Orthographic Learning and the Role of Text-to-Speech Software in Dutch Disabled Readers

Eva Staels and Wim Van den Broeck

J Learn Disabil 2015 48: 39 originally published online 16 May 2013
DOI: 10.1177/0022219413487407

Article

Hammill Institute on Disabilities

Journal of Learning Disabilities
2015, Vol. 48(1) 39–50

DOI: 10.1177/0022219413487407
journaloflearningdisabilities.sagepub.com
SAGE

Orthographic Learning and the Role of Text-to-Speech Software in Dutch Disabled Readers

Eva Staels, MSEd[1] and Wim Van den Broeck, PhD[1]

Abstract

In this study, we examined whether orthographic learning can be demonstrated in disabled readers learning to read in a transparent orthography (Dutch). In addition, we tested the effect of the use of text-to-speech software, a new form of direct instruction, on orthographic learning. Both research goals were investigated by replicating Share's self-teaching paradigm. A total of 65 disabled Dutch readers were asked to read eight stories containing embedded homophonic pseudoword targets (e.g., Blot/Blod), with or without the support of text-to-speech software. The amount of orthographic learning was assessed 3 or 7 days later by three measures of orthographic learning. First, the results supported the presence of orthographic learning during independent silent reading by demonstrating that target spellings were correctly identified more often, named more quickly, and spelled more accurately than their homophone foils. Our results support the hypothesis that all readers, even poor readers of transparent orthographies, are capable of developing word-specific knowledge. Second, a negative effect of text-to-speech software on orthographic learning was demonstrated in this study. This negative effect was interpreted as the consequence of passively listening to the auditory presentation of the text. We clarify how these results can be interpreted within current theoretical accounts of orthographic learning and briefly discuss implications for remedial interventions.

Keywords

reading acquisition, orthographic learning, self-teaching hypothesis, reading disability, text-to-speech software

The ability to recognize written words accurately and rapidly is generally considered as the hallmark of skilled automatic word reading (Perfetti, 1985, 1992; Share, 1995). This ability is based on the encoding of word-specific spelling patterns (unique sequences of letter strings) in discrete long-term memory representations (e.g., Coltheart, 1978; Forster, 1976; Grainger & Jacobs, 1996). However, contrary to fluent readers, disabled or dyslexic readers are characterized by either erratic or laborious and slow reading. According to the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995, 2008), orthographic learning, the process through which orthographic representations are formed, consists of two independent processes. First, in the phase of phonological recoding (or simply "decoding") the reader assembles independently from an external teacher the phonological code of an unfamiliar written word, based on his or her knowledge of grapheme–phoneme associations. If this step succeeds, the phonological code of the word can be mapped onto its orthographic counterpart, establishing word-specific knowledge of spellings. Hence, for the acquisition of orthographic knowledge, phonological recoding is a necessary condition or a sine qua non (Share, 1995). The precise mechanism by which orthographic representations develop in normal reading as well as in disabled reading is a central issue in current reading research. In this article, two research goals are examined. First, we investigated whether orthographic learning (see Note 1) is possible in dyslexic children learning to read in a relatively transparent orthography (Dutch). Second, we tested whether the phase of phonological recoding could be bypassed, without compromising orthographic learning, by means of a new form of direct instruction, text-to-speech-software. This software is nowadays propagated and used to support dyslexic readers, also in primary schools.

To formulate predictions for both research questions, we proceed by discussing the relevant research literature on orthographic learning in different reading groups.

[1]Vrije Universiteit Brussel, Brussels, Belgium

Corresponding Author:
Eva Staels, Vrije Universiteit Brussel, Faculty of Psychology & Educational Sciences, Department of Clinical and Lifespan Psychology, Pleinlaan 2, 1050 Brussels, Belgium.
Email: eva.staels@vub.ac.be

