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Interactions in the development of spelling, reading and phonological skills

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ABSTRACT

Early interactive processes of development in reading, spelling and implicit and explicit phonological awareness were assessed in a group of children at four time-points as they progressed through their first three years in school. Exploratory causal path analyses were used to investigate the contribution of each ability to the subsequent growth of skill in reading, spelling and phonological awareness. The resultant structural models demonstrate a role of spelling in the early stages of reading acquisition, as well as differential contributions of implicit and explicit phonological awareness to both reading and spelling. They also suggest a developmental cascade from implicit to explicit phonemic awareness in the normal acquisition of phonological knowledge and associated skills.

In the early formulative stages of reading implicit phonemic awareness and reading act reciprocally to build skill in each other. But, as ability in word recognition improves, implicit phonemic awareness plays a diminished role in reading. This pattern of initial reciprocal influence and later dissociation is repeated in the relationship between implicit phoneme awareness and spelling. Explicit phonemic awareness is an important factor in the first stages of spelling development but only emerges later as a significant contributor to reading. The early influence of explicit phoneme awareness on spelling, in conjunction with the major contribution of spelling to beginning reading, indicates that experience in spelling promotes the use of a phonological strategy in reading. Within a developmental context, explicit phoneme awareness initially appears to grow out of an implicit appreciation of the overall sound properties of words. Thereafter, ability to identify and segment phonemes develops independently of implicit phonemic awareness and plays an increasingly important role in the further growth of reading and spelling.

RÉSUMÉ

Les interactions dans le développement de l'écriture, de la lecture et des compétences phonologiques

On a relevé les processus d'interaction précoce de la lecture, de l'écriture et de la conscience linguistique dans un groupe de 28 enfants au cours de leurs trois premières années de scolarité. Les enfants ont été testés pendant cette période à quatre reprises en lecture et écriture de vrais mots et de non-mots, en segmentation phonétique et en catégorisation auditive. Le WISC préscolaire a été inclus dans cet ensemble d'évaluation initiale. On a utilisé un test de segmentation en phonèmes comme mesure de la conscience phonémique explicite et un test de catégorisation auditive comme mesure de la conscience phonologique implicite. La majorité des enfants venait tout juste de commencer à fréquenter l'école quand les premières évaluations ont été effectuées en début d'année. L'âge moyen lors de ces premiers tests était de 4 ans et 6 mois. Les enfants ont été testés à nouveau à la fin de leur première année d'école, en début de seconde année et enfin au commencement de la troisième année. On a utilisé des analyses de piste causale LISREL pour examiner la contribution de chaque capacité au développement ultérieur de la reconnaissance des mots, de l'écriture et de la conscience phonologique. Les structures d'interaction entre ces trois habiletés fournissent une trame préliminaire pour décrire les premiers niveaux de l'acquisition de la langue écrite. On examine séparément la relation entre les deux types de conscience linguistique en terms de conscience explicite des composantes phonémiques.

Dans les premiers niveaux de lecture proposés, la conscience phonologique implicite et la lecture agissent réciproquement pour construire l'habileté l'un de l'autre. Quand les enfants commencent à manifester une habileté en reconnaissance des mots le rôle de la conscience implicite dans la lecture va en diminuant. On trouve un écho de cette structure d'influence réciproque au début et de dissociation par la suite dans la relation entre la conscience phonémique implicite et l'écriture. La conscience phonémique explicite ne contribue pas directement à la capacité à reconnaître les mots avant une époque avancée, et cependant elle est un facteur important dans les premiers niveaux de développement de l'écriture. L'écriture agit fortement sur le développement au commencement de la lecture. L'influence précoce de la conscience phonémique explicite sur l'écriture et la contribution majeure de l'écriture au commencement de la lecture indiquent que l'expérience de l'écriture promeut l'utilisation d'une stratégie phonologique en lecture. Lors de la troisième année d'école l'habileté en écriture et la reconnaissance des mots ne contribuent plus significativement à leur croissance respective. Cette cassure dans le cours homogène du développement antérieur où la lecture se consolidait en s'appuyant sur les habiletés composantes précédemment établies reflète un changement de stratégie. La conscience phonémique explicite devient maintenant l'influence majeure du développement de l'écriture des vrais mots et de la lecture et écriture des mots sans signification. A ce moment là les enfants semblent être entrés dans le stade alphabétique de la lecture et de l'écriture.

D'accord avec le travail théorique antérieur, la lecture semble être ce qui entraîne l'utilisation d'une stratégie phonologique dans l'acquisition précoce de la lecture.

Dans un contexte de développement, la conscience phonémique explicite semble procéder d'une habileté rudimentaire qui repose sur une conscience tacite des propriétés sonores des mots. Les enfants semblent passer d'une appréciation implicite de la valeur sonore globale des mots à une compréhension implicite des composantes phonémiques. Au fur et à mesure qu'ils sont capables de segmenter les mots en phonèmes, les enfants semblent généraliser l'utilisation d'une stratégie analytique à des tâches phonologiques qu'ils abordaient précédemment de manière globale. La croissance ultérieure de la capacité à identifier et à segmenter en phonèmes se développe indépendamment de la conscience implicite et joue un rôle de plus en plus important dans le développement de la lecture et de l'écriture.

INTRODUCTION

Although the importance of phonological awareness in the acquisition of reading has been established, causal pathways between the two abilities elude clear definition (Bryant and Goswami, 1987; Shanahan and Lomax, 1986). Factors relevant to the development of phonological awareness and reading, and investigations thereof include (i) the range of phonological awareness skills tapped by different tasks (Lewkowicz, 1980; Ellis and Large, 1988; Stanovich, Cunningham and Cramer, 1984), (ii) the range of different types of reading tapped by different reading tasks and the child's ability to relate sound to graphic information (Lomax and Mcgee, 1987), (iii) short term and working memory (Ellis, 1988), and (iv) different methods of reading instruction (Morais, Cary, Alegria and Bertelson, 1979; Alegria, Pignot and Morais, 1982). Research that examines the relationship of phonological awareness to the emergence of literacy has often neglected spelling as a bona fide agent that independently influences and is influenced by phonological awareness and reading. Whilst it has been acknowledged that use of a phonological strategy plays a fundamental role in spelling before it becomes important in reading (Smith, 1973; Bryant and Bradley, 1980; Frith, 1980; Snowling and Perin, 1983; Juel, Griffith and Gough, 1986), comparatively little attention has been focused on the possible routes of interaction among reading, spelling and phonological skills. Correlational studies provide evidence of a strong relationship between early reading and spelling and between spelling and phoneme awareness (Snowling and Perin, 1983; Juel, Griffith and Gough, 1986; Ellis and Large, 1987). However, the form of causal connections cannot be determined from correlations alone.

