WHAT CHILDREN SEE AFFECTS HOW THEY SPELL

Piers Cornelissen
Lynette Bradley
Sue Fowler
John Stein

Most researchers agree that, when children first begin to spell, they use a predominantly phonological strategy in which they attempt to transcribe what they hear (Read 1986, Sterling and Robson 1992, Treiman 1993). With time, and especially after exposure to printed text through reading, children increasingly incorporate visual memories for letter strings into their spelling strategies.

Evidence to support this view has come from a number of sources. For example, Read found that even preschool children can invent spellings by applying their knowledge of letter names to represent the component sounds in the words they hear (Read 1971, 1986). The following examples from Read's data, 'FES SOWEMEG IN WOODR' for 'FISH SWIMMING IN WATER', and 'HALPT' for 'HELPED', demonstrate this point.

More recently, Treiman (1993) conducted a survey of the spelling errors made by 43 first-grade schoolchildren, at six or seven years of age. Her subjects' errors could best be explained from a phonological point of view: "... consider the errors HR for 'her' and HN for 'hen'. From an orthographic perspective, both errors involve the omission of an 'e' in the middle of a three-letter word. The errors should be about equally common. In fact, the first graders were much more likely to omit the 'e' of 'her' than the 'e' of 'hen'. This can be understood only if one considers the phonological forms of the words. From the child's point of view, the spoken form of 'her' contains /h/ followed by a syllabic liquid. The spoken form of 'hen' contains /h/ plus /ε/ plus /n/. Because 'her' contains only two segments for the child, the child often spells it as HR". (See Appendix for explanation of phonetic symbols.)

Unlike German or Italian, English orthography is particularly rich in irregular sound–letter mappings. It is argued that, in order to cope with such irregularities, children need to incorporate visual memories for letter strings which are gained through reading experience. So at what point in their development do children begin to use such visual information?

Bradley (1979, 1983) pointed out that the first 12 words of the Schonell Graded Word Spelling Test (Schonell 1950) can be worked out phonetically (*e.g.* net, fun, top). Success with these words indicates a spelling age of about 6 years 4 months. Above this level the spelling of many of the words is complex (*e.g.* doll, may, by), and children need to use additional strategies to spell them correctly. Indeed Bradley found that normal children who performed poorly on a test of visual memory for words failed on the Schonell at the point where irregular words are introduced. Therefore the shift away from a predominantly phonological strategy may coincide with children scoring above about 6½ years on the Schonell test.

Goswami partly corroborated these observations in a training study carried out in 1988. She found that six- to 7½-year-olds (mean spelling age seven years) could easily be taught to use analogies when writing. Thus children could transfer their orthographic knowledge about 'beak' to help them spell 'peak'. However, Goswami did not indicate whether children at this stage spontaneously use analogies to work out spellings. Treiman's (1993) results also suggest that children may use rudimentary orthographic knowledge at first-grade level. For example, she suggested that the sound /O/ may have been spelled by her subjects as 'a' because they had read words like 'water'. In addition, these children rarely produced spellings like 'ckap' or 'ssim'. Treiman suggested that this was because children discover, through their reading, that the phonemes /k/ and /s/ are spelled with 'ck' and 'ss' at the ends of words, but not at the beginnings.

It seems that the relative balance between children's visual and phonological strategies for spelling changes continuously during development. Initially the scales are tipped in favour of phonological skills when children begin to spell, but this situation changes with time as children increasingly make use of visual memories for letter strings which they glean through reading.

It should be noted that the interaction between children's spelling and reading skills does not progress in a smooth, reciprocal fashion (Bryant and Bradley 1980, Adams 1990, Ehri 1991). Instead, the direction of the influence may vary at different times during development. For example, Cataldo and Ellis (1988) conducted a three-year longitudinal study which showed that the spelling skills of five- and six-year-olds influenced their reading, but not vice versa. By contrast, Ehri (1980) asked eight-year-olds to imagine the spellings of words like 'listen' and to judge whether letters like 's', which are pronounced, and letters like 't', which are silent, were present in the stimulus. Ehri found that by this age children had no difficulty with the task, indicating that extensive reading experience does result in visual representations of particular letters in words. This situation was aptly summarized by Goswami (1992): 'early spelling, which requires an explicit phonological analysis of the sounds in words, helps early reading. When reading is fairly well developed, so that children have stored memories of the spelling patterns of different words, this knowledge in turn improves their spelling performance'.

