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# The Early Stages of Reading: A Longitudinal Study

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SUMMARY

Forty children were studied as they began to learn to read at 5 years old and as they developed their skill up to 7 years old. At each year they were tested for ability on 44 variables which measured ability in reading, spelling, vocabulary, short-term memory, visual perception and discrimination, auditory–visual integration, language knowledge, phonological awareness, grammatical knowledge, rote knowledge and ordering ability, and performance on the Weschler Intelligence Scale for Children. The data for the whole group of children were analysed in several ways: (1) At each year the patterns of associates of reading skill were determined (with and without control for IQ); (2) the abilities at one point in time which were associated with later reading skill were charted for the whole group, for a subset of children who at 5 years old started with no reading skill, and for another group of children who were progressing rapidly at 7 years old. Cross-lagged correlation comparisons were made to investigate causal paths. These analyses allowed us to chart the course of reading development and the interactive ways in which associated skills such as spelling, reading, phonological awareness and syntactic knowledge grow from each other differentially at different stages of development. The nature of reading skill changes rapidly in the first 3 years of acquisition. In information processing terms it begins as an undifferentiated skill associated with knowledge of the letters of the alphabet, phonological awareness, and visual symbolic short-term memory processes. It then changes in character, being associated with holistic visual pattern recognition skills. By 6 years old phonological awareness and verbal short-term memory processes are by far the strongest associates. By 7 years old the better readers' skills are associated with analytic visual perceptual analysis, the learning of new symbol–sound associations, and sound blending skill. Reading has become a multifaceted ability tapping a wide range of different skills from language comprehension to analysis of the order of elements in a visual array.

Our present knowledge of reading is assembled in reviews of thousands of individual studies of reading (e.g. Gibson and Levin, 1975; Mitchell, 1982; Vellutino, 1979; Vernon, 1971). The preponderance of these studies have been *ex post facto* bivalent designs with little or no attempt to look for differential abilities. They have been performed by different investigators, with children of different cultures, education, age, socioeconomic background and intelligence, and they have involved radically different numbers of subjects. They have taken place over the past 50 years when educational practices have been changing. It is quite possible that the conclusions of the reviews therefore constitute a nomothetic generality which, from a heterogeneous population, reflects none of the individuals studied. Such review efforts may also fail to lead to an understanding of the development of reading. If we want to study development we must do so directly.

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Only when the same persons are tested repeatedly over time does it become possible to identify developmental changes and processes of organization within the individual. Cross-sectional studies which compare different groups of people at different stages of acquisition must always come a poor second when small but reliable changes with age are to be detected, where teaching methods and teachers change with time, and where we do not wish to make the false assumption that the abilities of a younger cross-section were necessarily present in the older cross-section at a previous time (Kessen, 1960; Schaie, 1965). They also fail us with regard to the determination of causality: a cross-sectional study may show an association between two phenomena, but only a longitudinal investigation can determine which came first.

The aim of this study is to chart the first 3 years of reading development in the same children using a differential design (Baron and Treiman, 1980; Chapman and Chapman, 1973). The differential design allows determination not only of which skills are associated with reading, but also of their relative importance. The longitudinal nature of the study allows a meaningful analysis of the changing nature of individual children's reading skill and the determination of which skills promote reading development and which benefit from it. The study began in 1979 and the choice of relevant skills was guided by the then current reading literature.

## METHOD

### Subjects

Forty children were selected from five schools within a 5-mile radius in North Wales. There were 22 girls and 18 boys. They were initially assessed in their first year of school as they reached 5 years of age and were just beginning to show some reading ability. They were seen thereafter at 12-monthly intervals at 6, 7 and 8 years old. As a group the children were of slightly above average intelligence and reading ability. Details of their reading, spelling and intelligence scores at each year can be seen in Table 1 of Ellis and Large (1987).

### Materials and procedure

At 5, 6 and 7 years old the children were individually tested for ability on 44 variables during five sessions which lasted some 30–40 minutes. The 44 variables comprised a variety of measures of reading, spelling, vocabulary, STM, visual skills, auditory–visual integration ability, auditory/language abilities, language knowledge, rote knowledge and ordering ability, and the full WISC. The tests are described in Appendix 1 of Ellis and Large (1987).

### Analyses of data

For each year's set of data the scores for all 40 children on these 44 variables were normalized by conversion to stanines, a nine-point scale with mean 5.0 and SD 1.96 (Guilford and Fruchter, 1978). The child who had performed best on a particular variable would thus be given the score 9, the worst would score 1. This procedure

Table 1. Reading data for the whole group of 40 children at 5, 6 and 7 years old

| | Schonell reading | Reading D&D R. sentence comprehension | Reading D&D A phonically simple words | Reading D&D F phonically complex words | Reading D&D G reversible words | Reading D&D H nonsense words |
|---|---|---|---|---|---|---|
| *5 years old* | | | | | | |
| Raw mean | 3.25 | 8.75 | 2.90 | 3.30 | 1.20 | 0.73 |
| Raw SD | 7.30 | 20.40 | 4.88 | 5.09 | 2.72 | 2.16 |
| Stanine mean | 5.13 | 5.43 | 5.28 | 5.25 | 4.93 | 5.45 |
| Stanine SD | 1.67 | 1.55 | 1.68 | 1.58 | 1.67 | 1.13 |
| *6 years old* | | | | | | |
| Raw mean | 12.60 | 38.53 | 7.98 | 10.53 | 4.70 | 4.58 |
| Raw SD | 12.20 | 44.00 | 6.05 | 6.50 | 4.60 | 4.59 |
| Stanine mean | 5.08 | 5.18 | 4.95 | 5.10 | 5.15 | 5.15 |
| Stanine SD | 1.95 | 1.93 | 1.80 | 2.04 | 2.02 | 1.99 |
| *7 years old* | | | | | | |
| Raw mean | 24.40 | 71.33 | 22.45 | 21.30 | 7.50 | 7.15 |
| Raw SD | 12.40 | 45.90 | 10.10 | 9.49 | 3.33 | 3.96 |
| Stanine mean | 5.08 | 5.13 | 5.15 | 5.03 | 5.18 | 5.13 |
| Stanine SD | 1.98 | 1.91 | 2.02 | 1.98 | 1.82 | 1.88 |

allows the scores for different tests to become comparable, and a child's profile of abilities can thus be produced in the same way as is done on standard attainment tests such as the WISC. It has the additional advantage of ensuring normally distributed scores with equal variances.

Stanine conversion was generally very successful in producing normally distributed scores. It only failed severely with the 5-year-old data for spelling, counting backwards and days backwards where there were large floor effects, and letter recognition at 7 years old where there were ceiling effects. There were some floor effects with the reading tasks at 5 years old. Descriptive statistics for the group's performance on the six tests of reading ability can be seen in Table 1, along with the stanine transformations.

Subsequent analyses will all use Pearson's correlation and partial correlation. These correlations coefficients are affected by the number of subjects in the sample and by the spread of the data (Guilford and Fruchter, 1978). As stanine conversion was generally successful the variables are equated for spread and thus analyses using the same numbers of subjects are directly comparable.

## RESULTS AND DISCUSSION

### Reading development—the changing static pattern

One way to investigate the developmental changes in reading ability is to look for the cognitive skills that are associated with reading at several time samples. In this study we can determine associates of reading ability for the whole group of children as they progress from 5 to 7 years old. For an initial description we will take a comprehensive definition of reading which is ensured content validity: we will look for significant associates of Schonell reading, sentence comprehension reading (Daniels and Dyack (D&D) R), reading phonically simple words (D&D A), reading phonically complex words (D&D F), reading 'reversible' words (D&D G) and reading nonsense words (D&D H) and we will only attribute a skill to be associated with reading ability if it correlates significantly with all of these tests. We are thus ignoring the demand characteristics of different reading tasks and the strategically different blends of skills with which an individual may approach them—this is for later analyses. Here we wish to describe the generalities of reading. Furthermore we will be conservative and control for intelligence.[1]

First-order partial correlations (where full WISC IQ was controlled) were computed between the six measures of reading and all other tests for all 40 children at 5, 6 and 7 years old. The median size of correlation was then calculated for those tests which were significantly associated with all the reading tests. These are shown in decreasing order of magnitude in Table 2.