Theoretical analyses which assign spelling a major role in the development of phonological as well as reading skills include Chomsky (1977), Elkonin (1973), Lewkowicz (1980) and Ehri and Wilce (1987a). In a three-phase model of reading acquisition Frith (1985) proposes that an alphabetic or sound strategy is first utilized in spelling practice and later carried over to reading, which the child has previously approached using a logographic or visual strategy. Yet only a few studies have been designed to explore the manner in which spelling contributes to or benefits from phonological and reading skills. In a longitudinal study of children from first to second grades Juel et al. (1986) found that knowledge of the way speech maps onto letters is used in both early word recognition and spelling. Ehri and Wilce (1987a) have recently demonstrated transfer of phonological strategy from spelling to reading. Shanahan and Lomax (1986) used path analyses to test different models of

the reading-writing relationship. They compared interactive with non-interactive models of reading and writing development and, of the three models they used, the interactive model depicting bi-directional pathways between reading and writing best represented the data. However, because their interactive model does not open a pathway from spelling to word analysis it is impossible to make a direct comparison of the effect of early reading on spelling with the influence of early spelling on reading. The writing-to-reading model does open the pathway from spelling to word analysis and it is interesting that the major causal influence in this model is concentrated in the spelling to word analysis route. Thus their model that does allow for movement of knowledge from spelling to word analysis reveals that early reading skill relies on information gleaned from spelling.

Mommers (1987) also performed a series of path analyses using LISREL to investigate the development of various sub-skills in word recognition, reading comprehension, and spelling in 461 Dutch children as they progressed through the first three years of reading instruction. This study, which is exemplary with regard its large sample size and its analysis of the differential effects of different methods of reading instruction, found direct effects of spelling ability on reading (word decoding speed) after the children had received three or four months of reading instruction, but, at later stages, reading development promoted spelling acquisition more than the reverse. However, this study unfortunately does not allow analysis of the interactions between reading and spelling development and phonological skills, since auditory blending and segmentation abilities were only assessed at the first stage, before formal reading instruction had commenced.

These studies reveal the previously hidden role that spelling plays in the child's first steps towards literacy. But now we need a broader and more detailed description of the interactive development of all three components: reading, spelling and phonological awareness. The present study therefore uses a longitudinal design to identify the early sequences of interactive development in reading, spelling and phonological awareness skills. We elucidate the early causal relations among these three variables by following the development of each skill in a group of children as they move from preliteracy through the beginning stages of learning to read and spell.

Early research in the relationship between reading and phonological awareness did not discriminate between different types of phoneme awareness and thus used performance on very different types of phonemic awareness tasks to support or reject causal relations between reading and phonological awareness (Lewkowicz, 1980; Bradley and Bryant, 1985). More recent work reveals that the strength of the relationship between phonological awareness and reading is dependent on the level of phonemic awareness demanded by the phonological task (Backman, 1983; Stanovich, Cunningham and Cramer, 1984). Thus any investigation of the developmental interaction between reading, phonological awareness and spelling must consider more closely the course of development of phonemic skills.

Theories of the growth of phonemic awareness in children distinguish between a conscious awareness of language and a conscious reflection on speech. The fact that young children spontaneously play with rhyming and nonsense words (Chukovsky, 1968; Slobin, 1978; Clark, 1978) is usually interpreted as being a result of the child's implicit awareness of the overall sound properties of words rather than a product of conscious reflection on language (Shankweiler, Liberman, and Savin, 1972; Clark,

1978; Andresen, in Valtin, 1984a; Valtin, 1984a). Valtin (1984a) outlines three stages in the development of language awareness. In the first stage, awareness of the sound properties of language is unconscious. In the second stage a tacit but as yet non-analytic awareness is evident. Only in the third stage of 'conscious awareness' do children demonstrate an intentional, explicit manipulation of sounds in words. At this point, the child possesses a new ability. The impetus for this advancement is often linked with instruction in reading and spelling (Morais, Cary, Alegria and Bertelson, 1979; Alegria, Pegnot and Morais, 1982; Ehri, 1979). Thus, a plausible developmental sequence for phonological awareness begins with a rudimentary sound detection mechanism that is sensitive to the overall sound properties of words. As children become increasingly analytic in their approach to the phonemic structure of words, they are able to detect and manipulate smaller segments of phonemic content. But how do children who have reached different levels of phonemic awareness use phonological knowledge in reading and spelling?

Beginning readers who have reached an implicit level of phonemic awareness may forge initial associations between the spoken and written word by linking boundary sounds in the spoken word with knowledge of the letter-sound associations in the printed word (Ehri and Wilce, 1985). Bryant and Goswami (1987) suggest that children who can detect rhyme but who have not yet mastered the higher level skill of explicit segmentation may read by taking advantage of the fact that many words which share rhyming components are spelled similarly. The child who has reached an explicit level of phonemic awareness might approach unknown words with a sequential decoding strategy. Using this strategy, the learner produces a series of separate sounds represented by letters in a word and maps the sequence of sounds onto the pronunciation of the word. Marsh et al. (1980) suggest that practice using this strategy leads to an understanding of the alphabetic principle which can be beneficial to spelling. Whilst it is possible that the early stages of reading acquisition involve a rudimentary phonological awareness, the first stages of learning to spell are more likely to entail the development of a systematic phonological strategy. Whereas in beginning reading attention is largely centred on visual features of words and letters (Gough and Hillinger, 1980; Marsh, Friedman, Welch and Desberg, 1981; Seymour and Elder, 1985), early processes in spelling focus on an awareness of explicit phonemic content. The beginning speller learns to identify and isolate phonemic segments in spoken words. In this way practice in spelling might facilitate insight into the relationship into the spoken word and its corresponding sequence of phonemes. This insight may be valuable to beginning readers as they attack unfamiliar words by 'sounding-out' sequences of letter-sound correspondences.

In the present study we explore how the child approaches reading and spelling in the light of the developmental sequence of phonological awareness skills. We look at the growth of spelling, reading and phonological awareness from the initial formation of each skill through the early stages of their development. By using a longitudinal design we analyze the factors which contribute to the formation of phonological strategies in reading and spelling and those that facilitate later shifts to more sophisticated use of these strategies. Furthermore we identify the sequences of interactive development of all of these skills.

METHOD

Subjects

Forty children, aged between 4 and 5 years participated in a testing-training study. The children were selected from three schools in North Wales and at the beginning of the study they were attending either reception or infant classes. All of the children were English speaking. The children's reading and all other academic curriculum areas were taught exclusively in English. They were exposed to Welsh in the form of introductory Welsh lessons. None of the children demonstrated severe problems with hearing, speech or vision. No physical or emotional disabilities were evidenced by any of the children. The children were first assessed in the autumn of 1985 when they were between 4 and 5 years old. At this time the majority of the sample were non-readers and did not demonstrate evidence of even rudimentary skill in either reading or spelling. However, a small number of subjects who were first year infants when the study began had started to learn to read and spell. Three subsequent administrations of the tests were given; once when most of the children were at the end of their first year of school, again in the autumn of their second school year and finally at the beginning of their third year. Sample attrition resulted in 28 subjects taking the full complement of tests. The performance of these children is used in the LISREL analyses discussed in this study. Mean age and reading, spelling, segmentation, auditory categorization and letter-sound knowledge scores for each testing time can be seen in Table 1.

Following initial assessment, four groups matched for I.Q., reading, spelling, phoneme awareness, letter-sound knowledge, short-term memory, and rhyme generation were created. Training for children in each group commenced in March 1986 and continued (with breaks for periods of testing) until autumn 1986. Children in two of the groups practised analysing words for phonemic content. Members of the third group practised reading the same words using the 'look-say' approach. The fourth group practised categorizing the words semantically. The same teacher (Cataldo) performed the four types of training, these being matched for overall exposure to the training-words. All groups worked with the same words in training: real words were used in the various training tasks. Words used in training were exclusively consonant-vowel-consonant (C-V-C) words as were words on the reading and spelling tests. All children received training in the letter-sound associations used in the tests. Results of multivariate analyses revealed generally non-significant effects of training (see Cataldo and Ellis, 1988 for details): thus we could pool across the four groups and chart the longitudinal development in an effort to discover the interactive relationships among the abilities measured.