Conventional views of spelling and reading development assume that children's visual systems always deliver accurate representations of what is printed on the page. But what might happen if children's visual processing sometimes fails, so that they experience visual confusion of text? Indeed children sometimes complain of symptoms such as words or groups of letters 'moving about on the page', 'going blurry' or 'splitting into two'. In a carefully controlled study of 39 reading-disabled children and 43 controls matched for chronological age (mean 9 years 10 months), Evans found that 23 per cent of the reading-disabled children and 8 per cent of the controls complained of transient diplopia (double vision). Similar proportions were found for the symptom of transient blur for near vision (Evans 1991).

Recently we have shown, in a population of poor readers, that those who fail the Dunlop Test, which is used to assess the stability of binocular control (Stein and Fowler 1982), may make reading errors for visual reasons alone (Cornelissen *et al.* 1991, 1992). In these experiments, only children with unstable binocular control read differently if print size was reduced, or if they were asked to read with both eyes as opposed to one. The difference observed was an increase in the proportion of their reading errors which were neologisms (or non-words): misreading, for example, 'guest' as 'gustetit'. We suggested that the change in the proportion of neologisms made by children with unstable binocular control was the result of visual confusion when print size was reduced or when children read with both eyes.

If children have experienced frequent visual confusions of text during their development, then we predicted that they ought to have greater difficulty discovering the patterns and rules of English orthography than children with normal binocular vision. Consequently they ought to make less use of the visual spelling strategies which would help them to spell irregular words, to remember consistently spelled morphemes like '-ing' or '-ed', and to make use of spelling anologies. So we expect children who fail the Dunlop Test (*i.e.* those who experience visual confusion) to rely more heavily on sound–letter correspondence rules while spelling. In particular, we propose that these children would make spelling errors which were more phonologically plausible than those made by their peers with normal binocular vision, reflecting their greater reliance on a phonological spelling strategy.

We report an experiment which tests our prediction. The logic behind the design of the experiment is identical to that of our previous two papers (Cornelissen *et al.* 1991, 1992): if we can show that children with unstable binocular control make a larger number of phonologically plausible spelling errors than a control group, even though the two groups of children are matched for spelling ability, chronological age and IQ, then we can suggest a direct link between the efficiency of binocular vision and the kinds of spelling strategies that children adopt.

Method

Subjects

As in our previous studies (Cornelissen *et al.* 1991, 1992), subjects were selected from a population of mixed-ability children who had been referred to an orthoptic clinic because of suspected reading difficulties. We selected 20 children whose spelling ages were 7 years 6 months or above on the Schonell spelling test. 10 of these children (eight males, two females) passed the Dunlop Test and 10 (nine males, one female) failed it. The two groups of children were matched as closely as possible for spelling age, IQ and chronological age.

Orthoptic and psychological assessment

All subjects were examined to exclude orthoptic and gross ophthalmological pathology before they performed the Dunlop Test, which we used as a pass/fail visual task (Stein and Fowler 1982).

In the Dunlop Test, children viewed two fusion slides (each subtending less than 5° at the forea) through a synoptophore, a stereoscopic viewing device that allows the vergence angle to be varied systematically. The slide viewed with the right eye showed a house with an arrowhead post to the left of the front door, while the left eye saw a house with a post with a circle on top to the right of the front door. The angle of the synoptophore tubes was adjusted until the children fused the two scenes. Then the tester abducted the synoptophore tubes (at 1·5°/s), and the children attempted to diverge their eyes to maintain fusion. When the children understood clearly what they had to do, most gained a clear impression that one of the posts moved towards the door during this procedure. After about 5° divergence, diplopia occurred. The test was repeated 10 times, the slides being changed over frequently to try to prevent the children guessing. Children passed the test if they saw the post on the same side move in eight or more trials out of 10, indicating that they had a stable response. Otherwise they failed the Dunlop Test, and were said to have un unstable response.

