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The Impact of Early Metalinguistic Competencies and Memory Capacity on Reading and Spelling in Elementary School: Results of the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC)

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This paper reports on a longitudinal study dealing with the development of literacy in young children. A total of 163 children were first tested during their last year in kindergarten using a variety of tasks that tapped phonological processing, memory capacity, early literacy, and intelligence. Children's word decoding, reading comprehension, and spelling skills were assessed in elementary school several years later. As a main result, all of the predictor domains had a significant impact on the acquisition of literacy in elementary school, although the contribution of each domain differed as a function of the criterion measure. An attempt to identify children-at-risk using a kindergarten screening test provided encouraging results. Nonetheless, it was shown that whereas group predictions of reading and spelling performance can be quite accurate, the individual prognosis of school problems is far from perfect.

Introduction

In this paper, we summarize research that has been carried out as part of the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC, Weinert, & Schneider, 1987, 1992). The major goal of the LOGIC study was to assess young children's cognitive and social development from kindergarten to the end of elementary school. The study started in 1984 when children just entered German kindergarten at the age of four, and will be completed in July, 1993, after children finish sixth grade.

One subgoal of the study — and the one of core relevance for this paper — concerned the possibility to predict school performance in reading and spelling from cognitive processing skills assessed at the end of kindergarten. Given that we already had collected numerous data on various aspects of children's cognitive abilities (e.g., their verbal and nonverbal IQ) during the first two years of kindergarten, we took the opportunity to carry out a prospective study on cognitive prerequisites of reading and spelling. Thus our plan for the third and last year of kindergarten was to include a variety of cognitive measures tapping skills that, according to the literature, seemed suited to predict reading and spelling in elementary school.

One of the major problems we experienced at that time was to select kindergarten tasks that qualified as precursors of reading and spelling. Undoubtedly, longitudinal research on the preschool prediction of academic achievement has accumulated over the last 20 years, and numerous predictors of reading and spelling can be found in the relevant literature (cf. the reviews by Horn & Packard, 1985; Tramontana, Hooper, & Selzer, 1988). However, there seem to be at least two general problems with the majority of studies summarized by Horn and Packard (1985) and by Tramontana et al. (1988). First, the selection of predictor measures was not guided by theoretical considerations. That is, many measures were not proximal to reading processes (e.g., motor skills, behavioural-emotional functioning). Second, differential validity of predictor variables was either not assessed at all, or found to be low. In the latter case, predictors of reading and spelling also predicted performance in math or geography.

Fortunately, these problems were no longer apparent in a series of longitudinal studies published in the early and late eighties (e.g., Bradley & Bryant, 1985; Juel, 1988; Lundberg, Frost, & Petersen, 1988; Skowronek & Marx, 1989; Stanovich, Cunningham, & Feeman, 1984). In all of these studies, it was shown that phonological awareness (the ability to detect and differentiate phonemic units in speech) was a very good predictor of children's later reading and spelling performance (see also Tunmer & Nesdale, 1985; Wagner & Torgesen, 1987). Further, several studies demonstrated that memory capacity and information processing speed were additionally related to reading ability (e.g., Daneman & Blennerhassett, 1984; Ellis & Large, 1988; Perfetti & Lesgold, 1978; Skowronek & Marx, 1989), and that the presence or absence of preschool letter knowledge or early literacy turned out to be an issue strongly related to predicting early reading skills (cf. Bradley & Bryant, 1985; Lundberg et al., 1988).

Based on this evidence, we decided to include several indicators of phonological awareness, measures of memory capacity/information processing speed, and indicators of early literacy in our set of predictor instruments. In addition, measures of verbal and nonverbal intelligence were included because intelligence used to have a strong impact on later reading and spelling performance in many earlier studies.

Major goals of the study

Our study focused on four central problems (for details, see Näslund, 1990; Näslund & Schneider, 1991, 1993; Schneider, 1992; Schneider & Näslund, 1992):

1 — We were interested in exploring the relative impact of IQ, phonological awareness, memory capacity, and early literacy on reading ability (i.e., decoding speed and reading comprehension) and spelling. Regarding phonological processing, a distinction was made between phonological awareness in the broad and narrow sense (cf. Skowronek & Marx, 1989). Whereas the first one refers to the ability to segment the stream of speech sounds into larger units like syllables and rhyme words, the latter requires children to segment speech into the abstract linguistic units of phonemes. Combining indicators of phonological awareness in the broad and narrow sense in one single predictor set enabled us to judge the relative importance of both phonological awareness components for the acquisition of reading and spelling.

2 — Another related focus concerned the relative influence of early literacy as compared

with phonological awareness in the broad and narrow sense on later reading and spelling performance. This issue has been discussed controversely in the literature for quite a while. Although Bradley and Bryant (1985) and others have demonstrated phonological awareness in preschool children, Morais and colleagues (1991; Morais, Cary, Alegria, & Bertelson, 1979) claim that phonological awareness associated with reading cannot develop in the absence of grapheme-phoneme knowledge. For Morais and his colleagues, letter knowledge is necessary for the development of phonological awareness (see also Ehri, 1989; Read et al., 1986). In our view, one source of confusion was that Bradley and Bryant referred to phonological awareness in the broad sense, whereas Morais and colleagues focused on phonological awareness in the narrow sense. As German kindergarten children unlike American or British children do not learn to read before elementary school, their knowledge of the alphabet and phoneme-grapheme correspondences is usually very poor. Thus our study seemed suited to explore the issue whether phonological awareness does have an effect on later reading independent of letter knowledge.

