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The Double-Deficit Hypothesis and Difficulties in Learning to Read a Regular Orthography

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In 2 large longitudinal studies, we selected 3 subgroups of German-speaking children (phonological awareness deficit, naming-speed deficit, double deficit) at the beginning of school and assessed reading and spelling performance about 3 years later. Quite different from findings with English-speaking children, phonological awareness deficits did not affect phonological coding in word recognition but did affect orthographic spelling and foreign-word reading. Naming-speed deficits did affect reading fluency, orthographic spelling, and foreign-word reading. Apparently, in the context of a regular orthography and a synthetic phonics teaching approach, early phases of literacy acquisition (particularly the acquisition of phonological coding) are less affected by early phonological awareness deficits than are later phases that depend on the build up of orthographic memory.

The double-deficit hypothesis was developed by Maryanne Wolf and Patricia Bowers as an extension of the dominant phonological-deficit explanation of developmental dyslexia (e.g., Bowers & Wolf, 1993; Wolf & Bowers, 1999). The phonological-deficit hypothesis postulates an early difficulty in acquiring phonological awareness, which interferes with the acquisition of grapheme–phoneme coding as a word recognition mechanism, which in turn results in reduced self-teaching of orthographic word representations (Share, 1995). The early problem with phonological awareness is seen as resulting from less sharp phoneme boundaries in speech perception (Fowler, 1991) or from less distinct phonological word representations (Elbro & Peterson, 1998).

The double-deficit hypothesis acknowledges the phonological awareness deficit of dyslexic children but stresses a deficit in naming speed as a second and equally important cause of reading difficulties. The first demonstration that dyslexic children show impaired naming speed was provided by Denckla and Rudel (1976), whose Rapid Automatized Naming (RAN) Test became the standard assessment of naming speed. In the RAN test, a large array of repeatedly presented, well-known visual patterns (pictured objects, color patches, digits) has to be named as quickly as possible. Wolf, Bally, and Morris (1986) were the first to show that early differences in rapid naming are predictive of later reading difficulties. The double-deficit hypothesis is based on findings (reviewed by Wolf & Bowers, 1999) showing that, typically, there are only modest correlations between phonological awareness measures and RAN performance in groups of dyslexic children and that dyslexic children as a group exhibit both phonological awareness deficits and naming-speed deficits. From these findings, Wolf and Bowers derived the theoretically and practically important implication that there are three subtypes of dyslexic children: one exhibiting the well-known phonological awareness deficit but little naming-speed deficit; one exhibiting the naming-speed deficit but little phonological awareness deficit; and a group with both deficits. Obviously, the group with only a naming-speed deficit is the theoretically important one. The practically important implication is that the subgroup with only a naming-speed deficit may not be well-served when remediation or prevention is based solely on phonological awareness training.

Direct evidence on the applicability of this subtyping scheme for dyslexic children and on further implications is sparse but encouraging. In the review by Wolf and Bowers (1999), two conference presentations by Lovett and her collaborators (Goldberg, Wolf, Cirino, Morris, & Lovett, 1998; Lovett, 1995) are mentioned; the researchers found, in large samples of severe dyslexia cases, that about a fifth of these children suffered only from a naming-speed deficit and not from a phonological awareness deficit. The specific role of a naming-speed deficit for a subtype of dyslexic children has been documented by Lovett (1987), who distinguished between reading-accuracy-disabled children and reading-rate-disabled children. The rate-disabled children exhibited a naming-speed deficit only, whereas the accuracy-disabled subgroup (which was also rate disabled) showed a phonological awareness deficit and a naming-speed deficit among a variety of verbal deficits.

One could reason that the role of the naming-speed deficit tends to be overlooked in English-based dyslexia research because, as shown by Compton and Carlisle (1994), in most studies, only poor word recognition is used to diagnose reading disability. This is quite different in consistent orthographies. For example, in German-speaking countries, there are no graded word reading tests in use—only timed reading tests. This is due to the fact that even poor readers often show very few reading errors after the first 2 years in school (Klicpera & Schabmann, 1993). Their main reading problem is slow, laborious decoding for words that are read automatically and fluently by their normally reading peers. Errors often occur in attempts to save time and effort. This specific reading fluency impairment of German-speaking dyslexic children

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in the context of rather accurate word and nonword reading was demonstrated in a series of studies by our research group (Landerl, Wimmer, & Frith, 1997; Wimmer, 1993, 1996a, 1996b; Wimmer, Mayringer, & Landerl, 1998) and was also found for dyslexic children in other more consistent orthographies such as Spanish (Rodrigo & Jiménez, 1999), Italian (Zoccolotti et al., 1999), Norwegian (Lundberg & Hoien, 1990), and Dutch (Van den Bos, 1998; Yap & van der Leij, 1993).

In summary, there is an emerging pattern of evidence showing that, in consistent orthographies, the typical dyslexic child exhibits accurate word decoding skills but poor reading fluency; this pattern corresponds to Lovett's (1987) reading-rate-disabled dyslexic pattern. Also in correspondence with Lovett's finding is the naming-speed deficit observed in dyslexic German and Dutch children (Van den Bos, 1998; Wimmer, 1993; Wimmer et al., 1998). Whether this is their only major cognitive impairment, as was the case for Lovett's subgroup, is an open question (Landerl & Wimmer, 2000; Mayringer & Wimmer, 2000; Wimmer et al., 1998).

The present research presents a direct examination of the role of a naming-speed deficit and a phonological awareness deficit for difficulties in learning to read and write German. Three studies are reported. In two large longitudinal studies, the three deficit subgroups implied by the double-deficit hypothesis (phonological awareness deficit, naming-speed deficit, double deficit) were formed before children were exposed to reading instruction. Reading and spelling deficits were assessed about 3 years later, when children were expected to read fluently and spell many words correctly. To our knowledge, these are the first studies that have directly examined the double-deficit subtyping approach in a longitudinal predictive way and that were initiated before children were exposed to reading and spelling instruction. The double-deficit subtyping before learning to read is methodologically important, as it rules out that a naming-speed deficit and a phonological awareness deficit may be consequences of less reading experience of reading-disabled children. Our longitudinal follow-up of the three deficit subgroups implied by the double-deficit hypothesis is different from the typical approach, which takes into account the full range of scores on predictors such as phonological awareness and naming speed (e.g., de Jong & van der Leij, 1999; Näslund & Schneider, 1996; Wagner, Torgesen, Rashotte, & Hecht, 1997). This correlational predictive approach does not have direct implications for the role of deficits in phonological awareness and naming speed. Scarborough (1998) has pointed out that the moderate predictive correlations tend to reflect the pattern that high performance on a predictor such as phonological awareness is followed by good reading outcome, whereas low performance on a predictor quite often is not followed by low reading outcome. However, only the latter pattern is critical for an evaluation of the double-deficit hypothesis.