The Schonell spelling test was given to all 20 subjects. We also used the British Ability Scales (BAS) reading test to measure children's reading ability. Children's IQs were calculated from the mean of the BAS Matrices and Similarities subtest *t* scores. Finally we used a version of Bradley and Bryant's (1983) Rhyme-oddity task to ensure that the two groups of children did not differ in phonological awareness at the level of rhyme detection. Details of the two groups are given in Table I.

Experimental spelling list design and administration

All subjects were asked to spell to dictation 50 items from a set of test words which were selected from the Medical Research Council's psycholinguistic database to be appropriate for spelling ages above 7½ years. Each item from the experimental list was spoken once, repeated as part of a sentence and then repeated a second time on its own.

Further details about the design of the test word-list are as follows: (1) 50 words in total were presented: five groups of regular spellings, and five groups of irregular spellings, equally divided into four-, five-, six-, seven- and eight-letter words. The maximum number of syllables per word was four. (2) The word-frequency range was 301 to 836 per million (Thorndike and Lorge 1944). (3) Word concreteness was restricted to the range 158 to 670 (Colheart 1981). (Examples of words with high and low correctness are 'spoon' and 'unreality', respectively.)

TABLE I
Subject characteristics. Children are divided according to their Dunlop Test performance

	Passed Dunlop Test (N=10) Mean (SD)	*Failed Dunlop Test (N=10) Mean (SD)*
Spelling age (yrs:mths)	8:9 (0:11)	9:0 (1:0)
Reading age (yrs:mths)	9:4 (1:8)	9:2 (1:6)
Chronological age (yrs:mths)	10:1 (1:5)	10:2 (1:6)
IQ (BAS)*	107·7 (19·6)	104·0 (15·6)
Rhyme score (max. 16)	12·0 (2·0)	12·1 (2·9)

*British Ability Scales.

Analysis

DEFINING PHONOLOGICAL PLAUSIBILITY

The phonological plausibility of spelling errors is likely to vary with age, phonological awareness and spelling experience of the child, as well as with the nature of the test material presented (Read 1971, 1986; Pattison and Collier 1992). Moreover, children do not necessarily share the same phonological representation as adults (Treiman 1993). To illustrate this point, Treiman quotes the error WAT for 'want'. She suggests that "children may consider the spoken form of 'want' to contain three units—/w/, /ā/ and /t/. They may not consider it to contain /n/. Again, some children may consider 'sky' to contain /g/ rather than /k/, so they write SGY. In both cases children's phonemic representations differ from those embodied in the conventional English writing system and from those typically assumed for adults". Therefore, we argue that it is impractical to define absolute criteria against which a spelling error may be assessed for phonological plausibility.

There is a further problem. A range of different spelling errors may be produced in response to the same target word, all of which can be arranged on a continuum of phonological plausibility. The following examples from our database can all represent the pronunciation of 'audience', depending on how far one stretches grapheme–phoneme correspondence. Thus ORDIENCE, AUDIENS, ORDIENS, ORDEENS ('ordee' pronounced as written, followed by the name of the letter 'n'), ODEENS (where 'o' represents /O/) and ODINS (where 'i' represents /i/) can all be decoded as 'audience'. This argument is well demonstrated by presenting a text-to-speech synthesizer with the different spellings shown above. While examples like ODINS can still just be perceived as a recognizable rendition of 'audience', they are much further removed than examples like ORDEENTS.