3 — A third goal of the study was to explore the inter-relationships among the various sets of independent variables (i.e., phonological processing, memory capacity, early literacy, and IQ) in predicting reading and spelling performance. As traditional regression models based on observed variables are not suited for this purpose, a latent causal modeling approach (LISREL; cf. Jöreskog & Sörbom, 1984) was chosen instead. Based on this methodological approach, we explored the issue of how the predictor concepts influence reading skill and spelling performance in second grade, and whether different model structures result for the prediction of reading vs. spelling.

4 — The last major issue of interest concerned the problem of identifying children-at-risk in reading and spelling. Early interventions in the preschool and kindergarten years have been shown to yield positive results (cf. Lundberg et al., 1988). A screening test developed by the Bielefeld research group (Skowronek & Marx, 1989; to be described below) was used in the LOGIC study to identify children with obvious delays in phonological processing and reduced memory capacity. The question of major interest was whether those children classified as at-risk with regard to reading and spelling during the last kindergarten year would turn into dyslexic children in elementary school.

Description of sample and test instruments

Subjects

A total of 210 children were initially recruited for the LOGIC study. For various reasons, 22 children were not promoted to elementary school together with the rest of the sample but stayed in kindergarten for one more year. Reading and spelling data for these subjects are not considered in our analyses. Complete data sets from 163 children were available for the analyses dealing with spelling performance across the four years of elementary school. Due to organisational problems, not all of the children participated in the decoding and reading comprehension tests. Thus the analyses focusing on these variables were based on only 121 subjects.

The children began kindergarten at age 3-4. On average, they were almost 6 years old when they were presented with the phonological processing, memory capacity, and IQ tasks during the last year of kindergarten. Reading comprehension, decoding speed, and spelling skill were assessed both at the beginning and at the end of second grade. Additional spelling tests were given in the third and fourth grade.

Predictor tasks

The following tasks were given during the last year of kindergarten:

1) The *Bielefeld screening test* consisting of eight different tasks which according to the authors taps children's phonological awareness, their attention and memory performance (cf. Jansen, Knorn, Mannhaupt, Marx, Beck, & Skowronek, 1986; Marx, 1992; Skrowronek & Marx, 1989);
2) a *sound categorization task* developed by Bradley and Bryant (1985) tapping children's phonological awareness in the broad sense (rhyming);
3) *verbal memory capacity* assessed by a word span task (Case, Kurland, & Goldberg, 1982), and a listening span (sentence span) task developed by Daneman and Blennerhassett (1984);
4) *early literacy* assessed by children's letter knowledge, name writing, and sign knowledge, and
5) *verbal and nonverbal intelligence*, indicated by children's performance on the Hannover Wechsler Intelligence Test for Preschool Children (HAWIVA; Eggert 1978), and the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972).

Four subtests of the Bielefeld screening instrument assessed components of phonological awareness. The *rhyming task* consisted of 10 word pairs, half of which did rhyme. Children had to indicate which word pairs did rhyme and which did not. In the *syllable segmentation task*, 10 words were presented via audio tape. The children's task was to segment each word into its syllables, thereby clapping their hands for each syllable. In the *sound-to-word-matching task*, children were presented with a number of 10 audio-taped words. After having repeated each word, children had to indicate whether a specific sound pattern (e.g., an 'au') could be identified in the test word (e.g., 'Auge'). Finally, the *sound blending task* tapped children's awareness of isolated sounds. The words presented were segmented into their constituent sounds, and the children's task was to identify the words.

The remaining four subtests of the Bielefeld screening instrument tapped memory and attentional processes. The *visual word matching test* required children to identify the 'twin' (identical word) of a target word out of a number of four alternatives. The target word was always given in the upper row of a card, and three distractor items and the target word were depicted in a second row below. The number of correct solutions (max = 12) was taken as the dependent variable. In the *repetition of nonsense words* subtest, children were asked to listen carefully to a series of pseudowords ('Zippelzak', 'Binnebasselbus') that they should repeat as accurately as possible. The number of pseudowords correctly repeated was used as the dependent variable. Finally, two different *rapid naming tasks* were given because there is evidence in the literature that poor readers cannot access information in semantic or lexical memory as quickly as normal and good readers (cf. Blachman, 1984; Denckla & Rudel, 1976). The first task required rapid naming of the colours of objects from uncoloured line drawings. Here, the children's task was to indicate the correct colors as quickly as possible. The second task was structurally similar and required rapid naming of the correct colours of objects with incongruent colours (e.g., a blue lemon). This task differs from the first in that the child has to cope with interference and distraction problems. In both tasks, the number of mistakes and the time needed to complete the trials was assessed. The time measure (aggregated across both tasks) was used as dependent variable in the present analyses.

The *sound categorisation task (phonological oddity measure)* developed by Bradley and Bryant (1985) consisted of three different components. In the first subtest *(first sound oddity)*, series of four one-syllable words were given. Children's task was to identify the word with a different first sound (example: Fest, Feld, Fels, Helm). The number of correct solutions (max = 9) was used as the dependent variable. The two remaining subtests were similar in nature. In the *middle sound oddity task*, children had to find out which of four words did not share the same middle sound (example: Hahn, Sohn, Lohn, Mohn). In the *end sound*

oddity task, the same experimental structure was used. This time, the children's task was to identify the word that had a different end sound as the other three (example: Speck, Dreck, Stern, Fleck).

