Running head: DYSLEXIA AND HANDEDNESS

DYSLEXIA AND HANDEDNESS: DEVELOPMENTAL PHONOLOGICAL AND
SURFACE DYSLEXIAS ARE ASSOCIATED WITH DIFFERENT BIASES FOR
HANDEDNESS ¹

MARIAN ANNETT

University of Leicester, UK

¹Address correspondence to Dr. M. Annett, School of Psychology, University of Leicester, 106
New Walk, Leicester, UK, LE1 7EA or email (doc@le.ac.uk).

Summary. – Developmental disorders of reading and spelling have long been associated with increased left- and mixed-handedness but the evidence has been controversial. The right shift (RS) theory of handedness and cerebral dominance, developed by Annett from 1972 onward, offers resolutions to several puzzles about laterality in the so-called dyslexias. This review of findings in the light of the theory shows that ‘phonological’ dyslexics are less likely to be right-handed, while ‘surface’ or ‘dyseidetic’ dyslexics are more likely to be right-handed than the general population.

Most children learn to read and spell with very little explicit instruction, but some children have great difficulty. A small but significant proportion of the population is functionally illiterate. This has huge costs for the people affected and also for wider society. Many poor readers have poor awareness of speech sounds (phonology). However, some poor readers do not have poor phonology, but other problems which require different remedial methods. The research reviewed here was undertaken to show that two contrasting types of literacy problem are associated with different types of hand preference.

Dyslexia

‘Dyslexia’ is a controversial term for weakness in learning to read or spell which cannot be explained by other disabilities or lack of opportunity to learn (reviews, Beaton, 2004; Vellutino & Fletcher, 2005). Some reject the term as a medical sounding label for a condition better described as ‘poor reading’ or ‘poor spelling’ (Stanovich, 1994). Some researchers have restricted the term to poor readers who are of normal intelligence, on the assumption that most poor readers are handicapped by low ability. Teachers often do not accept this distinction. Children of low intelligence may learn to read well, as do some children with early brain injuries such as the cerebral palsies. ‘Dyslexia’ is used here as shorthand for poor reading or spelling that cannot be explained by other disabilities or disadvantages. The distinction between types of dyslexia of interest is not between different levels of intellectual ability, but rather between different types of reading problem called ‘phonological’ and ‘surface’ dyslexia (Castles & Coltheart 1993).

The idea that dyslexics are often left- or mixed-handed was first suggested by Samuel T. Orton (1925). He noticed that children with several types of developmental language problem were what he called ‘motor-intergrades’. In modern terminology this could include

‘mixed-handedness’ and ‘ambidexterity’. Many studies followed Orton’s observations, using two main research strategies. A ‘clinical’ strategy was to study ‘cases’ of poor readers and poor spellers for hand, eye, and foot preferences and to compare these with control children. This strategy generally found about twice as many nonright-handers among cases as controls (Hallgren, 1950; Naidoo, 1972). In small samples the difference was often not statistically significant. A second strategy was a ‘general population’ approach, classifying children for handedness and then comparing groups for literacy. This strategy almost invariably yielded nothing of interest (Satz & Fletcher, 1987). Not surprisingly overall conclusions were generally negative, and the possible association between handedness and dyslexia was dismissed as unimportant (Bishop, 1990). However, in a meta-analysis of clinical studies (Eglinton & Annett, 1994) children with literacy problems were more likely to be nonright-handed than control children. Clinicians assessing for possible dyslexia typically record hand and other preferences, with the implication that laterality might be part of the problem. But if dyslexics differ for handedness, why are the majority right-handed?

One of the most securely established facts about dyslexics is a tendency to weakness in processing speech sounds, described as poor phonology (Snowling, 2000; Wagner & Torgersen 1987). This is demonstrated on tasks where one is required to repeat a word with a sound missing, such as, “Say sit without the ‘se’”, or “Bind without the ‘ne’” (Stuart, 1990). For older participants the task might be to reverse the initial sounds of two words, such as ‘Chuck Berry’ to give ‘Buck Cherry’ (Perin, 1983). A problem characteristic of phonological dyslexics is inability to read nonsense words or new words that have to be constructed by translating letters into sounds (or graphemes into phonemes). Some phonological dyslexics learn to read well and enter higher education, but appear to rely on a remarkable visual

memory for words. However, they must first hear words spoken because they cannot sound the words out for themselves (Campbell & Butterworth, 1985).