There are 10 significant associates of reading ability at 5 years old, and by 7 years old over half of the abilities (26/44) are significant associates. It appears that the nature of reading is changing as it develops:

*At 5 years old* the measure of general reading ability is highly correlated with all the individual reading tests. This implies that there are not several different types of reading applied in different reading situations at this age. Rather there seems to be one rather undifferentiated blend of reading ability, a conclusion which validates

Table 2. Partial correlates of all reading tests controlling for IQ (variable must have been significantly correlated with all six reading tests, the measures here then represent the median correlation). Data for all 40 children

| 5 years old | | 6 years old | | 7 years old | |
|---|---|---|---|---|---|
| D&D A (phonically simple) | 79 | D&D reading (comprehension) | 80 | D&D reading (comprehension) | 80 |
| D&D F (phonically complex) | 78 | Schonell reading | 79 | Schonell reading | 78 |
| D&D reading (comprehension) | 77 | D&D F (phonically complex) | 78 | D&D G ('reversible') | 78 |
| Schonell reading | 76 | D&D A (phonically simple) | 75 | Vocab Carver | 78 |
| Vocab Carver spoken/printed | 70 | Vocab Carver spoken/printed | 74 | D&D F (phonically complex) | 74 |
| D&D H ('reversible words') | 62 | **Schonell spelling** | **66** | D&D A (phonically simple) | 73 |
| D&D H (nonsense words) | 62 | D&D H (nonsense words) | 65 | Schonell spelling | 70 |
| Vocab D&D picture/printed | 55 | D&D G ('reversible words') | 63 | **WISC Coding** | **70** |
| Letter recognition | 40 | Vocab D&D picture/printed | 63 | **Letter Search** | **69** |
| Auditory sentence span | 40 | **Phoneme segmentation** | **58** | Vocab D&D picture/printed | 68 |
| | | Letter recognition | 55 | D&D H (nonsense words) | 66 |
| | | **Days backwards** | **52** | Phoneme segmentation | 66 |
| | | **Auditory digit span** | **52** | **Rhyme generation** | **64** |
| | | **Visual serial ordering** | **45** | **Grammatical closure** | **61** |
| | | **Days forwards** | **40** | **Rhyme—odd one out** | **59** |
| | | **Sound–symbol learning** | **40** | Auditory sentence span | 59 |
| | | Auditory sentence span | 40 | Auditory word span | 58 |
| | | **Auditory word span** | **38** | **Colour naming rate** | **56** |
| | | | | **Sound blending** | **56** |
| | | | | Visual serial ordering | 54 |
| | | | | Letter recognition | 53 |
| | | | | Auditory digit span | 51 |
| | | | | **Token test** | **48** |
| | | | | **Visual closure** | **46** |
| | | | | **Syllable segmentation** | **44** |
| | | | | **Symbol–sound learning** | **42** |

Items in bold are new associates of reading—these skills were not associated with reading at the previous age.

the present analysis in terms of one general measure of reading ability. Vocabulary tests which involve the printed word are highly associated with reading but those which do not are not—at this stage of reading development a broad spoken or heard vocabulary is not necessary. The other associates concern verbal STM (auditory sentence span) and knowledge of the alphabet (letter recognition). These are the associated abilities which constitute the seed of basic reading ability.

*At 6 years old* reading has become a more multifaceted ability. Those core abilities from the basic reading ability are still present; but reading has additionally become involved with skills concerning the discrimination, manipulation, and short-term retention of the sounds of our language (phoneme segmentation, auditory digit span, auditory word span). The ability to associate particular sounds with particular symbols is important (sound–symbol learning), as is the short-term retention of the order of visual stimuli (visual serial ordering). Spelling has become an associated skill.

*At 7 years old* all of these abilities are even more associated. The complete range of phonological analysis skills is now represented (phoneme segmentation, syllable segmentation, rhyme generation, rhyme—odd one out, sound blending). There is now a visual theme (visual closure, letter search). Speed of lexical access and articulation for visual stimuli (colour naming rate) is now a correlate of reading and visual verbal association becomes bidirectional with the introduction of symbol–sound learning. The token test completes the set of verbal STM tests, and syntactic knowledge (grammatical closure) is also newly associated.

By 7 years old reading is indeed a blend of numerous skills. It is reassuring that those abilities that were included in the test battery on the basis of a review of the literature of reading associates are replicated as being significant correlations in this study. It is cautionary that the pattern of associations is not constant over time. It is gratifying that the design adopted here allows the description of what skills are associated with reading, in what relative importance, at what stage of development.

The major conclusion to be drawn from these analyses is that *the nature of reading skill changes rapidly in the first 3 years of its acquisition*. It begins as a fairly specific blend of knowledge of the visual characteristics of the letters of the alphabet and short-term working memory processes. Thereafter it develops in association with knowledge of the sounds of the language, the correspondence between sound and visual patterns, skills for the analysis of these visual patterns, syntactic skills . . . any description of reading ability which fails to take these changes into account must be in error.

The next step is to chart this development in detail and to try to understand the processes by which these related abilities partake in reading skill. We need to understand the changing nature of the *process* of reading, rather than merely the patterns of associates. But before we can make any firm theoretical sense of these data we need to clean and cross-check the data. The information in Table 2 is not suitable for fine-grained analysis as it stands. Although the major source of variation is between years, there is still marked variation within years. If, for example, we consider the pattern of reading associates at age 5 it is apparent that it represents a nomothetic blend of the abilities of 40 children who are developing at different rates—some have not yet reached the stage where they can read a single word whilst others already have a substantial sight vocabulary (the most precocious reader managed 36 words on the Schonell and 50 on the Carver). If we want to understand these rapid changes in reading skill then we must break down the data by reading ability rather than chronological age. Furthermore, it would be reassuring if we can demonstrate that the patterns which evolved here are replicable. Further discussion is therefore postponed until these steps have been taken.

**Reading development—the pattern of change**

The analysis of the changing static pattern of reading shows us the changing nature of the associates of reading, but the causal relationships underpinning such associations are indeterminate. For example the association between reading (R) and phonological awareness (PA) may reflect (1) PA being a prerequisite of R, (2) PA being a facilitator of R, (3) PA being a consequence of R, (4) R and PA in symbiotic development, or (5) a spurious correlation between R and PA resulting from their being tied to a common source (see Ehri, 1979, for a discussion of these possibilities). One way of distinguishing between these possibilities is the experimental design of the training study where one of these variables is manipulated experimentally (e.g. Bradley and Bryant, 1983). Another method which gives some discrimination between the alternatives is to study the 'natural experiment' in a collection of longitudinal studies. The present study can be analysed in this fashion. For example, 'nature' manipulates PA before the acquisition of R; if she does so fairly specifically, and variation is not tied to levels of general ability (or such general variation is controlled by taking out IQ as a partial correlate), then we can determine whether those children with high PA ability are those who more rapidly acquire R. In other words we can investigate the starting abilities which predict the initial acquisition of reading. We can similarly determine the abilities which predict the evolution of subsequent reading skill as it changes in character.

This type of analysis thus contributes some information useful in distinguishing between the causal alternatives. In addition it allows us to cross-check the patterns which resulted from the changing–static pattern analyses: totally different statistical tests need be performed (correlations between reading at one time and abilities at a *prior* time) yet the patterns of development and those changing–static descriptions should map onto each other in a meaningful way.

The data in Table 2 indicate that performance on the reading subtests is highly interrelated. Thus it seems reasonable to keep this analysis simple by choosing one prototypic reading ability on which to concentrate, rather than some blend of the six: the Schonell reading test will serve. Letter recognition and phoneme segmentation are highly associated with reading ability, and so we will also describe their developmental precursors.

Table 3 lists the correlations between all abilities tested at 5 years old and reading, phoneme segmentation and letter recognition at 6 years old. The items in bold are those that remain significant as first-order correlations controlling for full WISC IQ at 5 years old. We must remember that these data reflect 1 year's development of ability.

