Ann. of Dyslexia (2010) 60:18–39
DOI 10.1007/s11881-010-0035-8

Spelling deficits in dyslexia: evaluation of an orthographic spelling training

Elena Ise · Gerd Schulte-Körne

Received: 13 August 2009 / Accepted: 18 January 2010 / Published online: 30 March 2010

Abstract Orthographic spelling is a major difficulty in German-speaking children with dyslexia. The aim of the present study was to evaluate the effectiveness of an orthographic spelling training in spelling-disabled students (grade 5 and 6). In study 1, ten children (treatment group) received 15 individually administered weekly intervention sessions (60 min each). A control group (n=4) did not receive any intervention. In study 2, orthographic spelling training was provided to a larger sample consisting of a treatment group (n=13) and a delayed treatment control group (n=14). The main criterion of spelling improvement was analyzed using an integrated dataset from both studies. Repeated-measures analysis of variance revealed that gains in spelling were significantly greater in the treatment group than in the control group. Statistical analyses also showed significant improvements in reading (study 1) and in a measure of participants' knowledge of orthographic spelling rules (study 2). The findings indicate that an orthographic spelling training enhances reading and spelling ability as well as orthographic knowledge in spelling-disabled children learning to spell a transparent language like German.

Keywords Dyslexia · Intervention · Spelling disability · Spelling training · Transparent orthography

Introduction

Five to ten percent of school-aged children suffer from dyslexia, which is characterized by severe difficulties in the acquisition of reading despite normal intelligence and adequate schooling (Katusic, Colligan, Barbaresi, Schaid, & Jacobsen, 2001; Shaywitz, Shaywitz, Fletcher, & Escobar, 1990). Dyslexia is a neurodevelopmental disorder with a genetic origin (Scerri & Schulte-Körne, 2009) that occurs in alphabetic and non-alphabetic writing systems (Lindgren, DeRenzi, & Richman, 1985; Stevenson, Stigler, Lucker, & Lee, 1982).

E. Ise · G. Schulte-Körne (✉)
Department of Child and Adolescent Psychiatry, University of Munich, Pettenkoferstraße 8a, 80336 Munich, Germany
e-mail: Gerd.Schulte-Koerne@med.uni-muenchen.de

Dyslexia is characterized by phonological processing deficits (Ho, Law, & Ng, 2000; Paulesu et al., 2001), which are closely related to the development of poor reading and spelling skills (Caravolas, Hulme, & Snowling, 2001; Wagner et al., 1997; Wimmer, Mayringer, & Landerl, 2000). The difficulties in reading and spelling are highly persistent (Esser & Schmidt, 1993; Klicpera, Schabmann, & Gasteiger-Klicpera, 1993). Moreover, they are associated with a greater chance of school drop-out, low educational achievement, and unemployment (Daniel, Walsh, Goldston, Arnold, Reboussin, & Wood, 2006; Esser, Wyschkon, & Schmidt, 2002; Maughan, 1995; Maughan, Hagell, Rutter, & Yule, 1994), as well as emotional and behavioral problems (Arnold et al., 2005; Fluss, Ziegler, Warszawski, Ducot, Richard, & Billard, 2009; Maughan, Rowe, Loeber, & Stouthamer-Loeber, 2003; Morgan, Farkas, Tufis, & Sperling, 2008). Effective interventions are therefore critically needed.

Several studies have demonstrated positive effects of prevention programs for children at risk of dyslexia (e.g., Schneider, Küspert, Roth, Visé, & Marx, 1997; van Otterloo, van der Leij, & Henrichs, 2009). It has also repeatedly been found that intervention programs for dyslexic children in grade 2-4 have remedial effects on reading and spelling skills (e.g., Schulte-Körne, Deimel, Hülsmann, Seidler, & Remschmidt, 2001; Schulte-Körne, Deimel, & Remschmidt, 2003; Tijms & Hoeks, 2005). Unfortunately, a substantial number of dyslexic children do not receive early intervention because many parents do not seek professional help before the child has completed several years of formal schooling. In grade 5 and 6, dyslexic children learning to read a consistent language like German generally show slow, but accurate reading and master phonological spelling (Landerl & Wimmer, 2008; Wimmer, 1996). However, they demonstrate major difficulties with orthographic spelling (Landerl, 2003). The aim of the present study is to introduce an orthographic spelling training for German-speaking spelling-disabled children in grade 5 and 6 and to determine whether the training has a remedial effect on spelling ability. Implications for spelling intervention in other languages with transparent orthographies will be discussed.

Languages differ in the degree to which the pronunciation of a word can be predicted from its spelling. English is a *deep orthography* because it contains many inconsistent and complex grapheme-phoneme (or spelling-to-sound) correspondences, while German is regarded a *shallow (or transparent) orthography* with quite consistent grapheme-phoneme correspondences (Seymour, Aro, & Erskine, 2003). For example, in the German words *Hamster*, *Parade*, *Mars*, and *Ball* the grapheme *a* is always pronounced the same. In contrast, the grapheme *a* is pronounced differently in each of the English words *hamster*, *parade, mars*, and *ball*. Several cross-language comparisons show that a high degree of grapheme-phoneme consistency facilitates the acquisition of basic reading skill and that German-speaking children become accurate and fluent readers much earlier than English-speaking children (Aro & Wimmer, 2003; Frith, Wimmer, & Landerl, 1998; Seymour et al., 2003; Wimmer & Goswami, 1994).

Spelling differs from reading because it requires the production rather than the recognition of spelling patterns. Spelling is complicated by the fact that there are often several possibilities to write a word phonologically correct (e.g., *brain* and *brane*). Phoneme-grapheme (or sound-to-spelling) inconsistencies are caused by sound patterns that can be represented by different graphemes (as in *deep* and *heap*; Stone, Vanhoy, & Van Orden, 1997). Cross-language studies demonstrate that basic spelling skills are acquired faster in languages with a high degree of phoneme-grapheme consistency (Caravolas & Bruck, 1993; Wimmer and Landerl, 1997). Phoneme-grapheme correspondences in German are more consistent than in English (Borgwaldt, Hellwig, & de Groot, 2004) and the majority of German-speaking children are quite able to produce phonologically acceptable

spellings by the end of the first year of schooling (Landerl & Wimmer, 2008; Wimmer, 1996), while English-speaking children show difficulty with producing phonologically acceptable spellings even in grade 3 (Caravolas, 2004).

Orthographic consistency not only influences the development of reading and spelling in unimpaired children, but also affects the manifestation of dyslexia. In English-speaking children, dyslexia is characterized by poor word reading accuracy (for a review, see Rack, Snowling, & Olson, 1992), reading speed problems (Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003) and sustained difficulties with phonologically and orthographically accurate spelling (Bourassa & Treiman, 2003; Bruck, 1993; Cassar, Traiman, Moats, Pollo, & Kessler, 2005; Friend & Olson, 2008; Kemp, Parrila, & Kirkby 2009; Manis, Custodio, & Szeszulski, 1993; Pennington et al., 1986). German-speaking dyslexics, on the other hand, generally demonstrate reading accuracy problems only in the early phases of reading acquisition (Wimmer, 1996) and show slow, but accurate word reading after a few years of schooling (Landerl, Wimmer, & Frith, 1997; Landerl & Wimmer, 2008; Wimmer, 1993). Moreover, error analyses of spellings produced by German-speaking dyslexics in grade 4-6 reveal major difficulties in orthographic spelling (Landerl, 2003), while only few phonologically inaccurate spellings are made (Landerl & Wimmer, 2000; Wimmer, 1996). Intervention programs for German-speaking dyslexic children in higher grades should therefore focus on enhancing orthographic spelling.

In competent spellers, orthographic knowledge is, at least, partly acquired as a result of the self-teaching opportunities provided by phonological decoding (*self-teaching hypothesis*; Cunningham, Perry, Stanovich, & Share, 2002; de Jong & Share, 2007; Jorm & Share, 1983; Share, 1995, 1999). However, a longitudinal study of spelling development in German-speaking children demonstrated that some children showed high phonological decoding skills at the end of grade 1, but nevertheless developed below average orthographic spelling later on (Landerl & Wimmer, 2008). The authors conclude that these poor spellers had not been able to make use of the proposed self-teaching mechanism. This finding is supported by the clinical observation of dyslexic children who have difficulties in spelling high frequency words that have been read and written many times before. Dyslexic children seem to profit to a much lesser extent from the learning mechanisms which enhance orthographic spelling in unimpaired children. Consequently, intervention programs for dyslexic children should focus on alternative learning mechanisms.