There is a type of dyslexia that was first identified in studies of brain injured adults, and later as a developmental problem in children, called 'surface' dyslexia (Patterson, Marshall, & Coltheart, 1985). This contrasts with phonological dyslexia in that there is no problem in reading nonsense words but rather a good grasp of grapheme-phoneme relationships. There is difficulty in reading words which are exceptions to the usual grapheme-phoneme rules, irregular words like 'pint', 'yacht', 'peasant'. These words have to be recognized visually and learned specifically. Surface dyslexics have particular difficulty with homophones, real words that sound alike but have different spellings and meanings such as 'there' and 'their', 'isle' and 'aisle', 'root' and 'route'. A nurse complained of her difficulties with 'saw', 'sore' and 'soar'. The different meanings have to be learned along with the different sequences of letters. Further types of dyslexia have been described (Seymour, 1986) but phonological and surface dyslexia are the main types distinguished in children. A similar distinction was made by Elena Boder (1973) between 'dysphonetic' and 'dyseidetic' dyslexia, and by others using different terms (Baron & Strawson, 1976). Studies of handedness in dyslexics have not studied phonological and surface dyslexics separately. The idea that this might be important was suggested by the right shift (RS) theory.

Right Shift Theory

The RS theory (Annett, 1972) depended on the results of some 10 years empirical research and theoretical analysis. It was followed by explorations of the implications of the theory in several areas of new research which led to further insights, predictions and tests. This process was described in a book length review by Annett (2002). Critical comments on Annett

(2002) were given by Corballis (2004), Crow, (2004), Elias (2004) and McManus (2004) with author's reply (Annett, 2004). The present paper aims to bring the review of research prompted by the RS theory up to date with respect to types of dyslexia and handedness.

The RS theory is usually described as a genetic theory because it suggests that a gene (RS+) influences human laterality, but it is primarily an *environmental* theory. Culture also has an important role. The theory suggests that the chief cause of lateral asymmetries is accidental differences in the development of the two sides of the body. In translating the instructions for building the skeleton, muscles and nervous system, chance differences arise between the two sides, which make one side more efficient than the other. Envisage a pin-ball machine where small balls are dropped through a central funnel at the top and then fall at random through an array of pins below. The outcome is a chance distribution, the classic bell-shaped curve. If the balls represent individuals, those falling to the left can be hypothesized to have advantages for the left side of the body, those to the right advantages for the right side, but the majority fall in the centre with no clear asymmetry. Such individuals would be relatively evenly balanced on both sides. The *cultural* bias to the right hand in all human societies is likely to be sufficient to pressure most of those in the centre to use the right hand. In terms of relative hand skill, a 50/50 distribution of advantage for left and right is expected, but in terms of hand preference for socially relevant actions like writing and eating, there would be more right than left-handers. This is important for the investigation of dyslexia, because even if dyslexics were distributed for hand skill at random, the majority would use the right hand for writing.

The hypothesis that there is an RS+ gene which displaces the random distribution of carriers in a dextral direction can be envisaged as a small deflector placed just below the outlet of the pin-ball funnel which gives an initial bias to the right side. The deflector does not make

everyone right-handed. The balls still fall at random through the pins to give a normal probability distribution but the chances of right-handedness are increased and left- and mixed-handedness decreased in comparison with the unbiased distribution. If a single gene is involved then some people carry two copies and probably have a double bias of displacement to the right. The probability of right-handedness is increased, but some will be mixed- and left-handed, even in the RS ++ genotype. Measures of hand skill for peg moving find a continuous approximately normal distribution of relative differences between the hands. Hand preferences can be thought of as depending on thresholds which vary along the baseline, depending on cultural and other influences on the expression and recording of preferences.