Orthographic Learning and Phonological Decoding in Typical and Disabled Readers

Without any doubt, Share's self-teaching model is the most dominant account of the developmental process toward fully specified orthographic representations (Share, 1995, 1999). The outcome of the orthographic learning process is an item-specific orthographic code that is *fully specified*, implying that the precision of the code is sufficient to uniquely identify the word and to render it impervious to the partial activation of orthographically similar words (Perfetti, 1992). In recent years, an ever-growing number of studies have been performed in trying to unravel the factors that determine orthographic learning. The self-teaching hypothesis was supported in several studies using an experimental paradigm adapted from Reitsma (1983a). In these studies, target words were presented several (four or six) times in a natural text (Share, 1999). These targets were novel letter strings (pseudowords) representing a fictitious place, animal, or fruit. Every pseudoword (e.g., yait) had an alternative homophone spelling (e.g., yate), and in each case only one spelling, the target spelling, was presented to the child. Each child was asked to read aloud the stories and to answer some questions about the content of the stories afterward to ensure that he or she understood the text. Following Reitsma's (1983b) procedure, orthographic learning was assessed 3 days after text reading using three types of measures. For the first measure, orthographic choice, children were asked to select the correct spelling of the target among other alternatives. Second, children were requested to name a list of words appearing on a computer screen as quickly and accurately as possible. The list of words contained all targets and their homophone spellings. Finally, the last test of orthographic learning required children to reproduce the target spelling in writing. The general outcome of studies based on this paradigm was that 3 days after independently reading the stories aloud, target spellings were recognized more often, named faster, and spelled more accurately than their alternate homophone spellings. Relatively few successful identifications of an unfamiliar word appeared to be sufficient to acquire orthographic representations for young children (Hogaboam & Perfetti, 1978; Manis, 1985; Reitsma, 1983a, 1983b) and also for skilled readers (Brooks, 1977). Even one single encounter can induce a reliable degree of orthographic learning (Share, 2004) and is maintained for at least 1 month (Hogaboam & Perfetti, 1978; Share, 2004). Although most evidence for the self-teaching hypothesis is based on oral reading, recent studies have shown the appearance of orthographic learning in silent reading as well (Bowey & Miller, 2007; Bowey & Muller, 2005; de Jong, Bitter, van Setten, & Marinus, 2009; de Jong & Share, 2007). These findings provide important support for orthographic learning occurring in independent daily reading. Furthermore, Wang, Castles, Nickels, and Nation (2011) demonstrated that contextual information is important to orthographic learning, especially when decoding is partial, and only if the words to be learned contain irregular letter–sound correspondences.

A crucial issue to our understanding of the progress disabled readers can make is whether they are capable of orthographic learning. Although studies examining orthographic learning in disabled readers are rare, especially those that make use of the self-teaching paradigm, the extant studies seem to indicate that orthographic learning is indeed possible. Van der Leij and van Daal (1999) reported a large word frequency effect in Dutch disabled readers, which is a strong indication that they are capable of learning word-specific knowledge (also see van Daal & van der Leij, 1992). Although disabled readers can reach almost perfect accuracy in reading high-frequency words, they are consistently slower than typical readers (van der Leij & van Daal, 1999) and also need more exposure in building up orthographic knowledge than do normal readers (Ehri & Saltmarsh, 1995; Reitsma, 1983b; Share & Shalev, 2004). The fact that these poor readers show less orthographic learning than normal readers can be explained by the idea of the self-learning account that the degree of orthographic learning depends on the overall level of decoding success (Share, 1999; Share & Shalev, 2004). As an alternative interpretation, Van den Broeck and Geudens (2012) argued that disabled readers suffer from a specific problem in the acquisition of word-specific knowledge (also see Van den Broeck, Geudens, & van den Bos, 2010).

Studies on on-line orthographic learning, tested with the highly ecologically valid self-teaching paradigm, are almost nonexistent in disabled reading groups learning to read in a transparent orthography, except for the seminal work of Reitsma (1983a). However, in that study spelling patterns were taught explicitly, rather than discovered via a process of self-teaching. The issue of orthographic learning by disabled readers in transparent orthographies is theoretically important as well as practically relevant. Therefore, our first research goal was to establish whether this kind of on-line learning is possible for this specific group of readers. Notwithstanding the doubts in the literature about the possibility of lexical processing in transparent orthographies (Frost, Katz, & Bentin, 1987; Ziegler & Goswami, 2005; but see de Jong, 2006; Paulesu, 2006; Share, 2008; Wimmer, 2006), based on the available empirical evidence cited before, we expect orthographic learning in this population.

Is Text-to-Speech Software a Bypass for Phonological Recoding in Disabled Readers?

A second goal of our study was to examine the effect of text -to-speech software on the orthographic learning of Dutch disabled readers. As previously discussed, reading and studying written texts are difficult for many disabled readers. To assist these readers, technological aids, such as text-to-speech software, have been developed to compensate for their poor reading skills and have been increasingly recommended in practice the past few years. A potential positive consequence of these aids is that they could be helpful for poor readers to build up orthographic knowledge by simultaneously presenting a text auditorily (phonology) and visually (orthography). Basically, text-to-speech software recognizes the symbols on the page followed by reading aloud the text through speakers and at the same time presenting the written text on a computer screen. While the computer is reading aloud a word, that same word is highlighted on the computer screen. Thus, a synchronized auditory and visual presentation of the text is given to the user. These technological aids, such as text-to-speech software, not unexpectedly, have been shown to positively affect the speed of reading and the reading comprehension of poor readers (Dimmitt, Hodapp, Judas, Munn, & Rachow, 2006; Elkind, 1998; Higgins & Raskind, 2005). Poor readers can persist reading much longer when they are assisted by reading aloud software and above all experience reading as much less stressful (Elkind, 1998). Of importance, this kind of assistive technology is intended in the first place to compensate for weaknesses, rather than to fix or remediate the reading problems, nor to teach or instruct (Raskind & Higgins, 1999). However, in some advertisements text-to-speech software is recommended even by suggesting a remedial effect. Of course, using computer technology for a compensatory purpose doesn't exclude eventual remedial benefits. As an illustration of a remedial effect, improvements were found in reading and spelling as a result of the aid of speech recognition technology in writing texts (speech to text; Higgins & Raskind, 2004; Raskind & Higgins, 1999). The role of computer-generated speech feedback to support the development of phonological recoding skills has also been investigated (van Daal & Reitsma, 1990; Wise, Ring, & Olson, 2000). Notably, in these studies speech feedback was provided only on call after the reader tried to read the words independently. To the best of our knowledge, no research has been performed until now on the remedial effect of continuous text-to-speech feedback. Instead of examining the long-term effect of text-to-speech software on reading ability, which would be less practical and prone to all kinds of indirect and motivational effects, we preferred to test the direct effect on orthographic learning, making use of the self-teaching paradigm, which has been proven to be sensitive to this kind of learning. In our study we compared the amount of orthographic knowledge acquired during silent reading with or without the support of text-to-speech software.