ASSESSMENT OF PHONOLOGICAL PLAUSIBILITY OF SPELLING ERRORS

Assessment of phonological plausibility of spelling errors

To deal with these problems of definition, we presented all the children's errors to three raters, so that each rater could obtain a sense of the range of phonological plausibility represented by the variety of the errors. In order to generate as simple an analysis as possible, we asked the three raters to judge whether each of the children's spelling errors was more (phon+) or less (phon−) phonologically plausible. The raters worked independently and knew nothing about each child's performance on the Dunlop Test. Two of the raters were research workers in the field of developmental psychology, and the third was a linguist specializing in aphasia.

Under these circumstances, we felt that asking each rater to judge whether a particular error was more or less phonologically plausible would be comparable

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TABLE II
Correlation matrix of inter-rater agreement

	A	*B*	*C*
A	1·00		
B	0·91	1·00	
C	0·92	0·96	1·00

TABLE III
Examples of regular and irregular target words and children's spelling errors, according to whether they were more (phon+) or less (phon−) phonologically plausible

Target word	*Phon+*	*Phon−*
Irregular		
Sigh	Sie	Seaf
Wrote	Roat	Wrought
Health	Helth	Heare
Society	Siciyerty	Site
Audience	Ordience	Odins
Regular		
Inch	Intch	Enice
Lunch	Luntch	Lucuh
Permit	Permet	Prit
Protest	Protesd	Priest
Strength	Strenth	Sreh

TABLE IV
Main effects of multiple logistic regression models

	Rater A		*Rater B*		*Rater C*	
	Odds	*p*	*Odds*	*p*	*Odds*	*p*
Age	0·98	0·01	0·99	0·7	0·99	0·5
IQ	1·02	0·02	1·02	0·002	1·02	0·003
Rhyme oddity	1·00	0·9	1·00	0·9	1·02	0·6
DT*	3·15	<0·001	2·96	<0·001	3·47	<0·001

Regression coefficients expressed as odds ratios (p/1-p). Odds ratios >1 represent increased risk; odds ratios <1 represent reduced risk.
*Dunlop Test.

to standard forced-choice measurement techniques. In a typical experiment of this kind, a subject might listen to two tones. Both start at the same pitch and finish at the same, higher pitch; the only factor which differentiates them is the rate at which they increase in pitch. The subject's task is to say whether the tone rises fastest in the first or second interval. During the experiment, the difference in the rate of rise in pitch between the first and second tones is systematically reduced, until the subject's correct response rate reaches a predetermined level (often 75 per cent). This point on the psychometric function is then taken as the subject's discrimination threshold for the task. By analogy with the technique just described, we assumed that each of our raters could only perform his/her task if they set an internal threshold below which certain phonemic blends would be deemed less phonologically plausible (phon−) and those above, more plausible (phon+).

CALCULATION OF INTER-RATER AGREEMENT

One would expect each rater to set a slightly different threshold; this should not matter, provided there is good quantitative agreement between raters, because a sufficient test of our hypothesis is evidence of relative differences in the phonological plausibility of spelling errors when children with stable or unstable binocular control are compared.

We calculated inter-rater agreement in the following way. The data matrix for analysis comprised one row per child. Each row contained three estimates of the proportion of phon+ errors that the child made out of the 50 test items—one for each rater. The proportion of phon+ errors was calculated as (number of phon+ errors/total number of errors). We then used Spearman rank correlation and Kendall coefficient of concordance on these proportions to assess how well raters agreed with each other.

Table II shows the Spearman rank correlation coefficients for inter-rater agreement. All the correlation coefficients were greater than 0·9 and were significant at $p<0{\cdot}0001$. Kendall's coefficient of concordance was 0·96 (a value of 1 indicates perfect agreement). Both the rank correlation and concordance results indicate a high level of agreement between raters.

STATISTICAL MODELLING OF THE SPELLING ERROR DATA

We used a statistical package called GLIM3 (Generalized Linear Interactive Modelling) to run multiple logistic regression models to look for effects of

TABLE V
Main effects of multiple logistic regression model

Independent variables	*Regression coefficients expressed as risk values (odds ratios)*	*95% CL for for regression coefficients*	*p*
Age	0·99	0·98–1·00	0·2
IQ	1·02	1·01–1·04	0·005
Rhyme oddity score	1·00	0·93–1·09	0·8
DT	3·15	2·14–4·64	<0·0001

Odds ratios >1 represent increased risk; odds ratios <1 represent reduced risk.