To assess *verbal memory capacity*, two different tasks were used. The *word span task* developed by Case et al. (1982) consisted of 10 sets of one syllable words. The set sizes varied between three and seven items. Beginning with sets of three words, two trials were given for each set size. Children were instructed to first listen to the entire set, then repeat the words they heard. Children's word span was defined as the maximum number of words that could be repeated in the correct order.

In addition, the *sentence span/listening span task* adapted from Daneman and Blennerhassett was used to tap memory capacity. Seventy-five sentences (at maximum), ranging in length from three to seven words, were read to each child. Sentences were grouped in five sets each of one, two, three, four, and five sentences. Children were asked to repeat the sentences in each set verbatim. Testing ended when the child failed to recall all five sentences at a particular level. The total number of sentences (or words) recalled correctly was chosen as the dependent variable.

Three different tasks assessed *early literacy* and concepts about print in our kindergarten children. A *letter naming task* assessed children's knowledge about phoneme-grapheme correspondences. The number of letters correctly identified was used as dependent variable. The second task (*sign knowledge or Logo task*) was originally developed by Brügelmann (1986) and later modified by the Bielefeld group (Skowronek & Marx, 1989). The Logo task tapped children's knowledge of letters and words that are hidden in familar settings. Typical examples are traffic signs (e.g., the STOP sign) and trade marks. In some trials, only the original letters were given without any graphic context. In others, only the graphic context was given and the letters omitted. The dependent variable in the present analysis was the number of correct responses in trials focusing on the letters. Finally, *name writing* was chosen as another variable tapping early literacy. Children were asked to write down as many words as they already knew. The number of words correctly spelled was used as the dependent variable.

Tests of *verbal and nonverbal intelligence* were given to assess the importance of unspecific predictors of reading and spelling. *General verbal ability* was measured by the verbal section of the Hannover-Wechsler Intelligence Test (HAWIVA) for preschoolers. This section includes vocabulary and verbal comprehension items. The Columbia Mental Maturity Scale (CMMS) developed by Burgemeister, Blum, and Large (1972) was considered an appropriate test to assess children's *nonverbal intellectual ability*. This test taps general reasoning ability of children aged 3 years 6 months through 9 years 11 months. Depending on the subjects' age level, between 52 and 65 pictorial and figural classification items were administered. For each item, children were asked to look at the pictures on a card (varying between 3 to 5), and to select the one that was different from or unrelated to the others. The number of correct solutions was taken as the dependent variable.

Criterion tasks assessed in elementary school

The task assessing *word and nonword decoding speed* was adapted from Rott and Zielinski (1986). The items (four-letter words and pseudowords) were presented on a computer screen. An internal timing device measured children's responses from the moment of presentations on the screen. A total of 30 words and 30 nonwords were provided. Mean decoding speed was calculated separately for both types of words. The decoding speed tasks were first given at the beginning of second grade and repeated at the end of the school year.

A thirty-item test developed by Näslund was used to measure *reading comprehension* and *word knowledge* within the context of single sentences and longer texts (short stories). A total of 18 multiple-choice items tapped word knowledge. They included finding synonyms and antonyms within the context of a sentence. The text comprehension part consisted of five short stories followed by two or three multiple-choice questions. This task was designed to

test children's understanding of the text, deducing answers from inferences based only on information in the stories.

Finally, the first two *spelling tests* (word dictations) consisted of two partially overlapping versions, the first presented at the beginning of second grade and the other shortly before the end of second grade. Each test included about twenty target words which were taken from different sources and seemed particularly suited to assess spelling competence in second grade. The spelling tests provided in grades three and four were more comprehensive (60 words and 81 words in the third and fourth grade, respectively), and were given as sentence dictations. About two thirds of the materials consisted of familiar words taken from the official list of vocabulary for third and fourth graders distributed by the Bavarian Ministery of Education. The remaining items were less familar and irregular words. For all spelling measures, the number of correctly written words was chosen as the dependent variable.

Results

Table 1 gives the means, standard deviations, and the ranges for the various predictor and criterion variables. As can be seen from Table 1, children performed very well on most subtests of the Bielefeld screening test. This finding is in accord with the principles of test construction used by the Bielefeld research group. According to the authors, only those subtests were included in the final version of the screening test that particularly discriminated in the lower third of the distribution. A comparison of the Bielefeld rhyming test and Bradley and Bryant's sound categorisation task shows pronounced differences in task difficulty: On average, about 80 percent of the children succeeded on the Bielefeld rhyming test, whereas less than 50 percent of the responses to the first sound oddity task were correct.

Table 1
Means, standard deviations, and range for the major predictors and criterion variables included in the study

Variable	*M*	*SD*	Minimum	Maximum
Nonverbal IQ	109.51	11.70	79	137
Word span	3.48	.97	1	6
Sentence span (N of sentences)	14.04	6.64	2	38
Sign knowledge	.94	1.45	0	5
Letter knowledge	6.75	7.44	0	26
Names written	2.06	1.93	0	12
First sound oddity	4.21	2.07	1	9
Middle sound oddity	7.03	2.22	2	9
End sound oddity	6.62	2.31	2	9
Bielefeld screening				
Rhyming	8.12	1.39	3	10
Syllable segmentation	8.41	1.79	3	10
Sound-to-word matching	6.83	2.20	0	10
Sound blending	6.98	1.95	0	10
Visual word matching	10.13	2.11	0	12
Repetition of nonsen words	7.21	2.04	0	11
Rapid naming (time)	65.47	18.73	27	148.5
Word decoding speed (beginning Grade 2)	1.85	.57	.9	3.2
Word decoding speed (end of Grade 2)	1.68	.62	.8	3.3
Reading comprehension (beginning Grade 2)	22.17	6.45	7	28
Reading comprehension (end of Grade 2)	25.98	4.19	8	29
Spelling (beginning Grade 2)	10.22	2.18	4	17
Spelling (end of Grade 2)	11.04	3.97	5	18
Spelling (end of Grade 3)	31.07	5.92	8	40
Spelling (end of Grade 4)	51.69	6.30	25	60