Based on the theoretical accounts of orthographic learning discussed earlier, which predictions can be made about this effect? A first suggestion is that by providing the complete phonological representation of the words, the phonological decoding process is facilitated or even bypassed and consequently will lead to better orthographic learning. This idea is based on Share's conception of two independent processes, phonological recoding and an associative mapping process at the lexical level between phonology and orthography. In Share's account, the exclusive role of phonological recoding in orthographic learning is to provide the reader with the phonological form of the whole word, which has to be mapped onto its written word form. Bypassing this phonological bottleneck by presenting the whole-word phonological form to the reader reduces orthographic learning to the associative mapping process. However, Share (1995) is quite explicit about the potential problems of any form of direct instruction: "[I]t is questionable whether providing the identity of a printed word at the whole-word level is likely to draw a child's attention to the detailed orthographic structure which ultimately forms the basis for proficient word recognition (Ehri, 1992)" (p. 153). Apparently, in this quote Share assumes that phonological recoding demands that the identity and the precise sequence of letters be exhaustively attended and processed. It is indeed conceivable that children using text-to-speech software listen only passively to the auditory presentation of the text and that they are not actively involved in the phonological recoding activity, with the consequence that they pay less or no attention to the orthography of the presented words. In fact, by assuming that phonological recoding has an additional role in binding orthographic and phonological information at all grain sizes of the word, Share surpasses his initial bottom-up account of orthographic learning (also see McKague, 2005). If direct instruction indeed compromises attention for orthographic details, the prediction follows that text-to-speech software will result in a deleterious effect on orthographic learning, compared to normal, active reading.

Method

Participants

A total of 65 disabled readers participated in this study. The children were fourth (57%) or fifth (43%) graders (41 boys and 24 girls). All children attended regular elementary schools, located in several regions in Flanders (Dutch-speaking part of Belgium) and in urban and rural areas. Most children were from indigenous families (68%), and children from foreign origins (32%) were mainly of

Table 1. Participants' Mean Scores and Standard Deviations on Versions A and B of the Reading Test (One-Minute Test), the Vocabulary Subtest of the Dutch Version of the Wechsler Intelligence Scale for Children–Third Edition, and School Performance.

	OMT Version A[b]		OMT Version B		Vocabulary[c]		Math[d]		Dutch		French		World Studies		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Participants with dyslexia[a]	3.73	1.82	3.77	2.16	8.40	3.77	61.81	14.16	66.77	12.01	70.48	15.75	69.10	13.04	66.41	10.11
Poor readers	5.80	1.30	7.00	1.94	6.97	3.66	63.23	12.38	62.99	11.66	75.34	18.45	70.59	13.77	68.03	12.05

[a]Participants with a diagnosis of dyslexia in accordance with the definition of the Dutch Foundation of Dyslexia. [b]*One-Minute Test* (OMT) scores are standardized scores ($M = 10$, $SD = 3$). [c]Vocabulary scores are standardized scores. [d]School performance scores are mean percentages.

Moroccan or Turkish descent. All children were checked and had sufficient command of the Dutch language to be able to study the Dutch curriculum. Their ages ranged from 9 years 4 months to 11 years 8 months, with a mean age of 9 years 11 months. Four test assistants were instructed to perform this study.