Dunlop Test performance on the proportion of phon+ errors that the children made. The dependent variable in each model was the number of phon+ errors divided by total errors made by each child. The independent variables controlled for in each model were IQ, age and rhyme oddity. The models were of the form:

Logit (phon+ errors/total errors) = IQ + age + rhyme oddity task + Dunlop Test

Logistic regression analysis was used because the raters' responses were binary decisions, *i.e.* phon+ errors were treated as 'successes' while phon− errors were 'failures'. Therefore we were dealing with counted data where the appropriate distribution was binominal. In logistic regression, the significance of each independent variable is assessed by comparing changes in scaled deviance (expressed as values of χ^2) between the full model and a model with the variable of interest removed. The regression coefficients are expressed as log odds ratios, which are then converted to odds ratios or risk values (*i.e.* p/(1−p)). Odds ratios greater than one represent increased risk; values less than one represent reduced risk.

Results

On average, the two groups of children misspelled 56·3 per cent of the 50 test items. As would be expected in a spelling-age-matched design, a *t* test comparison between children with unstable binocular vision and the control group showed no difference in the mean total number of errors that they made (stable binocular control group, mean 23 (SD 9·2) errors; unstable group, mean 26·5 (SD 5·8) errors).

Table III shows some examples of the target words and children's attempts to spell them. The responses are grouped according to whether the raters judged them to be more (phon+) or less (phon−) phonologically plausible.

The fact that the entire database of spelling errors was assessed by three independent raters introduced the problem of repeated measures into our analysis. To deal with this, we ran three separate logistic regression models to look for effects of Dunlop Test performance on the proportion of phon+ errors (Table IV). Each of the three separate analyses show that children who failed the Dunlop Test made a significantly larger proportion of phon− errors than the control group of children who passed the Dunlop Test.

In view of the good quantitative agreement between raters (Spearman correlation and Kendall concordances in Table II), and the fact that the separate regression analyses produced qualitative agreement, we felt justified in averaging together the data from the three raters, thereby removing the problem with repeated measures.

Table V shows the results of the logistic regression analysis in which the mean proportion of phon+ errors according to the three raters was entered as the dependent variable. Children who failed the Dunlop Test made a significantly higher proportion of phon+ errors than the control group of children who passed

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TABLE VI

Table showing relationship between proportion of phon+ errors, spelling regularity, binocular control and word length

Binocular control	*4-, 5- and 6-letter words*		*7- and 8-letter words*	
	Mean	*(SE)*	*Mean*	*(SE)*
Stable (N = 10)				
Irregular	46·5	(7·4)	40·5	(9·2)
Regular	18·7	(5·1)	39·7	(7·5)
Unstable (N = 10)				
Irregular	64·4	(5·8)	66·4	(6·7)
Regular	44·2	(7·9)	55·9	(7·6)

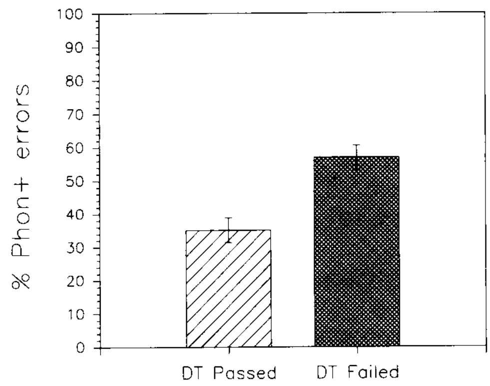

Fig. 1. Percentage of phon+ spelling errors made by children with unstable or stable binocular control. Error bars *represent one standard error.*

the test ($p<0{\cdot}0001$). There was also a significant effect of IQ ($p<0{\cdot}01$).