In comparison, the various tasks concerning early literacy turned out to be rather difficult. In particular, the findings regarding letter knowledge showed that most German kindergarten children do not know much about grapheme-phoneme correspondences. Almost 50% of the children did not know more than two letters or less; only a small minority of children (about 9%) knew between 22 and 26 letters and thus showed a certain familiarity with the alphabet. This finding certainly differs from those typically reported for 6-year-olds from Great Britain or the United States.

Relative importance of the predictor variables for subsequent reading and spelling

Multiple stepwise regression analyses were performed to determine the relative influence of the various predictor variables on reading related and spelling skills in elementary school. The dependent measures were word decoding speed, reading comprehension, and spelling. We adopted the procedure used by Bradley and Bryant (1985) in that (nonverbal) IQ was always the first variable to enter the regression equation, followed by those other predictor variables that additionally explained significant proportions of the variance in the respective criterion variable. Although such a procedure probably overestimates the influence of intelligence on the reading and spelling variables, it seems appropriate for our purposes because it ensures that the impact of the remaining predictors on the criterion variables is unconfounded with IQ. Contrary to expectations, the nonverbal IQ variable was generally more predictive of later reading and spelling than its verbal counterpart. Thus only nonverbal IQ was considered in the following analyses.

The results concerning *word decoding speed* are depicted in Table 2. As can be seen from

Table 2
Results of the stepwise regression analysis using word decoding speed as criterion variable

	Predictors	Proportion of variance explained (R^2)	R^2 change
(1) Beginning Grade 2	Nonverbal IQ	.07	.00
	Letter knowledge	.15	.08
	Listening span	.21	.06
	Word matching	.24	.03
	Sound-to-word matching	.26	.02
	Rapid naming	.28	.02
(2) End of Grade 2	Nonverbal IQ	.03	.00
	End sound oddity	.15	.12
	Rapid naming	.21	.06
	Letter knowledge	.25	.04
	Word matching	.27	.02

Table 2, different patterns of results emerged for the two testing occasions. IQ and letter knowledge accounted for most of the variance in decoding speed measured at the beginning of second grade, whereas memory capacity (listening span), attentional features (word matching), phonological awareness in the narrow sense (phoneme-word matching), and information processing speed (rapid naming) all made a significant but numerically small contribution. In comparison, only phonological awareness in the broad sense (end sound oddity task) and information processing speed contributed substantially to the prediction of word decoding speed assessed at the end of second grade. Regardless of measurement point, the total amount of variance explained in the criterion variable was only modest (28% vs. 27% for the first and second measurement point, respectively).

The findings concerning *reading comprehension* are given in Table 3. A closer inspection of this table shows that nonverbal IQ explained a considerable proportion of the variance in reading comprehension for both measurement points. Three indicators of phonological awareness (i.e., first sound oddity, middle sound oddity, and phoneme blending) accounted for the rest of the variance in reading comprehension assessed at the beginning of grade 2. While IQ explained about 15 percent of the variance in reading comprehension, the combined additional contribution of the phonological awareness variables (about 20%) was even more substantial. The findings for the second measurement point differed from those obtained for the first in that the impact of phonological awareness (middle sound oddity, syllable segmenting) was comparably low, and that IQ turned out to be the by far most influential predictor. Only 27 percent of the variance in reading comprehension assessed at the end of second grade was explained by the four predictors included in the regression equation.

Table 3
Results of the stepwise regression analysis using reading comprehension as the criterion variable

	Predictors	Proportion of variance explained (R^2)	R^2 change
(1) Beginning Grade 2	Nonverbal IQ	.15	.00
	First sound oddity	.28	.13
	Middle sound oddity	.33	.05
	Sound blending	.35	.02
(2) End of Grade 2	Nonverbal IQ	.17	.00
	Rapid naming	.21	.04
	Syllable segmentation	.24	.03
	Middle sound oddity	.27	.03

As the findings for *spelling* assessed in second grade were very similar on both occasions, only the results for the second measurement point obtained at the end of second grade are presented in Table 4. In addition to IQ, information processing speed (rapid naming) and letter knowledge made a substantial impact, followed by two phonological awareness variables (sound-to-word matching, sound blending). The impact of the remaining predictor variables (sign knowledge, listening span, and name writing) was comparably small. Overall, about 36 percent of the total variance in spelling assessed at the end of second grade was explained by the various kindergarten predictors.