As context for the choice of measures and interpretation of findings, information on the teaching approach experienced by the children in our studies, and on the orthography they are confronted with, is important. German is similar to English with respect to phonology (complex syllable structures, consonant clusters, etc.) but differs with respect to grapheme–phoneme regularity, and this is particularly so for vowel graphemes. For example, in the German words *Katze* (cat), *Ball* (ball), *Garten* (garden), and *Backen* (bake), the *a* always receives the pronunciation /a/, whereas the same letter in the corresponding English words receives different pronunciations. When the vowels in German morphemes change—in plural forms, for example—this is marked by diacritics (e.g., *Ball, Bälle*). Somewhat complex and partly inconsistent is the orthographic marking of vowel length (see Sprenger-Charolles, in press, for an analysis of orthography differences relevant to reading acquisition). However, these complexities are of little importance for word recognition, as very few words differ by vowel length only. Another difference from English, and particularly from French, is that German orthography makes little use of silent letters. For example, in *Katze,* the final *e* is sounded. Furthermore, there are few digraphs and only one grapheme consisting of three letters (i.e., *sch*). The critical point for teaching is that children can be presented with a set of grapheme–phoneme relations that appears more or less completely regular when applied to the reading material typical for Grade 1. The teaching approach that the present Austrian children experienced is a form of synthetic phonics. They are introduced to the graphemes one by one (no letter names) and immediately learn to blend the sounds into syllables without uttering the sounds in sequence. The first letters are for vowels and continuants so that blending into syllables can be demonstrated and practiced easily. The resulting synthesized pronunciations in the beginning hardly ever sound fully correct (e.g., vowels and continuants tend to be too long) but are close enough to the target pronunciations to allow recognition. Little attention is given to reading fluency because children are expected to pick up recurring letter patterns in words from self-reliant reading. Spelling in the first year receives less emphasis than reading, and children normally write words they have already read. Invented spelling is not encouraged, as the spellings would often differ from the conventional ones due to the fact that German is less consistent in the phoneme-to-grapheme direction than in the grapheme-to-phoneme direction.

An important difference from the English-speaking world is that in German-speaking countries the teaching of reading is the exclusive task of primary schools, in which children enter in the autumn after their 6th birthday. In kindergarten, there is no reading preparation involving letters, and reading preparation by parents does not play an important role. This lack of reading preparation has the effect that many preschool German-speaking children fail phonological awareness tasks that require awareness or manipulation of phonemes (Wimmer, Landerl, Linortner, & Hummer, 1991). Therefore, for a valid assessment of a phonological awareness deficit at school entrance, special efforts were necessary to develop tasks that differentiate in the lower ability range (see Studies 1 and 2 in subsequent sections of this article).

The question examined by the present research is how children with the specific impairment patterns (single phonological deficit, single naming-speed deficit, double deficit) postulated by the double-deficit hypothesis would fare under these circumstances. A plausible expectation is that children with only a single phonological awareness deficit (and no naming-speed deficit) should do quite well, as the explicit synthetic phonics approach in the context of an easy orthography may help them to overcome the early hurdles posed by the acquisition of phonological coding as a word-reading device. If acquisition of phonological coding (because of a phonological awareness deficit) is the major hurdle in reading acquisition, as posited by the dominant phonological-deficit hypothesis on developmental dyslexia (e.g., Catts, 1996;

Shankweiler, 1999; Shaywitz, 1996; Stanovich, 1988), then the single phonological deficit children should have few problems. In particular, these children should be able to build up a rich orthographic word lexicon by self-teaching (Share, 1995), that is, by storing the exact letter sequence of words (i.e., orthographic learning) that are successfully read by phonological coding. That orthographic learning should not be affected in children with a phonological awareness deficit is based on dual-route conceptions of visual word recognition (e.g., Coltheart, 1978), which posit two independent mechanisms: a phonological one based on grapheme–phoneme coding and a visual one based on visual-orthographic word representations (but see the Discussion for an alternative conception of orthographic learning).

For children with a single naming-speed deficit (and no phonological awareness deficit), no benefits of the combination of synthetic phonics teaching and an easy orthography can be assumed. These children, because of the absent phonological awareness deficit, should have little difficulty acquiring phonological coding, even under less favorable circumstances. Therefore, a plausible assumption is that, primarily, the build up of the orthographic lexicon should be affected. Bowers, Sunseth, and Golden (1999) indeed showed that children with a single naming deficit showed, in addition to poor reading fluency, very poor performance on an orthographic choice task. The theoretical expectation for children with a double deficit is similar to that for children with a single naming-speed deficit. Their phonological awareness deficit should have little negative effect on the acquisition of phonological coding in the context of an easy orthography and a synthetic phonics teaching approach. Therefore, as in the case of the single naming-speed deficit, only formation of the orthographic lexicon should be affected, which should lead to poor reading fluency and poor orthographic spelling.

Study 1

Method

Participants and Overview of Procedure

Participants were 530 boys who spoke German as their mother tongue and for whom complete data were available from the school entrance assessment and from the reading and spelling assessment at the end of Grade 3. Seven children had repeated Grade 2 and were tested as second graders. The sample involved 31 schools and 74 classrooms in the city of Salzburg and neighboring communities. We limited the sample to boys because, in our previous research, we found more boys than girls among dyslexic children (Landerl, Wimmer, & Frith, 1997; Wimmer, 1993; Wimmer et al., 1998). Children's age at time of first testing ranged from 5 years, 10 months to 8 years, 1 month (M = 6 years, 9 months; SD = 5 months). The longitudinal study started with 623 children. The 93 children (15%) who dropped out (mostly due to absence at the follow-up tests) did not differ from the final sample on the phonological awareness measure and the rapid-naming measure. None of the t tests reached significance.

The phonological awareness measure and the rapid-naming measure are part of a school entrance assessment of potential predictors of reading development. This individual assessment was done in a quiet room at school; it lasted about 30 min and included additional verbal and visual measures (see Mayringer, Wimmer, & Landerl, 1998, for a full description). Letter knowledge assessment at school entry showed that the large majority of children knew few letters and that there was rather high variation among children (M = 30% correct, SD = 29% correct). An initial assessment of reading and spelling at the end of Grade 1 was rather limited because graphemes had not been fully introduced. For the present analysis, we used reading and spelling data that were collected at the end of Grade 3. Reading performance was individually tested in a quiet room at school, and spelling was assessed with a classroom test.

Tests

Phonological awareness. This measure was based on the combination of an onset detection task and a rime detection task. The choice of onset and rime instead of phonemes was based on previous findings showing that a substantial proportion of school beginners fail tasks such as phoneme counting or phoneme substitution (Wimmer et al., 1991). The aim was to develop a phonological awareness task that would be easy for the large majority of children and to identify those with severe deficits in phonological awareness. The items of the rime detection task always presented a target word and two choices, one of which rhymed with the target (e.g., "What rhymes with *Feld*: *Geld* or *Gold*?"). The nonrhyming alternative differed from the rhyming one in either the vowel only (eight items) or the final consonant only (seven items, because one showed poor characteristics in item analysis). Three practice items introduced the task. Split-half reliability, corrected for test length, was .73.

For the onset task, we initially attempted to use the same task format as for the rime task, but pretests showed rather poor performance. This corresponds to findings showing that onset oddity detection is more difficult than rime oddity detection (de Jong & van der Leij, 1999; Wimmer, Landerl, & Schneider, 1994). Therefore, we used an easier task format for onset detection, one that directly specified the critical onset segment. For the first eight items, this segment was the initial syllable (e.g., "Tube, Pudel, Kugel: Which one begins with /pu/?"). The critical feature is that the first vowel was always shared by all three options. For the second eight items, the critical segment was a single consonantal continuant. The three options were always accompanied by three corresponding pictures to minimize memory demands. Each of the two blocks was preceded by two practice items. Split-half reliability, corrected for test length, was .74. Both tasks were easy for the large majority of the children, with means of 87% correct for rime detection (guessing level, 50%) and 77% correct for onset (guessing level, 33%). One criterion for poor phonological awareness was based on the combined score from the two tasks, although the association between the two tasks was only .34. A second, more stringent criterion for poor performance was based on a low score on each of the two tasks (see the following section).