Orthographic spelling trainings are promising approaches because they convey orthographic knowledge explicitly. About 50-60% of German words can be spelled correctly by simply applying phoneme-grapheme conversion rules (Reuter-Liehr, 1993). Most of the remaining words contain spelling patterns that follow relatively consistent orthographic spelling rules. For example, if a short vowel is followed by only one consonant within the same morpheme, then this consonant has to be doubled in the spelling (as in the German words *Ball [ball]*, *Kamm [comb]*, and *Mann [man]*). German students are well aware of the fact that spelling patterns are guided by spelling rules. In a study by Eckert and Stein (2004), spelling-unimpaired grade 5 students were asked to explain their spellings of previously dictated words. The majority of students formulated spelling rules. However, many students revealed incomplete knowledge of spelling rules (e.g., formulated incorrect or incomplete spelling rules) or failed to use these rules during spelling (e.g., produced incorrect spellings despite correct knowledge of spelling rules). Intervention programs should therefore not only convey orthographic spelling rules, but also teach strategies on how to use these rules during spelling. The intervention program used in the current study combines these two aspects by depicting spelling rules graphically as yes/no decision trees which help children to verbalize the spelling rules and to use them effectively

during spelling. The program is a modified version of a rule-based spelling training for spelling-disabled children in grade 2-4 (*Marburger Rechtschreibtraining [Marburg Spelling Training]*, Schulte-Körne & Mathwig, 2009) whose effectiveness has been demonstrated in several studies (Schulte-Körne et al., 1997, 1998, 2001, 2003).

The aim of the present study is to evaluate the effectiveness of the orthographic spelling training in German-speaking children with spelling disability (SD) in grade 5 and 6. In study 1, ten children with SD (treatment group) received 15 individually administered intervention sessions (60 min each). Intervention sessions were carried out in our clinic on a once-weekly basis. A control group (n=4) did not receive any intervention. Previous intervention studies with grade 2 and 3 students have shown that orthographic spelling training enhances not only spelling, but also reading ability (Schulte-Körne et al., 2001, 2003). We therefore expected both reading and spelling ability to improve during training.

In study 2, we aimed to replicate the results regarding spelling improvement with a larger sample consisting of a treatment group (n=13) and a delayed treatment control group (n=14). During the first training period, children in the treatment group received 12 weekly intervention sessions, while the control group did not receive any intervention. During the second training period, the control group received twelve training sessions and training was discontinued for the treatment group. In study 2, an additional outcome measure (knowledge of orthographic spelling rules) was included. We expected the treatment group to show training-induced gains in both orthographic knowledge and spelling ability. Moreover, we expected the control group to show no comparable gains during the no-treatment period, but to show enhanced orthographic knowledge and spelling after the second training period.

Method

Study 1

Design

The study consists of a traditional pretest-intervention-posttest design with a treatment group (n=10) and a control group (n=4). Outcome measures were spelling and reading ability. Pretests (T1) were conducted in the last week of February and the first week of March 2008. The treatment group then received 15 training sessions which lasted 60 min each. Training sessions were administered weekly and were carried out by the first author and advanced students in pedagogy and German literature. Sessions were carried out in the afternoons in our clinic. Each session began and ended with a 5-min talk, leaving 50 min to the spelling training program. No homework was given. Posttests (T2) were conducted in July 2008.

Participants

All grade 5 students who had previously been diagnosed with specific SD or dyslexia at our clinic (n=11) were contacted. Only one child had not started spelling training in the meantime and was asked to participate in the current study. In addition, children were recruited from ten public inner city schools in Munich, Germany. Flyers were sent to the schools and teachers were asked to pass these to parents of poor spellers. Thirty-five families responded to the flyer. Children that met the inclusion criteria of (1) no concurrent

reading or spelling remediation and (2) no formal diagnosis of attention-deficit hyperactivity disorder (diagnosed by a medical practitioner according to ICD-10 criteria) were screened for reading and spelling level with standardized tests (spelling: *RST 4-7*, reading: *ELFE 1-6*, for descriptions, see "Measures" section). They were also screened for IQ with the Culture Fair Intelligence Test (CFT 20-R; Weiß, 2006), except for children who had been administered an intelligence test within the previous 12 months. Children were included in the study if they had an IQ of 85 or above, and if their *T* value (standardized score, M=50, SD=10) in spelling was 40 or below.

Of the 16 children that were included in the study, 12 were allocated to the treatment group. Four children, whose parents had contacted us just before the start of the training period, were allocated to the control group and offered participation in study 2. The day before the first training session, one boy withdrew his participation in the treatment group due to lack of motivation. Another boy completed the training but was excluded from data analysis because he showed very poor concentration throughout the training, which prevented him from using the behavioral and cognitive skills taught in the spelling training. The final sample includes 14 children (nine boys and five girls) between the ages of ten and 12. All children attended grade 5, were native speakers of German and met the ICD-10 criteria for spelling disability. Four children also met the diagnostic criteria for reading disability (see Appendix 1). Because participants were recruited based on their spelling ability, we will refer to all participants as children with SD throughout the manuscript. Participation was free of costs. All children and at least one legal guardian gave signed consent to their participation in the study. Table 1 shows the background characteristics of the two experimental groups. Spelling, reading, and IQ scores for each subject at the onset of the study are documented in Appendix 1.

Orthographic spelling training

A main difficulty for German students is the mastering of the complex orthographic rules to mark long and short vowels (Klicpera & Gasteiger-Klicpera, 2000; Landerl, 2003). Short vowels are quite consistently marked following two algorithms: (1) "if a short vowel phoneme is followed by only one consonant phoneme within the same morpheme, then this consonant has to be doubled in the spelling" (e.g., *Mann [man]*, *Bitte [request]*), and (2) "if a short vowel phoneme is followed by two or more consonant phonemes in the same morpheme, then these consonants are not doubled in the spelling" (e.g., *Tante [aunt]*, *Bild [picture]*). In contrast, there are several possibilities to mark long

Table 1 Descriptive data for subjects at the onset of the study (study 1)

	Treatment group (n=10)	Control group (n=4)
Boys/girls	6/4	3/1
Age in months	133.4 (4.7)	137.0 (8.5)
IQ	111.4 (11.6)	110.3 (8.9)
spelling (T value)[a]	30.8 (5.5)	34.5 (6.5)
reading (T value)[a]	49.8 (10.5)	43.5 (4.5)

Except for the distribution of boys/girls, numbers represent mean values (standard deviations are in parentheses)

[a] Pretest results (T1)

vowels. Markers for long vowels are more complex and less consistent than markers of short vowels. Long vowels phonemes can be marked by adding a "silent h" (e.g., *Hahn [cock]*), by doubling the vowel grapheme (e.g., *Saal [hall]*), by marking the long vowel *i* with the bigram *ie* (e.g., *Tier [animal]*), or simply by the absence of a doubled consonant (the grapheme *a* is a long vowel phoneme in the word Schal *[scarf]*, but a short vowel phoneme in the word *Schall [sound]*). For example, the algorithm for markers of the long vowel phoneme *i* is: "If the vowel *i* is a long vowel phoneme, then it is spelled with the bigram *ie* (e.g., *Tier [animal]*), with the exception of (1) words that have a long vowel *i* in the word initial position (e.g., Igel *[hedgehog]*, Iglu *[igloo]*) and (2) the three pronouns *ihm*, *ihn*, and *ihr [him, his, her]*) in which the long vowel phoneme *i* is spelled with the bigram *ih*.

The algorithms are often not explicitly taught in regular classroom lessons, most likely because of their complexity. The orthographic spelling training used in the present study depicts the algorithms graphically as yes/no decision trees that are shaped like metro maps. The decision trees help children to memorize the algorithms through verbalization, thereby promoting the development of explicit orthographic knowledge. Moreover, the decision trees help to apply the algorithms to concrete words and thereby teach children how to use their explicit knowledge during spelling.

German closely adheres to the principle of morpheme consistency (Landerl & Reitsma, 2005). That is, orthographic spelling rules are only applicable to the word stem, which is consequently spelled with high consistency. The intervention program starts with a chapter on recognizing short and long vowels, and continues with a chapter on recognizing and isolating the word stem. Orthographic markers of short and long vowels are treated in the next chapters, along with the spelling of capital initial letters (e.g., all nouns are spelled with a capital letter), and the spelling of different s-sounds (*Gläser [glasses]*, *Grüße [greetings]*, *Küsse [kisses]*). Each chapter starts with simple exercises, which increase in difficulty, and contains systematic repetition of previous topics. Following a constructionist approach, children are encouraged to discover the algorithms themselves before the decision trees are given. Appendix 2 provides detailed information on the background of the spelling training, its frame story and general aspects, as well as a specification of content, organization, and instructional procedures of each chapter.

Fidelity of treatment

The spelling training is highly structured. Spelling exercises have clear instructions and are designed to be completed subsequently. An appendix provides correct answers to all exercises. In both studies, several actions were taken to ensure that treatment was implemented as intended.