Table 4
Results of the stepwise regression analysis using spelling in Grade 2 as the criterion variable

Predictors	Proportion of variance explained (R^2)	R^2 change
Non verbal IQ	.11	.00
Rapid naming	.21	.10
Letter knowledge	.26	.05
Sound-to-word matching	.29	.03
Sign knowledge	.31	.02
Sound blending	.34	.03
Listening span	.35	.01
Name writing	.36	.01

Interestingly enough, the predictor quality of the kindergarten variables seemed to improve

over time. When spelling in Grade 3 was chosen as the dependent variable, almost 50 percent of the variance in spelling could be accounted for by eight predictor variables. Again, IQ and letter knowledge made the comparably strongest impact. In addition, listening span and sound categorisation (middle sound oddity, end sound oddity) contributed significantly to the prediction of spelling skill at the end of third grade. A closer inspection of Table 5 shows that the four major predictor domains (i.e., IQ, letter knowledge, memory capacity, phonological awareness) accounted for similar proportions of the variance in the criterion variable. The fact that the kindergarten measures explained more variance in third grade spelling, as compared to spelling in grade 2, may be due to the larger variance in performance obtained for the later spelling tests. Results of the regression analyses performed for spelling at the end of fourth grade were similar to those reported in Table 5 and will not be discussed in detail because of space restrictions.

Table 5
Results of the stepwise regression analysis using spelling in Grade 3 as the criterion variable

Predictors	Proportion of variance explained (R^2)	R^2 change
Non verbal IQ	.13	.00
Letter knowledge	.29	.16
Listening span	.36	.07
Rapid naming	.40	.04
Name writing	.42	.02
Sound-to-word matching	.44	.02
Sign knowledge	.46	.02
Nonword repetition	.47	.01

The interplay of phonological awareness and early literacy in predicting reading and writing in elementary school

As noted above, the causal status of phononogical awareness in the process of learning to read has been discussed controversially in the literature. For some researchers, the emergence of phonological awareness is simply a by-product of learning to read (e.g., Morais; 1991; Morais et al., 1986). For others, it is just the other way around in that the ability to segment the speech stream into units of phoneme size makes children understand the alphabetical principle (cf. Bradley & Bryant, 1985; Lundberg et al., 1988). A third alternative is reciprocal causation, that is, a causal connection running in both directions (cf. Perfetti, Beck, Bell, & Hughes, 1987).

Although our data are correlational in nature which prevents us from causal inferences, they seem suited to test the assumption that phonological awareness can be found among nonreaders. Those 58 children in our sample who did not identify more than 2 letters obviously did not understand the alphabetic principle. When comparing this subgroup with the rest of the sample, we found that, on average, these children scored significantly lower on most tests of phonological awareness. However, performance was significantly above chance level even for this subgroup. These findings nicely replicate those reported by Lundberg and Hoien (1991) for Danish and Swedish children.

A second question of interest concerned the status of IQ, phonological awareness, and memory capacity as predictors of reading and spelling for the subgroup of children with minimal letter knowledge. In particular, we explored the question whether indicators of phonological awareness developed without insight into the alphabetic principle can predict reading and spelling in elementary school.

Multiple stepwise regression analyses carried out for this subgroup clearly confirmed this

assumption. As can be seen from Table 6, three phonological awareness measures (first sound oddity, end sound oddity, phoneme blending task) accounted for about 37 percent of the variance in the word decoding speed measure. The results were similar when reading comprehension was used as the dependent variable: The ability to categorise sounds (first sound odditty, end sound oddity) and to segment syllables explained most of the variance in the dependent variable (about 44%). Similar results were obtained for the various spelling mesaures. From these findings, we can conclude that it is possible to develop phonological awareness despite of a very limited knowledge of the alphabet, and that phonological awareness in the broad sense developed without insight into the alphabetic principle predicts subsequent reading and spelling. On the other hand, it seems important to note that letter knowledge was positively related to phonological awareness. At the end of kindergarten, those children who seemed to understand the alphabetic principle performed better than the children with low letter knowledge on most metalinguistic tasks. Moreover, this early advantage persisted over the elementary school years: On average, children who acquired the alpabetic principle before entering school turned out to be the better readers and spellers in elementary school.

Table 6

Results of the stepwise regression anlysis using word decoding speed and reading comprehension in Grade 2 as the criterion variables (subgroup with minimal letter knowledge)

Predictors	Proportion of variance explained (R^2)	R^2 change
Word decoding speed		
Nonverbal IQ	.15	.00
First sound oddity	.31	.16
Sound blending	.44	.13
End sound oddity	.52	.08
Rapid naming	.58	.06
Word repetition	.64	.06
Reading comprehension		
Nonverbal IQ	.12	.00
First sound oddity	.32	.20
Rapid naming	.43	.11
Syllable segmentation	.57	.14
End sound oddity	.67	.10

The interdependence of phonological processing, memory capacity, early literacy, and intelligence in predicting reading and spelling

One shortcoming of the regression analyses reported above is that they do not inform about possible interrelations among predictor variables. Path or causal modeling procedures seem more adequate for exploring this issue. To overcome the problems of traditional regression analyses based on observed variables, we chose Jöreskog and Sörbom's (1984) latent variable causal modeling procedure LISREL (cf. Näslund & Schneider, 1991; Schneider & Näslund, 1992). In short, one major advantage of this approach is that a measurement model describing the relationships among observed variables is distinguished from a structural model which represents the interrelations among the latent variables or theoretical constructs. Another advantage is that the number of latent constructs is relatively small given that structural/causal relationships are estimated at the level of latent variables and not at the level of fallible observed variables.