Rapid naming. This assessment, modeled after Denckla and Rudel (1976), consisted of two tasks. For each task, a random sequence of 20 pictured objects (5 different pictures, each repeated four times) had to be named. Digits could not be used because of the aforementioned absence of school-related activities in kindergarten. The pictures for each task were presented on a single page, with four lines of 5 objects on each page. Order of objects changed from one line to the next. The words of the first task started with different consonant clusters (*Kran, Frosch, Blatt, Schloß, Brot*); those of the second task started with the same single consonant (*Buch, Bett, Bär, Baum, Ball*). Two practice trials preceded each of the two tasks. The first practice trial introduced the 5 pictures, and the child was asked to name them. In the event of difficulty, the experimenter provided the intended word. The second practice trial consisted of two lines with 5 objects each and introduced the child to the rapid-naming procedure. Errors were not taken into account because they were very infrequent and most often immediately corrected by the child. The correlation between the naming times for the two tasks was .66. The time scores from the two tasks were added and transformed, for easy comparison with reading rate, into a words-per-minute measure.

Control measure. To control for the possibility that phonological awareness or naming-speed deficits may be confounded with intelligence deficits, we used three scales (spatial sequences, spatial integration, and spatial concepts) from the Primary Test of Cognitive Skills (Huttenlocher

& Cohen-Levine, 1990), which were administered at the end of Grade 1 as a group test. Because no norm data for Austrian children are available, the raw points from each scale were standardized within the present sample. The sum of the three standardized scales was standardized as an IQ scale (M = 100, SD = 15).

Reading and spelling outcome measures. At the end of Grade 3, we administered a reading and spelling test battery that was developed in our laboratory (Landerl, Wimmer, & Moser, 1997). Reading was assessed individually, and spelling was assessed in the classroom. For the present purpose, we used five subtests from the reading test. Each presented a single page of reading material in line-wise format, with the instruction to read quickly and accurately. Time for reading each page and errors were recorded. One subtest required participants to read aloud a short story of 57 words. Two subtests presented lists of words, one consisting of 30 short, high-frequency words (e.g., *Vater* [father], *Milch* [milk]), and the other consisting of 11 long, compound words (e.g., *Fruchtsaft* [fruit juice], *Wohnzimmer* [living room]). Of the additional two nonword lists, one consisted of 30 short items derived from the high-frequency word list by exchanging the consonantal onset graphemes (e.g., *Nater*, *Hilch*); the other one consisted of 24 long nonwords without consonant clusters and with low similarity to existing German words (mostly three syllabic; e.g., *tarulo*, *heleki*). Both the word lists and the nonword lists were preceded by a practice list to familiarize children with the list-reading procedure and with nonwords, respectively. The retest reliabilities of the five subtests range from .60 to .65 for the low error scores and from .93 to .95 for the reading time scores. For the present analyses, the scores for the two word lists were combined into an accuracy (percentage correct) and a rate measure (words per minute), and the same was done for the two nonword lists so that, altogether, there were accuracy and rate measures for text reading, word reading, and nonword reading.

The classroom spelling test consisted of 49 words, which were chosen in such a way that phonetic transcription alone did not reliably result in orthographically correct spellings. The experimenter provided a sentence context for each word. The resulting scores were the percentage of orthographically correct spellings (disregarding capitalization errors) and the percentage of phonetically acceptable spellings (including orthographically correct ones). Retest reliability is .90 for orthographic errors and .93 for phonetic errors.

Results

To form the three deficit groups implied by the double-deficit hypothesis (single phonological deficit, single naming-speed deficit, and double deficit), 1 SD below the sample mean on the phonological awareness and the rapid-naming measure was used as criterion. Furthermore, an attempt was made to ensure that children in each of the single-deficit groups performed within normal range on the other measure. This was easy to do, as the correlation between phonological awareness and naming speed was only .26. After deleting 9 children from the original single phonological deficit group, whose naming-speed scores came close to the criterion for the single naming-speed deficit group, the mean naming-speed score of the single phonological deficit group was about average. No such adjustment had to be made for the single naming-speed deficit group. All children from the no-deficit group who performed more than 1 SD above the total sample mean on the phonological awareness measure or the naming-speed measure were deleted. This exclusion avoided above-average performance levels on phonological awareness and naming speed by the no-deficit group. Table 1 (first two lines) shows the resulting combinations of average and low performance levels on the two criterion measures for the four groups. The performance levels are obvious from the percentiles (based on all 530 children), which correspond to the group means. For example, the mean phonological awareness score of the single phonological deficit group corresponds to a percentile of 9, whereas the mean rapid-naming score of this group corresponds to a percentile of 52.

Table 1
Performance of Subgroups on Double-Deficit Measures, Control Measures, and Outcome Measures of Study 1

	No deficit (n = 242)			Phonological deficit (n = 66)			Naming deficit (n = 64)			Double deficit (n = 25)		
Measure	M	SD	Percentile[a]	M	SD	Percentile[a]	M	SD	Percentile[a]	M	SD	Percentile[a]
Phonological awareness (% correct)[b]	$88.04_{2,4}$	6.84	54	$63.39_{1,3}$	8.21	9	$86.59_{2,4}$	7.72	50	$62.06_{1,3}$	10.04	8
Naming speed (words per min)[b]	$46.48_{3,4}$	5.59	52	$46.35_{3,4}$	6.12	52	$32.95_{1,2}$	3.12	7	$33.38_{1,2}$	3.09	7
Age (years;months)	6;9	0;5		6;9	0;5		6;9	0;5		6;9	0;6	
Nonverbal IQ[b]	$99.83_{2,4}$	13.78		94.59_{1}	14.72		97.14	16.76		93.45_{1}	18.88	
Reading accuracy (%)[c]												
Text	97.61	3.08		96.94	3.10		97.20	4.02		95.37	6.72	
Words	98.78	2.71		97.38	3.69		96.84	4.47		95.61	6.68	
Nonwords	93.13	6.65		90.99	6.54		90.71	6.91		86.15	13.47	
Reading rate (items per min)[b]												
Text	$98.89_{2,3,4}$	29.95	56	$90.30_{1,3,4}$	32.00	46	$72.43_{1,2}$	27.76	24	$68.54_{1,2}$	24.86	21
Words	$69.70_{3,4}$	22.85	55	$64.95_{3,4}$	26.25	48	$51.41_{1,2}$	20.74	25	$47.99_{1,2}$	19.63	22
Nonwords	$40.25_{3,4}$	11.75	55	$40.21_{3,4}$	12.69	55	$32.16_{1,2}$	11.16	29	$31.41_{1,2}$	9.37	26
Spelling (% correct)												
Orthographic[b]	$78.85_{2,3,4}$	16.23	47	65.43_{1}	20.15	27	67.44_{1}	20.61	30	61.06_{1}	22.05	23
Phonetic[c]	98.36	2.32		96.82	3.87		95.70	7.10		92.24	10.12	

[a] Percentiles corresponding to means.
[b] Group comparisons based on t tests, one-tailed (see text). A subscript number indicates that the mean differs reliably ($p < .05$) from the referred-to mean. Reference of subscript numbers: 1 = no-deficit group; 2 = phonological deficit group; 3 = naming deficit group; 4 = double-deficit group.
[c] No group comparisons because of ceiling effects.

The indexes (subscripts) in Table 1 indicate the results of group comparisons and refer to the group data columns from left to right. For example, the indexes (subscripts) 2 and 4, which correspond to the phonological awareness score of the no-deficit group (in the first data column), indicate that the mean of the single phonological deficit group (in the second data column) and of the mean of the double-deficit group (in the fourth data column) are reliably lower than the mean of the no-deficit group. The Type I error for these group comparisons was set at .05, one-sided. The reason for the one-sided alpha level and the multiple group comparisons is that the double-deficit hypothesis makes specific predictions about reading and spelling deficits. In addition, there is no suggestion from empirical findings (see the Introduction) that a single-deficit group should read or spell better than the no-deficit group or that the double-deficit group should perform better than any single-deficit group. Given this theoretical and empirical background, it seemed logically inappropriate to test the null hypothesis of no group differences with two-sided alpha levels. Significant group differences involving the no-deficit group have to be interpreted cautiously because of the very large size of this group (n = 240). Here, a statistically reliable deficit may not imply a substantial one.