First consider the results for letter recognition. There are a number of 5-year-old abilities which predict this skill at 6: all of the reading tests, phonological abilities

Table 3. Year 5 abilities which predict (zero-order correlations) at year 6:

| Schonell reading | | Phoneme segmentation | | Letter recognition | |
|---|---|---|---|---|---|
| **D&D reading (comprehension)** | **.8** | **Vocab Carver spoken/printed** | **.69** | **Vocab Carver spoken/printed** | **.64** |
| **Schonell reading** | .77 | **Letter recognition** | **.66** | **Letter recognition** | **.63** |
| **Vocab Carver spoken/printed** | .76 | **D&D reading (comprehension)** | **.61** | **D&D F (phonically complex)** | **.52** |
| **D&D F (phonically complex)** | .76 | **Vocab D&D picture/printed** | **.58** | **Schonell reading** | **.51** |
| **D&D A (phonically simple)** | .72 | **Schonell reading** | **.55** | **Vocab D&D picture/printed** | **.48** |
| **Vocab D&D picture/printed** | .65 | **D&D F (phonically complex)** | **.55** | **Sound blending** | **.47** |
| **Letter recognition** | .63 | **D&D A (phonically simple)** | **.47** | **WISC information** | **.45** |
| **D&D H (nonsense words)** | .62 | **Visual digit span** | **.46** | **D&D Reading (comprehension)** | **.45** |
| **D&D G ('reversible words')** | .56 | **WISC similarities** | **.45** | **D&D A (phonically simple)** | **.44** |
| **Colour naming rate** | .56 | **Colour naming rate** | **.43** | **Counting backwards** | **.42** |
| **WISC information** | .56 | Token test | .4 | Visual digit span | .4 |
| **WISC picture arrangement** | .55 | Sound blending | .39 | D&D G ('reversible words') | .4 |
| **Token test** | .53 | Visual serial ordering | .38 | **Colour naming rate** | **.38** |
| **Visual digit span** | .53 | D&D H (nonsense words) | .37 | WISC arithmetic | .37 |
| **Auditory sentence span** | .5 | D&D G ('reversible words') | .37 | Visual serial ordering | .36 |
| **Letter search** | .5 | Auditory sentence span | .37 | **D&D H (nonsense words)** | **.35** |
| Visual serial ordering | .47 | Auditory word span | .37 | Syllable segmentation | .33 |
| WISC arithmetic | .45 | Letter search | .37 | **Days backwards** | **.33** |
| **Syllable segmentation** | **.45** | **Counting backwards** | **.37** | Full WISC at 5 | .32 |
| Full WISC at 5 | .44 | WISC picture arrangement | .36 | WISC picture arrangement | .32 |
| WISC coding | .44 | WISC comprehension | .36 | Token test | .32 |
| Visual digit span & AS | .42 | WISC information | .35 | | |
| Picture completion WISC | .4 | Visual digit span & AS | .34 | | |
| Phoneme segmentation | .39 | **Days backwards** | **.34** | | |
| Vocab Peabody spoken/picture | .38 | **Days forwards** | **.33** | | |
| Sound blending | .38 | Full WISC at 5 | .32 | | |
| WISC similarities | .37 | Auditory word span | .32 | | |
| Grammatical closure | .36 | | | | |
| WISC block design | .36 | | | | |
| Auditory word span | .34 | | | | |
| Rhyme—odd one out | .33 | | | | |

Complete group of 40 children (items in bold remain significant as first-order correlations controlling for Full WISC IQ at 5 years old) such as sound blending and syllable segmentation, and diverse skills such as visual digit span, colour naming rate, counting backwards, visual serial ordering and WISC arithmetic. At first sight there is no clear and simple interpretation of these data. On further consideration these associations emphasize the fallacy of *post hoc ergo propter hoc* which threatens the interpretation of these (and all other) prediction data. Reading ability may well predict later letter recognition skills, but this does not imply causation—rather in this instance letter recognition may well have been a necessary skill for reading to develop at a prior stage and, because both of these abilities had developed to some extent in the group at 5 years old, each will predict the other at 6. This can indeed be seen to be the case in Table 3. However, the fact that letter recognition is a better predictor of reading ability than reading is of letter recognition suggests that letter recognition contributes more to the development of reading than vice-versa.

We must beware such traps of interpretation in the remainder of this section, and, as above, we will use one simple rule of thumb to guide us: in cross lagged correlational analysis, if $x$ causes $y$ rather than vice-versa, the correlation of $x_1$ with $y_2$ will be much bigger than that between $x_2$ with $y_1$. There are several problems with this principle (see Kenny, 1982) but it will serve as a rough check. Although 40 is a large number of individuals to follow through in such detail over 4 years, we have as many variables as subjects, and thus it is far too few to permit more powerful and sophisticated analysis techniques.

Another way of cleaning the picture is to pull out those children who had no reading ability at 5 years old and consider their development. We have therefore extracted two subgroups of children at age 5: eight individuals who showed no measurable reading ability on any of the tests at age 5, and 14 children with Schonell Reading scores at 5. The 5 to 6 year prediction data for these two subgroups are shown in Tables 4 and 5 respectively.

In Table 4 we have a clearer picture of early stages of the acquisition of letter recognition skills—the predictors are phonological skills such as phoneme and syllable segmentation, sound blending and, of course, the part–whole relationship where previous skills in letter recognition predict later levels. Since these phonological skills predict letter recognition, but the reverse is not the case, we can conclude that phonological awareness facilitates the acquisition of letter recognition.

We can use the data in tables 3–5 to chart the development of reading from 5 to 6 years old in the same way as we have done for letter recognition. *In the group who start with no reading ability as such* (Table 4) we again see that the important predictors of later reading skill concern phonological awareness (phoneme segmentation, syllable segmentation and sound blending), knowledge of the alphabet (letter recognition), and short-term memory for visual symbols which have sound equivalents (visual digit span, but not visual serial ordering for nonsense patterns or auditory STM spans). It is a relatively small set of significant predictors but we must remember that we are here dealing with only a few subjects.

*In the group who started with some reading ability at age 5* (Table 5) there is a rather different pattern of the next year's reading development. Reading ability has become a skill in its own right and reading at 5 is the best predictor of reading at 6 (D&D R, F, A, H, G, Schonell reading, Carver vocabulary). Thereafter, although some phonological awareness skills predict (syllable and phoneme segmentation),

Table 4. Eight children with no measurable reading on any of the tests at 5 years old. Year 5 abilities which predict (zero-order correlations) at year 6:

| Schonell reading | | Phoneme segmentation | | Letter recognition | |
|---|---|---|---|---|---|
| **Phoneme segmentation** | **85** | Auditory digit span | 68 | **Phoneme segmentation** | **78** |
| **Visual digit span** | **82** | Syllable segmentation | 66 | Sound blending | 65 |
| **Syllable segmentation** | **80** | Phoneme segmentation | 62 | Letter recognition | 65 |
| **Sound blending** | **72** | (Sound blending—just n.s. | 56) | WISC information | 63 |
| Letter recognition | 69 | | | Syllable segmentation | 60 |
| Visual digit span & AS | 65 | | | | |
| Grammatical closure | 62 | | | | |

Items in bold remain significant as first-order correlations controlling for full WISC IQ at 5 years old: this is a very stringent test with only 5 d.f. due to low *n*.

Table 5. Fourteen children with measurable Schonell Reading at 5 years old. Year 5 abilities which predict (zero-order correlations) at year 6:

| Schonell reading | | Phoneme segmentation | | Letter recognition | |
|---|---|---|---|---|---|
| **Reading D&D R comprehension** | **94** | **Letter recognition** | **56** | **Reading D&D F phonically complex** | **58** |
| **Carver vocabulary** | **87** | WISC block design | 51 | **Reading D&D G 'reversible words'** | **49** |
| **Letter search** | **77** | Symbol–sound learning | 50 | | |
| **D&D vocabulary** | **77** | Syllable segmentation | 49 | Ceiling effects—these children know | |
| **Schonell reading** | **77** | **Auditory word span** | **47** | their letters by 6 years old. | |
| **Reading D&D F phonically complex** | **70** | | | | |
| **Reading D&D A phonically simple** | **68** | | | | |
| **Reading D&D H nonsense words** | **66** | | | | |
| **WISC coding** | **66** | | | | |
| **WISC block design** | **65** | | | | |
| Visual closure | 64 | | | | |
| Visual digit span | 59 | | | | |
| Visual digit span & AS | 59 | | | | |
| **Colour naming rate** | **59** | | | | |
| Token test | 54 | | | | |
| **Syllable segmentation** | **53** | | | | |
| Auditory sentence span | 52 | | | | |
| WISC vocabulary | 51 | | | | |
| Reading D&D G reversible | 47 | | | | |
| Phoneme segmentation | 46 | | | | |
| (Picture completion WISC 72 only as first-order correlation) | | | | | |

(Items in bold remain significant as first-order correlations controlling for full WISC IQ at 5 years old.)

they do so less than in Table 4, and the major remaining set of predictors seem to involve visual pattern recognition (letter search, visual closure, WISC block design, visual digit span and articulatory suppression (AS), WISC picture completion). It is again the case that these skills are better predictors of reading at 6 than vice-versa. There are other significant predictors which involve the matching of visual symbols and other nameable ones (WISC coding), and the rate of access of lexical equivalents for visually presented material (colour naming rate). It seems that this secondary stage of reading acquisition emphasizes the visual charactersitics of words and grows from related visual analysis skills.

The reading data for the whole group in Table 3 can thus be seen to be a blend of these two initial stages of reading acquisition merged as a result of taking chronological years as units of development rather than stages of reading. However muddy, it serves as a useful baseline against which the development from 6 to 7 (Table 6) can be compared.