First, therapists were trained to deliver the spelling training. One supervision meeting was held before the start of the training period. It was ensured that therapists have sufficient background knowledge on dyslexia and spelling disability. Therapists were then taught the theoretical background of the rule-based approach and received the training material. Key skills were trained (e.g., differentiating long and short vowels phonemes), and the first training sessions were prepared by discussing and practicing individual spelling exercises.

Secondly, therapists received two supervision meetings during the training periods (2 and 6 weeks after the start of the training period). During these meetings, therapists had the chance to comment on the spelling training and to discuss difficulties they experienced with individual children. The supervisor (first author) ensured that therapists worked through the

exercises one after the other, at the child's pace. It was checked if omitted training sessions (due to illness or school activities) were caught up as individual sessions, instead of doing double sessions as was proposed by some parents. Therapists were asked to indicate whether they adhered to the instructions of the spelling exercises or if they added more instruction. In addition, therapists had the possibility to contact the supervisor anytime for individual supervision. After completion of the treatment, therapists reported each child's responsiveness to the training and its (subjectively experienced) improvement to their supervisor.

Measures

Spelling Spelling ability was assessed with a standardized spelling test (*RST 4-7, Rechtschreibtest für 4. bis 7. Klasse [spelling test for grades 4-7]*, Grund, 2003) in which children have to fill 60 dictated words into sentence frames. The experimenter first reads aloud the full sentence and then repeats the word to be spelled. Scoring is based upon the number of words written correctly. The test handbook reports high reliability (r=0.8, split-half method). Norm-referenced scores are standard scores (T values) with a mean of 50 and a standard deviation of 10. There are two norm periods: (1) October-December and (2) May-July. For each child, the T value for spelling at T1 was determined by calculating the intermediate value of the two norm periods. For T2, the norm period May-July was appropriate.

Reading Children's reading ability was assessed with a standardized reading test (ELFE 1-6, *Leseverständnistest für Erst- bis Sechsklässler [reading comprehension test for grades 1–6]*, Lenhard & Schneider, 2006) which consists of three time limited subtests: word recognition, sentence and text comprehension. Scoring is based upon the number of correct responses. The test handbook reports high reliability. Internal consistency (Cronbach's λ) is high for each subtest (λ=0.97 for word recognition, λ=0.93 for sentence comprehension, and λ=0.92 for text comprehension). Split-half reliability is also high (r= 0.95 for word recognition and sentence comprehension, r=0.89 for text comprehension). The test-retest reliability is r=0.85 in grade 5 and r=0.82 in grade 6. Norm-referenced scores are standard scores (T values) with a mean of 50 and a standard deviation of 10. For T1 measures, the norm table for the middle of the school year (November-February) was appropriate. For T2, the norm table for the last 2 months of the school year were used.

Data analysis

Because of the small number of children in the control group (n=4), we refrained from using statistical procedures to analyze gains in reading in this group. In the treatment group, Kolmogorov-Smirnov tests showed no significant deviations from a normal distribution for reading at T1 and T2. Improvements in reading were analyzed using a paired samples t test. The effect size (EF) was calculated based on the original standard deviations $\left(\text{Cohen's } d = M_1 - M_2 / \sigma_{\text{pooled}}\right)$. We refrained from calculating the EF based on t test values, because Dunlop et al. (1996) have convincingly argued that the EF will be overestimated if the pooled standard deviation is corrected for the correlation between measures (as in repeated-measures designs). Spelling ability was measured in both studies. Gains in spelling were therefore analyzed using an integrated dataset. Results are presented after the description of study 2.

Study 2

Design

The second study used a pretest-intervention-posttest design with a treatment group ($n=13$, including the four children from the delayed treatment control group in study 1) and a delayed treatment control group ($n=14$). Outcome measures were spelling ability and knowledge of orthographic spelling rules. Pretests were conducted in September 2008 (T1). From September to December (first training period), children in the treatment group received 12 individually administered weekly training sessions which lasted 60 min each. Training sessions were carried out in the afternoons in our clinic. Each session began and ended with a 5-min talk, leaving 50 min to the spelling training program. No homework was given. Sessions were carried out by the first author and advanced students in psychology, psycholinguistics, pedagogy, and German literature. In the treatment group, posttests were conducted at the end of December (T2). The training was then discontinued for the treatment group and begun for the children in the delayed treatment control group who had not received any reading and/or spelling intervention between T1 and T2. In the control group, posttests (T2) were carried out at the beginning of January 2009, just before the start of their training period. The control group received the same amount of training under the same conditions as children in the treatment group. In April 2009, a third assessment (T3) was conducted. Because the majority of children in the treatment group had been advised to continue spelling intervention after T2, they were not invited to participate in the T3 assessment.

Participants

Participants were recruited from ten public inner city schools in Munich, Germany. Flyers were sent to the schools and teachers were asked to pass them to parents of poor spellers. Screening procedure and criteria for inclusion in the study were the same as in study 1. The only difference between the two studies was that study 1 included only children in grade 5, while study 2 included grade 5 and 6 students. A total of 30 children met the inclusion criteria (see "Study 1" section), including the four control children from "Study 1" section. They were allocated over the two experimental groups in order of application for participation in the study. Children were assigned to the treatment group on a first come basis until the maximum capacity of 15 subjects was reached. Subsequent applicants were assigned to the delayed treatment control group. All 30 children completed the study. However, children whose spelling ability improved between screening and pretest (T1) and therefore did not meet the inclusion criteria at T1 were excluded from data analysis. The final sample therefore includes 27 children (21 boys and six girls) between the ages of ten and 12. All children were native speakers of German and met the ICD-10 criteria for specific spelling disability. Seven children also met the diagnostic criteria for reading disability (see Appendix 1). Because participants were recruited based on their spelling ability, we will refer to all participants as children with SD throughout the manuscript. Participation was free of costs. All children and at least one legal guardian gave signed consent to their participation in the study. Spelling, reading, and IQ scores for each subject at the onset of the study are documented in Appendix 1.

Table 2 shows the background characteristics of the two experimental groups. There were no meaningful differences between treatment and control group at pretest (T1) regarding IQ, spelling, and reading. The two groups also had very similar distributions of

Table 2 Descriptive data for subjects at the onset of the study (study 2)

	Treatment group (n=13)	Control group (n=14)
Boys/girls	10/3	11/3
Grade 5/grade 6	4/9	11/3
Age in months	138.3 (8.6)	131.4 (5.5)
IQ	110.5 (11.6)	108.1 (9.8)
Spelling (T value)[a]	29.9 (7.1)	29.9 (6.0)
Reading (T value)[a]	47.3 (6.3)	44.3 (12.6)

Except for the distribution of boys/girls and grade 5/grade 6 students, numbers represent mean values (standard deviations are in parentheses)

[a] Pretest results (T1)

boys and girls. However, the distribution of grade 5 and 6 students differed between the groups. In the treatment group, only four children (31%) were grade 5 students, while 11 children (79%) in the control group were grade 5 students. Consequently, children in the treatment group were on average 7 months older than children in the control group (Table 3).

See Study 1 sections: *Orthographic spelling training* and *Fidelity of treatment*.

Measures

Spelling The same spelling test was used as in study 1.

Reading The same reading test was used as in study 1.

Orthographic knowledge Children's orthographic knowledge was assessed with a questionnaire containing 11 questions that measure children's knowledge of orthographic spelling rules (e.g., makers of long and short vowels, spelling of s-sounds). Eight questions are in multiple choice format with three answer-options each, and three questions are open questions. The first open question asks children to explain why, in some German words, the vowel *i* is spelled with the bigram *ie* (for example in *Stiefel [boot]*, but not in *Gips [gypsum]*). The second open question asks children to split a word into prefix, word stem, and suffix. The third open question is divided into three subtests. A sentence is presented

Table 3 Means and standard deviations for spelling at pretest (T1) and posttest (T2; study 1 and 2)

	T1	T2
Spelling (T value)		
Treatment group (n=19)	30.3 (6.2)	35.6 (7.9)
Control group (n=18)	30.8 (6.3)	33.0 (6.2)
Spelling (raw score[a])		
Treatment group (n=19)	28.8 (10.4)	37.5 (8.8)
Control group (n=18)	24.4 (11.3)	28.7 (10.4)

Standard deviations are in parentheses

[a] Number of correctly spelled words (max=60)

and children are asked to explain why three of the words in the sentence are spelled with an initial capital letter (correct answers: “name”, “noun”, and “first word in a sentence”). The maximum score of the questionnaire is 13 points.