Procedure

Children between 4 and 5 years old were tested individually in reading, spelling, phoneme segmentation, auditory categorization, letter-sound knowledge, short-term memory (STM) and full WPPSI I.Q. (Wechsler, 1967; Saville, 1971). Tests were administered in a series of 10–15 minute sessions. Tests of reading, spelling, segmentation and auditory categorization were re-administered when most of the

Table 1: Age and raw scores in reading, spelling, phoneme segmentation, auditory organization and letter-sound associates at each testing point. Means (standard deviations).

	BEGINNING YR. ONE		END YR. ONE		BEGINNING YR. TWO		BEGINNING YR. THREE
WPPSI full	109 (10)						
Chronological Age (months)	54.9 (4.2)		62.9 (4.2)		66.9 (4.2)		78.1 (4.1)
READING	58.00 (69.40)	real	8.07 (14.29)	real	13.57 (15.59)	real	27.14 (16.72)
		non	7.04 (14.44)	non	10.29 (14.74)	non	18.61 (15.60)
SPELLING	24.61 (27.05)	real	3.25 (5.77)	real	6.07 (6.53)	real	11.36 (5.98)
		non	3.18 (5.72)	non	5.25 (6.51)	non	9.68 (5.91)
PHONEME SEGMENTATION	5.86 (11.16)		15.14 (14.46)		24.61 (13.52)		— —
AUDITORY ORGANIZATION	11.10 (4.78)		13.07 (5.23)		14.29 (5.76)		— —
LETTER SOUND	7.32 (6.48)		— —		18.61 (5.61)		— —

children were finishing their first year of school. At the completion of training (Cataldo and Ellis, 1988) the following autumn, the full set of original tests was given except for the WPPSI. One year later, a final administration of the reading and spelling tests was given. At this time most of the children were beginning their third year of school.

Test scores at each testing point were converted into stanine scores, thereby enabling comparisons of performances in different areas. Stanine scores range from 1 to 9 with 9 representing the highest performance and 1 the lowest. When all variables are converted into stanines, the mean of each variable becomes 5.0 and sd 1.96 (Guilford and Fruchter, 1978). Converting raw scores to stanines also normalizes the data and variances, allowing the data to meet the assumptions of causal modelling (Saris and Stronkhorst, 1984).

A description of each of the tests, testing procedures and scoring methods follows.

Tests of Reading and Spelling

The Reading and Spelling tests in reading and spelling used phonemically regular, consonant-vowel-consonant (C-V-C) words. All of the words contained short vowels.

(C-V-C) Reading test: The Reading test consisted of 96 consonant-vowel-consonant (C-V-C) words. Half of the words were real words and half were nonsense words. Each word was presented on an 11 cm by 8.5 cm white card, in large lower case letters. The order of presentation of words was randomized. Subjects had one chance to read each word before proceeding to the next. An initial score was taken by counting the number of words correctly read. At the first testing time most of the children were not yet scoring above floor level. In order to measure the development of reading from the most rudimentary stage of acquisition, a second scoring method was applied to the reading test data at the earliest testing point. This second score was calculated by counting the number of phonemes in each 'word' response which correctly represented sounds in the test word. This scoring method is sensitive to a child's earliest attempts to process the phonetic content of printed words.

(C-V-C) Spelling test: Each child was asked to spell, in writing, a subset of the 96 C-V-C words used on the reading test. 32 words were presented consisting of 16 real words followed by 16 nonsense words. Each real word was presented once alone, a second time in the context of a sentence, and a third time in isolation. Nonsense words were presented three times in isolation. To reduce memory load an alphabet of lower case letters was positioned in front of the child during the entire test. The order of words in each set was randomized. As in the reading test, two scores were taken for spelling.

Tests of Phonological Awareness (PA)

Two different types of phonological tasks were chosen, a rhyme detection task and a phoneme segmentation task. Performances on these two tasks afforded a rough measure of the level of phonological awareness achieved. In line with the theory outlined above, the minimal requirement for success in rhyme detection is a global awareness of the sound properties of words, while successful performance on segmentation tasks requires an explicit awareness of individual sounds within words.

Implicit Awareness: Test of Auditory Organization (Bradley, 1980). The test of auditory organization is divided into three conditions: initial (comprised of words that begin with the same sound), final (with words that end with the same sound), and medial (containing words that share the same vowel sound). For each condition the child listens as a series of four words are spoken. S/he is asked to identify the 'odd one out' of the four words (the word that does not share a common sound component with the other three words). A warm-up procedure similar to that suggested by Bradley (1980) was used before testing each child.

Explicit Awareness: Phoneme segmentation test. A modification of the Elkonin procedure (Elkonin, 1973; Helfgott, 1976) was used to test ability in explicit phoneme segmentation. Each child was asked to perform three types of segmentation on 8 real C-V-C words and 8 nonsense C-V-C words given in spoken form. In the initial segmentation task subjects were asked to segment words into 2 parts; the initial consonant and the remaining vowel-consonant portion (C-VC). For the final segmentation task, the children were asked to segment the final sound from each word by producing the initial CV component followed by the final phoneme (CV-C). The complete segmentation task required each child to segment words into three distinct sound components (C-V-C). The children practised each type of

Table 2: Percent correct in auditory organization (implicit awareness) and phoneme segmentation (explicit awareness) for three testing times. (As different words were used in the tests of Implicit and Explicit Phonological Awareness, scores within tests are directly comparable, whereas scores across tests are not.) Mean (standard deviation).

TEST	BEGINNING YR. ONE	END YR. ONE	BEGINNING YR. TWO
TOTAL IMPLICIT	37.14 (15.94)	43.57 (17.45)	47.62 (19.20)
TOTAL EXPLICIT	12.13 (23.30)	31.55 (30.12)	51.26 (28.16)
INITIAL IMPLICIT	28.93 (16.18)	39.29 (19.04)	47.86 (22.83)
INITIAL EXPLICIT	14.51 (28.31)	46.65 (41.96)	74.11 (32.75)
FINAL IMPLICIT	39.29 (21.93)	46.43 (19.29)	43.21 (20.56)
FINAL EXPLICIT	8.93 (22.34)	12.50 (23.26)	22.10 (35.25)
MEDIAL IMPLICIT	43.21 (22.62)	45.00 (24.72)	51.79 (25.25)
COMPLETE EXPLICIT	12.95 (26.57)	35.49 (38.04)	57.59 (32.51)

segmentation task before testing on that task commenced. Words within each type of task were presented in random order: real words were presented first, followed by nonsense words. Scores represent the total number of test words correctly segmented. Descriptive data for the results of these phonological tests at each testing time are shown in Table 2.

Letter-sound associations

Knowledge of isolated letter-sound associations alone does not account for success in learning to read and spell. However, it does contribute to the development of reading (Ellis, 1988). Use of letters also helps children learn to segment words into constituent phonemes (Hohn and Ehri, 1983).