Table 6 does not include data for letter recognition because of ceiling effects. *The pattern of predictors of reading from 6 to 7* is somewhat different from that from 5 to 6. The phonological awareness and processing tasks are now strong predictors (phoneme and syllable segmentation, rhyming tasks) and auditory–verbal STM tasks (auditory digit, word and sentence spans, token test) have become very good predictors, much better than the visual STM tasks which were effective before. The learning of the sound equivalents for symbols has for the first time become important (even though the majority of children already know their letters, and speed of access of lexical entries for visual stimuli is again an important predictor. The visual analysis tasks that were strong predictors in Table 4 (visual digit span +and-AS, WISC block design) are present but to a much lesser degree, visual closure, which involves patterns as a whole, has dropped out. WISC information and comprehension and grammatical closure and knowledge of syntax are all predictors before full IQ is partialled out.

We can also see that here, as in Table 3, the prediction of phoneme segmentation ability at 7 from reading at 6 is stronger than the prediction of reading by earlier phoneme segmentation skill, and this emphasizes the symbiotic development of these skills where both develop from each other; in Table 4 it is reading that appears to be developing from phonemic categorization skill.

Several investigators have suggested that the mature reader operates by means of an orthographic strategy where the word is segmented into letter-by-letter units, with direct lexical access based on the resultant abstract orthographic description rather than phonologically mediated lexical access (e.g. Allport, 1979; Morton's 1979 logogen model; Kolers, 1970; and, for the reading of deep dyslexics, Patterson, 1981) and this prompts us to ask whether the later stages of reading acquisition in our study show these changes. We have thus extracted the 10 children who were *the best readers at 6 years old and analysed their abilities at 6 which predicted reading at 7*. These data are shown in Table 7.

There are many fewer significant predictors than for the whole group in Table 6, and this reflects the four-fold reduction in group size. There is in addition a difference in emphasis. It is not the case that phonological skills have disappeared, but the phonological skills that are predictors for these superior readers are a different set. Phoneme and syllable segmentation have dropped out: the knowledge of the sounds of the language and the ability to segment continuous speech into

Table 6. Complete group of 40 children. Year 6 abilities which predict (zero-order correlatios) at year 7:

| Schonell reading | | Phoneme segmentation | |
|---|---|---|---|
| **D&D F (phonically complex)** | **.83** | **Phoneme segmentation** | **.88** |
| **Vocab Carver spoken/printed** | **.81** | **D&D F (phonically complex)** | **.8** |
| **Schonell reading** | **.79** | **Syllable segmentation** | **.8** |
| **D&D A (phonically simple)** | **.79** | **Vocab Carver spoken/printed** | **.79** |
| **Vocab D&D picture/printed** | **.77** | **Vocab D&D picture/printed** | **.75** |
| **D&D G ('reversible words')** | **.76** | **Schonell reading** | **.75** |
| **D&D Reading (comprehension)** | **.74** | **D&D G ('reversible words')** | **.73** |
| **Schonell spelling** | **.72** | **Letter recognition** | **.71** |
| **Rhyme generation** | **.7** | **D&D reading (comprehension)** | **.7** |
| **D&D H (nonsense words)** | **.69** | **Schonell spelling** | **.7** |
| **Letter recognition** | **.68** | **D&D A (phonically simple)** | **.69** |
| **Auditory digit span** | **.64** | **Rhyme generation** | **.68** |
| **Phoneme segmentation** | **.64** | **Visual serial ordering** | **.67** |
| Full WISC at 6 | .63 | **Token test** | **.66** |
| WISC information | .63 | **D&D H (nonsense words)** | **.65** |
| **Syllable segmentation** | **.61** | **Auditory digit span** | **.61** |
| **Auditory sentence span** | **.61** | Full WISC at 6 | .61 |
| WISC picture arrangement | .58 | Auditory sentence span | .56 |
| Knowledge of syntax | .58 | **Days backwards** | **.55** |
| **Sound–symbol learning** | **.57** | WISC similarities | .55 |
| Token test | .54 | Grammatical closure | .54 |
| Grammatical closure | .54 | **Rhyme—odd one out** | **.53** |
| **Days backwards** | **.54** | Knowledge of syntax | .49 |
| WISC coding | .53 | Sound blending | .49 |
| WISC similarities | .53 | **Colour naming rate** | **.48** |
| Rhyme—odd one out | .5 | Days forwards | .48 |
| **Auditory word span** | **.48** | **Symbol–sound learning** | **.48** |
| **Colour naming rate** | **.48** | Letter search | .47 |
| **Symbol–sound learning** | **.48** | Sound–symbol learning | .47 |
| Sound blending | .47 | **Auditory word span** | **.46** |
| Letter search | .47 | WISC coding | .43 |
| Visual digit span | .44 | Vocab WISC spoken/spoken | .42 |
| Days forwards | .43 | Visual digit span | .42 |
| Vocab WISC spoken/spoken | .42 | Picture completion WISC | .42 |
| Visual digit span & AS | .42 | WISC arithmetic | .41 |
| WISC block design | .37 | WISC picture arrangement | .41 |
| WISC comprehension | .35 | WISC comprehension | .4 |
| Picture completion WISC | .33 | Visual closure | .33 |
| Vocab Peabody spoken/picture | .33 | | |

(Items in bold remain significant as first-order correlations controlling for Full WISC IQ at 6 years old).

phonemic segments is no longer limiting reading development—it appears that these children have acquired sufficient knowledge in these respects. Yet for these children who already know their letters and their sounds sound–symbol and symbol–sound learning are strong predictors of reading, as are sound blending skill and verbal short-term memory (auditory digit and sentence spans) which may be serving as the working memory system for sound manipulation and blending. The same set of skills predict phoneme segmentation ability at 7. This suggests that there is still a strong element of phonological mediation in these children's reading,

Table 7. Group of 10 superior readers at age 6. Year 6 abilities which predict (zero order-correlations) at year 7:

| Schonell reading | | Phoneme segmentation | |
|---|---|---|---|
| **D&D F phonically complex** | **81** | **Phoneme segmentation** | **92** |
| **Sound–symbol learning** | **73** | **Symbol–sound learning** | **68** |
| WISC similarities | 67 | **Auditory word span** | **65** |
| Symbol–sound learning | 65 | Visual serial ordering | 63 |
| Schonell reading | 64 | Sound blending | 63 |
| Visual serial ordering | 64 | Syllable segmentation | 58 |
| D&D R sentence comprehension | 63 | Sound–symbol learning | 57 |
| Auditory sentence span | 62 | | |
| Sound blending | 63 | | |
| Full WISC IQ at 6 | 59 | | |
| Auditory digit span | 58 | | |
| **Vocab Carver** | **58** | | |
| D&D G 'reversible words' | 56 | | |

(Items in bold remain significant as first-order correlations for Full WISC IQ at 6 years old)

but that the units are not the individual letters. It seems likely that the new symbol–sound correspondences that they are learning, and which facilitate their reading, involve larger units—sequences of letters. We cannot tell from these data whether these letter groups are small letter groups, syllables, morphemes or whole words.

Visual serial ordering is a significant predictor in these superior readers. VSO involves the analysis of the order of component symbols in an array; these symbols must be processed according to their visual characteristics since they have no ready name equivalents. It is an analytic visual perception task which emphasizes the order of component items rather than a holistic one. This systematic, analytic visual perception skill with its emphasis on the order of components may be involved in their reading in a number of ways. It must be necessary in phonologically mediated grapheme by grapheme reading and the pattern of other predictors certainly suggests that the better readers' reading skill includes these decoding strategies. But this analytic visual decoding skill must also be essential to orthographic reading which is not mediated by analysis of phonological segments and blending. We must therefore see whether the other significant predictors in Table 7 lend any support to the idea that these children are acquiring orthographic reading strategies. In Table 7 it is the reading tests which involve phonologically irregular words rather than phonologically regular or nonsense words which are the significant predictors of later reading skill in these superior readers. These are the words which cannot be successfully decoded by simple grapheme–phoneme correspondence rules. Successful reading of these words must operate in bigger units than letters, and cannot be phonologically mediated in the same low-level way as for nonsense words. Thus the pattern of predictors in Table 7 is at least consistent with the notion that the superior 7-year-old readers are entering a stage of orthographic reading.

## GENERAL DISCUSSION

If we compare the two types of analysis, the pattern of change and the changing–static pattern we can see that in general each endorses the other. However, the pattern of change is more useful since it is cleaner data resultant from more homogeneous groups, and it allows us to chart the developmental process. The analyses have implicated several skills as associates of reading ability, and we must now consider how they might contribute to the process of reading. The present study has only gathered longitudinal individual differences data concerning skills associated with reading; it is not a detailed process analysis of reading *per se*. We have concentrated on this type of data because we are convinced that reading does not develop in isolation; in its acquisition it is not a separable module, but rather it grows from a number of different tributaries of skill. Here we have charted the development of this reading delta. But reading process data is needed to make sense of these changing patterns of associated skill, and we take these from the literature. We believe that the changing pattern of associated abilities is consistent with the changing strategies of reading which Marsh, Friedman, Welch and Desberg (1981), and Frith (1985), have described from their analyses of the beginning readers' process and errors.