Data analysis

In both groups, distribution of scores on the orthographic knowledge measure was approximately normal for T1, T2, and T3. Improvements in orthographic knowledge were analyzed by comparing measures at T1, T2, and T3 using repeated-measures designs (analysis of variance (ANOVA) and paired-samples *t* test). Improvements in spelling ability were analyzed using an integrated datasets from study 1 and 2. The main analysis was done with a treatment group ($n=19$) and a control group ($n=18$). The treatment group is composed of $n=10$ students from study 1 and $n=9$ students from study 2 ($n=4$ students that participated in the control group in study 1 were excluded). The control group is composed of $n=4$ students from study 1 and $n=14$ students from study 2. In both groups, distribution of spelling scores was approximately normal for T1, T2, and T3. A repeated-measures design (ANOVA) was used to analyze gains in spelling from T1 to T2. In addition, gains in spelling from T2 to T3 in the delayed treatment control group were analyzed with a paired-samples *t* test. EF were calculated based on the original standard deviations $\left(\text{Cohen's } d = M_1 - M_2 / \sigma_{\text{pooled}}\right)$.

Results

Spelling Table 3 shows mean values and standard deviations for spelling (*T* values and raw scores) for the integrated data set. The norm table of the spelling test does not differentiate below *T* value 22. The improvement of children whose pre-treatment spelling level was $T=22$ is therefore better depicted by their raw scores (number of correctly spelled words). For example, participant 31 spelled five words correctly at pretest and 14 words at posttest, but his *T* value was $T=22$ at both pre- and posttest. Therefore, analyses of spelling improvement were performed on both raw scores and *T* values. To determine whether gains in spelling were greater in the treatment group than in the control group, a repeated-measures analysis of variance (ANOVA) was performed on the pre- and posttest spelling measures (raw scores) with ‘experimental group’ as between-subject variable. There was a significant main effect, indicating that participants’ spelling improved during the first training period, $F_{(1,35)}=44.35$, $p<0.001$. There was also a significant interaction, indicating that the treatment group showed significantly greater improvement in spelling than the control group, $F_{(1,35)}=5.13$, $p=0.03$. Performing the same analysis on *T* values also yielded a main effect of “time”, $F_{(1,35)}=26.02$, $p<0.001$, and a significant interaction, $F_{(1,35)}=4.61$, $p=0.04$, confirming that the treatment group showed significantly greater improvement in spelling than the control group.

In study 2, the delayed treatment control group ($n=14$) receive treatment between T2 and T3. Their *T* values in spelling improved from $M=32.1$ (SD=5.6) to $M=35.6$ (SD=8.5). A paired-samples *t* test showed that this improvement was significant, $t_{(13)}=2.49$, $p=0.02$ (one-sided), Cohen’s $d=0.48$. Their raw scores on the spelling test improved from $M=27.8$ (SD=8.9) to $M=31.3$ (SD=9.6). A paired-samples *t* test showed that this improvement was also significant, $t_{(13)}=1.83$, $p=0.045$ (one-sided), Cohen’s $d=0.38$.

Reading Table 4 shows mean values and standard deviations for reading at pretest (T1) and posttest (T2) for study 1. Reading improvement in the treatment group was tested with a paired-samples *t* test. There was a significant increase in reading ability, $t_{(9)}=3.13$, $p=.006$ (one-sided), Cohen's $d=0.60$. The average difference between pretest and posttest was 6.2 *T* values in the treatment group. Children in the control group gained on average 2.5 *T* values.

Orthographic knowledge Table 5 shows mean values and standard deviations for orthographic knowledge in the original experimental groups in study 2 for all three measurement times (T1, T2, and T3). A repeated-measures ANOVA was performed on the T1 and T2 orthographic knowledge measures with 'experimental group' as between-subject variable. Due to experimenter error, T1 measures of orthographic knowledge were missing for two children in the control group. Consequently, data from only 12 children in the control group was used in the repeated-measures ANOVA. The results reveal a significant main effect, indicating that participants' orthographic knowledge improved during the first training period, $F_{(1,23)}=5.68$, $p=0.026$. There was also a significant interaction, indicating that the treatment group showed significantly greater gains in orthographic knowledge than the control group, $F_{(1,23)}=4.37$, $p=0.048$. A paired-samples *t* test revealed that the control group made significant gains during the second training period (T2-T3), $t_{(13)}=8.53$, $p<0.001$ (one-sided), Cohen's $d=2.85$.

Additional analyses

For each child that participated in study 2, training-induced spelling improvement was defined by the difference between pre-treatment spelling level and post-treatment spelling level (T1 and T2 in the treatment group, T2 and T3 in the delayed treatment group). Raw scores were used instead of *T* values because they depict gains of low-achieving students more precisely. Likewise, training-induced gain in orthographic knowledge was defined by the difference between pre-treatment orthographic knowledge score and post-treatment orthographic knowledge score. Independent *t* tests revealed that the two experimental groups did not differ significantly in spelling, and orthographic knowledge, improvement. Differences between boys and girls were also non-significant. In order to explore which factors relate to spelling—and orthographic knowledge—improvement, bivariate correlations (Pearson) were calculated in both experimental groups. Spelling improvement did not correlate significantly with age ($r=0.07$, $p=.75$) or IQ ($r=-0.21$, $p=.29$). Likewise, orthographic knowledge improvement did not correlate significantly with age ($r=-0.07$, $p=0.73$) or IQ ($r=-0.12$, $p=.55$). A significant correlation between orthographic knowledge at T1 and training-induced orthographic

Table 4 Means and standard deviations for reading at pretest (T1) and posttest (T2; study 1)

	T1	T2
Reading (*T* value)		
Treatment group ($n=10$)[a]	49.8 (10.5)	56.0 (10.1)
Control group ($n=4$)	43.5 (4.5)	46.0 (6.9)

Standard deviations are in parentheses

[a] Significant difference between pre- and posttest ($p<0.05$)

Table 5 Means and standard deviations for orthographic knowledge at T1, T2, and T3 (study 2)

	T1	T2	T3
Orthographic knowledge (raw scores)			
Treatment group (n=13)	8.1 (2.6)	10.6 (1.9)	-
Control group (n=14)	7.3 (2.5)	7.1 (1.5)	11.1 (1.3)

Standard deviations are in parentheses

knowledge improvement (r=−0.78, p<0.001) indicates that training-induced gains in orthographic knowledge increased with low initial knowledge of orthographic spelling rules. Interestingly, no significant correlation between spelling improvement and orthographic knowledge improvement was found (r=0.12, p=.56).

Figure 1 shows each participant's spelling level before training (T1 for the treatment group and T2 for the delayed treatment group) and each participant's spelling improvement. There was no significant correlation between pre-treatment spelling ability and training-induced spelling improvement (r=−0.15, p=0.39), indicating that spelling improvement did not relate to initial spelling ability.

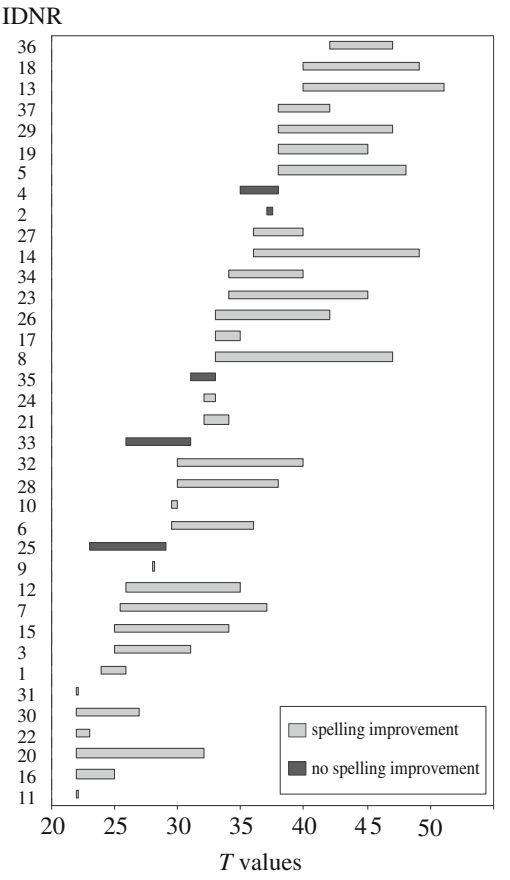


Fig. 1 Spelling improvement during training. *Gray bars* left ends mark pre-treatment spelling level (*T* value), right ends mark post-training spelling level. *Black bars* rights ends mark pre-treatment spelling level (*T* value), left ends mark post-treatment spelling level

Discussion

The aim of the present study was to evaluate the effectiveness of an orthographic spelling training for children with spelling disability (grade 5 and 6) in a consistent orthography like German. In line with our expectations, short-time intervention was found to significantly enhance spelling ability. By analyzing an integrated dataset from study 1 and 2, we found that children in the treatment group (n=19) showed significantly greater progress in spelling ability than children in an untrained control group (n=18). In addition, results from study 1 show that children in the treatment group (n=10) showed significant improvement in reading ability, while an untrained control group (n=4) did not show comparable gains. In study 2, children in the treatment group (n=13) showed significantly greater improvement in a measure of knowledge of orthographic spelling rules than children in an untrained control group (n=14). Moreover, when the children in the control group received treatment during a second training period, they also show significant improvements in spelling and orthographic knowledge. Together, the results of the present study provide evidence that an orthographic spelling training is effective in enhancing basic literacy skills in German-speaking children with spelling disability.