Test of Letter-Sound Knowledge: Each of the 26 lower case letters was presented individually on an 8.5 cm by 11 cm white card. The child was asked, 'What sound does this letter make?'. If the child responded with a letter name s/he was asked if s/he knew the sound it made; if the child gave the sound, the response was scored as correct.

Weschler Preschool and Primary Scale of Intelligence

Five verbal and five performance tests were given to each child. Full scale scores on this test were used in the initial matching of groups for training and for purposes of partialling out the effect of IQ in the LISREL analyses.

THE LISREL ANALYSIS APPROACH

Structural equation modelling (SEM) is a valuable technique for analysing causal relations among variables. In the present study LISREL (Jöreskog and Sörbom, 1984) is used to formulate a descriptive model that identifies significant contributors to the growth of literacy. With small samples LISREL is only appropriate for

exploratory purposes (Crano and Mendoza, 1987) and the limited number of subjects in this study limits us to the construction of a preliminary SEM which needs further validation with a larger number of subjects. Despite these constraints SEM is the preferred means of providing a basis for a model of relations among reading, spelling, and phonological awareness since it allows the determination of causal paths whilst controlling for indirect effects and common causes.

LISREL uses the observed correlation matrix to estimate the strength of pre-specified causal paths. The strength of a given path is indicated by the magnitude of its path weight. For standardized data a pathweight represents the amount of change in a variable (in standard deviation [sd] units) caused by one sd of change in another variable. Linear structural equation modelling estimates direct effects of two types of variables. Exogenous (x) variables are predetermined by unexplained causal factors. Endogenous (y) variables are explained by exogenous or other endogenous variables. Gamma (γ) pathweights are estimates of the direct effects of exogenous variables and Beta (β) pathweights represent effects of endogenous variables on other endogenous variables. Unlike Mommers (1987), who tested a priori models where only some causal paths were specified and then tuned them to better fit the data, our analyses were more inductive and exploratory. We examined low-constraint time-interval type models (Ellis, 1988) where each ability could result from an effect of *any* ability measured at the prior time. Exogenous variables in each model include I.Q., reading, spelling, explicit phoneme awareness, implicit phoneme awareness, and letter-sound knowledge. These abilities were measured at the beginning of the first school year. Four endogenous variables, reading, spelling, explicit phoneme awareness and implicit phoneme awareness, were measured at the end of the first year. These abilities, along with letter-sound knowledge, were measured again in the autumn of the children's second school year. Finally, one year later, the children were again tested in reading and spelling. The effect on the i^{th} endogenous variable of the j^{th} exogenous variable is denoted by the pathweight γ_{ij}. Similarly, the effect on the i^{th} endogenous variable of the j^{th} endogenous variable is denoted by the pathweight β_{ij}. In each of the pre-specified models all paths are freed between abilities measured at one point in time and abilities measured at the next testing time. This type of model allows us to compare the effects of two different abilities on the development of a third ability. For example we can compare the relative contributions of reading and spelling to the growth of phonological awareness. We also freed all possible covariation within each time-period to allow for ***unexplained*** covariation resultant from unknown causes operating between time-periods, thus avoiding over-estimation/inflation of the *specified* between-time-period effects in the model.

We describe three models. In the first we look at reading alone in relationship to explicit and implicit phoneme awareness. The second model examines the relationship between spelling and each type of phoneme awareness. Both reading and spelling are included in the third model in an effort to determine how each influences the other and to isolate the effects of reading and spelling on each type of phoneme awareness ability. Model 3 is illustrated in Figure 1, but, in order not to clutter the diagram, we have not shown all the paths between stages — we emphasise that *any ability at one stage was allowed to influence any ability at the next stage of development*, although we have only illustrated this for spelling in the Figure. We use these three stages, rather than going straight to the final and complete model, both in

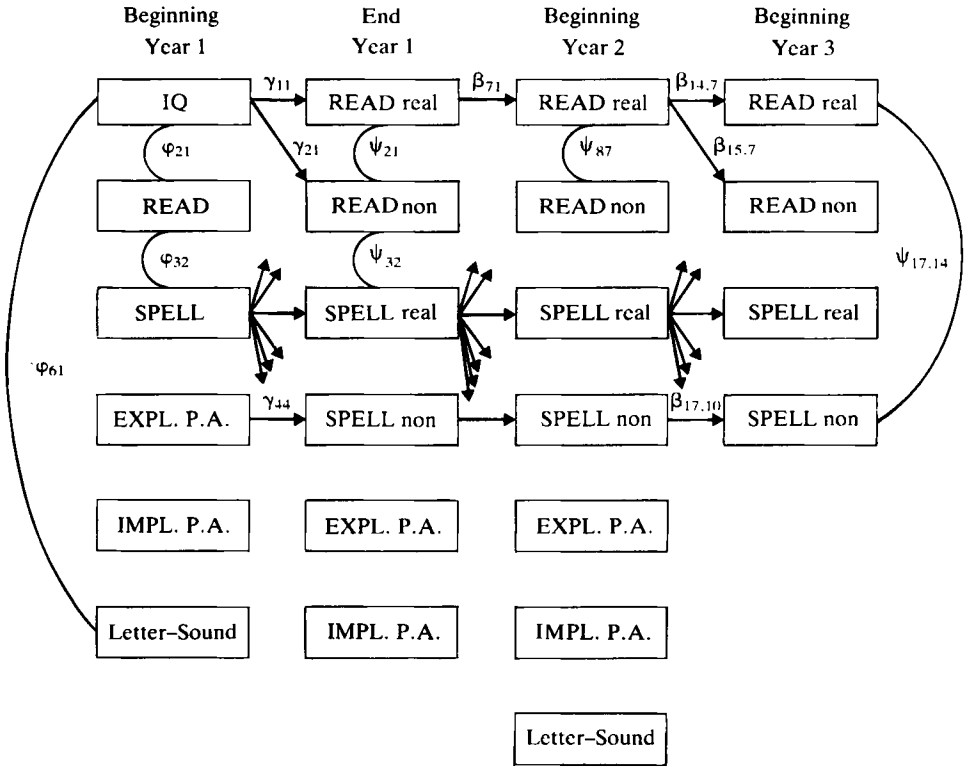

Figure 1 An illustration of the type of LISREL model used: Model 3 — Reading and Spelling. *All possible paths were allowed between adjacent time periods, thus allowing each variable to potentially contribute to the development of every other variable at the next time-point.* However, in order not to clutter the diagram, we have not shown all the paths between stages — we have only illustrated this for Spelling in the Figure. See text for further details.

order to simplify the argument and also for statistical reasons: a reasonably high intercorrelation between early reading and spelling caused us to be wary of effects of multicollinearity.

Initial measures of reading and spelling ability in each model represent what are at this stage rudimentary skills. Because only a few of the children were performing above floor level at the time of the first assessment, skill in reading and spelling was measured by summing the number of phonemes correctly represented in each child's responses. As the children began to demonstrate skill in reading and spelling words at the later assessment points we were able to look at the ability to either read or spell real and nonsense words separately. The division of reading ability into skill with real and nonsense word reading helps to clarify the relationship between reading and phonological awareness since children have optimal opportunity to apply a phonological strategy when reading nonsense words. Thus the paths between phoneme awareness and skill in reading nonsense words should highlight any early relations between phoneme awareness and reading. Performance on nonsense words also helps the determination of the direction of transfer between reading and spelling. For example, if information about the sound structure of words is passed from

spelling to reading, children might initially use this information to help them read nonsense words whilst they might continue to use a visual strategy to read real words. Alternatively, if phonological information is transferred from reading to spelling, we might expect to find evidence of this carry over in performance on both real and nonsense word spelling tasks: since the above review suggests that beginning spelling strategy involves more of segmentation of the spoken word into separate sounds, children should use the same strategy to spell real and nonsense words.