Figure 1 shows the averaged proportions of phon+ spelling errors made by children with unstable binocular control and the control group. Children with unstable binocular control made a larger proportion of phon+ spelling errors than children with normal binocular vision.

Table VI shows the proportions of phon+ errors made by children with unstable binocular vision and the control group, and is further subdivided according to whether the test words were irregularly or regularly spelled, as well as to whether they were more or less than six letters long.

Discussion

In two previous reports we have shown that poor readers with unstable binocular control may make reading errors for visual reasons (Cornelissen *et al.* 1991, 1992). This was significant because it showed that a visual problem could directly affect reading in some children. In this paper we have extended this work by looking at the relationship between unstable binocular control and spelling in a similar clinically referred population of children.

According to the developmental model outlined above, children whose spelling age is eight years or above on the Schonell test would be expected to make extensive use of visual memories for letter strings when they spell. The spelling ability of the children in this study was 7 years 6 months or higher. Because we matched children with stable or unstable binocular control for spelling age, the two groups made the same number of errors overall. However, we found that the character of the children's spelling errors depended on whether or not their binocular control was stable. Children who failed the Dunlop Test made more phonologically plausible spelling errors than those who passed it, even when age, IQ and phonemic awareness were taken into account. This result supports our hypothesis: that if they experience frequent visual confusion of text, children with unstable binocular control may not form as many stable visual memories for letter strings as children who pass the test. Consequently, they might have restricted access to the kinds of orthographic images of words that could help them to use spelling analogies, or to recall irregular spellings or even the patterns of consistently spelled morphemes. Instead they may have to rely more on direct sound–letter mapping, which was reflected, in this experiment, in the character of the children's spelling errors.

We are not suggesting that poor spellers/readers with unstable binocular control are completely incapable of using visual strategies for spelling. This would imply that their visual confusion of the text is so persistent that they never see what is actually printed on the page. Indeed, if this were so, it would be difficult to imagine how they could learn anything at all about grapheme–phoneme correspondences. What we are proposing is far more subtle: that intermittent visual confusion of text may be sufficient to destabilize the 'visual memory map' sufficiently to make it unreliable. From a connectionist perspective (cf. Adams 1990, Plunkett and Marchman 1991), although isolated examples of irregular sound–letter mappings could still be learned, intermittent visual confusion may prevent a child from discovering efficient, generalized rules which can be applied to a wide variety of situations. Thus the balance between phonological and visual spelling strategies may be shifted in the phonological direction.

It is thought that visual memories for letter strings are particularly useful for spelling words which contain irregular sound–letter mappings. According to our hypothesis, therefore, children who experience visual confusion (*i.e.* who fail the Dunlop Test) ought to have greater difficulty with irregular words than regular ones. Table VI shows the proportions of phon+ errors made by those who passed or failed the Dunlop Test. The data are divided according to whether the test words were spelled irregularly or regularly, as well as whether they were longer (seven- and eight-letter words) or shorter (four-, five- and six-letter words). Table VI shows a trend for children with unstable binocular control to make most phon+ errors on longer irregularly spelled target words, which supports the prediction. The fact that this relationship was not a statistically strong one may partly be explained by the fact that the test words were quite difficult overall; children got more than half of them wrong.