The RS + gene is a hypothetical construct which does not at present have direct empirical foundation but it is supported by circumstantial evidence in the fruitful research guided by the theory. The theoretical analysis depends on the idea that the gene is 'for' left hemisphere speech, which is present in most but not all of the normal population. The gene is not for speech itself but for the lateralization of speech to the left side of the brain. The advantage for speech gives an incidental advantage to the right hand which is controlled by the left hemisphere. The frequency of the hypothesized gene and, therefore, of the genotypes, was deduced from the proportions of cases of speech disorder (dysphasias) with left and right sided brain injuries in patients drawn from the general population. These frequencies were then found to explain handedness in families Annett (1978, 1996). Successful predictions from dysphasias to family data in the literature, and in new samples collected subsequently, as well as findings for twins, strongly support the hypothesis that the gene is 'for' left hemisphere speech (Annett, 2002, 2003). Some people have speech functions located in the right hemisphere, suggesting that the RS+ gene is absent. When the gene is absent, asymmetries

occur at random. The key hypothesis here is that RS - - genotypes lack something which promotes the lateralization of speech to the left hemisphere so that lateralization occurs by chance.

The estimated genotype distributions imply that almost one half of the population carry one copy of the gene (RS+ - heterozygotes). Fifty percent is the maximum possible heterozygosity for a pair of alleles at a single locus. Just under one in five were estimated to be RS - - homozygotes and about one in three RS+ + homozygotes. The genotype frequencies suggest there could be a genetic balanced polymorphism with heterozygote advantage and relative disadvantages for both homozygotes. What could these disadvantages be?

The most likely disadvantage for those who lack a gene which aids the development of speech in the left cerebral hemisphere would be risk of developmental disorders of speech and related language functions. Because people at risk lack the genetic shift to the left hemisphere they would be likely to include a higher proportion of left- and mixed-handers than the general population (although the cultural shift to the right would make the majority right-handers, as explained above). The RS - - genotype could explain the handedness of children with speech and literacy problems observed by Orton.

What disadvantages are expected of the RS + + genotype? A clue to possible problems was given by the finding that strong right-handers tend to have weak left hands on a test of peg moving skill. Perhaps the typical bias to the left hemisphere is achieved by handicapping the right hemisphere. This led to the suggestion that RS + + genotypes might have weak right hemisphere functions, such as poor visuospatial abilities. It was also predicted that there would be weakness in sports and other skills that required coordinated performance by two sides of the body. The raised incidence of left-handers among professional tennis players, baseball

players, and cricketers is consistent with the presence of RS - - and RS + - genotypes but absence of RS + + genotypes. With regard to dyslexics, among children attending a remedial clinic, there was a raised proportion of left- and mixed-handers as expected, but also some who were strongly right-handed for hand skill. Could these children be RS + + genotypes? They would not be expected to have poor phonology but rather over-reliance on left hemisphere speech mechanisms. They might also have other problems possibly associated with visuospatial awareness. Thus a combination of theoretical analysis and surprising empirical findings led to the idea that there could be problems for literacy at both sides of the laterality distribution, phonological dyslexia to the left and surface dyslexia to the right.

Dissociations for handedness

In looking for dissociations for handedness between the two types of literacy problem, phonological and surface, the aim was to assess representative samples of the population (of undergraduates or children, not selected for handedness) and distinguish groups with poor literacy who show, or do not show, weakness in phonology. Another strategy was to select for weak phonology in contrast with weakness for real word homophones (Hanley & Gard, 1995). The hypothesis was that those with poor phonology would include *more* nonright-handers while those without poor phonology would include *fewer* nonright-handers than the rest of the sample. It is important to recognize, from the overlap of the normal distributions associated with the three genotypes, that differences are not absolute but only a matter of relative probabilities. This makes statistical significance hard to find. There is a strong theoretical background to the research, but large samples are required for results to be convincing.

In studies of undergraduates, who are selected, of course, for relatively good literacy, it was possible to distinguish some with poor phonology and others with weakness for real word

homophones. Differences for handedness were in the directions predicted. There were more left- and mixed-handers in those with poor phonology and fewer left- and mixed-handers in those weak for homophones (Annett, 1999). In a cohort of nearly 500 schoolchildren, reading, spelling, and other abilities were assessed (Annett, Eglinton, & Smythe, 1996). We distinguished poor readers, nearly all of whom satisfied criteria of discrepancy with nonverbal intelligence. Among poor readers with poor phonology, 29% were left-handed writers (5/17) while among 18 poor readers without poor phonology there were no left-handed writers. In the rest of the sample of normal readers and spellers there were 10% left-handed writers.