MODEL 1: READING ALONE

The path coefficients for this model are shown in the left-hand side of Table 3. The column headers are the abilities at the prior time, the row headers, those at the later time. Thus the pathweight from Implicit PA at the start of the first school year to Reading Real Words at the end of that year is 0.34.

During the first phase of measured reading development there is evidence of an interactive relationship between reading and phonological awareness. (We remind the reader that when we refer hereafter to the exogenous variable 'reading' we are talking about a rudimentary reading skill; the ability to produce a spoken response that contains some of the phonemic content of the printed word.) Reading contributes significantly to implicit PA (0.37) and implicit PA is a significant predictor of reading real and nonsense words (0.34, 0.39). In the next stages of development implicit PA plays a greatly reduced role in reading. Path coefficients for the second and third phases indicate that implicit PA has lost its influence on reading (implicit PA to reading: phase 2; −0.28, −0.21, phase 3; 0.10, 0.01). In contrast, while reading and explicit phonological awareness (explicit PA) are initially dissociated, by the third phase explicit PA begins to contribute to reading. To begin with, reading does not influence the growth of explicit PA (0.01) nor does explicit PA significantly affect either type of reading (0.05, 0.22). Explicit PA increases its contribution to reading during the second phase (0.30, 0.27) and in the third phase predicts ability to read nonsense words (0.50). Reading real words contributes to explicit PA in the second phase (0.39) but not significantly. In the two early measured stages of development, reading contributes significantly to its own later growth but in subsequent stages relies more heavily on other abilities for its development. At the onset reading is a significant predictor of real word reading (0.50) and as it continues to develop predicts real and nonsense word reading (0.67, 0.47). This pattern then changes, as neither the ability to read real or nonsense words predicts its own growth in the third developmental phase (0.20, 0.17). Relevant path coefficients for each stage of development reveal a non-interactive pattern of development between the two types of phoneme awareness. Whereas initially implicit PA feeds the growth of explicit PA (0.35), explicit PA only minimally influences the development of implicit PA (0.17). Hereafter, the effect of implicit PA on the growth of explicit PA is greatly diminished (0.01) while explicit PA increases its contribution to implicit PA (0.29). Explicit PA is a strong predictor of its later growth in each stage (0.45, 0.52). Implicit PA is an early predictor of its own development (0.44), but subsequently contributes little to its own further growth (0.16). Although letter-sound knowledge does not initially predict reading (0.13, 0.13), it has become a significant contributor to reading by the third phase of measured development (0.37, 0.29).

Table 3: LISREL path coefficients indicating contribution of early abilities to development of later abilities (Path coefficients in bold are significant at $p < .05$.)
(READ: Reading; SPELL: Spelling; EXPL.PA: Explicit Phonological Awareness; IMPL.PA: Implicit Phonological Awareness; LS: Letter Sound. See text for details.)

PHASE ONE: BEGINNING FIRST SCHOOL YEAR TO END FIRST YEAR

READING MODEL						SPELLING MODEL					
	READ	EXPL. PA	IMPL. PA	LS	IQ		SPELL	EXPL. PA	IMPL. PA	LS	IQ
READ (real)	**0.50**	0.05	**0.34**	0.13	**0.29**	SPELL (real)	**0.41**	**0.33**	**0.37**	0.08	−0.06
READ (non)	0.28	0.22	**0.39**	0.13	0.13	SPELL (non)	0.27	**0.32**	**0.31**	0.21	0.10
EXPL. PA	0.01	**0.45**	**0.35**	0.14	0.20	EXPL. PA	0.11	**0.41**	**0.37**	0.11	0.15
IMPL. PA	**0.37**	0.17	**0.44**	−0.08	0.06	IMPL. PA	**0.62**	0.07	**0.47**	−0.20	−0.05

PHASE TWO: END OF FIRST SCHOOL YEAR TO AUTUMN OF SECOND YEAR

READING MODEL					SPELLING MODEL				
	READ REAL	READ NON	EXPL. PA	IMPL. PA		SPELL REAL	SPELL NON	EXPL. PA	IMPL. PA
READ (real)	**0.67**	0.10	0.30	−0.28	SPELL (real)	0.55	−0.01	**0.35**	0.08
READ (non)	0.32	**0.47**	0.27	−0.21	SPELL (non)	**0.74**	−0.23	**0.45**	0.04
EXPL. PA	0.39	0.00	**0.52**	0.01	EXPL. PA	−0.08	0.37	**0.49**	0.15
IMPL. PA	0.20	0.08	0.29	0.16	IMPL. PA	0.01	0.04	0.35	0.28
LS	0.31	−0.04	0.21	0.05	LS	−0.04	0.12	0.26	0.09

PHASE THREE: BEGINNING SECOND YEAR TO BEGINNING THIRD YEAR

READING MODEL						SPELLING MODEL					
	READ REAL	READ NON	EXPL. PA	IMPL. PA	LS		SPELL REAL	SPELL NON	EXPL. PA	IMPL. PA	LS
READ (real)	0.20	0.17	0.25	0.10	**0.37**	SPELL (real)	0.06	−0.09	**0.63**	0.11	0.09
READ (non)	0.03	0.19	**0.50**	0.01	0.29	SPELL (non)	−0.37	0.36	**0.53**	0.27	0.16

DISCUSSION OF DEVELOPMENTAL PATTERNS IN THE READING MODEL

Both explicit and implicit phonological awareness play crucial roles at different stages in the early development of reading. Initially reading and implicit PA influence each other reciprocally. These results support the findings of a recent

longitudinal study by Ellis and Large (1988) which reveal the interactive nature of the early relation between reading and phonological awareness. Experience with the printed word may help to build phonological awareness by providing the beginner with a concrete symbol with which to conceptualize the sound structure of spoken words. Once the child realizes there is a connection between the letters in the written word and the sound content of a spoken word, the next step is to use letters as cues to the sound structure of the word. A logical way to approach this task is proposed by Ehri and Wilce (1985). They suggest that children make associations between the boundary sounds of the spoken word and the first and last letters of the printed word. Indeed, in experimental studies (Ehri and Wilce, 1985, 1987b) they found that children who could not yet apply a systematic decoding strategy could still use partial phonetic cues in reading. Conversely, the type of phonological awareness evidenced in the ability to detect and produce rhymes could contribute to reading by drawing attention to the sound properties of words. As the exclusive use of visual and contextual cues becomes increasingly inefficient in early reading, the child begins to search for a more effective strategy. At this point the beginning reader turns to available knowledge about the sound properties of words. Awareness of the overall sound properties of words may help the child to make initial connections between letters in written words and phonetic content of spoken words. Thus, it is feasible that phonetic-cue reading is facilitated by implicit PA. Another way that children might use the sound properties of words in beginning reading is proposed by Bradley and Bryant (1985) and Goswami (1987). They suggest that, given the opportunity to read words which share common spellings, children use analogical reasoning to work out that words that sound the same are spelled similarly, and Goswami (1987) confirmed this by showing that young children were more successful in reading target words when they were presented with another word which shared a spelling than when the target words were given in randomized lists. Our data suggest that, at this early stage, reading and implicit PA act reciprocally to build skill in each other.