In a recent study (Schneider & Näslund, 1992), a theoretical framework suggested by Wagner and Torgesen (1987) was used to categorize the predictor variables into three major latent

constructs. *Phonological awareness* comprised the sound categorisation tasks, the syllable segmentation task, and the sound-to-word matching task. *Phonological recoding in lexical access* was indicated by the two rapid naming tasks, and *phonetic recoding in working memory* was represented by the two memory-span tests. In addition to these three components of phonological processing, *early literacy* (represented by letter knowledge, sign knowledge, and name writing) and *intelligence* served as predictors of reading comprehension and spelling. Finally, the *reading comprehension* and *spelling* criterion variables were each represented by two different tests.

As can be seen from Table 7, the intercorrelations among the latent variables were indeed considerable.

The LISREL modelling approach seemed particularly suited for data analysis because it makes use of this information. Separate causal models were specified for reading comprehension and spelling. In order to explore the validity of our theoretical assumptions, alternative models were specified for each dependent variable, and goodness-of-fit tests were conducted to assess overall model fit. The best fitting structural equation models accounted for about 54 and 62 percent of the variance in the reading comprehension and spelling criterion measures, respectively. Interestingly enough, different causal patterns were obtained for the reading comprehension and spelling models. In the model explaining reading comprehension, IQ, phonological awareness, and working memory served as independent variables, influencing early literacy and recoding in lexical access, which in turn directly affected the dependent variable. Phonological awareness turned out to be the strongest predictor of reading comprehension, followed by recoding in lexical access (i.e., information processing speed). The direct effect of IQ on reading comprehension was comparably low.

Table 7
Intercorrelations among latent variables (data from Schneider & Näslund, 1992)

Variables	(2)	(3)	(4)	(5)	(6)	(7)
1) Verbal IQ	.40	.53	.25	.38	.38	.36
2) Working memory		.60	.46	.28	.36	.41
3) Phonological awareness			.45	.42	.47	.50
4) Recoding in lexical access				.43	.60	.51
5) Early literacy					.39	.49
6) Reading comprehension						.41
7) Spelling						

In the best-fitting model for the spelling construct, only IQ served as independent variable. IQ had a very strong impact on working memory, which in turn heavily influenced phonological awareness. Again, phonological awareness was the strongest single predictor variable, followed by recoding in lexical access. Although IQ did not have a direct impact on spelling, its indirect effect via working memory and phonological recoding in lexical access was essential. Compared to the reading comprehension model, the direct effects of phonological awareness and recoding in lexical access on spelling were more pronounced. Taken together, the major outcome of the study was that components of phonological processing skills represent important prerequisites for the development of subsequent reading and spelling skills. While the strength of the interrelationship seems to vary as a function of the skill under consideration, all components function as reliable predictors of literacy.

The early identification of children-at-risk

A last step of analysis concerned the evaluation of the Bielefeld screening instrument

which was given in the last year of kindergarten. As noted above, the Bielefeld screening test consisted of comparably easy tasks that could be mastered by the majority of children. Only those tasks were included in the battery that discriminated well in the lower third of the distribution (cf. Skowronek & Marx, 1989). In order to identify children-at-risk concerning reading and spelling, we adopted the procedure used by the Bielefeld research group. That is, children who belonged to the lowest 15 percent of the sample in a specific subtest were given a 'risk point' for this test. Next, the number of risk points was summed up for each child. Those 31 subjects who collected four or more risk points were considered children-at-risk.

How many of these children actually had problems in school? We detected several difficulties when trying to answer this question. First, for various reasons almost half of the children-at-risk sample ($N = 14$) were not promoted to elementary school but had to stay in kindergarten for one more year. Although we followed up on these children later on, their reading and spelling data could not be directly compared with those of the rest of the sample. Thus our subsample of children with school problems may actually represent an underestimation of the true base rate.

Second, we experienced problems with defining the adequate criterion measure (grades vs. test scores). While grades usually are less reliable than test scores, achievement tests may have validity problems because they are not always closely related to the curriculum. For the present analysis, test scores obtained for the spelling tests at the end of the third grade were used as criterion variable because spelling skills largely determine children's success in German elementary schools. For more than 100 years, spelling has been given more attention than reading in German classrooms, mainly due to the fact that many teachers and school administrators share the false belief that spelling is the most important indicator of verbal intelligence. Those 16 children who belonged to the bottom 10 percent of the sample in the spelling test were considered problem children.

Table 8 gives the results of the classification procedure for several predictor domains. In addition to the Bielefeld screening test, letter knowledge, memory capacity, and the ability to categorise sounds were also used to define children-at-risk. An inspection of hit rates obtained for the various predictor variables shows that the Bielefeld screening test yielded the comparably best results. As can be seen from Table 8, the maximally possible hit rate (defined as difference between selection rate and base rate) equals about 97 percent, compared to a chance hit rate of about 80 percent. It seems important to note that the actual hit rate (88%) is significantly above chance level but not very close to the optimal level. While the specificity of the screen is high in that 95 percent of the children-at-risk belong to the group of problem children, its sensitivity is only moderate: Less than 50 percent of the problem children at school were already correctly identified in kindergarten.