Word reading ability was measured with the A and B versions of the widely employed Dutch *One-Minute Test* (OMT; Brus & Voeten, 1973). Both versions consist of 116 real words (nouns, verbs, adjectives, etc.) that are printed in four columns. These words are ordered from lower to higher reading difficulty degree. Most words (112) are multisyllabic. All words in the test are regular words, which is customary in Dutch reading tests. The mean log frequency of the words, based on the Dutch corpus of the CELEX database (Baayen, Piepenbrock, & van Rijn, 1995), is 0.711. The participants were instructed to read aloud correctly as many words as possible. The raw score is the number of words read correctly after 1 minute of reading. In many English-language studies, word reading tests are pure accuracy measures. However, word reading skill is determined both by accuracy and speed (cf. Landerl & Wimmer, 2008; Share, 2008). Therefore, a word reading fluency test such as the OMT is arguably the better choice. By fixing the allowed time to read (1 minute), interpretation difficulties due to accuracy-speed trade-offs are largely avoided (cf. Salthouse & Hedden, 2002). Van den Bos, lutje Spelberg, Scheepstra, and de Vries (1994) report parallel test reliabilities of .96 for Grade 4 and .87 for Grade 5. Thus, the test is highly reliable and has a high discriminative power because it is a combination of a power test and a speed test. Children scoring lower than one standard deviation below the mean of their grade level for both versions of the test were selected to participate. Of the 65 participants, 30 (46%) were diagnosed at the time of testing as dyslexic as their standardized reading score was more than two standard deviations below their age-norm mean, which is in accordance with the definition of the Dutch Foundation of Dyslexia (Kleijnen et al., 2008). The rest of the participants (35, 54%) were poor readers, but they didn't satisfy the aforementioned criteria (see Table 1).

As a measure of verbal intelligence, the Vocabulary subtest of the Dutch version of the *Wechsler Intelligence Scale for Children–Third Edition* (Wechsler et al., 2005) was administered. As can be seen from Table 1, the participants who were diagnosed as dyslexic scored in the normal range on verbal intelligence ($M = 8.40$), corresponding to the traditional discrepancy definition of developmental dyslexia (Stanovich, 1991; Van den Broeck, 2002). The poor reading group performed subaverage ($M = 6.97$), although not statistically different from the dyslexic group ($t = 1.54$, $df = 63$, $p = .127$). However, it is important to note that this group cannot be described as "garden-variety" poor readers (nondiscrepant poor readers; Stanovich, 1988) because this group's school performances were not statistically different from those of the dyslexic group on math, languages (Dutch and French), and world studies (all ps > .40).

Experimental Design and Procedure

Testing took place on an individual basis in a quiet room at the participant's school. The procedure consisted of a reading phase (self-teaching) followed by a phase of posttest measures. During the reading phase, the participants were asked to read eight stories in silence. No feedback was given to the participant. Immediately after each text, three questions were asked about the content of the stories to check text comprehension. For example, after the story about the butterfly, the experimenter asked, "What was so special about the animal in the story?" "Why were the other butterflies jealous?" and "What did the children do to make the butterfly happy?"

Half of the participants read the stories supported by the text-to-speech software Kurzweil 3000 (Cambium Learning Group, 2005), the other half read the stories without any help of text-to-speech software. In both cases, the texts were presented on a computer screen. Orthographic learning was assessed 3 or 7 days after reading texts by three posttest measures in the following fixed order: orthographic choice task, naming task, and spelling task.

A 2 × 2 factorial between-subjects design was created for this study by crossing two independent variables: the

Table 2. Means and Standard Deviations per Condition of Participants' Age, Scores on Both Versions of the One-Minute Test, and Scores on the Vocabulary Subtest of the Dutch Version of the Wechsler Intelligence Scale for Children–Third Edition.

	Method of Reading Texts									
	Without Text-to-Speech Software				With Text-to-Speech Software					
	3 Days		7 Days		3 Days		7 Days			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(3, 61)$	p
Age in years and months	10:4	0:8	9:8	0:9	9:6	0:10	9:8	1:2	2.13	.105
OMT A[a]	46.69	7.34	47.69	5.76	48.17	7.06	44.27	8.84	0.89	.449
OMT B	46.94	6.66	48.31	7.37	48.61	7.44	46.73	8.88	0.26	.857
Vocabulary[b]	7.31	3.14	6.75	3.62	8.78	4.11	7.53	4.07	0.89	.451

[a]*One-Minute Test* (OMT) scores are raw scores. [b]Vocabulary scores are standardized scores.

method of reading texts (with or without the support of text-to-speech software) and the interval of 3 or 7 days between the reading phase and the posttest phase. Time was manipulated between subjects to avoid expected cross-over effects that can arise as a result of the repetition of the homophone spellings. Each participant was randomly assigned to one of the four resulting conditions. Of importance, reading group (dyslexic and poor readers) was not a factor in this experimental design, implying that reading group was not balanced but randomly assigned over the conditions. The mean reading level, age, and vocabulary scores per condition are given in Table 2 and show that the randomization procedure did its work in avoiding systematic differences between the conditions.

Furthermore, a number of control variables were introduced in the design. The order of presenting the eight texts to the participants was counterbalanced to control for order effects by using a Latin square design. In this design the number of orders is equal to the number of conditions, with each condition appearing in each place in the order. In addition, counterbalancing was applied for the assignment of the participants to one of the four experimenters, for the assignment of the participants to an interval of 3 or 7 days, and for the assignment of the participants to one variant of the word list in the posttest naming task.