After this initial stage, reading develops more from explicit PA, the ability to analyze the phonemic content of words, and no longer relies on implicit PA. Whereas explicit PA was initially dissociated from reading, in subsequent developmental stages of reading this analytic ability becomes important. This change from the use of a global to an analytic sound strategy is first evidenced in second stage path coefficients from explicit and implicit PA (real words: 0.30, −0.28; nonsense words: 0.27, −0.21). In the next stage explicit PA significantly predicts reading for the first time (nonsense words: 0.50). This strategy change suggests that beginners find it advantageous to become increasingly analytic in their approach to forming associations between written and spoken words. It seems that, just as previously the major use of a visual strategy in reading gave way to a phonological processing strategy, so the use of a global awareness of the sound properties of words is itself later superseded by the use of a more analytic phonological ability. During the final stage of development in this model explicit phonological awareness emerges as an important contributor to reading. Here is evidence of entry into a new stage in the acquisition of reading. During this stage children begin to apply explicit knowledge of the phonemic content of words to reading. In the reading model entry into this new stage is indexed by a large rise in the contribution of explicit PA and a decrease in the influence of implicit PA. In the final stage of the model, explicit phoneme

awareness and letter-sound knowledge predict reading for the first time; however reading does not predict itself. The way children are approaching reading has changed and explicit phonological awareness seems to be largely responsible for this transition.

The results of the reading model suggest little direct mutual interaction in the development of explicit and implicit phonological awareness. Although explicit PA initially takes from implicit PA, thereafter it develops independently of contributions from implicit PA. This indicates that there is development of an analytic awareness of phonemic content from a more generalized, wholistic awareness of the sound structure of words, but then it is experience with written words which rationalizes and makes relevant explicit PA. Growth of phonological awareness follows a developmental sequence which progresses from an ability to detect overall sound properties in words to ability to isolate constituent sounds in words.

MODEL 2: SPELLING ALONE

In the spelling model we see a similar pattern in the relation between implicit PA and spelling to that previously evidenced between implicit PA and reading. To begin with, the relation is interactive: spelling is the best predictor of implicit PA (0.62) and, to a lesser degree, implicit awareness predicts spelling real and nonsense words (0.37, 0.31). Spelling and implicit PA are unrelated in the next stage. Neither type of spelling serves to enhance implicit PA (0.01, 0.04) nor does implicit PA facilitate spelling (0.08, 0.04). Spelling benefits somewhat from implicit PA in the last measured stage (nonwords: 0.27). While implicit PA exhibits a declining influence on spelling, explicit PA maintains a strong influence from the onset of spelling skills through the early stages of acquisition. At the outset, explicit PA is a major contributor to the growth of each type of spelling (0.33, 0.32). However, spelling is not enhancing explicit PA (0.10). This pattern is repeated in the developmental stages that follow. Explicit PA continues to contribute significantly to spelling in the second stage (0.35, 0.45). In the final stage explicit PA is by far the best predictor of the spelling of both real and nonsense words (0.63, 0.53). In the second phase the ability to spell nonsense words benefits explicit PA (stage 2: 0.37, stage 3: 0.36) whereas skill in spelling real words does not (stage 2: -0.08; stage 3: -0.37).

The first measure of spelling, the ability to use letters to represent partial phonemic content of words, predicts later ability to spell real and nonsense words (0.41, 0.27). At phase two, spelling real words and explicit PA jointly predict the ability to spell nonsense words (0.74, 0.45). Neither type of spelling significantly predicts its own development during the final stage, although there is a pathweight of 0.36 from spelling nonwords to itself at the beginning of the third year. At this point in the developmental pattern, explicit PA is the only significant predictor of spelling (0.63, 0.53). Letter-sound knowledge does not appear to have any large deterministic affect on spelling in either the first (0.08, 0.21) or last measured stages (0.09, 0.16).

The spelling model does not provide any new information about the early development of the relationship between the two types of PA. Consistent with the reading model, implicit PA initially predicts explicit PA (0.37) but not the reverse (0.07). Subsequently, implicit PA loses its power to predict the growth of explicit PA

(0.15). In comparison, there is a moderate increase in the effect of explicit PA on implicit PA from the first to the second stages (0.07, 0.35).

To summarize, both explicit and implicit PA contribute to the formation of spelling skills. Thereafter, explicit PA becomes a powerful factor in the acquisition of spelling while the effect of implicit PA is greatly diminished.

DISCUSSION OF DEVELOPMENTAL PATTERNS IN THE SPELLING MODEL

The pattern of development in model 2 highlights the key role of explicit PA in beginning spelling. Explicit phoneme awareness figures prominently in the early formation and later development of spelling ability. Implicit PA is equally important in the initial stage of spelling development but later exhibits greatly diminished influence on spelling progress. How can we account for the pattern of decreasing influence of implicit PA and the increasing effect of explicit PA on early spelling development? To begin with, the contribution of phonological awareness to spelling is equally divided between implicit and explicit PA (spelling real words: 0.37, 0.33; spelling nonsense words: 0.31, 0.32). That both types of PA are useful at this stage makes sense in terms of the task confronting the novice speller. The beginning speller must ultimately learn to represent a word's constituent sounds with letters. It is reasonable to propose that the earliest attempts to spell involve both sensitivity to the overall sound properties of words and a rudimentary segmentation of individual phonemes from the sounds of words. An awareness of the general sound characteristics of a word could help the beginner to attend to acoustic properties that give definition to the sound content of a word. The ability to detect the acoustic boundaries, or the beginnings and ends of words, would provide the novice speller with a way to begin processing the sound content of words. The significant contribution of spelling to implicit PA in the first phase of development (0.62) supports the proposition that first attempts at spelling involve the use of a wholistic approach to the sound content of words. The next step towards successful spelling requires a more analytic approach. At some point the child begins to develop skill in isolating and extracting a sequence of individual phonemes that correspond to the sounds of a word as they occur in the stream of speech. This is a difficult task when approached in either an auditory or articulatory manner. In the final phase of the model, explicit PA has become the dominant factor in spelling development. Spelling, which previously played an important part in its own development, is now approached principally through an analytic phonological strategy. It is notable that proficiency in spelling nonsense words is now contributing to explicit phoneme awareness. The spelling of nonsense words may promote a more conscious awareness of the phonemic structure of words than the spelling of real words since, when spelling nonsense words, the beginner's attention is centred solely on the procesess of segmentation and spelling without interference from specific orthographic, visual, or semantic knowledge of the word.