Table 8
Accuracy of classification as 'at risk': Results for the Grade 3 spelling test criterion variable

Predictor	Selection rate	Base rate	Maximal hit rate	Chance hit rate	Total hit rate	Sensitivity	Specifity	Predictor hit rate
Bielefeld screening	9.4	12.2	97.2	80.6	90.0	47.6	96.0	62.5
Letter knowledge	13.2	15.1	98.1	76.9	80.0	40.0	82.6	39.2
Sign knowledge	18.3	19.7	98.6	72.9	72.1	35.0	67.0	21.5
Memory capacity	18.3	22.8	95.5	67.2	74.4	42.5	81.5	34.0
Sound categorisation	18.3	24.2	94.1	66.3	76.7	42.5	86.9	39.6

As indicated by the specificity score, almost all of the children without school problems were correctly identified as not at-risk in the kindergarten screening. Overall, the predictor

hit rate indicating the probability of a correct at-risk classification is comparably high for the Bielefeld screening test, a finding also confirmed by the data of the Bielefeld research group (cf. Marx, 1992). Almost all of the subjects identified as children-at-risk indeed had problems learning to read and to spell in elementary school. On the other hand, however, the value of the screening instrument seems restricted because a large proportion of those children with school problems were not detected as children-at-risk in the kindergarten screening.

Conclusions

In our view, the longitudinal analysis of the LOGIC data gave interesting information on the respective roles of phonological awareness, memory capacity, early literacy, and intelligence on reading and spelling performance in German elementary school. We found that all four predictor domains significantly influenced the acquisition of literacy in school, although their impact differed as a function of both the dependent measure under study and the measurement point chosen. For example, whereas children's letter knowledge and IQ turned out to be the best predictors of early word decoding speed, the predictor quality of indicators like phonological awareness and information processing speed seemed to improve over time.

The analyses of the reading comprehension data yielded important contributions of the IQ variable, supplemented by a moderate impact of phonological awareness. Finally, regression analyses for the spelling measures showed that the overall impact of the four predictor domains appeared to increase over time, explaining almost 50 percent of the variance in spelling assessed at the end of Grade 3. Given that the type of stepwise regression analysis chosen generally overestimated the impact of IQ, the results indicate that letter knowledge and phonological awareness had the comparably strongest impact, closely followed by memory capacity and information processing speed.

Our findings concerning the 'causal' status of phonological awareness in the process of learning to read and spell square well with results obtained in Scandinavian longitudinal studies. First, it seems important to note that phonological awareness in the broad sense (e.g., sound categorisation) does predict later reading and spelling performance even in those children with minimal letter knowledge. However, phonological awareness in this subgroup is generally lower than that observed for the rest of the sample. Thus letter knowledge in kindergarten clearly makes a difference with regard to phonological processing skills. Finally, the data show that compared with the subgroup of children with minimal letter knowledge, those children who already detected the alphabetical principle in kindergarten performed better on most reading and spelling tests presented two or three years later. Accordingly, early differences in letter knowledge seem to have long-lasting effects, as far as reading and spelling is concerned.

One important goal of our causal modeling analyses was to explore the interrelationship among the predictor variables in determining the criterion variables. As a major result, the analyses showed that different structural models fitted the spelling and reading comprehension data. Regardless of dependent variable, however, phonological processing skills appeared to exert the strongest direct influence, followed by the early literacy construct. The structural models indicate that the impact of IQ and working memory is mostly indirect but still substantial. Needless to say, replications and cross-validations are needed to evaluate the practical significance of these findings.

A final step of analysis concerned the problem of identifying children-at-risk. The findings obtained with the Bielefeld screening test seem encouraging in that almost all of the children identified as children-at-risk in kindergarten later had to cope with reading and spelling problems in elementary school. However, the sensitivity of the screening instrument seemed to be far from perfect: Only about half of the problem children in school were detected by the screen. This finding indicates that problems of individual prognosis seem to remain despite the theoretical advances made in the field during the last few years. On the other hand, predictions for groups

of children based on the predictor domains described above yield promising results, particularly when reading comprehension and spelling is concerned.

References

Blachman, B. A. (1984). Relationship of rapid naming ability and language analysis skills to kindergarten and first-grade reading achievement. *Journal of Educational Psychology, 76*, 610-622.

Bradley, L., & Bryant, P. (1985). *Rhyme and reason in reading and spelling*. Ann Arbor: The University of Michigan Press.

Brügelmann, H. (1986). *Lese- und Schreibaufgaben für Schulanfänger* (Assessment of reading and writing in beginning school children). Technical Report, University of Bremen.

Burgemeister, B., Blum, L., & Lorge, J. (1972). *Columbia Mental Maturity Scale*. New York: Harcourt Brace.

Denckla, M. B., & Rudel, R. G. (1976). Rapid 'automatized' naming (R.A.N.): Dyslexia differentiated from other learning disabilities. *Neuropsychologia, 14*, 471-479.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33*, 386-404.

Daneman, M., & Blennerhassett, A. (1984). How to assess the listening comprehension skills of prereaders. *Journal of Educational Psychology, 76*, 1372-1381.

Eggert, D. (1978). *Hannover-Wechsler-Intelligenztest für das Vorschulalter* (Hannover-Wechsler intelligence test for preschoolers and kindergarteners). Bern, Switzerland: Huber-Verlag.

Ehri, L. C. (1989). The development of spelling knowledge and its role in reading acquisition and reading disability. *Journal of Learning Disabilities, 22*, 356-365.

Ellis, N., & Large, B. (1987). The development of reading: As you seek so shall you find. *British Journal of Psychology, 78*, 1-28.

Horn, W. F., & Packard, T. (1985). Early identification of learning problems: A meta-analysis. *Journal of Educational Psychology, 77*, 597-607.

Jansen, H., Knorn, P., Mannhaupt, G., Marx, H., Beck, M., & Skowronek, H. (1986). *Bielefelder Screening zur Vorhersage von Lese- und Rechtschreibschwierigkeiten* (The Bielefeld Screening test for the prediction of reading and spelling difficulties). Technical Report, University of Bielefeld.