Eglinton and Annett (2008) looked at poor spellers (after excluding poor readers). Some spelling errors sound like the target word, showing good grasp of grapheme-phoneme relationships. Poor spellers who made good phonetic equivalent (GFE) errors were distinguished from those who did not. Poor spellers not giving GFEs, like phonologically dyslexic poor readers, were expected to include more RS - - genotypes, and 24% were found to be left-handed writers. Poor spellers who did give GFEs included 2% left writers. The contrast for poor spellers replicated that for poor readers.

Smythe and Annett (2006) looked at the handedness of children with poor phonology who were not poor readers, did not have slow hand speeds during peg moving, and had IQ on a vocabulary test of 90+ (so excluding those with signs that might be regarded as evidence of pathology). Among 30 children with poor phonology there were 23% left-handers. Another way to look at this question was to find ‘cases’ who were specifically poor on phonology test scores but not poor on spatial ability test scores (as measured by factor analysis). This group included 29% left-handed writers, and only 19% were consistent right-handers. The difference

between the hands for their peg-moving skill did not differ significantly from zero. In other words, the distribution was without bias to either side as expected for the RS - - genotype.

On the question of the nature of the difficulty of children with surface type dyslexia among poor spellers, Eglinton and Annett (2008) tested nonverbal intelligence and gave two tests of spatial abilities. None of these measures found any specific weakness, evidence that suggests surface dyslexia is not associated with visuospatial disability. This agrees with other researchers who have also found no visuospatial weakness. However, we did find a tendency for the surface type poor spellers to process homophonic words differently from the phonological and control groups. The nature of this difference needs further exploration.

Implications

What are the implications of this work for research and remediation of dyslexia? There are at least two types of problem which give rise to difficulties in learning to read and spell in normal schoolchildren. The distinction between phonological and surface dyslexia has been made several times, using different terminologies, but it now has independent support in the finding of differences for handedness. The implication must be that there are different patterns of cerebral dominance, different types of underlying problem, and different needs for remedial teaching. It is important to recognize that the differences are due to patterns of cerebral asymmetry, not to handedness itself. From this perspective, clinicians and teachers who believe dyslexia can be cured by treating the handedness are profoundly mistaken and are wasting time that should be spent in teaching reading and spelling.

Handedness is a *weak* indicator of underlying differences for brain asymmetry because the fundamental cause of handedness is any accidental difference between the two sides of the body. The overlap of normal distributions for the three genotypes means that the RS + -

genotype straddles all the main handedness categories (left, mixed, and right). It is most unlikely that classifying normal children for handedness and testing for literacy (the research strategy adopted in most of the negative research in the literature) would yield significant findings because RS + - genotypes are both the most numerous and the most advantageous for development. To find significant effects it is necessary to start with the clinical perspective and identify children with problems. It is then important to distinguish the type of problem, phonological or surface in most cases, and then look for differences for laterality. Relatively small samples can give significant findings if the selection of cases is theoretically driven. The error of combining different types of dyslexia, not distinguishing those with and without problems of phonology, is sufficient to explain the weak and controversial findings in this field for nearly a century. The weakness of statistical findings in previous research does not mean that the issues are trivial. The RS analysis suggests that there are genuine distinctions which need to be made between children with different types of problem because they have different patterns of brain asymmetry and require different teaching strategies for remediation.

