sound correspondences are the focus of teaching (e.g. teaching the child the sound for *c* in *cat*, *g* in *gold*), about the complexity of the relationships that are taught (e.g. teaching all possible correspondences, for example *c* in *cat* vs. *circus*, *g* in *gold* vs. *giant*), and whether larger groups of letters with systematic correspondences to sound (*ight*, *tion*, *ing*, etc.) and other strategies, such as rhyme analogy (*light–fight*, *beak–peak*), are also taught.

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TABLE 1 Consistency of spelling–sound relations in English monosyllables with a Consonant-Vowel-Consonant structure (from Treiman *et al*., 1995)

Segmentation metric	Example	Consistency from spelling to sound
C-V-C segmentation		
Initial consonant	's' in seal, sun, sing	
	'g' in game, goal, gin	96 per cent
Vowel	'u' in sun, bud, pull	
	'ea' in seal, beam, deaf	51 per cent
Final consonant	'p' in soap, cup, rip	
	'b' in tab, rib, lamb	91 per cent
Large unit segmentation		
CV–	'ca' in cap, call, car	
	'pea' in peat, pearl, pear	52 per cent
–VC	'un' in bun, fun, run	
	'eaf' in leaf, deaf	77 per cent

position. English retains inconsistency even at the 'large unit' level of the rime, because of the many English words with no spelling 'neighbours' (such as *yacht* and *choir*), and because there is inconsistency at the rime level too (e.g. *speak*/*steak*, *five*/*give*, *bone*/*gone*).

These spelling statistics show that the learning problem of linking letters to sounds is relatively easy for a Greek or a Spanish child to solve. Learning 'phonics' (letter–sound correspondences that are 1:1) enables these children not only to decode any new word that they encounter, but also to decode it accurately. An English child applying 'phonics' to many highly frequent words (*her*, *here*, *five*, *once*) will not arrive at an accurate pronunciation. English children with good cognitive precursor skills and good vocabularies (i.e. relatively well-developed language systems) can use clues from phonics to arrive at the probable real-word target from their metaknowledge about the language (realising for example that a four-letter word spelt phonetically 'huh–eh– ruh–eh' makes the word *here* and not *herreh*). However, many four- and five-year-old children come to school with relatively impoverished language skills, and need experience with language play and nursery rhymes in order to develop good precursor skills and wide vocabularies.

A particularly clear demonstration of the point that it is the spelling system and not the child that causes the learning problem for English comes from the case of Welsh. Children growing up in Wales who are either native Welsh or English speakers offer a particularly valuable opportunity for cross-language comparisons. They are experiencing extremely similar cultures and identical schooling, yet Welsh is a language with almost 1:1 consistency for letter–sound relations, whereas English is not. Hanley *et al*. (in press) followed a group of five-year-old Welsh-speaking children who were learning to read Welsh and a matched group of English-speaking children living in the same area of Wales who were learning to read English. By the age of 10 the groups of children were comparable in tests of single-word reading in their native languages, and in nonword reading. But up until then, the English children had been significantly less accurate than their Welsh peers at each test point (suggesting slower reading acquisition). In terms of reading rate, however, the English children were significantly faster than the Welsh children. This is probably because reading Welsh via the application of sequential letter–sound correspondences (a relatively slow reading strategy) is highly efficient in terms of accuracy, whereas for English it is not. Hence English children develop multiple reading strategies, for example recognising whole words, making rhyme analogies (*light*/*fight*), using letter–sound recoding, which (when they work) can be faster than letter–sound recoding alone.

Cognitive precursor skills

Along with good general intelligence, memory and language skills there are some quite specific cognitive precursor skills that are required for a child to become a proficient reader. These are similar across all languages so far studied, and depend on the brain's ability to extract the sound regularities within language. This 'phonological awareness', the child's awareness of the phonological structure of words, is usually measured by simple tasks like rhyme recognition (see Table 2 overleaf). In typically developing children phonological awareness is the most accurate predictor of later reading and spelling acquisition that we have. This is even true for languages that do not use the alphabetic principle, such as Chinese (e.g. Ho & Bryant, 1997).

For reasons yet to be determined, dyslexic children find it difficult to represent mentally the sound patterns of the words in their language in a detailed and specific way. Their 'phonological representations' of the words in their vocabulary are underspecified, or fuzzy, and this makes it difficult for them to develop an awareness of the internal sound structure of different words (Snowling, 2000). This in turn makes it difficult for them to learn letter–sound relationships. This is not because they can't learn about letters, but because the sounds to which they need to match the letters are relatively poorly specified.