From the first section of Table 1, it is evident that the four groups differed according to the selection procedure on phonological awareness and rapid naming. Of importance is that the single phonological deficit group (second data column) did not differ at all from the no-deficit group on the rapid-naming measure (second line); conversely, the single naming-speed deficit group (third column) did not differ from the no-deficit group on the phonological awareness measure (first line). Finally, the double-deficit group (fourth column) did not differ from the phonological-deficit group on the awareness measure and also did not differ from the naming-deficit group on the rapid-naming measure. Therefore, the four groups represent unconfounded combinations of absent or present deficits in phonological awareness and rapid naming. Table 1 also shows that there were no group differences with respect to age, but the nonverbal IQ of the phonological-deficit and the double-deficit groups was slightly below that of the no-deficit group. However, the mean of 93 for the double-deficit group implies that the IQ scores for children in this group were mainly within the normal range.

As evident from the means for reading accuracy, all three deficit groups showed close to ceiling accuracy for text and word reading, and even nonword reading accuracy was around 90%. Statistical comparisons of means were not meaningful because of the ceiling effects. For interpretation of the already very high accuracy scores, it has to be remembered that children were instructed to read quickly. Therefore, some of the few errors may have resulted from attempts to gain speed. For reading rate, there was a more differentiated pattern of results. The single phonological deficit group exhibited a reliable reading rate deficit for text only and showed no rate deficit at all for nonword reading. Even the reliable rate impairment for text reading was not substantial, as the percentile rank corresponding to the mean rate for text was close to average. In contrast, both the single naming-speed deficit group and the double-deficit group exhibited reading rate impairments for text, words, and nonwords and differed reliably from both the no-deficit group and the single phonological deficit group. The percentiles corresponding to the means (about 25) for text and words indicate rather poor reading performance for a substantial number of children in the single naming-speed group and the double-deficit group. The spelling scores complement the reading scores in an interesting way. With respect to orthographically correct spelling, that is, reproduction of the exact letter sequence (e.g., *Bälle* for the plural form of *Ball*), all three deficit groups were markedly impaired and to a similar degree. In contrast, phonetic spelling accuracy (e.g., *Belle* instead of *Bälle*) was high for all three deficit groups, with means above 90% correct.

A possible concern is that the phonological awareness deficit of the single phonological deficit group and of the double-deficit group may not be a serious one, as the means were slightly above 60% correct on the combined score from the onset- and the rime-detection tasks. These means have to be evaluated with respect to a mean of 41% expected from guessing (onset detection, 33%; rime detection, 50%). As a further control for the mentioned concern, we used a stricter criterion for the inclusion of a child in the single phonological deficit group. This stricter criterion required scores of 1 *SD* below the mean on both the rime task and the onset task. With this criterion (and the additional one of not scoring 1 *SD* below the mean on the rapid-naming task), only 15 children (instead of 66) qualified for the single phonological deficit group . However, reading and spelling performance of this more strictly defined phonological-deficit group was very similar to that of the larger group in Table 1. Mean reading accuracy was 96% and 88% for words and nonwords, respectively (old group: 99% and 93%, respectively); mean reading rates were 60 and 39 words per minute, respectively (old group: 65 and 40, respectively); and means for orthographic and phonetic spelling accuracy were 58% correct and 96% correct, respectively (old group: 65% and 94%, respectively).

In summary, Study 1 found that the deficit groups implied by the double-deficit hypothesis differed with respect to reading and spelling deficits. The single phonological deficit group showed highly accurate word and nonword reading and about average reading rates, and the double-deficit group (phonological awareness deficit combined with a naming-speed deficit) did not score below the single naming-speed deficit group. An early naming-speed deficit had a clearly negative effect on reading rate but not on reading accuracy. For spelling, the pattern was different: All three deficit groups showed similarly impaired orthographic spelling achievement but had no difficulty with phonetically accurate spelling.

Study 2

The main finding of Study 1, that an early phonological awareness deficit was not accompanied by a later reading problem, may be explained by our use of onset and rime detection as phonological awareness assessment. Muter, Hulme, Snowling, and Taylor (1998) presented findings suggesting that onset and rime awareness is of lesser importance than awareness of phonemes for progress in learning to read (but see Bryant, 1998, and Hulme, Muter, & Snowling, 1998, for discussion). This is particularly plausible for learning to read German with a synthetic phonics teaching approach, which requires phoneme synthesis but makes no demands on rime awareness. On the basis of these considerations, the present study used a phoneme segmentation task for the early identification of children with poor phonological awareness.

However, as noted in the Introduction, standard phoneme segmentation tasks such as phoneme counting or phoneme naming are too difficult for German children at school entrance, as they have not had any reading preparation in kindergarten. To circumvent this problem, we introduced a new segmentation task that simply required children to imitate the segmentation of a word modeled by the experimenter. For example, the experimenter provided a segmentation such as *cat*: /k/-/a/-/t/, and the child simply had to repeat the word and its segments. The idea was that a child who understands the relationship between the word and its segments should have little difficulty, whereas a child without such an understanding should have difficulty. Of course, a child may simply imitate the modeled segmentation in a rote fashion without understanding the relationship between the word and the phonemic segments. However, this concern about task validity applies only to the interpretation of high performance and not to the interpretation of poor performance. Only poor performance is of relevance for the present study. The overall design of Study 2 was similar to that of Study 1. Phonological awareness and rapid-naming deficits were assessed in the first months of Grade 1, when children were just beginning to learn to read. Reading and spelling were assessed in Grades 3 and 4.

Method

Participants

The sample in the present study were 301 children (156 boys, 145 girls) who came from 8 schools and 23 classrooms in the city of Salzburg and from neighboring communities. All children spoke German as their native language. Their age at school entrance testing was close to 7 years ($M = 6$ years, 10 months; $SD = 5$ months). The phonological awareness task and the rapid-naming task, as in Study 1, were part of a larger school entrance assessment done in a quiet room in the school. Reading and spelling achievement was assessed in a rather limited way at the end of Grade 1. At this time, Raven's Coloured Progressive Matrices Test (Schmidtke, Schaller, & Becker, 1978) was used as an assessment of nonverbal intelligence. In the middle of Grade 3, classroom tests were used for reading and spelling assessment. A more thorough individual reading assessment was done during the first months of Grade 4. For the present study, we used only the reading and spelling outcome measures taken in Grades 3 and 4.

Tests

Phonological awareness. The imitation task used for phonological awareness assessment consisted of 12 items. The experimenter first explained that words can be divided into smaller parts and demonstrated this with *Fee*: /f/-/e/. Between the word and the beginning of the segment presentation, and also between the segments, there were pauses of about 1 sec. The instruction was to imitate the word divisions provided by the experimenter. The ritual was that the experimenter always pointed at herself during presentation of the item and, when finished, pointed at the child to indicate that it was the child's turn to repeat the item. The test items were presented only when the child had successfully imitated the practice item, which after repeated demonstration, was always possible. The first block of 6 items used simple words consisting of an initial consonant and a subsequent vowel (CV words): *Schuh, See, Muh, Du, Kuh, Tee.* For these CV words, phoneme segmentation is equivalent to onset–rime segmentation. The second block of 6 items used words consisting of an initial consonant, a subsequent vowel, and another consonant (CVC words): *Fuß, Schal, Fisch, Bus, Tisch, Ball.* For these words, segmentation involved the division of the rime into a vowel and a consonant. The second block was preceded by a practice item, which was repeated until successful imitation was achieved. Children's responses were transcribed immediately and recorded for later inspection. An item was scored correct if both the word and its subsequent segments were repeated in correct order. As expected, children found it easier to imitate the shorter onset–rime segmentations (CV word followed by two segments) than the longer phoneme segmentations (CVC word followed by three segments). The mean percentages correct were 77% and 42%, respectively. Because of a correlation of .58 between the scores for the two subtasks, a combined score was used.