There are several implications of the pattern of developmental interaction between spelling and phonological ability. As spelling skill begins to take form, the beginner relies on a phonological strategy based on an overall impression of the sound content of words which may contain rudimentary information pertaining to individ-

ual phonemes. In turn, these early endeavours in spelling contribute to an awareness of the general sound properties of words. In the next stage, as children begin to demonstrate proficiency in spelling with complete phonemic descriptions, the novice speller employs a more explicit or analytic phonological strategy. This progression in spelling from the use of wholistic to analytic phonological strategies is analogous to the movement from semi-phonetic to phonetic spelling proposed by Gentry (1982). Entry into the phonetic stage is marked by the first successful attempts at sequentially mapping the phonemic content of words. The results of the spelling model are in accord with the idea of progression from an inchoate stage in spelling where the beginner makes crude analyses of phonetic content to a more advanced stage in which the novice speller can distinguish sequences of separable phonemes. The power of explicit PA to facilitate this progression appears to supplant the influence of implicit PA and eventually, spelling itself. This sequence of development in spelling and phonological awareness is similar to the pattern seen in the reading model but there is one important difference. Explicit PA plays a major role at the onset of spelling skill and sustains its facilitating role through later developmental stages. Reading and explicit PA arise independently, however, and only at a later stage of development does explicit PA begin to contribute significantly to reading.

MODEL 3: READING AND SPELLING

Model 3 allows us to chart the early development of the reading-spelling relationship. The pathweights are shown in Table 4.

If we compare the pathweights for the contribution of spelling to reading (0.31, 0.23) with those for reading to spelling (0.10, 0.06) we see evidence of an early one-way transfer of knowledge from spelling to reading. The same comparison with second-stage pathweights provides additional support for the predominantly unidirectional flow of information between spelling and reading (spelling real words to reading: 0.64, 0.60; reading real words to spelling; 0.14, 0.00). The third stage of development measured in this study marks a change in the reading-spelling relationship. Reading is now developing from abilities other than spelling, while the analytic and generalized spelling skills applied to nonwords are beginning to benefit from reading (0.21, 0.43). Letter-sound knowledge has become the best predictor of real word reading (0.38) while explicit PA is now the best predictor of nonsense word reading (0.53). Explicit PA maintains its strong influence over spelling (0.63, 0.49); however, other abilities contribute to spelling to a lesser degree. Model 3 serves to elucidate the early contribution of spelling to reading: it otherwise supports the pattern of results seen in the two previous models. To summarize, reading develops in the first year from spelling, implicit PA, and rudimentary ability in reading. During the second year, reading initially grows from skill in reading real words, and from spelling. However, later we find a divergence in development of the two reading skills: real word reading takes mainly from letter-sound knowledge, whereas nonsense word reading benefits primarily from explicit PA. Consistent with the reading model, both types of phonemic awareness and incipient spelling ability contribute to the growth of spelling in the first year. Implicit PA leaves the set of contributors at the beginning of the second year and explicit PA is the sole significant predictor of spelling at the beginning of the third year. The pattern of relations

Table 4: LISREL path coefficients indicating contributions of early ability to development of later abilities (Path coefficients in bold are significant at $p < .05$.)
(READ: Reading; SPELL: Spelling; EXPL.PA: Explicit Phonological Awareness; IMPL.PA: Implicit Phonological Awareness; LS: Letter Sound. See text for details.)

READING–SPELLING MODEL

PHASE ONE: BEGINNING FIRST SCHOOL YEAR TO END OF FIRST SCHOOL YEAR

GAMMA	READ	SPELL	EXPL.PA	IMPL.PA	LS
READ (real)	**0.37**	**0.31**	0.08	**0.36**	0.06
READ (non)	0.18	0.23	0.17	**0.41**	0.08
SPELL (real)	0.10	0.35	**0.32**	**0.38**	0.07
SPELL (non)	0.06	0.24	**0.31**	**0.31**	0.21
EXPL. PA	−0.04	0.13	**0.42**	**0.36**	0.11
IMPL. PA	0.15	**0.53**	0.06	**0.49**	−0.20

PHASE TWO: END OF FIRST YEAR TO AUTUMN OF SECOND YEAR

BETA	READ REAL	READ NON	SPELL REAL	SPELL NON	EXPL. PA	IMPL. PA
READ (real)	**0.66**	−0.34	0.64	−0.10	0.21	−0.25
READ (non)	0.31	0.07	**0.60**	−0.09	0.18	−0.09
SPELL (real)	0.14	−0.33	**0.76**	−0.02	**0.34**	0.07
SPELL (non)	0.00	−0.04	**0.77**	−0.22	**0.45**	0.05
EXPL. PA	0.34	−0.10	−0.02	0.20	**0.50**	0.03
IMPL. PA	0.27	0.37	−0.22	−0.19	0.35	0.12
LS	0.36	0.24	−0.20	−0.14	0.26	−0.08

PHASE THREE: BEGINNING OF SECOND YEAR TO BEGINNING OF THIRD YEAR

BETA	READ REAL	READ NON	SPELL REAL	SPELL NON	EXPL. PA	IMPL. PA	LS
READ (real)	0.20	0.24	0.00	−0.12	0.30	0.08	**0.38**
READ (non)	0.03	0.22	0.00	−0.05	**0.53**	0.01	**0.30**
SPELL (real)	0.03	0.01	0.04	−0.10	**0.63**	0.09	0.09
SPELL (non)	0.21	0.43	−0.32	0.13	**0.49**	0.27	0.17

between implicit and explicit PA seen in Model 3 is consistent with that in both the reading and spelling models. Implicit PA initially contributes to explicit PA but not the reverse. In the second year the pattern changes: explicit PA no longer benefits from implicit PA but begins to assist in the growth of implicit PA. As in the previous two models, letter-sound knowledge takes from reading and explicit PA and becomes a significant predictor of real word reading in the second school year.

DISCUSSION OF DEVELOPMENTAL PATTERNS IN READING AND SPELLING MODEL

The inclusion of reading and spelling together with phonological awareness in Model 3 enables us to follow the routes of interaction among these skills through the early course of their development. We are particularly interested in charting strategy shifts in reading and spelling and in examining how implicit and explicit phonological awareness come into play in such changes. The three phases of measurement in this model of early reading and spelling development portray a changing configuration of contributors to these abilities.

Phase One: Early formation of skills

Beginning readers use a rudimentary form of phonological processing that draws from two sources of information about the sound content of words: the ability to detect general sound properties of words and a rudimentary explicit awareness of their phonemic content. Implicit information about the sound properties of words directly affects early reading: explicit knowledge of phonemic content comes to reading via spelling experience. There are two ways that beginners could be using implicit phoneme awareness in the formative stages of reading. One involves the concept of a simple phonetic learning mechanism proposed by Ehri and Wilce (1985). They describe a process in which the beginner uses knowledge of letter-sound correspondences to make associations between phonetic cues in spoken words and letters in printed words. According to Ehri and Wilce, this type of reading is possible without an explicit understanding of how letter-sounds map onto pronunciations. Beginning readers might also use an implicit awareness of rhyming components in words to read using an analogy strategy (Bryant and Goswami, 1987). When children realize that words that sound the same are spelled similarly, they can use this knowledge to generalize from the pronunciation of a familiar word to the pronunciation of an unknown word that shares the same spelling. Results of the reading-spelling model indicate that in addition to using a visual strategy in the early stages of reading acquisition, beginners approach reading via a phonological (albeit rudimentary) route. This model identifies spelling as an important contributor to the early acquisition of reading. This result is contrary to Shanahan and Lomax's hypothesis (1986) that word recognition is not affected by spelling knowledge. They suggest that the effect of spelling on word recognition in their writing-to-reading model is due to an earlier influence of phonemic knowledge or word knowledge. Our results support an alternative interpretation: spelling influences the development of word recognition in the early stages of reading acquisition. Although explicit PA does not contribute directly to reading at this point, it seems to be influencing

reading development through spelling. The present study supports Mommers' (1987) conclusions that spelling experience is contributing to reading by promoting the use of phonological processing.