Jöreskog, K. G., & Sörbom, D. (1984). *LISREL IV — Analysis of linear structural relationships by maximum likelihood instrumental variables, and least squares methods (User's Guide)*. Mooresville, IN: Scientific Software.

Juel, C. (1988). Learning to read and write: A longitudinal study of 54 children from first through fourth grades. *Journal of Educational Psychology, 80*, 437-447.

Lundberg, I., Frost, J., & Petersen, O. P. (1988). Effects of an extensive program for stimulating phonological awareness in preschool children. *Reading Research Quarterly, 23*, 261-284.

Lundberg, I., & Hoien, T. (1991). Initial enabling knowledge and skills in reading acquisition: Print awareness and phonological segmentation. In D. J. Sawyer & B. J. Fox (Eds.), *Phonological awareness in reading*, (pp. 73-96). New York: Springer Verlag.

Marx, H. (1992). *Vorhersage von Lese-rechtschreibschwierigkeiten in Theorie und Anwendung* (The prediction of reading and spelling problems in theory and practice) Unpublished habilitation, University of Bielefeld.

Morais, J. (1991). Phonological awareness: A bridge between language and literacy. In D. J. Sawyer & B. J. Fox (Eds.), *Phonological awareness in reading*, (pp. 31-72). New York: Springer Verlag.

Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition, 7*, 323-331.

Näslund, J. C. (1990). The interrelationships among preschool predictors of reading acquisition for German children. *Reading and Writing, 2*, 327-360.

Näslund, J. C., & Schneider, W. (1991). Longitudinal effects of verbal ability, memory capacity, and phonological awareness on reading performance. *European Journal of Psychology of Education, 6*, 375-392.

Näslund, J. C., & Schneider, W. (1993). *How do letter knowledge and phonological skills in kindergarten affect later reading and spelling performance?* Paper submitted for publication. University of New Mexico.

Perfetti, C. A., Beck, I., Bell, L. C., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merrill-Palmer Quarterly, 33*, 255-281.

Perfetti, C. A., & Lesgold, A. M. (1978). Coding and comprehension in skilled reading and instruction. In L. B. Resnick & P. A. Weaver (Eds.), *Theory and practice of early reading*, Vol. 1, (pp. 57-84). Hillsdale, NJ: Erlbaum.

Read, C., Yun-Fei, Z., Hong-Yin, N., & Bao-Quing, D. (1986). The ability to manipulate speech sounds depends on knowing alphabetic writing. *Cognition, 24*, 31-45.

Rott, C., & Zielinski, W. (1986). Entwicklung der Lesefertigkeit in der Grundschule (The development of reading skills in elementary school). *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 18*, 165-175.

Schneider, W. (1992). *Möglichkeiten und Probleme bei der frühen Vorhersage von Lese-Rechtschreibleistungen* (Perspectives and problems related to the early prediction of reading and spelling). Paper presented at the biennial meetings of the German Psychology Association, Trier.

Schneider, W., & Näslund, J. C. (1992). Cognitive prerequisites of reading and spelling: A longitudinal approach. In A. Demetriou, M. Shayer, & A. Efklides (Eds.), *Neo-Piagetian theories of cognitive development: Implications and applications for education*, (pp. 256-274). London: Routledge.

Skowronek, H., & Marx, H. (1989). The Bielefeld longitudinal study on early identification of risks in learning to write and read: Theoretical background and first results. In M. Brambring, F. Lösel, & H. Skowronek (Eds.), *Children at risk: Assessment, longitudinal research, and intervention*, (pp. 268-294). New York: De Gruyter.

Stanovich, K., Cunningham, A. E., & Feeman, D. J. (1984). Intelligence, cognitive skills, and early reading progress. *Reading Research Quarterly, 19*, 278-303.

Tramontana, M. G., Hooper, S. R., & Selzer, S. C. (1988). Research on the preschool prediction of later academic achievement: A review. *Developmental Review, 8*, 89-146.

Tunmer, W. E., & Nesdale, A. R. (1985). Phonemic segmentation skill and beginning reading. *Journal of Educational Psychology, 77*, 417-427.

Wagner, R., & Torgesen, J. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*, 192-212.

Weinert, F. E., & Schneider, W. (Eds.) (1987). *The Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC), Report N.º 2: Documentation of assessment procedures used in waves one to three* (Technical Report). Munich: Max Planck Institute for Psychological Research.

Weinert, F. E., & Schneider, W. (Eds.) (1992). *The Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC), Report N.º 8: Assessment procedures and results of wave five* (Technical Report). Munich: Max PLanck Institute for Psychological Research.

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Schneider, W., & Bjorklund, D. F. (1992). Expertise, Aptitude, and Strategic Remembering. *Child Development, 63*, 461-473.

Schneider, W., & Näslund, J. C. (1992). Cognitive prerequisites of reading and spelling: A longitudinal approach. In A. Demetriou, M. Shayer, & A. Efklides (Eds.), *Neo-Piagetian theories of cognitive development: Implications and applications for education*, (pp. 256-274). London: Routledge.

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Most relevant publications in the field of Educational Psychology:

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Näslund, J. C., & Schneider, W. (1991). Longitudinal effects of verbal ability, memory capacity, and phonological awareness on reading performance. *European Journal of Psychology of Education, 6*, 375-392.