Naming speed. As in Study 1, naming speed was assessed by a rapid-object-naming task. Four object pictures (car, ball, dog, mouse) were introduced first with their intended names. A further practice trial (with two lines of pictures) familiarized children with the demands of rapid naming. The test page for this task consisted of eight lines, four pictures on each line (total of 32 pictures), with the sequence of the four pictures varying from line to line.

Reading. Reading was assessed using a classroom reading test in the middle of Grade 3 and with an individual reading test (similar to the one in Study 1) in the first months of Grade 4. The classroom tests required verification of 70 sentences, which were ordered with respect to number of words and word length. Each sentence was presented in one line and had to be marked at the end of the line as *true* (checkmark) or *false* (cross). The following are examples of the sentences that were used: "Dogs can bark," "Chairs are for sitting," "Elephants are heavier than mice," "For singing you need a pocket calculator." The time limit was 10 min. Measures were accuracy (percentage of correctly marked sentences) and rate (sentences per minute). Reliability, examined with parallel test forms, was .91 for a separate Grade 3 sample.

The individual reading test was a more difficult version of the reading test used in Study 1. For word reading, we used only complex compound words (two parallel subtests with 11 items each), and for nonword reading (two parallel subtests with 14 items each), we used only complex items with consonant clusters and digraphs (e.g., *Schlesompf, Breunz*). The correlations between the two compound word subtests were .40 for errors (which were rather infrequent) and .92 for reading time; the corresponding correlations between the two nonword subtests were .61 for errors and .95 for reading time. For text reading, we used the same subtest as in Study 1. This section of the individual reading test led to accuracy (percentage correct) and rate scores (items per minute) for text, word, and nonword reading. A new reading subtest without speed instruction consisted of a list of 20 foreign words of mainly English origin. These words were capitalized, adhering to the German rule for nouns (e.g., *Baby, Clown, Gameboy, Garage*). Criteria for the selection of these words were that they are in the spoken vocabulary of the children and that they have a good chance of being seen in print. Because of their foreign language origin, these words do not conform to the grapheme–phoneme correspondences of German, and therefore, correct pronunciation must depend on memories for the letter patterns of the words.

Spelling. We used the same classroom spelling test as in Study 1 as part of the assessment in the middle of Grade 3.

Results and Discussion

For group formation, we used the same inclusion and exclusion criteria as in Study 1. The correlation between the phonological awareness and the rapid-naming score was higher (.43) than the one observed in Study 1. As evident from the means in the first section of Table 2, the resulting groups represent the four possible combinations of about average and of poor performance levels on the phonological awareness measure and the rapid-naming measure. For example, the single phonological deficit group exhibited a mean of only 18% correct phoneme segmentation trials. This mean performance is less than half the performance of the no-

Table 2
Performance of Subgroups on Double-Deficit Measures, Control Measures, and Outcome Measures of Study 2

	No deficit (n = 131)			Phonological deficit (n = 24)			Naming deficit (n = 31)			Double deficit (n = 11)		
Measure	*M*	*SD*	Percentile[a]	*M*	*SD*	Percentile[a]	*M*	*SD*	Percentile[a]	*M*	*SD*	Percentile[a]
Phonological awareness (% correct)[b]	$55.34_{2,4}$	17.02	53	$17.01_{1,3}$	9.02	8	$58.33_{2,4}$	22.87	55	$17.42_{1,3}$	8.70	8
Naming speed (words per min)[b]	$54.62_{3,4}$	6.83	54	$54.05_{3,4}$	5.66	50	$39.42_{1,2}$	4.09	6	$40.57_{1,2}$	2.51	8
Age (years;months)	6;9	0;5		6;9	0;4		6;9	0;5		6;8	0;4	
Gender (boys/girls)	76/55			16/8			14/17			4/7		
Nonverbal IQ (CPM)[b]	116.56	11.89		114.88	9.24		114.65	12.97		113.73	13.01	
Reading accuracy (%)												
Sentence verification[c]	98.33	2.06		96.83	6.91		97.66	2.61		95.50	7.10	
Text[c]	97.82	2.74		96.71	3.74		97.00	3.51		95.37	3.79	
Compounds[c]	96.18	4.91		93.75	8.02		94.13	7.89		90.50	10.65	
Nonwords[b]	$79.72_{3,4}$	14.42	55	76.19	11.90	43	72.00_{1}	12.65	33	69.16_{1}	17.88	25
Foreign words[b]	$83.97_{2,3,4}$	16.63	44	73.75_{1}	22.03	25	73.55_{1}	20.38	25	62.27_{1}	30.93	14
Reading rate (items per min)[b]												
Sentence verification	$9.18_{2,3,4}$	2.12	52	8.41_{1}	1.69	36	7.72_{1}	2.09	23	7.37_{1}	1.70	19
Text	$116.27_{2,3,4}$	29.25	50	101.32_{1}	26.50	31	90.53_{1}	28.90	21	91.68_{1}	28.67	22
Compounds	$45.76_{2,3,4}$	15.19	53	$39.08_{1,3}$	14.08	37	$30.87_{1,2}$	12.57	21	33.89_{1}	14.22	26
Nonwords	$33.06_{3,4}$	10.78	54	30.67_{3}	10.22	50	$24.77_{1,2}$	9.72	27	26.76_{1}	10.26	35
Spelling (% correct)												
Orthographic[b]	$77.68_{2,3,4}$	15.04	46	65.39_{1}	17.38	24	65.11_{1}	16.77	24	59.55_{1}	16.80	18
Phonetic[c]	98.32	2.67		97.35	4.85		97.37	3.66		94.25	7.12	

Note. CPM = Raven's Coloured Matrices Test.
[a] Percentiles corresponding to means are based on the total sample of 288 children.
[b] Group comparisons based on *t* tests, one-tailed. A subscript number indicates that the mean differs reliably ($p < .05$) from the referred-to mean. Reference of subscript numbers: 1 = no-deficit group; 2 = phonological deficit group; 3 = naming deficit group; 4 = double-deficit group.
[c] No group comparisons because of ceiling effects.

deficit group and corresponds to a percentile of lower than 10 (in relation to the whole sample of 301 children). The large majority of the few correct word segmentations of the phonological-deficit group came from the subtask with CV words (a consonant followed by a vowel). For these words, segmentation into phonemes is equivalent to segmentation into onset and rime. For CVC words with further segmentation of the rime segment, like in *cat*: /k/-/a/-/t/, the phonological-deficit group scored close to bottom level, with only 6% correct. In contrast to this poor phonological awareness performance of the single phonological deficit group, the mean rapid-naming score of this group was rather similar to that of the no-deficit group and corresponded to a percentile of 44. Of importance is that all three deficit groups showed similar IQ means. The rather high IQ means may be due to the dated German norms (Schmidtke, Schaller, & Becker, 1978) for Raven's Coloured Progressive Matrices. The age means of the four groups were close to identical. The proportion of boys and girls in the groups differed. Specifically, in the single phonological deficit group, there was twice the number of boys than girls, whereas in the other deficit groups, the numbers of boys and girls were more balanced.