Self-Teaching Phase

The self-teaching phase of this study is based on Share's (1999) self-teaching paradigm. Eight short Dutch texts, similar to Share's stories, were composed for this study. All texts were adjusted to the overall reading level of the participants and ranged in length from 102 to 164 words (mean length = 126). Targets were eight novel letter strings (pseudowords) representing a fictitious place, animal, flower, or planet. Each target included a phoneme that could be represented by two alternate graphemes. These alternate letters occurred at various positions across target strings. The eight designed target pairs ranged in length from one to three syllables and from four to nine letters (average 6.5). Two versions of each story were created, each employing one of the two homophone spellings of the following target pairs: Snauwtje/Snouwtje; Targ/Tarch; Krijminie/Kreiminie; Knoepsik/Knoepzik; Weildo/Wijldo; Kowand/Kowant; Adenap/Adenab; Blot/Blod. Each target appeared six times in one of the eight texts. Half of the participants were presented one set of spellings, whereas the other half saw the alternate spellings. All pseudowords were in the reading ability range of the participants, as indicated by the high proportion (.90) of correctly read targets in the naming task. Texts were presented on a computer screen, with or without the support of the text-to-speech software Kurzweil 3000. This software displays the entire text on the computer screen. As the computer speaks, the words are highlighted on the screen. The entire text is sounded out by the software. The reading toolbar contains an option to specify the reading speed. Participants had the opportunity to practice using the software during the week preceding testing. In the self-teaching phase they were instructed to adjust the reading speed to their preference. As a consequence, the reading speed was the same for all words, including the novel pseudowords. However, not a single participant felt the need to adjust the reading speed during the test phase.

Orthographic Learning Tasks

Orthographic learning was assessed 3 or 7 days after the self-teaching task with an orthographic choice task, a naming task, and a spelling task (Share, 1999). Because construct validity, which is typically derived from earlier research and theoretical considerations, is of primary importance in experimental research, the reliabilities of the dependent measures are often not reported. Although this is also the case in the literature on orthographic learning using the self-teaching paradigm, we report here the composite reliabilities for the scores on each task as they can shed some light on the sensitivity of each task to capture the effects of orthographic learning. For each task item homogeneity was tested by fitting a unidimensional model. For all three tasks a congeneric model was tested, in which the constraints of equal true scores and equal error variances are relaxed.

Orthographic choice task. Participants were first asked a question to recall the target word (e.g., "Do you remember the name of the beautiful big butterfly in the story?"). Participants were then shown both alternatives of the target word. The examiner presented two paper cards to participants, each containing one alternate spelling of the homophone target. The cards were presented side by side in a random position on a table in front of participants. Participants were asked to choose the spelling of the pseudoword they had read in the stories 3 or 7 days before. The score on this task was the total number of items correctly chosen, with a maximum score of 8. The estimated composite reliability was .71, which is reasonable.

Naming task. Participants were asked to read aloud as accurate and fast as possible a series of words presented on a computer screen one at a time. Each word was presented centre screen until the participant pressed the space bar and the following word appeared. The list of 64 words consisted of both alternate spellings of each pseudoword, supplemented by high-frequency filler items to reflect the natural range and distribution of word frequency in children's reading material (the mean log frequency of the filler items, based on the Dutch corpus of the CELEX database, is 1.68). Each alternate spelling was presented twice to increase statistical power. To control for priming effects, two variants of the word list were designed. Pseudowords appeared in both lists in the same position but the two spelling variants were switched. Both lists are presented in the appendix. The task was programmed in E-prime version 1.2 (Schneider, Eschman, & Zuccolotto, 2002). Reading times for each item were registered automatically between the presentation of the item and the moment that the participant pressed the space bar. By pressing the space bar the next item was automatically presented. In this way the pace of the presentation of the items was determined by the participant, and the entire processing time for each item from presentation until the end of the utterance was recorded. By using this procedure, the reading times consisted of three components: time to onset of articulation, articulation time, and rest time (time between articulation offset and button press). We assume that all three components contain "central" reading processes as well as "peripheral" processes (e.g., sensory input and motor output processes). Of importance, this procedure captures all central processes starting from the presentation of the stimulus to the moment the participant indicates that she or he is ready for the next stimulus. Therefore, it can be considered as an ecologically valid procedure, compared to procedures that capture only parts of the entire reading process. This procedure, which has an aspect of fluency, resulted in a smooth progression of the experiment. Reading accuracy of the pseudowords was scored by the examiner. The differences in reading errors and reading times between the target items and the homophone foils were taken as indices of orthographic learning. The estimated composite reliability of the reading times was .90, and for the crucial differences in reading times between target and homophone items it was a moderate .52.