If a spelling error was judged to be less phonologically plausible (phon−), does this mean that it was orthographically closer to its target, as though phonological plausibility and orthographic accuracy lie at opposite ends of the same spectrum? The following examples from our database suggest that this was not necessarily true: AXTENDONTON for ACCIDENT, WEAM for WORN, ENICE for INCH, WISSES for WITNESS, LUCUH for LUNCH, SLAY for SIGH, SLUND for FLOOD and CEAIR for CIRCLE would seem to be just as poor orthographic representations of their targets as they are poor phonological representations. In contrast, the misspellings BISY for BUSY, ROTE for WROTE, HELTH for HEALTH, SOFTLE for SOFTLY, MATEREAL for MATERIAL, ARTEST for ARTIST and BEAWTY for BEAUTY are both orthographically and phonologically close to their respective target. Nevertheless, other examples show that spelling errors can be both phonologically close and orthographically dissimilar to their targets: SIY for SIGH, ROATE for WROTE, SURCUL for CIRCLE, CIRCITY for SOCIETY, JENRL for GENERAL, ACASHON for OCCASION, PHORE for FOUR, SDOREEY for STORY. Accordingly, misspellings could in principle be classified in four ways: (1) phonologically and orthographically close, (2) phonologically and orthographically distant, (3) phonologically close and orthographically distant, and (4) orthographically close and phonologically distant. In this paper, we have concentrated on only the one dimension of phonological plausibility, and not orthographic (dis)similarity. Indeed it is not obvious from a physiological perspective how one might define a 'visual' spelling error. For example 'beml' and 'betn' are misspellings of 'bent'. As far as retinal images of these lower-case letter strings are concerned, 'beml' is topologically closer to 'bent' than is 'betn', yet the latter contains the same letters as 'bent'. Which of the two is 'visually' more similar? Should 'visual' errors account for potential abnormalities with binocular vision, like diplopia? If so, should spelling errors which happen to have more letters than the target be considered as visual?

Finally, we feel we should defend our use of the Dunlop Test, which has been criticized on the grounds that a number of investigators (*e.g.* Bishop *et al.* 1979, Newman *et al.* 1985, Evans 1991) have failed to replicate the original findings of Stein and Fowler (1982). In that and subsequent publications, Stein and colleagues claimed that while two-thirds of dyslexic children failed the Dunlop Test, only 20 per cent of unselected primary-school children of the same age failed it. Thus they suggested that Dunlop Test failure might be a physiological marker for dyslexia. However, in the light of the reported failures to replicate this finding, the Dunlop Test may not be reliable at distinguishing between dyslexic and normal readers.

As far as the present paper is concerned, we did not use the Dunlop Test to discriminate between dyslexic and normal children, but only as a measure of the stability of binocular control: a use which, as far as we are aware, has never been questioned. Therefore, in this paper we asked a simple question which was unrelated to distinctions between dyslexic and normal children: can children's vision affect their spelling? In order to design the experiment, children who passed or failed the Dunlop Test had to be matched for age, spelling ability and IQ, so that they only differed in their performance on the visual task. Since this was the only difference between the two groups, it was then reasonable to suggest that children with unstable binocular control may have made more phonologically plausible spelling errors for visual reasons.

Bishop (1989) also criticized a cross-over intervention study in which Stein and Fowler (1985) gave dyslexic children who failed the Dunlop Test monocular occlusion for six-month periods. Bishop contested Stein and Fowler's claim that monocular occlusion stabilized binocular control, which in turn led to an improvement in reading. Again, though the criticism of the intervention study may be valid, it has no bearing on our use of the Dunlop Test in the current study because we only used the test as a measure of binocular stability, and were not directly concerned with dyslexia or the consequences of any intervention on reading.

In conclusion, the results from this study of clinically referred children show that if they have unstable binocular control at a time when they would normally be expected to be making use of visual memories for letter strings, their spelling errors seem to be more phonologically plausible than those made by a control group with normal binocular vision. This finding extends our previous experiments on the same kind of clinical population, and suggests that unstable binocular control in children like these may affect not only how they read, but also how they spell. It would be interesting to repeat the same kind of experiment with children from a 'normal' school population.

Appendix

Phoneme symbols

Consonants		*Vowels*	
Phoneme	*Example*	*Phoneme*	*Example*
/b/	bob	/aɪ/	pie
/d/	dad	/aʊ/	out
/ʤ/	judge	/æ/	at
/ð/	the	/ɒ/	odd
/f/	faff	/O/	or
/g/	gig	/eɪ/	aid
/ɛ/	etch	/ʌ/	but
/k/	kick	/i/	eel
/l/	lull	/I/	it
/m/	mime	/oʊ/	oat
/n/	nine	/ɔɪ/	oil
/ŋ/	sing	/u/	ooze
/p/	pip	/U/	put
/r/	roar	/ɒ̃/	nasalized /ɒ/
/s/	suss		
/ʃ/	she		
/t/	tot		
/tʃ/	church		
/v/	verve		
/w/	wow		
/z/	zoo		
/ʒ/	measure		
/θ/	thank		