The mean reading accuracy scores in Table 2 show high reading accuracy of all three deficit groups (above 90%) for sentence verification and for text and compound-word reading. For these means, no statistical comparisons were performed because of ceiling effects. Reading accuracy was much lower for foreign words and nonwords. The *t* test results for foreign words show that all three deficit groups scored lower than the no-deficit group. The percentiles corresponding to the means indicate substantial impairment, with the double-deficit group reading particularly poorly. Nonword reading accuracy was reliably impaired for the single naming-speed deficit and the double-deficit groups only. For the single phonological deficit group, the difference from the no-deficit group was not reliable, and the percentile corresponding to the mean indicates that this group showed close to average nonword reading accuracy.

The reading rate measures in Table 2 show that the single phonological deficit group read reliably slower than did the no-deficit group on all reading tasks, with the exception of nonword reading. The percentiles (between 30 and 40) corresponding to the means indicate moderate reading rate impairments. The single naming-speed deficit group tended to show lower reading rates than did the single phonological deficit group, but the differences were reliable only for compound-word and nonword reading and not for sentence verification and text reading. The double-deficit group showed reading rates very similar to the single naming-speed deficit group.

For spelling, the pattern of differences, and even the absolute group means, closely replicate Study 1 (testing was done at about the same point in time in Grade 3). On the orthographic spelling measures (exact reproduction of the letter sequences of the words), each deficit group performed more poorly than the no-deficit group, with no differences between the groups; however, as in

Study 1, nearly all of the orthographically wrong spellings were phonetically acceptable.

In summary, despite a more difficult phonological awareness task that focused on a phoneme segmentation deficit and not on an onset- and rime-awareness deficit as in Study 1, the findings of Study 2 were similar. Again a single deficit in phonological awareness had little negative effect on reading accuracy about 3 years later as long as the reading material (text, compound words, nonwords) conformed to German grapheme–phoneme correspondences. However, the pattern was different when orthographic deficits in reading and spelling were examined. Accurate reading of foreign words that do not allow grapheme–phoneme recoding for correct reading was impaired in the single phonological deficit group to a similar extent as in the single naming-speed deficit group, and there was a trend toward particularly poor reading of these words in the double-deficit group. Orthographic spelling deficits showed the same pattern, with the single-deficit groups being similarly impaired and, again, the double-deficit group showing a trend toward particularly poor performance. There also was a moderate reading fluency impairment of the single phonological deficit groups for sentence verification and for text and compound-word reading but not for nonword reading. The fluency impairment was more pronounced for all reading material for the single naming-speed deficit group and the double-deficit group.

Study 3

Study 3 extended the double-deficit subtyping approach to a sample of poor readers and spellers in Grade 3. The main advantage of testing children in Grade 3 was that a standard phoneme segmentation task and a standard rapid-naming task (digit naming) could be used.

Method

Participants

Participants were 27 third graders with poor reading or spelling performance (poor literacy group) and 30 third graders with normal reading and spelling performance (average literacy group). The present data were collected when a subgroup of the longitudinal sample of Study 2 was invited for a more extensive individual assessment of reading and spelling deficits and of associated cognitive deficits at the end of Grade 3. The phoneme segmentation and the rapid-digit-naming task were administered as part of an individual cognitive deficit assessment at the end of Grade 3, which took place in our laboratory. Nineteen of the poor literacy children of the present study were included because their performance on the sentence verification classroom reading test administered in Grade 3 (see Study 2) was below percentile 20 and, in addition, their reading rate on the Salzburg reading test described in Study 1 (as part of the individual assessment) was below percentile 20 on at least two of three subtests (frequent words, compound words, and text). Reading errors could not be used for selection because they occurred infrequently. An additional 8 children were included in the poor literacy sample because they performed below percentile 10 on the spelling test used in Studies 1 and 2. The 30 children of the average literacy group performed above percentile 35 on the classroom reading test. The whole sample came from seven schools and 14 classrooms. As a control for nonverbal intelligence, we used data from Raven's Coloured Progressive Matrices Test, which was administered at the end of Grade 1.

Tests

Phonological awareness. Children were presented with nine complex two-syllable nonwords that started and ended with a consonant cluster (e.g., *blowisk, flamont*). Children were required to first repeat each word—to guarantee correct perception—and then to name each of the phonemes. The instruction stressed naming of sounds instead of naming letters, but letter names were also accepted as correct responses. Because the clusters were the most difficult parts to segment, only segmentation of the onset clusters and the offset clusters was evaluated. Thus, the scores ranged from 0 to 18 correct cluster segmentations. Children's segmentations were transcribed simultaneously by the experimenter and recorded for later inspection. Two practice items familiarized the children with the task.

Naming speed. Denckla and Rudel's (1976) rapid-digit-naming task was used, that is, children had to name as quickly as possible a sequence of 50 digits (5 different digits were repeated ten times) in different order on a single page. Children were familiarized with the rapid-naming demand by a practice page presenting three lines of digits. Both errors and time to read the page were recorded. Because naming errors hardly occurred, we used words per minute as the measure.

Reading and spelling. Reading and spelling measures were largely identical to those already described for Study 1. For nonword reading, only the subtest with word-analogous nonwords was used, and a subtest with familiar foreign words was added. The 12 foreign words were *Clown, Shampoo, Garage, Chef, Baby, Trainer, Computer, Jeans, Chinese, Orange, Skateboard,* and *Team.* For these words, application of German grapheme–phoneme recoding does not lead to correct pronunciation.

Results and Discussion

To form the deficit groups, we used performance levels below percentile 20 (based on the average literacy group) on the phoneme segmentation and the naming-speed tasks. The correlation between the segmentation and the naming score was only .20. A criterion of higher than percentile 30 on both tasks was used to assign children to the no-deficit group.

The numbers of children in the deficit groups (given in the column headers in Table 3) is already revealing with respect to the limited role of a single segmentation deficit for reading difficulties, as only 7 children exhibited such a deficit and only 3 of these came from the poor literacy group. In contrast, 11 of the 15 children from the single naming-speed deficit group and 6 of the 8 double-deficit children came from the poor literacy group. The large majority of the no-deficit children (15 of 18) showed reading and spelling in the normal range. As in Studies 1 and 2, the four groups represent rather unconfounded combinations of average (absolutely high in the case of segmentation) and low performance levels for phoneme segmentation and naming speed. An interesting observation is that segmentation performance of the single phonological deficit group and of the double-deficit group was better for initial word clusters than for final word clusters; percentages correct (for the two groups combined) were 73% and 56%, respectively. Therefore, the poor segmentation performance of the single phonological deficit group and of the double-deficit group is due, to some extent, to a memory problem. Table 3 further shows that groups were similar on age and nonverbal intelligence, but there was a clear overrepresentation of boys in the deficit groups, which is due to the fact that most of the poor readers and spellers were boys (22 of 27).