Spelling task. Participants were asked to spell the target spelling of the name of the place, animal, flower, or planet they had read in the story 3 or 7 days earlier. If participants could not recall the name of the target, the name was provided by the examiner. The number of target words written correctly, the number of pseudowords written in the alternative spelling, and the number of any other incorrect written pseudowords were counted. On the spelling task, two scores were computed. One score was the accuracy of spelling the complete word. The other score was exclusively based on the spelling of the critical target letters. Thus, in this scoring method the item was scored correctly if the target letters were spelled correctly, regardless of whether other letters in the item were spelled correctly. For each scoring method the estimated composite reliability was clearly insufficient (.28 and .19, respectively). This means that the score on one item was hardly predictive of the score on another item.

Results

Because we used a silent reading procedure, it was not possible to determine the proportion of correctly decoded pseudowords. On the comprehension questions, all children scored at the maximum, indicating that these questions were simple yet effective in checking whether the children paid attention to the stories. The results of the three orthographic learning tasks are presented in two subsections. First, corresponding to our first research goal, we present the results concerning the occurrence of orthographic learning among Dutch disabled readers. Afterward, answering our second research goal, the results about the use of text-to-speech software are presented.

The dichotomous categorical (success/failure) data from the orthographic choice and the spelling tasks were tested using two-tailed t tests for the divergence of the predetermined chance-level proportion of 50%. Two-tailed t tests are appropriate because there is no theoretical reason why results can be only above chance level. Differences between target and homophone items in naming accuracy and naming speed were tested using multivariate analyses of

Table 3. Mean Proportions of Responses on the Orthographic Choice Task, the Spelling Task, and the Naming Task and Mean Reading Speed on the Naming Task.

	Target						Homophone						Other					
	3 Days		7 Days		Overall		3 Days		7 Days		Overall		3 Days		7 Days		Overall	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Orthographic choice task	0.63	0.17	0.62	0.19	0.63	0.18	0.37	0.17	0.38	0.19	0.37	0.18						
Naming task (accuracy)	0.90	0.12	0.92	0.15	0.91	0.13	0.92	0.12	0.89	0.16	0.90	0.14						
Naming task (reading speed in seconds)	1.46	0.36	1.58	0.42	1.52	0.39	1.55	0.42	1.66	0.44	1.60	0.43						
Spelling task	0.56	0.19	0.58	0.17	0.57	0.18	0.28	0.14	0.25	0.13	0.27	0.13	0.16	0.13	0.16	0.16	0.16	0.14

covariance (MANCOVAs), with targets versus homophones as a within-subjects factor and the scores on both versions of the OMT as covariates, to reduce the error variance and to improve statistical power. Finally, the effects of the between-subjects factors, method of reading texts and interval period, on the three dependent variables were also tested using (M)ANCOVAs. For all presented analyses, data were collapsed across reading groups, as after already controlling for reading ability (OMT), this factor was no longer statistically relevant (all *p*s larger than .30).

Orthographic Learning

In Table 3 the proportions of responses on the orthographic choice and spelling tasks 3 or 7 days after reading texts are presented. Differences between the 3-day interval and the 7-day interval conditions appeared to be small. The overall proportion of correct choices on the orthographic choice task was 0.63 (SD = 0.18), which was significantly larger than the chance level proportion correct of 0.50, $t(64) = 5.68$, $SE = 0.022$, $p < .001$, two-tailed. The proportion of completely correct spelled target words in the spelling task was 0.57 (SD = 0.18), which was also significantly larger than the proportion correct of 0.50, $t(64) = 3.27$, $SE = 0.022$, $p < .005$, two-tailed. The proportion of pseudowords in which the target letters were spelled correctly was 0.73 (SD = 0.13), which was again significantly larger than the chance level proportion of 0.50, $t(64) = 14.17$, $SE = 0.016$, $p < .001$, two-tailed. With the aim to compare the performance of the spelling task with the orthographic choice task, the odds ratio was determined. The odds ratio of letters spelled correctly versus correct choices made in the orthographic choice task was 1.63, indicating that the odds of correctly spelling the target letters were 63% higher than the odds of making a correct choice in the orthographic choice task. After taking the log odds to determine the endpoints of the 95% confidence interval (CI), and then exponentiating these endpoints, the 95% CI was 1.25–2.12, implying that the odds ratio was statistically different from 1. Apparently, recognizing the correct spelling from two visually presented homophonic spellings was more difficult than producing the correct target letters when no distracters were present.

For the naming task, the proportion of correctly read targets was 0.91 and the proportion of correctly read homophonic spellings was 0.90. No significant main effect of item type (target vs. homophone) was found in a MANCOVA on the number of correctly read items (targets: $M = 14.49$, $SD = 2.12$; homophones: $M = 14.46$, $SD = 2.24$), $F(1, 55) = 1.902$, $MSE = 0.575$, $p = .173$, $\eta^2_p = .033$). Mean reading speed of the targets and homophone spellings in the naming task 3 or 7 days after reading texts are also presented in Table 3. The difference between the mean reading speed of target words and the mean reading speed of homophone foils in seconds was 0.08 (Cohen's $d = 0.44$). This main effect was statistically significant in a MANCOVA: $F(1, 55) = 7.816$, $MSE = 18531$, $p = .007$, $\eta^2_p = .124$. The main effect of interval period was not significant, $F(1, 55) = 1.475$, $MSE = 243874$, $p = .23$, $\eta^2_p = .026$. To summarize, these results demonstrate that both 3 and 7 days after independent reading the eight stories, target spellings were recognized more often, named faster, and correctly spelled more often than their alternate homophone foils.