In German children, training phonology skills before school entry lowers the risk of becoming dyslexic and significantly improves reading and spelling in grade 1 and 2 (Schneider et al., 1997). However, it has repeatedly been found that training phonology skills in grade 2-4 is not beneficial (Schulte-Körne et al., 2001; Wimmer & Hartl, 1991), most likely because the high orthographic consistency of the German language enables German-speaking dyslexics to master basic phonological skills after a few years of schooling. Our results are in line with the consistent finding that improving orthographic knowledge meliorates spelling ability in German-speaking dyslexics (Reuter-Liehr, 1993; Schulte-Körne et al., 1997, 1998, 2001, 2003; for an overview, see Mannhaupt, 2002).

Our results indicate that the effectiveness of orthographic spelling does not decrease with increasing age, which is consistent with previous intervention studies (Tijms & Hoeks, 2005). The orthographic spelling training used in this study is based on the *Marburg Spelling Training* (*Marburger Rechtschreibtraining,* Schulte-Körne & Mathwig, 2009), which is designed for German-speaking spelling-disabled children in grade 2 and older. Appendix 2 gives a description of how the original version was modified for use with older students. In the present study, the average training-induced spelling improvement was +5.3 T values in the integrated dataset and +3.5 T values in the delayed treatment control group. These gains are slightly higher than the average improvement that was found in an intervention study that investigated grade 2-4 children's responsiveness to short-term intervention with the *Marburg Spelling Training* (+3.2 T values). This finding indicates that orthographic spelling training might be used even more effectively with older spelling-disabled students.

In the present study, children received treatment over a 3-month period. One of the limitations of the study is that despite significant gains in spelling, the attained spelling level was still below average. In study 1, only two of the ten children in the treatment group showed spelling ability within the normal range (T value>40) after completion of the training. In study 2, only five of the 13 children in the treatment group and three children of the 14 children in the delayed treatment control group showed post-treatment spelling ability within the normal range. However, several other intervention studies also report below average post-treatment spelling levels (e.g., Lovett, Borden, DeLuca, Lacerenza, Benson, & Brackstone, 1994; Torgesen, Alexander, Wagner, Rashotte, Voeller, & Conway, 2001). It is widely recognized that clinically significant intervention effects in dyslexic children require long-term treatment and studies reporting spelling improvements within the

average range have administered treatment over longer periods of time, lasting up to 2 years (e.g., Schulte-Körne et al., 2003; Tijms & Hoeks, 2005). In the present study, it was regarded unethical to withdraw support after the training period. Parents therefore received advice on how to continue spelling remediation. Unfortunately, this approach made it impossible to investigate unique long-term effects of the orthographic spelling training. Future studies should therefore increase the training duration so that improvements within the average range can be realized for more participants and long-term effects be investigated. Another limitation of the study is that reading was only assessed in study 1 and knowledge of orthographic spelling rules was only assessed in study 2. Future research is needed to confirm training-induced gains in reading and orthographic knowledge.

Due to practical reasons, participants were not randomly assigned over the experimental groups. In study 1, children whose parents contacted us just before the start of the intervention were allocated to an untrained control group because there were no resources for offering treatment. For study 2, recruitment began in June 2008 which was 3 months before the start of the first training period. Many parents who responded immediately to the flyer were not willing to take part in the study if their child would be assigned to the delayed treatment control group whose training period did not start until January 2009. Children were therefore allocated over the two experimental groups in order of application for participation in the study. It is not possible to rule out completely that this approach has resulted in differences between the experimental groups. However, both groups benefited equally from the training, as there was no significant difference between the two groups regarding training-induced improvement in spelling and orthographic knowledge.

In the present study, the once-weekly training sessions lasted 60 min each. The sessions could be carried out in our clinic, because German students usually do not have classes in the afternoon. However, students have a tremendous amount of homework and it was impracticable to enhance the frequency of weekly sessions. As a consequence of the lengthy training sessions, we sometimes observed difficulties in staying concentrated. In study 1, one boy showed such poor concentration throughout the intervention, that he was excluded from data analysis. This leads us to suggest that the practice of shorter but more frequent training sessions should be preferred whenever possible.

Despite these limitations, the present study provides strong evidence that the major difficulties with orthographic spelling that characterize German-speaking children with spelling disability can be alleviated by means of an orthographic spelling training. This finding is not only relevant for German-speaking children, but also for dyslexic children learning to read and write other languages with transparent orthographies. For example, Dutch also uses letter doubling to mark short and long vowels. While German closely adheres to the principle of morpheme consistency, morphological knowledge is less relevant for spellings of Dutch words. In Dutch, the same word stem is spelled differently depending on the phonological context (Landerl & Reitsma, 2005). However, much like German, Dutch spelling patterns follow spelling rules that can be formulated as algorithms. Several studies have shown that a Dutch treatment for dyslexia that uses these algorithms is effective in enhancing reading and spelling ability (Tijms & Hoeks, 2005; Tijms, Hoeks, Paulussen-Hoogeboom, & Smolenaars, 2003). Based on this convergent evidence, we argue that orthographic spelling trainings are likely to be effective in all languages with transparent orthographies.

Acknowledgments The authors wish to thank Christina Boronkay, Frances Bühn, Sandra Geldmacher, Sarah Gerstner, Carina Günther, Anne Hoyler, Meike Kampert, Marcia Klimek, Sabine Kürzinger, Josefine Rothe, Anton Stumpf, Romina Sukiennicki, and Isabelle Wenig for their help in collecting data and conducting training sessions. The work reported in this article was done in partial fulfillment of the first author's dissertation at the Department of Child and Adolescent Psychiatry, University of Munich, Germany.

Appendix 1

Table 6 Spelling, reading and IQ scores for each subject at the onset of the study

Subject	Boy/Girl	Group[a]	Spelling (*T* value)	Reading (*T* value)	IQ score (*M*=100, SD=15)
Study 1					
1	Girl	TG	24	39	107
2	Boy	TG	37.5	49	132
3	Girl	TG	25	38	104
4	Girl	TG	38	56	112
5	Boy	TG	38	59	115
6	Boy	TG	29.5	44	102
7	Boy	TG	25.5	58	90
8	Boy	TG	33	66	122
9	Girl	TG	28	35	112
10	Boy	TG	29.5	56	118
11	Boy	CG	24	38	105
12	Boy	CG	35.5	45	112
13	Boy	CG	39	49	122
14	Girl	CG	38.5	43	102
Study 2					
11[b]	Boy	TG	22	38	105
12[b]	Boy	TG	26	52	112
13[b]	Boy	TG	40	51	122
14[b]	Girl	TG	36	43	104
15	Boy	TG	25	48	102
16	Boy	TG	22	42	134
17	Boy	TG	33	50	106
18	Boy	TG	40	39	109
19	Boy	TG	38	49	106
20	Boy	TG	22	47	115
21	Girl	TG	32	62	111
22	Girl	TG	22	49	87
23	Boy	TG	34	46	123
24	Boy	CG	27	64	115
25	Girl	CG	23	36	112
26	Boy	CG	37	50	113
27	Girl	CG	35	47	117
28	Boy	CG	32	67	109
39	Girl	CG	31	38	100
30	Boy	CG	22	34	112
31	Boy	CG	22	17	115
32	Boy	CG	27	50	85
33	Boy	CG	30	54	118
34	Boy	CG	35	42	110
35	Boy	CG	22	36	92
36	Boy	CG	37	41	113
37	Boy	CG	38	44	103

[a] *TG* treatment group, *CG* control group

[b] Children with IDNR 11-14 participated in both experiments

Appendix 2: description of the orthographic spelling training

Background

The orthographic spelling training used in this study is based on the *Marburger Rechtschreibtraining* [*Marburg Spelling Training*] (*Schulte-Körne & Mathwig, 2009*), which is an orthographic spelling training for German-speaking spelling-disabled children in grade 2 and older. The effectiveness of the *Marburg Spelling Training* in enhancing spelling ability has been demonstrated in several studies (Schulte-Körne et al., 1997, 1998, 2001, 2003). The original version was modified for use with older students in several ways. (1) The overall design was changed. The frame story is now age-appropriate and algorithms are shaped like metro maps. (2) The new program contains age-appropriate word material and texts. (3) The main themes are conserved (e.g., consonant doubling, markers of long vowel phonemes) but are now trained in more detail: the new program also trains the more complex extensions of spelling rules (e.g., the doubling of the letters *k* and *z*). In addition, new rules as introduced (e.g., spelling of the different s-sounds).