As evident from Table 3, reading accuracy of the deficit groups was very high for text and word reading, with even the double-deficit group exhibiting means of about 90% correct. Even for

Table 3
Performance of Subgroups on Double-Deficit Measures, Control Measures, and Reading and Spelling Measures of Study 3

	No deficit (*n* = 18)			Phonological deficit (*n* = 7)			Naming deficit (*n* = 15)			Double deficit (*n* = 8)		
Measure	*M*	*SD*	Percentile[a]	*M*	*SD*	Percentile[a]	*M*	*SD*	Percentile[a]	*M*	*SD*	Percentile[a]
Segmentation (% correct)[b]	$93.83_{2,3,4}$	4.62		$66.67_{1,3}$	7.86		$90.37_{1,2,4}$	6.11		$63.19_{1,3}$	20.34	
Naming (digits per min)[b]	$133.23_{3,4}$	12.80		$126.46_{3,4}$	11.39		$89.64_{1,2}$	12.44		$92.87_{1,2}$	20.74	
Age (years;months)[b]	$9;2_{2}$	0;4		$9;5_{1}$	0;5		9;4	0;2		9;2	0;5	
Gender (boys/girls)	7/11			6/1			14/1			5/3		
Nonverbal IQ (CPM)[b]	116.39	9.00		115.43	7.59		118.67_{4}	9.08		111.75_{3}	7.54	
Reading accuracy (%)												
Text[c]	97.76	1.88		92.73	10.40		97.08	3.55		93.42	7.31	
Words[c]	99.05	1.70		93.38	14.34		96.42	3.67		87.80	8.94	
Nonwords[c]	93.89	7.69		81.43	23.79		90.00	5.49		81.25	10.83	
Foreign words[b]	82.41_{4}	21.56		63.10	39.34		71.67_{4}	24.96		$48.96_{1,3}$	33.17	
Reading rate (items per min)[b]												
Text	$105.91_{2,3,4}$	19.74	63	$83.22_{1,4}$	18.71	37	69.55_{1}	28.22	22	$56.82_{1,2}$	28.66	13
Words	$73.67_{3,4}$	15.12	60	63.15_{4}	19.95	45	48.58_{1}	20.51	23	$41.14_{1,2}$	22.46	13
Nonwords	$49.15_{3,4}$	12.25	65	43.30	12.68	50	32.78_{1}	13.95	21	30.08_{1}	13.40	15
Spelling (% correct)												
Orthographic[b]	$78.80_{2,3,4}$	11.35	47	66.47_{1}	20.91	29	65.17_{1}	17.95	27	52.81_{1}	18.91	15
Phonetic[c]	98.98	1.44		94.13	7.96		98.64	1.84		91.58	9.22	

Note. CPM = Raven's Coloured Matrices Test.
[a] Norm percentiles corresponding to means.
[b] Group comparisons based on *t* tests, one-tailed. A subscript number indicates that the mean differs reliably ($p < .05$) from the referred-to mean. Reference of subscript numbers: 1 = no-deficit group; 2 = phonological deficit group; 3 = naming deficit group; 4 = double-deficit group.
[c] No group comparisons because of ceiling effects.

nonword reading accuracy, *t* test results are not meaningful due to the near ceiling performance of the no-deficit group. The means in Table 3 show trends toward lower accuracy for the single phonological deficit group and the double-deficit group. However, inspection of scores showed that the mean of the single phonological deficit group was distorted by an outlier with only 30% correct. Without this outlier, the mean accuracy of the single phonological deficit group was 91% correct. For foreign words, accuracy was lower and highly variable, particularly among the single phonological deficit children. The *t* test results for foreign words in Table 3 show that only the double-deficit group differed reliably from the no-deficit group, whereas the two single-deficit groups only showed trends toward lower accuracy for foreign words.

For reading rate, findings replicate those of Study 1. Again the single phonological deficit group showed a reliable lower rate for text reading only and not for word and nonword reading. The percentile corresponding to the mean rate for text reading indicates an only moderate impairment, and for nonword reading, the rate of the single phonological deficit group was average. In contrast, mean reading rates of the single naming-speed deficit group and the double-deficit group were depressed, with the double-deficit group exhibiting very poor reading rates. For orthographic spelling, both the single phonological group and the single naming-speed deficit group showed lower performance than did the no-deficit group, and the double-deficit group performed very poorly. However, most of the orthographically wrong spellings were phonetically acceptable, and even the double-deficit group exhibited a mean of over 90% phonetically acceptable spellings.

In summary, Study 3 extended the double-deficit subtyping to a German-speaking sample of poor readers and spellers in Grade 3. This allowed the use of standard tasks for the assessment of phoneme awareness (segmentation of consonant clusters) and of rapid-naming deficits (digit naming). There was remarkable agreement with the findings of Studies 1 and 2. Despite the standard phoneme segmentation task, the single phonological deficit group showed little reading impairment. Only a minority of the single phonological deficit group belonged to the poor literacy group. Reading accuracy of the single phonological deficit group was high as long as the material conformed to German grapheme–phoneme correspondences (with the exception of 1 child with poor nonword reading accuracy), and reading rate was largely in the normal range. Also, phonetic spelling was close to perfect. This may seem paradoxical, as the single phonological deficit group was defined by poor cluster segmentation. However, there are experimental studies that have shown that phonemic segmentation of nonwords is easier when children can write them down than when they have to do the task without paper and pencil (Landerl & Wimmer, 2000; van Bon & Duighuisen, 1995). As in Study 2, the single phonological deficit group exhibited a difficulty with orthographic processes. Orthographic spelling was poor, and accurate reading of foreign words was highly variable. The findings for the single naming-speed group and the double-deficit group replicated those of Studies 1 and 2. The single naming-speed deficit group exhibited mainly a reading rate and an orthographic spelling deficit. The double-deficit group exhibited more reading errors than did the single naming-speed deficit group, particularly for foreign words and nonwords, and orthographic spelling was particularly depressed.

General Discussion

For a theoretically oriented discussion of the differences between the deficit groups, it is useful to distinguish between a phonological coding impairment, a reading fluency impairment, and an orthographic memory impairment. Our focus is on the longitudinal findings because, here, the deficits postulated by the double-deficit hypothesis cannot be interpreted as being due to lesser reading experience or poor readers.

Phonological Coding

The expectation formulated in the Introduction is that, given the combination of a synthetic teaching approach and an easy orthography, even children with a phonological awareness deficit may exhibit little difficulty with the acquisition of phonological coding in reading. Actually, as pointed out in the Introduction, phonological coding is exactly what the synthetic phonics approach attempts to achieve. The stringent test case for phonological coding is accuracy of nonword reading because, here, any difficulty with grapheme–phoneme coding and phonological assembly cannot be compensated for by reliance on the phonological lexicon. However, note that nonword reading was assessed with speeded reading tests, and therefore, some errors may have been due to attempts to gain speed.

Overall, the findings show that accurate nonword reading at the end of Grade 3—even when assessed with speeded tests—posed little difficulty for children with a phonological deficit at the beginning of reading instruction. For the easy nonwords of Study 1, the single phonological deficit group scored about 90% correct and only 4% lower than did the no-deficit group. For the difficult nonwords of Study 2 (clusters plus digraphs), the single phonological deficit group scored 76% correct but, again, only 4% lower than did the no-deficit group. The single phonological deficit group also showed no speed impairment in reading the nonwords. Even more impressive than nonword reading accuracy was phonetic spelling accuracy, as the single phonological deficit groups scored close to ceiling and the double-deficit groups also exhibited means of over 90% correct.

In summary, these results suggest that indeed, as formulated in the Introduction, a synthetic phonics teaching approach in the context of an easy orthography may bring children with an initial phonological awareness deficit to competent phonological coding in reading and writing. The present findings are consistent with our previous findings that German dyslexic children (selected by poor reading fluency) show high phonological coding accuracy and high scores on phoneme segmentation tasks (Landerl & Wimmer, 2000; Wimmer, 1993, 1996b; Wimmer et al., 1998).