**Letter recognition**

At kindergarten is typically a strong predictor of reading 1 year later (DeHirsch, Jansky and Langford, 1966; Stevenson, Parker, Wilkinson, Hegion and Fish, 1976; Bruininks and Mayer, 1979). There seems little mystery why this should be so for those who are to learn to deal with an alphabetic script—these are the building blocks from which all words are made, and so it is essential to learn to recognize them. But in addition it seems quite likely that the strong predictive value of letter recognition skill reflects more than a mastery of a low-level component. It is the norm, if not the rule, that the best predictor of a particular skill in a year's time is ability now (Bloom, 1964)—this is the part–whole relationship. Letter recognition is the ubiquitous entry point to the acquisition of reading, and those who have taken this step are henceforth apprentice readers—they are committed to learn just as others are to teach. The predictive power of letter recognition may well reflect this initiation to literacy as much as its being a subcomponent skill. Within a year or two letter recognition is no longer a useful predictor of reading skill. The letters have all been learned and other skills become limiting.

**Phonemic awareness**

Has long been implicated in reading acquisition (see Ehri, 1979; Liberman and Shankweiler, 1979; Rozin and Gleitman, 1977; Valtin, 1984, for reviews). Syllable segmentation is easier than phonemic segmentation because in continuous speech the phonemes are not discrete units but are encoded at the acoustic level into larger units of approximately syllabic size. Phonemes are abstract units and thus the acquisition of phonemic analysis and manipulation skills is a highly demanding conceptual task (Ehri, 1979; Helfgott, 1976). Yet they are skills which must be acquired if the child is to capitalize on the (flawed) alphabetic nature of our written language and use grapheme–phoneme conversion rules to decode new words: no knowledge of phonemes entails no reason nor basis for grapheme–phoneme rules (Treiman and Baron, 1981). The child must learn that '*orthographic units correspond to highly abstract and inaccessible phonological segments*' (Gleitman and Rozin, 1973). The greatest increase in phonemic segmentation abilities occurs between kindergarten and first grade (Liberman, Shankweiler, Fischer and Carter, 1974; Rosner and Simon, 1971).

It seems likely that phonological awareness and reading ability develop in symbiotic relationship. Both Ehri (1979) and Valtin (1984) stress that phonological awareness is only of real value to the child when she is confronted with the need to read from a particular alphabetic system, and they thus stress how reading plays an active part in the acquisition of a comprehensive phonemic classification system. However, the training studies of Bradley and Bryant (1983), Fox and Routh (1976) and Goldstein (1976) have demonstrated that training children in phonemic segmentation skills can facilitate reading acquisition. In the present study we also see that phonological awareness is both a contributor to and a consequence of learning to read: phonological awareness facilitates letter recognition and early reading acquisition (Table 4), it grows from reading skill at later stages (Table 6).

The successful Phoenician reader (Treiman and Baron, 1981) who reads by decoding using spelling–sound rules must be able to generate the appropriate phonemes. But in addition he or she must be able to blend sounds to produce words (Venezky, 1974). The child may well know that an attempt should be made to produce a sound for each letter and then articulate the sounds in rapid succession. But it is impossible to produce single phonemes without embedding them in syllables containing other phonemes. So the child needs to learn how to abstract the critical part from each syllabic segment, that part associated with the printed letter, and to blend just these abstract sounds. And pronunciation cannot proceed letter-by-letter, but must weave together strands larger than a letter, sometimes extending across syllables, before the correct sound can be produced (Ehri, 1979). There are stages of reading acquisition where this ability is far more limiting than being able to identify the phonemes—in the present study (Table 7) the superior readers' ability at 7 years old was not predicted by phoneme segmentation ability, rather it was the learning of sound–symbol correspondences and sound blending skill which seemed to determine their reading development.

**Visual pattern analysis skills**

Have been implicated in reading (e.g. Benton, 1962; Ingram, 1971; Lyle and Goyen, 1975; Stanley and Hall, 1973) but these findings have been later discounted (Ellis and Miles, 1981; Vellutino, 1979; Stanovich, 1982a,b). The vast majority of studies have failed to find a relationship between visual information processing ability and reading skill (Stanovich, 1982a,b), and those studies that have suggested such a relationship have typically failed to isolate a specific visual processing operation since their criterion tasks have been contaminated with speech recoding (Vellutino, 1979). The general conclusion is that good and poor readers do not differ in basic visual information processing skills. However, in the present study where we look at the pattern of associated abilities at different stages of reading acquisition, there does seem to be evidence for transfer from particular visual processing skills to reading at particular stages of development.

At the beginning of reading acquisition (Table 4) visual digit span and AS predict later reading skill. Visual digit span of course fails as a clean (Calfee, 1977) test of visual pattern recognition since it involves symbolic material, it requires a verbal response, and it may thus be performed using strategies which place demands on verbal STM (although this seems more likely to be the case with older rather than *younger* children—see later section on STM). However, if we consider the whole group of children (Table 3) we do find a number of abilities present at 5 years old which are significant predictors of reading ability at 6 and which are fairly pure visual tasks—WISC block design and picture completion, visual serial ordering, WISC coding (though some of the symbols to be matched in this task are nameable as 'star' or 'cross', etc.—see Miles and Ellis, 1981). It appears that these associates are characteristic of those children progressing through the second stage of reading acquisition (Tabel 5) where we also see visual closure as a strong and significant predictor, but they are not characteristic of those children who have not yet started (Table 3). Whilst these visual abilities still predict reading at 7 years old, they do so to a lesser degree and there are at this stage many other abilities which outrank them in importance. At the top levels of reading ability in our study, the 10 superior readers as they progress from 6 to 7 years old, we find that the only visual task which serves as a significant predictor is visual serial ordering.

It appears that there are visual skills that determine reading ability to some degree, but their determining influence is fleeting. Holistic visual analysis skills (visual closure, WISC picture completion and block design) are associated in the second stage of reading acquisition where children have learned their letters, but before there is a marked phonological style to reading skill. This does seem to make sense in this population of children. At this point in their development their teachers were concerned with 'look and say' methods of instruction to help the children build up a small working sight vocabulary—the children are being directed to deal with the words as visual patterns. This strategy has been termed '*logographic*' by Frith (1985), the instant recognition of familiar words where salient graphic cues may act as important cues, but letter order is largely ignored and phonological factors are entirely secondary. Such a developmental progression is quite common (see e.g. Torrey, 1979). It appears from the present study that the children who had superior visual discrimination and perceptual skills did progress better through this logographic stage of reading. This should come as no surprise—just as the comprehension elements of reading build on those systems responsible for the analysis of the meaning of heard language (Perfetti and Lesgold, 1979), so the visual analysis task demands on reading capitalize on those generalized systems which have evolved to perform visual perception.

Frith (1985) suggests that in logographic reading strategies there is little attention paid to the order of constituent elements (letters) and the present data are at least consistent with this idea: although the holistic visual analysis skills were predictors of reading development at this stage, visual serial ordering, which emphasizes the order of constituent elements in a visual array, was not a significant predictor. VSO does become an important predictor at the end of our study, however, where the superior readers were progressing in reading ability from 6 to 7 years old. For these children the analysis of the order of elements in visual arrays becomes an important component of their reading skill, yet the holistic visual analysis has waned in importance. We also see in the whole group of readers at 7 years old that the speed of detection of the visual features (letter search) becomes an important associate (Table 2).

### Visual–verbal cross-modal mapping

Reading aloud involves the retrieval of the phonological equivalents of written symbols. This can be performed either by whole-word lexical access and lexical retrieval of pronunciation (Morton, 1969; Kolers, 1970), application of grapheme–

phoneme rules (Venezky, 1970), or pronunciation by analogy with that of words or word segments which share orthographic features with the to-be-named word (Marcel, 1979; Glushko, 1979). In the lexical route the effective units for accessing pronunciation are whole words or morphemes, in the grapheme–phoneme route they are letters or letter groups, in the analogy route they are again sublexical—letters or word segments. Reading new words, either aloud or tacitly, must involve one of the latter two processes since with new words there are no corresponding visual lexical entries (or logogen units). And so, when the child is building up her reading vocabulary, the ability to pronounce new words is probably the most important and relevant set of skills to apply.