References

- Annett, M. (1972) The distribution of manual asymmetry. *British Journal of Psychology*, 63, 343-358.
- Annett, M. (1978) *A single gene explanation of right and left handedness and brainedness*. Coventry: Lanchester Polytechnic.
- Annett, M. (1996) In defence of the right shift theory. *Perceptual and Motor Skills*, 82, 115-137.
- Annett, M. (1999) Handedness and lexical skills in undergraduates. *Cortex*, 35, 357-352.
- Annett, M. (2002) *Handedness and brain asymmetry: the right shift theory*. Hove, Brighton: Psychology Press.
- Annett, M. (2003) Cerebral asymmetry in twins: predictions of the right shift theory. *Neuropsychologia*, 41, 469-479.
- Annett, M. (2004) Perceptions of the right shift theory. *Cortex*, 40, 143-150.
- Annett, M., Eglinton, E., & Smythe, P. (1996) Types of dyslexia and the shift to dextrality. *Journal of Child Psychology and Psychiatry*, 37, 167-180.
- Baron, J., & Strawson, C. (1976) Use of orthographic and word-specific knowledge in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance*, 2, 386-393.
- Beaton, A. (2004) *Dyslexia, reading and the brain: a sourcebook of psychological and biological research*. Hove, Brighton: Psychology Press.
- Bishop, D. V. M. (1990) *Handedness and developmental disorder*. Oxford: Blackwell.
- Boder, E. (1973) Developmental dyslexia: a diagnostic approach based on three atypical reading-spelling patterns. *Developmental Medicine and Child Neurology*, 15, 663-687.

- Campbell, R., & Butterworth, B. (1985) Phonological dyslexia and dysgraphia in a highly literate subject: a developmental case with associated deficits of phonemic processing and awareness. *Quarterly Journal of Experimental Psychology*, 37A, 435-475.
- Castles, A., & Coltheart, M. (1993) Varieties of developmental dyslexia. *Cognition*, 47, 149-180.
- Corballis, M. C. (2004) Taking your chances. *Cortex*, 40, 117-119.
- Crow, T. J. (2004) What Marian Annett can teach Noam Chomsky and could have taught Stephen Jay Gould if he'd had time to listen. *Cortex*, 40, 120-134.
- Eglinton, E., & Annett, M. (1994) Handedness and dyslexia: a meta-analysis. *Perceptual and Motor Skills*, 79, 1611-1616.
- Eglinton, E., & Annett, M. (2008) Good phonetic errors in poor spellers are associated with right-handedness and possible weak utilisation of visuospatial abilities. *Cortex*, 44, 737-745.
- Elias, L. (2004) Acknowledge the ambition, but look elsewhere for the alternatives. *Cortex*, 40, 135-137.
- Hallgren, B. (1950) Specific dyslexia: a clinical and genetic study. *Acta Psychiatrica et Neurologica Scandinavia*. Suppl. 65, 1-287.
- Hanley, J.R., & Gard, F. (1995) A dissociation between developmental surface and phonological dyslexia in two undergraduate students. *Neuropsychologia*, 33, 909-914.
- McManus, I. C. (2004) Grappling with the hydra. *Cortex*, 40, 139-141.
- Naidoo, S. (1972) *Specific dyslexia*. London: Pitman.
- Orton, S. T. (1925) "Word blindness" in school children. *Archives of Neurology and Psychiatry*. 14, 581-615.

- Patterson, K. E., Marshall, J. C., & Coltheart, M. (1985) *Surface dyslexia: neuropsychological and cognitive studies of phonological reading*. London: Erlbaum Associates.
- Perin, D. (1983) Phonemic segmentation and spelling. *British Journal of Psychology*, 74, 129-144.
- Satz, P., & Fletcher, J.M. (1987) Left-handedness and dyslexia: an old myth revisited. *Journal of Pediatric Psychology*, 12, 291-298.
- Seymour, P. H. K. (1986) *Cognitive analysis of dyslexia*. London: Routledge & Kegan Paul.
- Smythe, P., & Annett, M. (2006) Phonology and handedness in primary school: predictions of the right shift theory. *Journal of Child Psychology and Psychiatry*, 47, 205-212.
- Snowling, M. (2000) *Dyslexia: a cognitive developmental perspective*. 2nd Ed. Oxford: Blackwell.
- Stanovich, K. E. (1994) Does dyslexia exist? *Journal of Child Psychology and Psychiatry*, 35, 579-595.
- Stuart, M. (1990) Processing strategies in a phonemic deletion task. *Quarterly Journal of Experimental Psychology*, 42A, 305-327.
- Vellutino F. R., & Fletcher, J. M. (2005) Developmental dyslexia. In M. J. Snowling & C. Hulme (Eds.) *The science of reading: a handbook*. Oxford: Blackwell. Pp. 362-379.
- Wagner, R. K., & Torgersen, J. K. (1987) The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101, 192-212.