Table 4 presents correlations indicative of a positive relationship between the overall decoding ability of the reader and the amount of orthographic knowledge acquired. For the interpretation of these correlations, it is important to know that word reading and nonword reading ability are highly correlated in Dutch when using a speeded test (correlations between .75 and .90 for each age group). But also in English, the correlations between word reading and nonword reading ability are fairly high (correlations between .47 and .70 for each age group using a test without speed requirements; Castles et al., 2009; A. Castles, personal communication, November 23, 2010). As contended by Van den Broeck et al. (2010), such high correlations strongly indicate that word-specific knowledge substantially contributes to the fluent reading of nonwords. Therefore, word reading ability can be seen as a valid proxy for decoding ability. Significant correlations were found between participants' scores on the OMT and their scores on the orthographic choice task and reading speed differences between

Table 4. Correlations Among Scores on Both Versions of the One-Minute Test and the Posttest Measures of Orthographic Learning.

	OMT B	OC	Spelling Words	Spelling Letters	Naming Accuracy	Naming Time
OMT A	.865**	.294*	.141	–.166	.204	.279*
OMT B		.472**	.236	–.104	.181	.271*
OC			.351**	.298*	.060	–.030
Spelling words				.601**	.053	.031
Spelling letters					–.112	.129
Naming accuracy						.076

Note. naming accuracy = reading accuracy difference between target and homophone items; naming time = reading time difference between target and homophone items; OC = *Orthographic Choice Test*; OMT = *One-Minute Test*.
*$p < .05$. **$p < .01$.

targets and foils in the naming task. This was true for both versions of the OMT. Because all measures of orthographic learning were symmetrically distributed, statistically testing correlations for their significance was appropriate. Orthographic learning in the naming task was determined by calculating difference scores. Although difference scores are often believed to be rather unreliable, they have been shown to be a valid measure of real differences (cf. Rogosa & Willett, 1985; Van den Broeck, 2002). The correlations strongly suggest that the orthographic choice task is the most sensitive task to detect effects of orthographic learning, a finding that is consistent with observations made by Share (2004).

Text-to-Speech Software

Differences between the conditions were analyzed with (M) ANCOVAs, with orthographic choice, spelling, reading accuracy, and reading speed as dependent variables. In these analyses, the method of reading texts (with or without text-to-speech software) and the interval period were between-subjects factors.

For the orthographic choice task as dependent variable, all interaction effects were nonsignificant (all *p*s > .40), so we proceeded by testing a model with only the main effects (see Maxwell & Delaney, 2004, for a justification of this procedure). The only statistically significant effect that was observed was a negative effect of the text-to-speech software on the orthographic choice task, $F(1, 57) = 4.03$, $MSE = 1.541$, $p = .0496$, $\eta^2_p = .066$. The estimated marginal mean (corrected for the influence of the covariates) of correct choices in the text-to-speech software condition was 4.69, whereas the estimated marginal mean for the normal reading condition was 5.33; the observed means and standard deviations were 4.79 ($SD = 1.32$) and 5.25 ($SD = 1.54$), respectively. Thus, an estimated 0.64 fewer correct choices were made in the text-to-speech software condition, which is a medium-sized effect (Cohen's $d = 0.44$). Neither the interval period nor reading group had a significant effect (all *p*s > .40 and η^2_ps < .025). For the two scoring methods of the spelling task (entire target word correct or only target letters correct), no significant main effects or interaction effects were observed (all *p*s > .15 and η^2_ps < .027). For the naming task, the difference between the accuracy of reading the target words and the homophone foils was taken as an index of orthographic learning. Again no interaction effects reached significance (all *p*s > .28), but the main effect of the interval period was statistically significant, $F(1, 57) = 6.07$, $MSE = 1.108$, $p = .017$, $\eta^2_p = .096$, indicating that orthographic learning was manifest only after 7 days. The other main effects were nonsignificant (*p*s > .35 and η^2_ps < .023). For the differences in reading times between the target words and the homophone foils, no significant interaction effects or main effects were detected (all *p*s > .15 and η^2_ps < .065).