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Authors' Appointments
*Piers Cornelissen;
John Stein;
Physiology Department, Parks Road, Oxford OX1 3PT, UK.
Lynette Bradley, Developmental Psychology Department, South Parks Road, Oxford.
Sue Fowler, Orthoptic Department, Royal Berkshire Hospital, Reading.

**Correspondence to first author.*

SUMMARY
The authors predicted that children who have experienced frequent visual confusion of text during their development because of unstable binocular control may be prevented from discovering the rules and patterns of English orthography. The authors compared the spelling errors made by children who had unstable binocular vision with those of children who had stable binocular vision and the

same spelling ability. The subjects were drawn from a clinical population of children referred because of suspected reading difficulties; though they were of mixed abilities, they were generally poor spellers and readers. Children with unstable binocular control made spelling errors which were more phonologically plausible than those made by the control group with normal binocular vision.

RÉSUMÉ

Ce que voit les enfants altère l'orthographe

Les auteurs prévoyaient que les enfants ayant expérimenté de fréquentes confusions de texte durant leur apprentissage en raison d'un contrôle insuffisant de la stabilité binoculaire, pouvaient être freinés dans la précision des règles et formes orthographiques de l'anglais. Les auteurs ont comparé les fautes phonétiques faites par des enfants avec instabilité de la vision binoculaire, avec la capacité d'enfants ayant une vision stable. Les sujets provenaient d'une population clinique de d'enfants ayant consulté en raison de suspicion de dyslexie: bien que présentant des aptitudes variées, ils présentaient globalement plus de fautes d'orthographe et de lecture. Les enfants avec instabilité de la vision binoculaire font des erreurs plus faciles à expliquer sur un plan de phonétique que celles des enfants du groupe contrôle ayant une vision binoculaire normale.

ZUSAMMENFASSUNG

Was Kinder sehen, beeinflußt ihre Rechtschreibung

Die Autoren haben postuliert, daß Kinder, die in ihrer Entwicklung aufgrund eines gestörten binokulären Sehvermögens häufig visuelle Probleme mit Texten hatten, die Regeln und Schreibweisen der englischen Orthographie möglicherweise nicht erlernen. Die Autoren haben die Schreibfehler von Kindern, die ein gestörtes binokuläres Sehvermögen hatten, mit denen von Kindern mit normalem Sehvermögen und gleichen Rechtschreibkenntnissen verglichen. Die Probanden wurden aus einer Population von Kindern ausgewählt, die mit dem Verdacht einer Leseschwäche überwiesen worden waren: obwohl sie unterschiedliche Fähigkeiten hatten, waren sie in Rechtschreibung und im Lesen generell schlecht. Kinder mit instabilem binokulärem Sehvermögen machten Rechtschreibfehler, die phonologisch einleuchtender waren als die der Kontrollkinder mit normalem binokulären Sehvermögen.

RESUMEN

Lo que los niños ven afecta el deletreo

Los autores predicen que los niños que han sufrido una frecuente confusión visual del texto a seguir durante su desarrollo, debido a un control binocular inestable, pueden tener interferida su capacidad de descubrir las leyes y patrones de la ortografía inglesa. Los autores comparon los errores de deletreo cometidos por niños que tenían una visión binocular inestable, con los de los niños una visión binocular estable y la misma capacidad de deletreo. Los sujetos fueron obtenidos de una población clínica que había consultado por sospecha de dificultades en la lectura. Aunque tenían un nivel medio de habilidades, en general eran unos lectores pobres i eran también pobres deletreadores. Los niños con control binocular inestable cometían errores de deletreo que eran más plausibles fonológicamente, que los cometidos por el grupo control con visión binocular normal.

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