The present longitudinal finding that a phonological awareness deficit has surprisingly little negative effect on the acquisition of phonological coding has to be interpreted in relation to our phonological awareness assessment. This assessment proved to be difficult for German-speaking children at school entrance, who in kindergarten had not been exposed to any reading preparation and consequently had little letter knowledge when phonological awareness was assessed. In Study 1, a deficit in phonological awareness was defined by poor onset and rime detection. The task was deliberately easy, but most children of the single and the double-deficit group scored at guessing level on at least one phonological detection task. Furthermore, even when a very stringent criterion for inclusion in the single phonological deficit group (1 *SD* below the mean on both the onset- and the rime-detection tasks) was applied, high accuracy levels were still found for nonword reading and for phonetic spelling. Study 2 defined the single phonological deficit group by poor performance on a task that required imitation of segmentation. The single phonological deficit group (and also the double-deficit group) scored close to bottom level for imitating phoneme segmentation, but again, nonword reading accuracy and phonetic spelling accuracy were unimpaired 3 years later. Study 3 defined single phonological deficit group among third graders by using a task that focused exclusively on segmentation of consonant clusters. Again, with a single exception, reading of nonwords was highly accurate and the same was the case for phonetic spelling.

Obviously, the present results of largely unimpaired phonological coding processes in German children with phonological awareness deficits differ from the results of the English-based subtyping studies mentioned in the Introduction. In the case of Lovett (1995) and Wolf (1997), the poor nonword reading simply followed from the selection procedure, which took poor nonword reading as a proxy for poor phonological awareness. Bowers et al. (1999) used a nonreading measure (Auditory Analysis Test) for the assessment of poor phonological awareness. The phonological-deficit groups of Bowers et al. were less stringently defined (below percentile 35) than the present groups (below percentile 17), but despite this less stringent selection, the single phonological deficit group, and particularly the double-deficit group, showed impaired nonword reading accuracy. This difference from our findings suggests that phonological awareness deficits have negative effects on the acquisition of phonological coding in an instructional/orthographic context that is less favorable than the one experienced by the present children.

Reading Fluency

As pointed out in the Introduction, a reading fluency deficit was found to be characteristic of dyslexic children in several consistent orthographies, and the expectation was that a naming-speed deficit would be a major precursor of impaired reading fluency. This expectation found clear support in the present longitudinal findings. On all reading tasks (i.e., silent sentence verification, reading aloud of text, word lists and nonword lists), the single naming-deficit children exhibited substantially impaired reading speed. The double-deficit children performed similarly to the single naming-speed deficit children. In contrast, there was little reading-speed impairment for the single phonological deficit children, and this was largely limited to text reading and sentence verification and, surprisingly, was not present at all for nonword reading.

The present finding that an early single naming-speed deficit is predictive for later reading fluency impairments is consistent with the converse findings that German dyslexic children (defined by poor reading fluency) exhibit a massive concurrent naming-speed deficit but little phonological awareness deficit (Wimmer, 1993; Wimmer et al., 1998; Wolf, Pfeil, Lotz, & Biddle, 1994). The finding of a persistent effect of a naming-speed deficit on reading fluency is also consistent with the longitudinal correlational finding of de Jong and van der Leij (1999) with Dutch children. Their study showed that early rapid naming had a more persistent association with reading than did phonological awareness. This higher predictive importance of early naming speed rather than early phonological awareness differences in German and Dutch children seems to be the opposite of what is found in studies with American children (Cronin & Carver, 1998; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997).

Orthographic Memory

In the present research, a difficulty in storing the letter strings of words should be evident from poor orthographic spelling and from poor reading accuracy for foreign words. The former is due to the fact that German orthography is much more consistent in the grapheme–phoneme direction than in the converse direction. The latter is due to the fact that foreign words such as *gameboy* or *skateboard* do not conform to German grapheme–phoneme relations. Main findings were that, in all three studies, the two single-deficit groups showed similarly depressed orthographic spelling performance, and there was a tendency toward even poorer orthographic spelling of the double-deficit group. The same pattern was found in Studies 2 and 3 for accurate reading of foreign words.

The observation of poor reading of foreign words in our deficit groups allows the direct linkage of the present findings with the English-based findings concerned with the double-deficit hypothesis. In short, when our German children had to read English (the present foreign words were largely English), then in correspondence with the English-based findings, both a phonological awareness deficit and naming-speed deficit were predictive for difficulties with accurate reading. In contrast, when our children had to read German words, a phonological awareness deficit did not affect reading accuracy or reading fluency, and a naming-speed deficit affected reading fluency only.

The negative effect of a single phonological awareness deficit on orthographic memory formation (without a negative effect on phonological coding) requires comment. It speaks against the assumption that formation of orthographic memories is solely a function of visual memory (e.g., Castles & Coltheart, 1993) but rather speaks for phonological effects on orthographic memory formation (Ehri, 1992; Perfetti, 1992). We recently proposed that poor storage of spelling pronunciations (i.e., pronunciations that closely follow how the word is spelled) may contribute to poor orthographic memory in German dyslexic children. This proposal was based on findings that dyslexic children exhibit poor learning of new phonological word forms (Mayringer & Wimmer, 2000). The negative effect of a single naming-speed deficit on orthographic memory formation also deserves comment. Bowers, Golden, Kennedy, and Young (1994) offered a visual deficit explanation for this link by assuming that deficient visual processes lead to slow single-letter recognition, which prevents the simultaneous activation of letters of a sequence, which in turn prevents the formation of interletter associations. We prefer a proposal that locates the deficit not at the formation of visual interletter associations but at the formation of associations between the phonemes triggered by the grapheme or at the formation of associations between the graphemes of the written word and the segments of the phonological representation (Mayringer & Wimmer, 2000). This perspective on orthographic memory would keep the double-deficit hypothesis within the general conception of dyslexia as a language impairment (e.g., Catts, 1996).

Teaching and Orthography Effects

Of interest is the present observation that children with an early phonological awareness deficit exhibited highly competent nonword reading and generally showed close to perfect reading accuracy (with the exception of foreign-word reading) 3 years later. This occurred in the context of an orthography with simple regular relations between graphemes and phonemes and an initial teaching approach that systematically induces children to use these relations for word decoding. The finding shows that a deficit in phonological awareness under favorable conditions is not an obstacle to the acquisition of phonological coding. Early difficulty with phonological coding in the first year of school can be observed in some children with a phonological awareness deficit (Wimmer, 1996a), but as the present findings show, these early difficulties are nearly always overcome in Grade 3. In their sample of Dutch children, de Jong and van der Leij (1999) also found that the effect of early phonological awareness differences were limited to Grade 1 reading.

However, the presently observed success of children with initial poor phonological awareness was limited to phonological coding in word recognition and did not extend to competencies that require orthographic memory representations such as orthographically correct spelling and the correct reading of foreign words. The other main finding is that, for children with a single early naming-speed deficit, the synthetic phonics teaching approach in the context of a regular orthography did not offer specific advantages. As expected, for these children, the acquisition of phonological coding posed little difficulty, but in correspondence with their early deficit, they exhibited poor reading fluency, and they also performed poorly when reading accuracy (foreign words) and spelling required orthographic representations.

In summary, the main difference between the present German-based findings and the well-known English-based findings has to do with the developmental locus where the impairments postulated by the double-deficit hypothesis exert their negative effect. In the case of English, the negative effect of a phonological awareness deficit occurs early and affects the acquisition of self-reliant phonological coding in word reading and thereby endangers all further progress—in particular, the build up of the orthographic lexicon. In the case of German and other regular orthographies, the early acquisition of self-reliant phonological coding in word reading is relatively immune to negative effects of a phonological awareness deficit for the reasons explicated. The negative effects of factors that underlie the early phonological awareness deficit and the early naming-speed deficit occur later, when reading fluency and orthographic spelling become important.

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