Frame story

Summary of introduction Some people have a good orientation and hardly ever get lost. Others do not have a good orientation and might get lost from time-to-time. If you cannot find your way back home, there are two possibilities: you can ask someone to show you the way, or you can have a look at a map. With spelling, it is quite similar. Some people have good spelling skills and hardly ever misspell a word. Others have difficulties remembering the right spellings. You can always ask someone how to spell a word. But would not it be great to have a map that shows you the way to the right spelling? You will soon meet two children (Lotte and Moritz) who will go on a journey to get some spelling maps. They will guide you through the program.

General aspects

1. The spelling rules to be learned are not simply presented to the children. Whenever possible, children are guided by carefully chosen questions to discover the underlying spelling rule.
2. Whenever possible, children are encouraged to use the algorithms during spelling tasks.
3. Each chapter's exercises increase in difficulty. After the learning a new rule, children complete one or several exercises that involve inserting single graphemes into incomplete words. The next exercises involve the spelling of whole words. Likewise, each chapter starts with exercises in which the children need to attend to only one rule (or algorithm). Subsequently, exercises are introduced that require the application of the newly learned spelling rule as well as previously learned spelling rules.
4. Each chapter contains exercises that are intended to enhance a deeper understanding of the spelling rules. For example, children might be asked to explain the spelling of an inflected verb, which requires insight into the principle of morphological consistency.

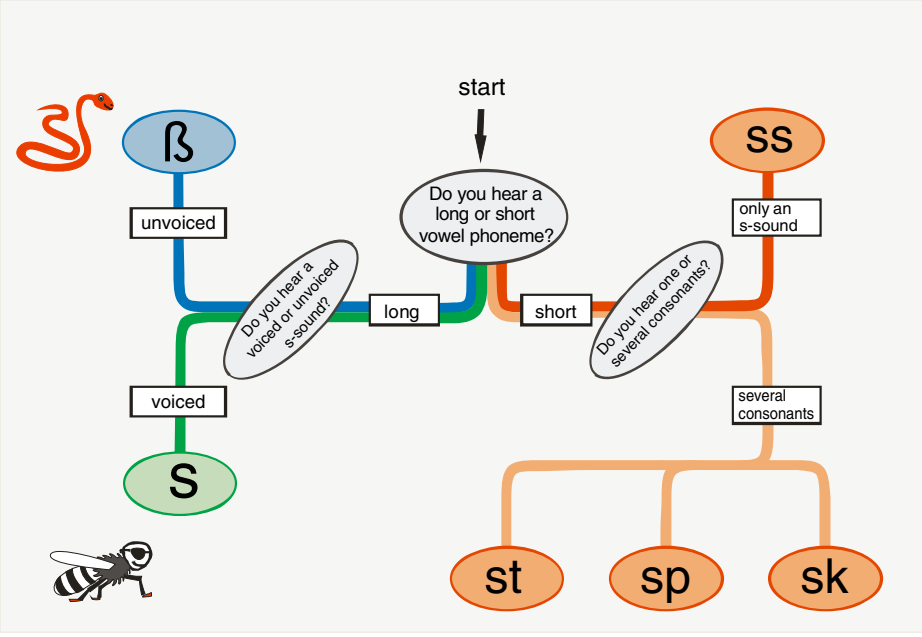
Specification of content, organization, and instructional procedures of each chapter

Chapter 1: Children learn to differentiate short and long vowel phonemes and to mark a short vowel with a dot and a long vowel with a line. Subsequently, selected word material is presented and the children are asked to (1) mark long and short vowel phonemes, and (2) draw a circle around the consonants phonemes that follow the vowel phoneme. They thereby discover the first spelling rule: "If a short vowel phoneme is followed by only one consonant phoneme within the same morpheme, then this consonant has to be doubled in the spelling". The presentation of the algorithm is followed by examples demonstrating how the algorithm can be applied to words. After several exercises on simple consonant doubling, the more complex doubling of the consonants *k* (doubling: *ck*, as in *Stock [stick]*) and *z* (doubling: *tz*, as in *Satz [sentence]*) are introduced.

Chapter 2: German closely adheres to the principle of morpheme consistency. In chapter 2, children learn that spelling rules only apply to the word stem, which is consequently spelled with high consistency. Children learn to identify the word stem in verbs, nouns, and adjectives. They are also introduced to common prefixes and endings, whose spellings have to be memorized as they are not conform orthographic spelling rules. The chapter contains exercises on adding prefixes and endings to incomplete words, exercises on identifying the word stem in verbs and adjectives (based on their uninflected form), exercises on morphological consistency, exercises on complex nouns with two word stems (e.g., *Gepäckwagen [baggage bar]*), exercises on the syllables *end-* and *ent-* (as in *endlich [finally]*) and *entscheiden [to decide]*) that sound similar but differ in meaning (words with *end-* relate to *Ende [end]*), and exercises in which the child writes words to dictation (prefixes and endings are given). In addition, consonant doubling is repeated throughout the chapter.

Chapter 3: The goal of chapter 3 is to convey the spelling of capital initial letters. Five spelling rules are trained, namely: a word is spelled with a capital initial letter if (1) it is the first word in a sentence, (2) it is a name, (3) it is a noun, (4) it is the first word after a colon (only if a complete sentence follows), or (5) it is one of the pronouns *you* and *your* occurring in a letter or direct speech. German-speaking children with spelling disability usually demonstrate knowledge of these rules, but have difficulty in applying this knowledge. The chapter therefore starts with an exercise, in which a sentence is given and the children are asked to explain why three of the words are spelled with capital initial letters. Moritz admits that he often forgets to apply these rules during spelling and throughout the chapter children are encouraged to correct his texts. Further exercises include the spelling of pronouns in a letter and the marking of the correct spelling of names, nouns, and first words in a sentence. In the remaining chapters of the spelling training, Moritz repeatedly reminds the child to check the spelling of initial capital letters. Chapter 3 also provides additional material for advanced learners. In German, nominalizations are spelled with capital initial letters. The additional material provides exercises on how to identify a nominalization in a sentence, as this can be quite a challenge in German sentences. Previous topics are reviewed intensively throughout chapter 3.

Chapter 4: There are several possibilities to mark long vowel phonemes. Chapter 4 trains two of these: the "silent h" (e.g., *Hahn [cock]*) and the "vowel separating h" (e.g., *sehen [to see]*). In the frame story, Lotte and Moritz are surprised by a sudden rainfall and their map for markers of long vowel phonemes gets wet. Some of the stations are now covered by water drops and are illegible. The children's task is to fill in the water drops one-by-one. They first learn about the green line, which leads to the final stations "silent h" and "no silent h". Selected word material is given and the children are asked to circle the consonant they hear after the long vowel phoneme (the silent h is not audible). The children thereby discover the spelling rule "If a long vowel phoneme is directly followed by any of these consonants phonemes *l*, *m*, *n* or *r*, then a 'silent h' is used to mark vowel length (e.g., *Pfahl [pile]*, *Uhr [clock]*). Likewise, children are lead to discover the next rule "If a word stem begins with any of the consonant graphemes *t*, *sch*, *sp* and *q*, then it does not have a 'silent h'" (e.g., *Tal [valley]*, *Spur [trace]*). The children now have sufficient information to fill in the two water drops that have masked stations of the green line. The children then complete exercises in which they need to apply the algorithm depicted by the green line and review earlier topics. Subsequently, they discover the next rule: "Two vowels are separated by a 'vowel separating h'". They can now fill in the water drop that covers a station



Note: The unvoiced s-sound has a sibilant sound that reminds of a snake (as in *Grüße [engl. greetings]*), while the voiced s-sound has a humming sound that remind of a bee (as in *Gläser [engl. glasses]*).

Fig. 2 Algorithm for the spelling of the different s-sounds

of the blue line which leads to the final station 'vowel separating h'. After the completion of exercises that require the application of the blue line, the children do exercises that require application of all rules learned so far, as well as exercises reviewing earlier topics and one exercise highlighting exceptions from the rules learned in this chapter.