But grapheme–phoneme rules for English are not invariant; there are many more than 26 correspondences. Venezky (1970) demonstrates that more than 60 identifiable spelling patterns (like *a*, *b*, *ai*, *gh*, *eau*, etc.) require 100–200 rules, few of which are invariant (e.g. *f*→ /f/). In most cases the spelling units can be pronounced in several ways, and the grapheme–phoneme rules specify the contextual conditions under which a particular pronunciation applies (e.g. (1) *c* followed by *i*, *y*, or *e*→/s/ (as in circus, ceiling); else, in most other cases, *c*→/k/; e.g. (2) *k* corresponds to zero in initial position before *n* (as in *knee*, *know*, etc.); in all other positions *k* corresponds to /k/). These complex and specific rules are acquired gradually and different rules are acquired at different stages of reading (Calfee, Venezky and Champman, 1969; Venezky and Johnson, 1973). Perhaps this ability to learn symbol–sound rules limits the development of reading.

There is certainly an association between reading ability and ability to learn sound–symbol correspondences (Birch and Belmont, 1965; Done and Miles, 1978; Venezky and Johnson, 1973), but correlational studies such as these leave causality indeterminate and it is quite likely that those progressing in reading are concomitantly picking up these associations (indeed this notion is implicit in theories of analogical pronunication—the more lexical entries, the more analogues). Training studies (Bishop, 1964; Jeffrey and Samuels, 1967) have shown that detailed training on specific grapheme–phoneme correspondences does improve ability in reading new words. But there is no reason to suppose that these skills are naturally used in all types of reading at all ages. We can analyse their involvement in the reading of our 5–7 year olds in this study, and use cross-lagged correlational analyses again to investigate causal paths. The relevant tests were sound–symbol and symbol–sound learning.

Ability to learn new sound–symbol correspondences does not seem to be associated with the early stages of reading ability at age 5 (Tables 2–5). There is some association at 6 years old and more at 7 (Table 2). Reading ability at 7 years old is clearly predicted by sound–symbol and symbol–sound learning at age 6 (Table 6: 0.57 and 0.48 respectively) and in the superior readers at age 7 both sound–symbol and symbol–sound are the abilities at age 6 which best predict reading at 7 (Table 7: 0.73 and 0.65 respectively)—they are better predictors than reading itself. It appears that symbol–sound correspondence learning is not a particularly strong feature of early reading, but later stages of reading ability are heavily associated with this skill. However, we cannot tell from these data whether these skills of the superior readers reflect grapheme, syllable, morpheme, or even whole-word to sound correspondences, although it seems likely that all levels of symbol–sound correspondences are involved—the fact that the reading of phonically complex words (like *who*) is the best 6–7 predictor in the superior readers suggests whole-word analysis, since the grapheme–phoneme correspondence rule for this type of very particular irregularity demands remembering the instances (*wh* in *who*, *whore*, *whole* corresponds to {h}, elsewhere *wh* corresponds to {hw-}. Venezky, 1970: 88). It is tempting to interpret the predictive power of WISC Similarities (In what way are . . . and . . alike?) at age 6 to reading at age 7 in the superior readers (Table 7: 0.67) as reflecting the sorts of classification and recognition procedures that are involved in analogic pronunciation strategies.

Cross-lagged correlational comparisons allow us some insight into the causal paths of the development of these skills and the picture that emerges is again one of interaction. Neither sound–symbol nor symbol–sound learning at 5 significantly predicts reading at 6 for the whole group (0.27, 0.13), but reading ability at 5 does predict these abilities at age 6 (0.47, 0.35 respectively)—skill in naming derives from reading acquisition. From 6 to 7 years old, however, sound–symbol learning predicts later reading as much as the reverse (0.57, 0.58), although reading is a better predictor of later symbol–sound learning (0.73) than the reverse (0.48). In the light of these findings it would be perverse to suggest a unidirectional causation whereby progress in one set of abilities causes the development of the other but not the reverse—they are mutually interdependent since each skill is involved in, and makes relevant, the other.

**STM**

Reading ability is typically related to short-term memory span. In adults memory span is roughly equivalent to the number of words that can be read in 1.5 seconds (Baddeley, Thomson and Buchanan, 1975). One of the most striking features of dyslexic children (who have reading problems) is their impaired digit span (Naidoo, 1972; Ellis, 1981; Vellutino, 1979). Why are these skills related?

There are a number of possible roles for a short-term working memory system in reading (see Jorm, 1983; Baddeley, 1978; and Carr, 1981, for reviews). There is evidence to suggest a component of short-term memory, the articulatory loop, which stores a small amount of verbal information in a phonological code and which is under control of the other component, the central executive (Baddeley and Hitch 1974, 1977). Baddeley (1978) has suggested that the articulatory loop may serve as the working storage system used in the decoding of unfamiliar words using the 'word-attack' skills of applying grapheme–phoneme conversion rules and sound blending. In this view both poor reading and limited short-term memory may reflect a deficiency in phonological processing (Shankweiler, Liberman, Mark, Fowler and Fischer, 1979). A second potential role of short-term memory in reading concerns the comprehension of sentences. Kleiman (1975) suggests that in order to extract the meaning of a phrase the reader must have stored information about previously identified words in order to relate this to the words currently being identified, and the phonological component of working memory may well serve for this storage (see Slowiaczek and Clifton, 1980; Baddeley, 1978; and Levy, 1977, 1978, for tests of this possibility in adults). Perfetti and Lesgold (1977) showed that retarded readers are poorer at retaining the wording of clauses that have just been read, and this, in conjunction with Guthrie's (1973) finding that older retarded readers comprehend less than younger normal readers who are matched in ability to read single words, is consistent for a role of short-term working memory in sentence comprehension in young children.

These suggestions make plausible the association between short-term memory and reading ability, but the causal relations are indeterminate. It cannot be concluded that the memory deficit is a cause of reading retardation since STM deficit may be an effect of reading failure resultant from retarded readers having had less practice in certain cognitive skills connected with reading (Deutsch, 1978). It is also possible that there is a third factor producing both memory deficit and reading failure. Both Morrison (1978) and Jorm (1983) advocate longitudinal studies which test pre-reading children's congitive skills and relate this to their subsequent reading performance in order to tease out these causal relations. It is exactly this design which is used in the present study, and we can thus investigate the development of the association between STM ability and reading skill. In Table 8 we show the predictive correlations between the range of STM abilities tested in this study and Schonell Reading ability 1 year later. The reverse predictions are shown for comparison.

The only STM ability at 5 years old which markedly better predicts reading at 6 than the reverse is visual digit span. The cross-lagged correlations between reading and visual digit span and AS, auditory word span, auditory sentence span, and token test are roughly similar in both directions. Reading at 5 is a better predictor of auditory digit span at 6 than vice-versa. These findings suggest that at these stages visual STM span tasks are tapping essentially different abilities from auditory STM tests, and this is consistent with Keeney, Cannizzo and Flavell (1967) and Conrad (1972), who suggest that 4–6-year-old children use a visuospatial scratch–pad for remembering visually presented nameable material, whereas older children name the material and use articulatory rehearsal. Furthermore, in these early stages of reading acquisition, it is the visual STM tasks that predict later reading ability, not the auditory ones. This indicates that these early stages of reading are essentially visual in nature, building on these visual STM skills (see 'Visual pattern

Table 8. Cross-lagged prediction correlations between reading and the various short-term memory tests

| Prediction 5-year-old → 6-year-old | | Prediction 6-year-old → 7-year-old | |
|---|---|---|---|
| Reading → Visual digit span | 37 | Reading → Visual digit span | 62 |
| Visual digit span → Reading | 53 | Visual digit span → Reading | 44 |
| Reading → Visual digit span & AS | 45 | Reading → Visual digit span & AS | 46 |
| Visual digit span & AS → Reading | 42 | Visual digit span & AS → Reading | 42 |
| Reading → Auditory digit span | 68 | Reading → Auditory digit span | 59 |
| Auditory digit span → Reading | 31 | Auditory digit span → Reading | 64 |
| Reading → Auditory word span | 26 | Reading → Auditory word span | 75 |
| Auditory word span → Reading | 34 | Auditory word span → Reading | 48 |
| Reading → Auditory sentence span | 45 | Reading → Auditory sentence span | 70 |
| Auditory sentence span → Reading | 50 | Auditory sentence span → Reading | 61 |
| Reading → Token test | 60 | Reading → Token test | 80 |
| Token test → Reading | 53 | Token test → Reading | 54 |

analysis skills', above). Although reading and auditory STM are associated in these early stages, they seem to be developing in unison and with mutual benefit.