Dyslexic children across languages show impairments in tasks designed to measure their phonological awareness (Goswami, 2000). Dyslexic children find it more difficult than their peers to decide whether words rhyme, to count the syllables in a word, to delete sounds from the beginnings of words (*spill* to *pill*), and to make up spoonerisms (*Bob Dylan* to *Dob Bylan*). They also find it very difficult to decode nonwords like *dem* and *fip*. However, if the dyslexic children are being taught to read languages with highly consistent spelling systems, then a measurable deficit in terms of accuracy disappears very quickly. Instead, the dyslexic children's phonological difficulties manifest themselves in painfully slow performance, even for nonword reading. Dyslexic children in Greece, Germany and Spain can read nonwords or perform phonological awareness tasks with a high degree of accuracy, but they do so extremely slowly. Dyslexic children in England rarely reach high levels of accuracy in nonword reading, and are both slow and inaccurate in phonological awareness tasks.

Different languages, different manifestations of dyslexia

What are the reasons for this cross-language difference in the manifestation of dyslexia? Again, spelling consistency seems to hold the key. Dyslexic children who learn to read consistent spelling systems can use letters as a way of solving phonological awareness tasks. Learning to read appears to improve the specificity of their phonological representations for familiar words. Letters provide an anchor to the variability of sound, and because for such languages this anchor is 1:1 for reading (i.e. from spelling to sound), accurate decoding can develop (decoding is never efficient because it is so slow). Note that spelling rarely becomes highly accurate in dyslexia, because very few languages have 1:1 correspondence from sound to spelling (i.e. only one way of writing a possible sound: think of *stair*, *there*, *wear*, *spare*). Hence, persistent problems with spelling is the usual basis for the diagnosis of dyslexia in languages other than English.

As well as spelling consistency another important factor for the different manifestations of dyslexia lies in the phonological structure of different languages. Phonological awareness skills develop in all children, with syllable- and rime-level skills usually well developed before reading is taught, and 'phoneme-level' skills (phonemes are much smaller units of sound, corresponding approximately to alphabetic letters) developing as reading is taught. Hence most children approach the task of reading able to segment their phonological representations for familiar words to at least the onset–rime level (dividing syllables at the vowel, as in *spr–ing*, *st–amp*, *z–oo*, *h–at–p–in*, *c–o–c–oa*, *y–o–y–o*). For languages like Spanish and Italian, the majority of words are like *cocoa* and *yoyo*: words tend to have simple CVCV (C = consonant, V = vowel) syllable structures. Words like *yoyo* have just one phoneme in the onset and rime of each syllable. This makes the learning problem of mapping letters to sounds much easier for children. Children's phonological representations of words are already segmented at the appropriate level, since onsets and rimes are often equivalent to phonemes.

But this is not the case for languages like English and German. These languages have complex syllabic structures, so onsets and particularly rimes may not be equivalent to phonemes. For these languages, onsets and rimes often contain clusters of phonemes (e.g. *spring*: three phonemes in *spr*, two phonemes but three letters in *ing*). Children learning to read

TABLE 2 Examples of phonological awareness tasks for children

Phonological level	Instructions	Example	Answer
Syllable	Tap once for each beat in the word	popsicle	3 taps
Syllable	Do these words share a sound at the end?	compete, repeat	yes
Onset–rime	Which is the odd word out?	cat, pit, fat	pit
Onset–rime	Do these words share a sound at the beginning?	plea, plank	yes
		twist, brain	no
Phoneme	Do these words share a sound at the beginning?	plea, pray	yes
		bomb, drip	no
Phoneme	Tap once for each sound in the word	book	3 taps
Phoneme	Delete the first sound from this word	star	tar

References

Goswami, U. (2000). Phonological representations, reading development and dyslexia: Towards a cross-linguistic theoretical framework. *Dyslexia, 6*, 133–151.

Goswami, U., Porpodas, C. & Wheelwright, S. (1997). Children's orthographic representations in English and Greek. *European Journal of Psychology of Education, 3*, 273–292.

Goswami, U., Thomson, J., Richardson, U., Stainthorp, R., Hughes, D, Rosen, S. *et al.* (2002). Amplitude envelope onsets and developmental dyslexia: A new hypothesis. *Proceedings of the National Academy of Sciences, 99*(16), 10911–10916.

Hanley, J.R., Masterson, J., Spencer, L.H. & Evans, D. (in press). How long do the advantages of learning to read a transparent orthography last? An investigation of the reading skills and incidence of dyslexia in Welsh children at 10 years of age. *Quarterly Journal of Experimental Psychology*.

Ho, C.S.H. & Bryant, P. (1997). Phonological skills are important in learning to read Chinese. *Developmental Psychology, 33*, 946–951.

Lundberg, I., Olofsson, A. & Wall, S. (1980). Reading and spelling skills in the first school years predicted from phonemic awareness skills in kindergarten. *Scandinavian Journal of Psychology, 21*, 159–173.

Schneider, W., Roth, E. & Ennemoser, M. (2000). Training phonological skills and letter knowledge in children at-risk for dyslexia: A comparison of three kindergarten intervention programs. *Journal of Educational Psychology, 92*, 284–295.

Scott, S.K. (1998). The point of P-centres. *Psychological Research, 61*, 4–11.