Chapter 5: The goal of chapter 5 is to convey the spelling of the long vowel phoneme *i*. The children first learn that if the vowel *i* is a long vowel phoneme, then it is spelled with the bigram *ie* (e.g., *Tier [animal]*). After completion of exercises in which the children have to decide whether a word is written with the grapheme *i* or with the bigram *ie*, the children learn that the three pronouns *ihm*, *ihn*, and *ihr [him, his, her]*, which have a long vowel phoneme *i*, are spelled with the bigram *ih*. They then receive a map that contains an orange line for consonant doubling, a green line for the 'silent h', a blue line for the 'vowel-separating-h', and a yellow line with the final stations 'ie' and 'ih'. The chapter continues with exercises in which children need to apply only the yellow line, as well as exercises, in which the whole map must be used. In addition, there are exercises on the spellings of endings that contain the phoneme *i* but are not spelled conform the spelling rules (e.g., *Rosine [raisin],* which has a long vowel phoneme *i*, but is not spelled with the bigram *ie*). There are also exercises on the spellings of the words *wider* and *wieder*, which sound similar but differ in meaning: the word *wider* relates to *against* (as in *Widerstand [opposition]*), while the word *wieder* relates to *again* (as in *Wiederholung [repetition]*). Previous topics are reviewed throughout the chapter.

Chapter 6: Chapter 6 introduces a map depicting an algorithm for the different s-sounds (e.g., *Gläser [glasses]*, *Grüße [greetings]*, *Küsse [kisses]*). As in previous chapters, children are first given selected word material, asked to mark long and short vowels and to circle the consonants following the vowel phonemes. The children thereby discover that the graphemes *s* or *ß* follow a long vowel phoneme, while the bigrams *ss*, *st*, *sp*, or *sk* follow a short vowel phoneme. There is no rule that specifies whether a word contains the grapheme *s* or the grapheme *ß*. However, the sounds of the two graphemes differ and children are intensively trained to differentiate these two sounds. Chapter 6 also contains exercises on applying the new algorithm, as well as exercises reviewing previous topics and one exercise highlighting exceptions from the rules learned in this chapter. Figure 2 depicts the algorithm for the spelling of the different s-sounds.

References

Arnold, E. M., Goldston, D. B., Walsh, A. K., Reboussin, B. A., Daniel, S. S., Hickman, E., et al. (2005). Severity of emotional and behavioral problems among poor and typical readers. *Journal of Abnormal Child Psychology, 33*, 205–217.

Aro, M., & Wimmer, H. (2003). Learning to read: English in comparison to six more regular orthographies. *Applied Psycholinguistics, 24*, 621–635.

Borgwaldt, S. R., Hellwig, F. M., & de Groot, A. M. B. (2004). Word-initial entropy in five languages. *Written Language and Literacy, 7*, 165–184.

Bourassa, D. C., & Treiman, R. (2003). Spelling in children with dyslexia: analyses from the Treiman-Bourassa early spelling test. *Scientific Studies of Reading, 7*, 309–333.

Bruck, M. (1993). Component spelling skills of college students with childhood diagnoses of dyslexia. *Learning Disability Quarterly, 16*, 171–184.

Caravolas, M. (2004). Spelling development in alphabetic writing systems: a cross-linguistic perspective. *European Psychologist, 9*, 3–14.

Caravolas, M., & Bruck, M. (1993). The effect of oral and written language input on children's phonological awareness: a cross-linguistic study. *Journal of Experimental Child Psychology, 55*, 1–30.

Caravolas, M., Hulme, C., & Snowling, M. J. (2001). The foundations of spelling ability: evidence from a 3-year longitudinal study. *Journal of Memory and Language, 45*, 751–774.

Cassar, M., Traiman, R., Moats, L., Pollo, T. C., & Kessler, B. (2005). How do the spellings of children with dyslexia compare with those of nondyslexic children? *Reading and Writing: An Interdisciplinary Journal, 18*, 27–49.

Cunningham, A. E., Perry, K. E., Stanovich, K. E., & Share, D. L. (2002). Orthographic learning during reading: examining the role of self-teaching. *Journal of Experimental Child Psychology, 82*, 185–199.

Daniel, S. S., Walsh, A. K., Goldston, D. B., Arnold, E. M., Reboussin, B. A., & Wood, F. B. (2006). Suicidality, school dropout, and reading problems among adolescents. *Journal of Learning Disabilities, 39*, 507–514.

De Jong, P. F., & Share, D. L. (2007). Orthographic learning during oral and silent reading. *Scientific Studies of Reading, 11*(1), 55–71.

Dunlop, W. P., Cortina, J. M., Vaslow, J. B., & Burke, M. J. (1996). Meta-analysis of experiments with matched groups or repeated measures designs. *Psychological Methods, 1*, 170–177.

Eckert, T., & Stein, M. (2004). Ergebnisse aus einer Untersuchung zum orthographischen Wissen von HauptschülerInnen [Results of a study on orthographic knowlegde in students attending general education secondary school]. In U. Bredel, G. Siebert-Ott, & T. Thelen (Eds.), *Schriftspracherwerb und Orthographie*. Hohengehren: Schneider.

Esser, G., & Schmidt, M. (1993). Die langfristige Entwicklung von Kindern mit Lese-Rechtschreibschwäche [Long-term outcome of children with specific reading retardation]. *Zeitschrift für Klinische Psychologie, 22*, 100–116.

Esser, G., Wyschkon, A., & Schmidt, M. (2002). Was wird aus Achtjährigen mit einer Lese- und Rechtschreibstörung [Long-term outcome in 8-year-old children with specific reading retardation: results at age 25 years]. *Zeitschrift für Klinische Psychologie und Psychotherapie, 31*(4), 235–242.

Fluss, J., Ziegler, J. C., Warszawski, J., Ducot, B., Richard, G., & Billard, C. (2009). Poor reading in French elementary school: the interplay of cognitive, behavioral and socioeconomic factors. *Journal of Developmental & Behavioral Pediatrics, 30*(3), 206–216.

Friend, A., & Olson, R. K. (2008). Phonological spelling and reading deficits in children with spelling disabilities. *Scientific Studies of Reading, 12*, 90–105.

Frith, U., Wimmer, H., & Landerl, K. (1998). Differences in phonological recoding in German- and English-speaking children. *Scientific Studies of Reading, 2*(1), 31–54.

Grund, M. (2003). *RST 4-7. Rechtschreibtest für 4-7. Klassen [RST 4-7. Spelling test for grades 4 to 7]*. Baden-Baden: Computer & Lernen.

Ho, C. S., Law, T. P., & Ng, P. M. (2000). The phonological deficit hypothesis in Chinese developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal, 13*, 57–79.

Jorm, A. F., & Share, D. L. (1983). Phonological recoding and reading acquisition. *Applied Psycholinguistics, 4*, 103–147.

Katusic, S. K., Colligan, R. C., Barbaresi, W. J., Schaid, D. J., & Jacobsen, S. J. (2001). Incidence of reading disability in a population-based birth cohort, 1976–1982, Rochester, Minn. *Mayo Clinic Proceedings, 76*, 1081–1092.

Kemp, N., Parrila, R. K., & Kirkby, J. R. (2009). Phonological and orthographic spelling in high-functioning adult dyslexics. *Dyslexia, 15*, 105–128.

Klicpera, C., & Gasteiger-Klicpera, B. (2000). Sind Rechtschreibschwierigkeiten Ausdruck einer phonologischen Störung? [Are spelling difficulties an expression of a phonological deficit?]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 32*(3), 134–142.

Klicpera, C., Schabmann, A., & Gasteiger-Klicpera, B. (1993). Lesen- und Schreibenlernen während der Pflichtschulzeit: Eine Längsschnittuntersuchung über die Häufigkeit und Stabilität von Lese- und Rechtschreibschwierigkeiten in einem Wiener Schulbezirk [The development of reading and spelling skills from second to eighth grade: a longitudinal study on the frequency and stability of reading and spelling retardation in a Viennese school district]. *Zeitschrift für Kinder- und Jugendpsychiatrie, 21*, 214–255.

Landerl, K. (2003). Categorization of vowel length in German poor speller: an orthographically relevant phonological distinction. *Applied Psycholinguistics, 24*, 523–538.