Experience in spelling may encourage children to approach the written word in terms of its component sounds. Spelling provides the opportunity to link phonemic awareness with letter-sound knowledge. The making of this connection is thought to be a necessary prerequisite to the development of a phonological strategy in reading (Juel, Griffith and Gough, 1986). Evidence of carry-over from explicit phoneme awareness to spelling and from spelling to reading suggests that spelling is the vehicle through which the beginner learns to utilize letter-sound knowledge as a map of the sound structure of words.

Phase Two: Early development

In the next developmental stage we see a dramatic decrease in influence of implicit PA on reading, spelling and explicit PA. Spelling, however, maintains a strong influence on reading. We account for the decline in the influence of implicit PA in terms of the increasing usefulness of explicit PA as an effective phonological strategy in spelling, and, through spelling, in reading. As children become more proficient in dividing a word into a sequence of constituent phonemes they may come to prefer this strategy over a strategy that does not provide as much information about the component sounds in words. And it seemed that at about this point beginners recognize the relevance to reading of the explicit strategy used in spelling. Other than real word reading, spelling is the only major contributor to reading at this stage. Spelling may thus be serving as a vehicle for the transference of an explicit phonological strategy to reading. The applicability of explicit PA to word spellings is more obvious in the act of spelling than in reading and practice in applying explicit segmentation skills in spelling encourages learners to see word spellings as maps of phonetic content. When children adopt a sound strategy in reading they learn to decipher words by relating letter-sound knowledge to pronunciations of words. The stumbling block for the beginning reader is in mapping individual sequences of letter-sound correspondences onto the overlapping sequences of phonemes in the spoken word. We suggest that through spelling, children come to deal with words as sequences of sounds embedded in larger units and they learn that individual overlapping sounds can be represented by series ofseparate letters. In this way, experience in spelling could make a vital contribution to the formation of a source of knowledge which can be accessed for both spelling and reading. This knowledge base is generally described as a group of rules pertaining to letter-sound mapping and has been called the alphabetic principle or the orthographic cipher (Juel, Griffith and Gough, 1986). The pattern of interactions among reading, spelling, and phonological awareness in the first two phases of model 3 provides evidence that use of an alphabetic strategy in reading is derived from spelling experience.

Phase Three: Continuing development; entry into the alphabetic stage

Later in the developmental pattern, when the alphabetic principle is established, beginners directly access explicit PA to help them read nonsense words. This agrees

with the findings of previous longitudinal studies that have similarly identified phoneme segmentation ability as a strong predictor of later reading skills (Lundberg, Olofsson and Wall, 1980; Ellis and Large, 1988; Share, Jorm, Maclean and Matthews, 1984). The direct influence of explicit PA indicates a change in reading strategy that signals entry into an alphabetic stage of reading (Frith, 1985). Now children begin to decode printed words through the processes of sounding out and blending. Between the second and third year in school, skill in spelling and reading no longer contribute significantly to their own growth. Explicit phonemic awareness becomes the most important influence in the development of spelling and reading nonsense words. We see this as evidence that children are beginning to read and spell via an alphabetic strategy. Seen together, the influence of spelling on reading in the previous two phases, and the emergence of explicit PA as a predictor of reading in the third phase, support Frith's (1985) theoretical model of reading and writing acquisition. She postulates that spelling is the pacemaker for use of the alphabetic strategy. The reading-spelling model gives us additional insight into the changing pattern of early contributors to the growth of literacy.

From this investigation two important implications emerge for future studies: implicit and explicit phonological awareness affect reading and spelling at different points in their development, and experience in spelling promotes the use of a phonological strategy in reading.

A developmental hierarchy for phonological awareness

The results of the reading-spelling model give credence to the existence of a hierarchical sequence of abilities in the development of phonological awareness (Bradley and Bryant, 1985). Our data suggest that, within this sequence, implicit and explicit PA represent different levels of ability. In the formative stage implicit PA is an important factor in the growth of explicit awareness of phonemes within words (0.36). Yet at this early stage beginning skill in explicit segmentation does not contribute to the growth of implicit PA (0.06). This one-way carry-over of information from implicit to explicit PA implies a developmental progression from a general sensitivity to the sound properties of words to a more analytic awareness of separable phonemic components. At the initial testing point subjects found it easier to detect rhyme than to isolate individual phonemes: this evidence supports the proposition that implicit PA precedes explicit PA developmentally (Clark, 1978; Bryant and Goswami, 1987). Stanovich et al. (1984) found a similar developmental distinction between implicit and explicit PA. They found that kindergarten children are able to perform tasks involving rhyme with ease, whereas tasks requiring more explicit insight into phonemic structure proved more difficult for the young children in their sample. In addition, their results show that performance on several different tasks demanding an explicit awareness of constituent phonemes was highly correlated and these tasks thus formed a distinct group. They conclude that this interrelatedness of the analytic (nonrhyming) phonological tasks indicates that they tap the same phonological ability. Our results support this idea of a developmental continuum in which knowledge of rhyme precedes knowledge of specific phonemic composition. Additionally, the present data suggest that explicit phonemic awareness arises from a tacit awareness of the overall sound content of words. From the results of phase one we can construct a tentative description of the way in which

children begin to develop insight into the phonemic structure of words. By utilizing information about the general sound form of words, they begin to define with increasing accuracy the composition of phonemes within words. The pivotal point in the transition from global to analytic strategies may lie in the ability to attend to the boundary sounds of words, or to some other salient phonetic feature. It seems that, once the child is able to focus on one of these aspects, s/he has established a point of departure from which to begin to penetrate explicit phonemic content. Pathweights for the next phase indicate that explicit PA ceases to benefit from implicit PA (0.03). Explicit PA now emerges as an independent phonological ability. It appears that with the development of skill in isolating phonemic segments, this newly acquired analytic approach is more useful in the decomposition of sound components than implicit means of accessing sound content. At this point in the growth of phonological awareness implicit PA begins to benefit from explicit PA (0.35). As children become increasingly proficient in segmenting phonemes, they seem to generalize the use of an analytic strategy to phonological tasks which were previously approached with a global strategy. In charting the interactive process of development of implicit and explicit PA, we see the emergence of explicit PA from a rudimentary ability which relied on a tacit awareness of the sound properties of words. We also see evidence of the subsequent influence of explicit PA on implicit PA. In accordance with theoretical models of development in phonological awareness (Elkonin, 1973; Andresen, in Valtin, 1984), the present study provides evidence that children move from an implicit appreciation to an explicit understanding of the sound structure of words. Further longitudinal research is needed that addresses the question of how different levels of PA fit into a developmental pattern of growth leading to sophistication in identifying and manipulating phonemic components in words.

The small sample sizes in this study entail that the present causal path analysis can only be exploratory. However, they provide insight and foundations for future research into the interactive processes of growth in reading, spelling and phonological awareness. In line with theoretical work and recent experimental studies (Stanovich, Cunningham and Crammer, 1984; Backman, 1983), our results indicate that the growth of phonological awareness follows a developmental continuum and that different levels of PA play specific roles in the acquisition of reading and spelling skills. It is via an ongoing, interactive pattern of development among growing ability in spelling, reading and phonological awareness that the child advances into literacy.

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