Scott, S.K. & Wise, R.J.S. (in press). The functional neuroanatomy of prelexical processing in speech perception. *Cognition*.

Seymour, P.H.K., Aro, M. & Erskine, J.M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*, 143–174.

Snowling, M.J. (2000). *Dyslexia* (2nd edn). Oxford: Blackwell.

Treiman, R., Mullennix, J., Bijeljac-Babic, R. & Richmond-Welty, E.D. (1995). The special role of rimes in the description, use, and acquisition of English orthography. *Journal of Experimental Psychology: General, 124*, 107–136.

languages like English and German do not have the luxury of onset–rime segmentation corresponding to the letter–sound relations being taught in phonics. Nevertheless, the children learning to read German have a significant advantage. Their spelling system has consistent 1:1 mappings between letters and sounds. This helps German children to learn and represent phonemes more quickly than English children, despite the fact that children learning either language need to segment complex syllables.

Biological underpinnings?

So far I have argued that intrinsic weaknesses in phonological representation explain the reading acquisition problems experienced by dyslexic children across languages. These weaknesses presumably stem from the way that the dyslexic brain processes incoming auditory information. There are a number of debates about whether this is so. There are also debates regarding the particular form that an auditory processing deficit might take. Rather than review these here, I will end by discussing our new theory about the nature of the auditory processing deficit in dyslexia.

One important source of the development of the phonological awareness skills so critical for reading is the language games and nursery rhymes of early childhood. Most of these language games emphasise phonological patterning, and many are based on rhyme and rhythm. There is some direct evidence that clapping along to nursery rhymes in preschool promotes reading development (Lundberg *et al*., 1980; Schneider *et al*., 2000), and there is a lot of indirect evidence that children enjoy such routines and that it benefits their linguistic development. Once we consider that speech rhythm is one of the earliest cues used by infants to discriminate syllables, a link with the development of phonological awareness becomes plausible. If infants rely on rhythm and prosody as a means of segmenting the speech stream into words, then perceiving these aspects of the auditory signal accurately may also be important for representing the words themselves.

In auditory perceptual terms, speech rhythm is principally determined by the acoustic structure of amplitude modulation at relatively low rates in the signal. Put simply, this corresponds to noticeable changes in the amount of sound as syllables are pronounced: the ‘beats’ of natural speech. If required to speak to a regular rhythm, speakers align the onsets of their vowels, creating rhythmic patterns (e.g. if counting aloud to a rhythm, the vowel sound in *three* is timed with the vowel sound in *four* even though it is slightly delayed by the consonant group at the beginning of the word; see Scott, 1998). The ability to detect speech rhythm is thus intimately linked to vowel perception and production. It follows that the auditory cues contributing to speech rhythm may be important for representing the syllable in terms of onset–rime segments (e.g. *s–eat*, *sw–eet*, *str–eet*). As discussed earlier, onset–rime processing of syllables is deficient in dyslexic children across languages. A likely perceptual cause of this difficulty is a deficit in their perceptual experience of regularity or rhythmic timing.

In recent work we have indeed shown significant differences between dyslexic and normally reading children, and between young early readers and more typical developers, in ‘beat’ detection (Goswami *et al*., 2002). The dyslexic children were significantly less sensitive than the precocious readers to the auditory parameters that yield the ‘stress beats’ in speech. We further found that individual differences in sensitivity to these auditory parameters accounted for 25 per cent of the variance in reading and spelling acquisition even after controlling for individual differences in age, nonverbal IQ, and vocabulary. It is unusual for a perceptual task to determine such a large amount of variance in written language skills. The fact that beat detection also predicted spelling acquisition was particularly interesting, as in most languages developmental dyslexia is diagnosed on the basis of persistent spelling difficulties. Recently, we replicated our results with English dyslexic children, and in ongoing data collection we are finding beat detection deficits in Finnish and French dyslexic children as well.

Implications for teaching?

If our hypothesis about beat detection is correct, then it would be important to spend time in nursery and preschool developing children’s informal knowledge about syllables and rhymes. Traditional early years activities such as singing nursery rhymes and playing clapping games may have important developmental consequences for literacy. Children may benefit from focusing on the rhythmic patterns in language prior to learning to read. It may also be beneficial for later literacy acquisition to experiment with other forms of rhythm in preschool, such as musical and motor rhythms.

This is purely speculative. However, the neural pathway underpinning beat detection is probably the posterior stream of processing involved in mapping speech sounds on to motor representations of articulation (Scott & Wise, in press). As this is the pathway underlying the motor production of sounds, other forms of practice in mapping motor production to sound may also be helpful for the development of rhythm perception. In current work we are attempting to investigate this empirically, using the experimental methods of scientific psychology that Donald Broadbent himself would have recommended. The gap between the real-world problems of the classroom and the world of the scientific laboratory needs to be bridged by well-developed theories and rigorous methods.

■ *Professor Usha Goswami is at the Faculty of Education, University of Cambridge. E-mail: ucg10@cam.ac.uk.*