Landerl, K., & Reitsma, P. (2005). Phonological and morphological consistency in the acquisition of vowel duration spelling in Dutch and German. *Journal of Experimental Child Psychology, 92*, 322–344.
Landerl, K., & Wimmer, H. (2000). Deficits in phoneme segmentation are not the core problem of dyslexia: evidence from German and English children. *Applied Psycholinguistics, 21*, 243–262.
Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: an 8-year follow-up. *Journal of Educational Psychology, 100*, 150–161.
Landerl, K., Wimmer, H., & Frith, U. (1997). The impact of orthographic consistency on dyslexia: a German-English comparison. *Cognition, 63*, 315–334.
Lenhard, W., & Schneider, W. (2006). *ELFE 1-6 Ein Leseverständnistest für Erst- bis Sechsklässler. [ELFE 1-6 A reading comprehension test for students from the 1st through the 6th grade]*. Göttingen: Hogrefe.
Lindgren, S. D., DeRenzi, E., & Richman, L. C. (1985). Cross-national comparisons of developmental dyslexia in Italy and the United States. *Child Development, 56*, 1404–1417.
Lovett, M. W., Borden, S. L., DeLuca, T., Lacerenza, L., Benson, N. J., & Brackstone, D. (1994). Treating the core deficits of developmental dyslexia: evidence of transfer of learning after phonologically- and strategy-based reading training programs. *Developmental Psychology, 30*, 805–822.
Manis, F. R., Custodio, R., & Szeszulski, P. A. (1993). Development of phonological and orthographic skill: a 2-year longitudinal study of dyslexic children. *Journal of Experimental Child Psychology, 56*, 64–86.
Mannhaupt, G. (2002). Evaluation von Förderkonzepten bei Lese-Rechtschreibschwierigkeiten—Ein Überblick [Evaluation of treatment approaches for children with reading and spelling difficulties—an overview]. In G. Schulte-Körne (Ed.), *Legasthenie: Zum aktuellen Stand der Ursachenforschung, der diagnostischen Methoden und der Förderkonzepte* (pp. 243–258). Bochum: Winkler.
Maughan, B. (1995). Annotation: long-term outcomes of developmental reading problems. *Journal of child psychology and psychiatry and allied disciplines, 36*, 357–371.
Maughan, B., Hagell, A., Rutter, M., & Yule, W. (1994). Poor readers in secondary school. *Reading and Writing: An Interdisciplinary Journal, 6*, 125–150.
Maughan, B., Rowe, R., Loeber, R., & Stouthamer-Loeber, M. (2003). Reading problems and depressed mood. *Journal of Abnormal Child Psychology, 31*, 219–229.
Morgan, P. L., Farkas, G., Tufis, P. A., & Sperling, R. A. (2008). Are reading and behavior problems risk factors for each other? *Journal of Learning Disabilities, 41*(5), 417–436.
Paulesu, E., Démonet, J.-F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N., et al. (2001). Dyslexia: cultural diversity and biological unity. *Science, 291*, 2165–2167.
Pennington, B. F., McCabe, L. L., Smith, S. D., Lefly, D. L., Bookman, M. O., Kimberling, W. J., et al. (1986). Spelling errors in adults with a form a familial dyslexia. *Child Development, 57*, 1001–1013.
Rack, J. P., Snowling, M. J., & Olson, R. K. (1992). The nonword reading deficit in developmental dyslexia: a review. *Reading Research Quarterly, 27*, 29–53.
Reuter-Liehr, C. (1993). Behandlung der Lese-Rechtschreibstörung nach der Grundschulzeit: Anwendung und Überprüfung eines Konzeptes [Treatment of dyslexia after grade 4: evaluation of a new approach]. *Zeitschrift für Kinder- und Jugendpsychiatrie, 21*, 135–147.
Scerri, T. S., & Schulte-Körne, G. (2009). Genetics of developmental dyslexia. *European Child and Adolescence Psychiatry*. doi:10.1007/s00787-009-0081-0.
Schneider, W., Küspert, P., Roth, E., Visé, M., & Marx, H. (1997). Short- and long-term effects of training phonological awareness in kindergarten: evidence from two German studies. *Journal of Experimental Child Psychology, 66*, 311–340.
Schulte-Körne, G., & Mathwig, F. (2009). *Das Marburger Rechtschreibtraining—Ein regelgeleitetes Förderprogramm für rechtschreibschwache Kinder (4th edition) [The Marburg Spelling Training—a rule-based treatment program for children with spelling difficulties]*. Bochum: Winkler.
Schulte-Körne, G., Schäfer, J., Deimel, W., & Remschmidt, H. (1997). Das Marburger Eltern-Kind-Rechtschreibtraining [The Marburg parent-child spelling training program]. *Zeitschrift für Kinder- und Jugendpsychiatrie, 25*, 151–159.
Schulte-Körne, G., Deimel, W., & Remschmidt, H. (1998). Das Marburger Eltern-Kind-Rechtschreibtraining—verlaufsuntersuchung nach zwei Jahren [The Marburg parent-child spelling training—follow up after two years]. *Zeitschrift für Kinder- und Jugendpsychiatrie, 3*, 167–173.
Schulte-Körne, G., Deimel, W., Hülsmann, J., Seidler, T., & Remschmidt, H. (2001). Das Marburger Rechtschreib-Training—Ergebnisse einer Kurzzeit-Intervention [The Marburg Spelling Training Program—results of a short-term intervention]. *Zeitschrift für Kinder- und Jugendpsychiatrie und Psychotherapie, 29*, 7–15.
Schulte-Körne, G., Deimel, W., & Remschmidt, H. (2003). Rechtschreibtraining in schulischen Fördergruppen—ergebnisse einer Evaluationsstudie in der Primarstufe [Spelling training in school based intervention groups—results of an evaluation trial in secondary school]. *Zeitschrift für Kinder- und Jugendpsychiatrie und Psychotherapie, 31*, 85–98.

Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94*, 143–174.

Share, D. L. (1995). Phonological recoding and self-teaching: *sine qua non* of reading acquisition. *Cognition, 55*, 151–218.

Share, D. L. (1999). Phonological recoding and orthographic learning: a direct test of the self-teaching hypothesis. *Journal of Experimental Child Psychology, 72*, 95–129.

Shaywitz, S. E., Shaywitz, B. A., Fletcher, J. M., & Escobar, M. D. (1990). Prevalence of reading disability in boys and girls. *Journal of the American Medical Association, 264*, 998–1002.

Stevenson, H. W., Stigler, J. W., Lucker, G. W., & Lee, S. (1982). Reading disabilities: the case of Chinese, Japanese, and English. *Child Development, 53*, 1164–1181.

Stone, G. O., Vanhoy, M., & Van Orden, G. C. (1997). Perception is a two-way street: feed forward and feedback phonology in visual word recognition. *Journal of Memory and Language, 36*, 337–359.

Tijms, J., & Hoeks, J. (2005). A computerized treatment of dyslexia: benefits from treating lexico-phonological processing problems. *Dyslexia, 11*, 22–40.

Tijms, J., Hoeks, J. J. W. M., Paulussen-Hoogeboom, M. C., & Smolenaars, A. J. (2003). Long-term effects of a psycholinguistic treatment for dyslexia. *Journal of Research in Reading, 26*, 121–140.

Torgesen, J. K., Alexander, A. W., Wagner, R. K., Rashotte, C. A., Voeller, K. K. S., & Conway, T. (2001). Intensive remedial instruction for children with severe reading disabilities: immediate and long-term outcomes from two instructional approaches. *Journal of Learning Disabilities, 34*, 33–58.

van Otterloo, S. G., van der Leij, A., & Henrichs, L. F. (2009). Early home-based intervention in the Netherlands for children at familial risk of dyslexia. *Dyslexia, 15*(3), 187–217.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., et al. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: a 5-year longitudinal study. *Developmental Psychology, 33*, 468–479.

Weiß, R. H. (2006). *CFT 20-R Grundintelligenztest Skala 2 (revision) [Culture Fair Test Scale 2—revision]*. Göttingen: Hogrefe.

Wimmer, H. (1993). Characteristics of developemental dyslexia in a regular writing system. *Applied Psycholinguistics, 14*, 1–33.

Wimmer, H. (1996). The early manifestation of developmental dyslexia: evidence from German children. *Reading and Writing: An Interdisciplinary Journal, 8*, 171–188.

Wimmer, H., & Goswami, U. (1994). The influence of orthographic consistency on reading development: word recognition in English and German children. *Cognition, 51*, 91–103.

Wimmer, J., & Hartl, M. (1991). Erprobung einer phonologischen multisensorischen Förderung bei jungen Schülern mit Lese-Rechtschreibschwierigkeiten [Evaluation of a phonological multisensoric treatment in young students with reading and spelling difficulties]. *Heilpädagogische Forschung, 2*, 74–79.

Wimmer, H., & Landerl, K. (1997). How learning to spell German differs from learning to spell English. In C. A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: research, theory and practice across languages*. Mahwah: Erlbaum.

Wimmer, H., Mayringer, H., & Landerl, K. (2000). The double-deficit hypothesis and difficulties in learning to read a regular orthography. *Journal of Educational Psychology, 92*, 668–680.

Ziegler, J. C., Perry, C., Ma-Wyatt, A., Ladner, D., & Schulte-Körne, G. (2003). Developmental dyslexia in different languages: language-specific or universal? *Journal of Experimental Child Psychology, 86*, 169–193.