The patterns of prediction from 6 to 7 years old are again markedly different. All of the STM abilities tapped here show a much stronger developmental association with reading, but it is the auditory STM skills which now come to the fore. Reading and visual digit span and articulatory suppression remain in low association, whereas reading has become a strong predictor of visual STM span without suppression. This again accords with the Keeney *et al.* findings: blocking articulation has little effect on the visual STM span of younger children because they do not naturally name and rehearse the material anyway—they deal with the material using its visual characteristics. Older children do differentiate between visually presented symbolic and non-symbolic material by capitalizing on the phonological and lexical associates of the former. These strategies are practised and made meaningful in the second stage of reading acquisition where symbol–sound conversion is emphasized.

From 5 to 6 the other auditory STM abilities (word and sentence spans and the token test) develop symbiotically with reading. From 6 to 7 the interdependence has increased, and reading is a better predictor of these auditory STM skills than the reverse. It is as if practice at the meaningful and sensible (Istomina, 1975) skill of reading develops the child's abilities in attending to, manipulating and remembering the sounds of words and sentences. Furthermore it nurtures the ability to make sense of sentences where word order and syntax is paramount—by far the largest prediction in Table 8 is that from reading at 6 to token test performance at age 7. {This pattern of development of syntactic skills, language comprehension and reading is replicated with other tests (grammatical closure, knowledge of syntax, WISC similarities and comprehension) in the next discussion section.}

The relationship between phonological coding in STM tasks and learning to read is indeed important. We suggest that it is the acquisition of reading skill which underpins the developmental changes in strategies and skills used in STM tasks. Developmental studies of ST and working memory which ignore reading development ignore the key components. For further discussion of these data with regard to the interactive development of STM, reading and phonological skills see Ellis (in press).

**Language comprehension skills and syntactic knowledge**

Since the demonstrations of Tulving and Gold (1963) on top-down effects of context on visual word recognition thresholds everyone acknowledges the importance of context on perception. Contextual information through the operations of the 'cognitive system' constitute half of the data source of logogen units (Morton, 1969). Smith (1978) has characterized reading as a *psycholinguistic guessing game*. The involvement of contextual information is acknowledged at almost every stage from the very beginnings which Marsh, Friedman, Welch and Desberg (1981) call the *linguistic substitution stage*, and where known words are read by rote (whole-word pattern recognition as in Frith's logographic reading above), unknown words out of context are not attempted, but unknown words in context are guessed at on the basis of context alone (their example: see 'the cime went to the store', read as 'the boy went to the store'). These are the situations where the child searches for clues more from the accompanying picture than in the printed page. For phenomenological evidence at the top levels of reading skill we need look no further than the proof-reader's error. For experimental evidence we find high correlations (0.6–0.8) between listening and reading comprehension in adults (Daneman and Carpenter, 1980; Jackson and McClelland, 1979; Jenkins and Pany, 1981).

There are a number of different sources of contextual information which help to constrain the possibilities for the next words to be encountered. For reviews of the use of these, and whether they facilitate word-recognition or comprehension of text, see Mitchell, 1982; Sanford and Garrod, 1983; Stanovich, 1980. The major debate concerning the use of context in the early stages of the acquisition of reading has centred on whether good readers rely more on context than do poor readers. Arguments for both sides have been made: perhaps the fluent reading of good readers is due to their superior ability to utilize contextual redundancy to facilitate word recognition (Smith, 1978); perhaps poor readers paradoxically make more use of contextual cues because good readers, although better at prediction, are so skilled at context-free recognition that this skill is the dominant influence on their performance (Perfetti, Goldman and Hogaboam, 1979; Stanovich, 1980). Numerous experiments have failed to find that good readers rely more on context than poor readers (Stanovich, 1982a,b reviews 24 of these studies). Yet it is well documented that young children's ability to produce the missing word in visually or orally presented sentences is related to their reading comprehension performance (Bickley, Ellington and Bickley, 1970; Perfetti and Roth, 1981; Ryan and Ledger, 1984). Stanovich (1982b) concludes that poor readers are not deficient in the basic processing mechanisms that mediate context effects, but, in reading actual text, the slow and inaccurate word decoding processes of the poor reader may in fact degrade the contextual information, rendering it unusable.

This short review suggests that contextual information will be an important part of reading skill at all stages of development and levels of ability. Possible exceptions to this generalization are when, at a particular stage of reading acquisition, a new decoding skill must be learned and either (1) a child may be reluctant to work at this, preferring to stay with mastered strategies which capitalize on context, or (2) the new skill and use of context may compete for limited resources of attention or working memory (LaBerge and Samuels, 1974). In these situations there might be a null or negative relationship between reading development and use of contextual information.

In the present study the tests of grammatical closure and knowledge of syntax tap the children's knowledge of grammatical structures, and the WISC comprehension, similarities and information subtests tap a range of applications of schematic knowledge. How are they associated with reading at different stages of acquisition?

In Table 2 we see that neither grammatical closure nor knowledge of syntax is associated with reading at age 5, but grammatical closure and reading have become associated by 7 years old. In Tables 3 and 6 we see that only grammatical closure at 5 predicts reading at 6, but both grammatical closure and knowledge of syntax at 6 are good predictors (0.54 and 0.58) of reading ability at 7 years old. In all cases, however, the prediction of grammatical knowledge at the later year from reading at the prior one is considerably larger than the reverse (Read5 > GrCl6 0.61; Read6 >GrCl7 0.79; Read5 > KnSy6 0.54; Read6 > KnSy7 0.63). These data suggest that early reading skill at 5 years old makes little use of grammatical context cues. Thereafter grammatical knowledge and reading skill become associated, and it appears that their development is mutually supportive, although the cross-lagged analysis does suggest that grammatical knowledge grows more from developing reading skills than the reverse.

The tests which tap (in a less than clean fashion) schematic knowledge are WISC information, comprehension and similarities. It appears that reading and information develop symbiotically—they predict each other at the next year with equal weight, but reading is a better predictor of later WISC similarities and comprehension than vice-versa (Read5 > WISCSim6 0.54, WISCSim5 > Read6 0.37; Read6 > WISCSim7, 0.66, WISCSim6 > Read7 0.53; Read5 > WISCCom6 0.53, WISCCom5 > READ6 0.21; Read 6 > WISCCom7, 0.61, WISCCom6 > Read7 0.35). It seems these types of knowledge grow from the application of reading skill more than they contribute to it in these early years of reading.

The conclusions regarding the use of language comprehension skills and syntactic knowledge parallel those in all the types of skill discussed so far. The skills are differentially applied at different stages of reading as the changing task demands of reading make them appropriate. And as they are practised in reading so these skills themselves develop.

## CONCLUSIONS

The main involvements of the different skills in the different stages of reading which were emphasized in the discussion are shown in Figure 1. After the initial stage, where children are acquiring knowledge of the letters of the alphabet, we show four broad stages which characterize the development of reading up to that attained by the precocious 7-year-old. The skills that best predict and contribute to the development of a particular stage are shown on the left; those that grow from reading practice are shown on the right. Time thus progresses top-down and, to some degree, from left to right. Thus, for example, phonological awareness and sound blending are the significant predictors of letter recognition (from Table 4). This summary thus draws on data from Tables 2–8 and from the whole discussion section.

*Stage 1* of reading corresponds to those children who could read no words at 5 years old, and it was phonological awareness, letter recognition, and performance on visual digit span tasks which predicted their reading development over the next year (Table 4).

*Stage 2* is predominantly visual (Table 5). There is little evidence of involvement of grapheme–phoneme decoding. From Tables 3 and 4 there does seem to be an association with the use of script-based knowledge (picture arrangement and information).

These first two stages of reading that derive from an analysis of associated skills map onto the first stage of reading that has been proposed from the analysis of children's early reading errors (Biemiller, 1970; Torrey, 1979; Weber, 1970). Marsh *et al.* (1981) call this the stage of linguistic substitution where the child uses a strategy of simple rote association between a simple unsynthesized visual stimulus and an unanalysed oral response. 'The child typically centres on one aspect of the visual stimulus such as the first letter and associates that with the oral response . . .

Their natural strategy is congruent with the "whole word" approach to teaching reading' (pp. 201–202). Hence Frith (1985) calls this the *logographic* stage. If the child does not know the word she may guess on the basis of contextual cues. Marsh *et al.* suggest that the child next progresses to a stage of *discrimination net substitution*, where 'the number of graphemic features a young child can process is limited initially to the first letter, and it is only later that additional features such as word length, final letter etc. are added. The child at this stage appears to be operating according to a 'discrimination net' mechanism in which graphemic cues are processed only to the extent necessary to discriminate one printed word from another.' (p. 203).

The associated skills which predict reading development through stages 1 and 2 here are exactly those which would allow this type of logographic reading. The letter recognition and visual digit span predictors of stage 1 are consistent with the children concentrating on the analysis of the letters in words. We cannot tell from these data just how many letters of a word they can perceive in the right order, but

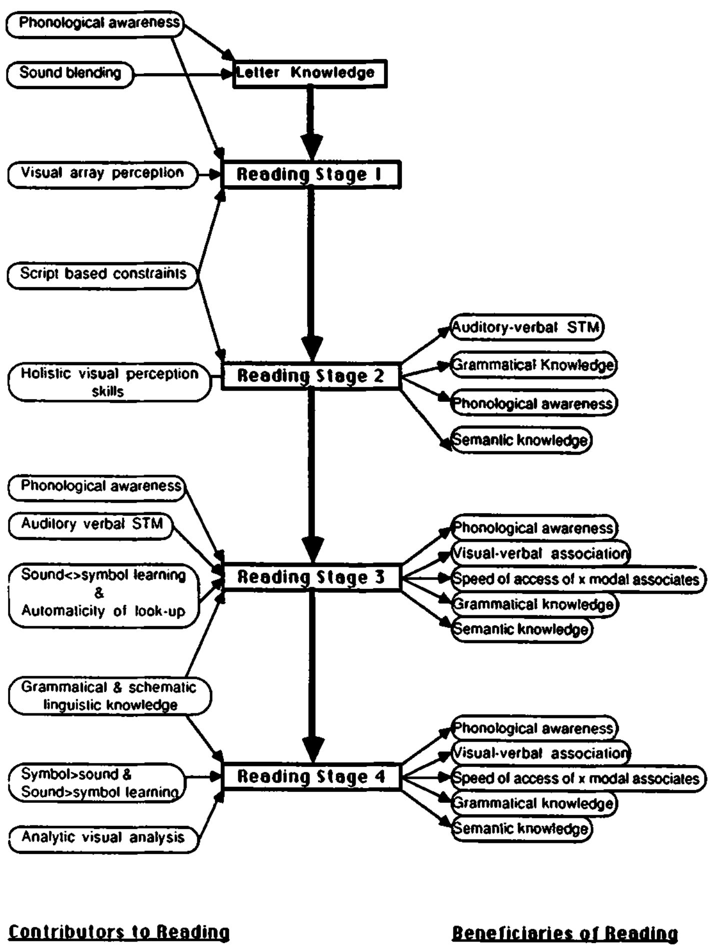


Figure 1. The developmental stages of reading skill.

their visual digit span of 2.9 items at 6 years old does not suggest a large letter span. It seems likely that many of the words they are reading are guessed at from the analysis of a few letters. The visual predictors of stage 2 suggest that children in this stage are using a strategy of remembering the visual features of the words they can read. The visual analysis seems to involve the whole word shape (associations with visual closure and block design) as well as analysis into features (letter search and visual digit span).

*Stage 3* is very different, in that this next style of reading, whilst capitalizing on development so far, becomes much more concerned with phonological awareness, sound–symbol transcoding, and auditory–verbal STM. Again this stage parallels that proposed from the analysis of children's reading errors. Marsh *et al.* call their next stage that of *sequential decoding*; Frith terms it *alphabetic*. In both of these models this next stage is characterized by the use of individual graphemes and phonemes and their correspondences. 'It is an analytic skill involving a systematic approach, namely decoding grapheme by grapheme. Letter order and phonological factors play a crucial role. This strategy enables the reader to pronounce novel and nonsense words' (Frith, 1985: 308). As with the previous stages we see from the present analysis of the reading-associated skills that the shift to stage 3 capitalizes on these already present skills which enable this reading strategy. But in Figure 1 we can also see the true interactive nature of reading development: the phonological awareness and auditory–verbal STM which stage 3 builds upon were to a large degree themselves growing from stage 2 reading.

In *stage 4* the set of grapheme–phoneme correspondence rules is becoming much more extensive, and the ease with which children learn these new associations determines their progress in reading. Analytic visual perceptual skills are also associated. Marsh *et al.* characterize their next stage of reading as being an extension to the simple decoding strategy (which was based on one-to-one correspondence, where the child now learns more complex rules of orthographic structure—the units are letter groups and higher-order conditional rules (like the magic *e* rule) are used. In the present findings the new sound–symbol learning and the visual analysis of these orthographic units are certainly consistent with this characterization. Frith, however, suggests that the next stage of reading involves *orthographic* strategies where the words are instantly analysed into orthographic units without phonological conversion. 'The orthographic units ideally coincide with morphemes. They are internally represented as abstract letter-by-letter strings. These units make up a limited set that—in loose analogy to a syllabary—can be used to create by recombination an almost unimited number of words' (Frith, 1985: 308). Both the models of Frith, and Marsh *et al.*, emphasize analysis of multiple-letter orthographic units, but Frith is implying that practice at the analysis of orthographic sequences will eventually allow non-phonological whole-morpheme direct lexical access, with post-lexical phonological retrieval. It is possible that the patterns of associations found here reflect the superior reader's entry into this final stage (see discussion section on visual–verbal cross-modal mapping). Both models ignore the increasing use of grammatical and schematic linguistic knowledge through stages 3 and 4.

At first sight this may appear a perverse sequence of reading development. If we were building a reading machine this is not the most obvious approach. If the device already possesses visual perception skills, a broad vocabulary and linguistic capabilities we would surely start by specifying the visual descriptions (symbolic or orthographic) for each lexical entry. But this associative approach, with its exhaustive demands for data input, would soon pall and we would be analysing the task for redundancy which might allow procedural short-cuts. Surely we need not describe *lift*, *lifted*, *lifter*, *walk*, *walked* and *walker*. . . . We will save considerable time if we can specify rules of combination and syntax and procedures to deal with them because then we need only input the root morpheme. But the units for reading are then no longer bounded by spaces; we must specify procedures for parsing and segmentation of the letter strings. And what then of the exceptions (*light*, *?*, *lighter*)? Must we teach them all explicitly? But the child already knows many of the exceptions—there is a substantial aural–oral vocabulary which can be tapped; what is lacking is the visual descriptions for mapping onto this system. Is there any other patterning in the data which we can exploit—are there any rules from which we can specify procedures for mapping which will obviate the need to specify each and every orthographic description? It is an alphabetic language; there are rules for grapheme–phoneme conversion. There are an awful number of them, and they are often unsuccessful, but if we implement procedures for using at least the most frequent of them then version 0.1 ('quick and dirty') would work, at least with some words. And if the device has the capability for abstracting its own concepts, then with enough instances from practice it can form its own rules or learn to search for analogues. And enough practice would allow the mechanism to build its own set of orthographic descriptions.

The more we analyse the situation, the more we realize that we are not starting with a dumb device—it already has many powerful cognitive skills and knowledge structures. *So we need not teach it to read, we must help it learn to read.* In specifying some grapheme–phoneme conversion rules, some rules of syntax, the need to left–right parse letter strings, and some complete orthographic descriptions we are teaching task-relevant heuristics which the mechanism can apply in a problem-solving approach to reading.

These heuristics are essentially independent—whilst string parsing is a necessary precursor to graphemic and whole-word analysis, it matters little whether we teach syntactic rules before these, or whole-word or grapheme–phoneme methods first. Why then with the child are there the characteristic developmental sequences of acquisition? There are at least two likely reasons.

(1) Unlike mechanisms, people need motivation—they need to know the potential value of acquiring a new and very difficult skill, and they constantly need reassurance that their efforts along the way are to good effect. They need feedback that they are succeeding.

(2) The teachers have evolved traditional instructional practices that they reapply because these methods have usually worked in the past. These methods take into account the child's need for motivation and interim success. Thus they find it useful to allow children to acquire the symbolic descriptions of some 100–200 words in the early stages of reading tuition to allow the children success before they embark on more abstract, rule-based grapheme–phoneme work.

The present study has confirmed that there is no one 'reading', but rather very different strategic blends of information processing skills at different stages of development. It has charted these stages of reading development and demonstrated that entry into each new stage is to some degree determined by the child's ability at the necessary subcomponent skills. This does not necessarily imply that this is the only possible progression to literacy—reading is a taught skill and thus its growth must surely reflect the style and content of the teaching programme—however, popular English language reading programmes are generally similar, after initial instruction over the first 2 years or so progress is essentially self-determined, and thus the developmental progression described here may well be typical. Furthermore we have shown the development of a wide variety of skills (such as verbal STM) resulting from practice at reading. This is not to say that these skills would not have developed without the child's progression to literacy, just that in our culture, which nurtures reading, they do.

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## NOTE

1. A significant correlation between reading and another ability might indicate a causal association between the two skills. Or it might be a spurious association due to some common cause such as intelligence. First-order partial correlations (where intelligence is controlled) eliminate these common causes, but they also eliminate other important factors related to reading ability (Singer, 1982). We would therefore like to report both types of analysis, but lack of space restricts us to the first-order correlations. The zero-order analyses and a discussion of their implications are available from the authors.