Conclusions and Discussion

Several researchers demonstrate the ability of children to acquire orthographic knowledge during oral independent reading in English (Cunningham, 2006; Cunningham, Perry, Stanovich, & Share, 2002; Kyte & Johnson, 2006; Share, 1999, 2004). This study replicates these findings for disabled Dutch readers, reading in silence. In the orthographic choice task, target words were recognized well beyond chance. In the spelling task, the correct target spellings were also reproduced more often than chance level. In the naming task, the naming of target spellings occurred significantly faster than the naming of the homophone spellings. Thus, despite the moderate reliability of the difference scores in reading times of target versus homophone spellings and the clearly insufficient reliability of the spelling task, the three dependent measures proved to be sensitive enough to detect the impact of orthographic learning. Apparently, the experimental validity of the three tasks was not jeopardized by the restricted composite reliability of some tasks, which is a measure of item homogeneity. These results support the findings of previous studies demonstrating that orthographic learning does occur during silent independent reading (Bowey & Miller, 2007; Bowey & Muller, 2005; de Jong et al., 2009; de Jong & Share, 2007). Most important, our study strongly suggests that even disabled readers in a transparent orthography are able to acquire orthographic knowledge during independent reading in the self-teaching paradigm. In particular, the effect on the *Orthographic Choice Test* suggests some form of lexicalized processing, yet faster naming times may be due to more efficient recoding, lexicalized processing, or both. These findings pertain to the two reading groups, including the most severely impaired dyslexic readers. These results seriously question the sometimes explicit idea (as in the orthographic depth hypothesis; Frost et al., 1987) and often more implicit suggestion (as in psycholinguistic grain size theory; Ziegler & Goswami, 2005) that readers of transparent orthographies, such as Dutch, would show very limited or even no word-specific orthographic learning at all. In our view, this misunderstanding about learning to read in a transparent orthography is the result of an exceedingly schematic interpretation of the dual-route account of word recognition applied to differences in *accurate* word reading in inconsistent versus transparent orthographies (also see Share, 2008). However, learning to read *quickly and fluently* in any orthography requires that the relatively slow and laborious recoding style of reading is substituted by a lexicalized mode of processing (also see Duñabeitia & Vidal-Abarca, 2008).

A second goal of this study was to examine the effect of text-to-speech software on the orthographic learning of Dutch disabled readers and thus to determine whether this form of direct instruction could function as a bypass for the phonological recoding phase. Despite the sensitivity of the three tasks to detect orthographic learning, in none of these a positive effect of text-to-speech software was observed. This result is in contradiction with the expectation based on one interpretation of Share's two-stages account of orthographic learning, that is, that providing the phonological form of the word would bypass the bottleneck of decoding, enabling improved orthographic learning. However, the reported negative effect of the use of text-to-speech software on the orthographic choice task seems to be more in agreement with Share's contention that direct instruction of the phonological word form would distract the attention of the child from the orthographic details of the word. But if the debilitating factor is diminished visual attention to the word spelling, why were no negative effects of text-to-speech software found on the spelling and naming tasks?

Instead of assuming that the only negative effect we observed was the result of Type I error and that we witnessed an exceptional event that occurs once in 20 cases ($p = .05$), we take our results as they are and offer an explanation that takes account of some additional observations in our study and previous findings in the literature on orthographic learning. We suggest that the observed pattern of results can be understood as the result of an interaction between the depth of processing instigated by the method of reading texts and the sensitivity of the dependent measure for the quality of the orthographic representations. In this line of reasoning, only a negative effect of direct instruction would be expected if the reading task requires high-quality orthographic representations. The absence of a negative effect of text-to-speech software on the naming task is not surprising, given that the differences between target and homophone naming times have been shown to be small and unstable (de Jong et al., 2009; de Jong & Share, 2007; Kyte & Johnson, 2006). De Jong et al. (2009) found that concurrent articulation, which can be viewed as another instance of diverting attention during reading, did not have an effect on target naming speed, whereas concurrent articulation substantially impaired orthographic recognition. Moreover, these differential effects are in accordance with the low correlations between the naming task and other orthographic measures, as reported in this study (see Table 4), as well as in other studies (de Jong et al., 2009). Apparently, the naming of target spellings relies on quite different aspects of orthographic knowledge, presumably a more implicit kind of knowledge (Share, 1999).

To explain the absence of a negative effect of text-to-speech software on the spelling task, a few observations are relevant that also point in the direction of a diminished sensitivity of our version of this task for the quality of the orthographic representations. First, because no instruction was given to pay attention to the correct spelling of the word, the participants may have perceived this task as a mere word memory task, facilitating a more automatic and implicit way of spelling the words. Second, as reported, the spelling task was significantly easier than the orthographic choice task, presumably because the absence of distracter items also facilitated automatic processing. Finally, although the spelling task was sensitive enough to detect orthographic learning in general, the low composite reliability of the spelling scores implies that implicit knowledge of correct spellings is rather item specific and is hardly predictive for other items. In contrast, knowing explicitly the spelling of a word is more predictive for the explicit knowledge of other items, as can be inferred from the reasonable composite reliability of the orthographic choice task.

To summarize, we suggest that the negative effect of text-to-speech software was observed only in the orthographic choice task because this task was the most sensitive task of the three in detecting high-quality orthographic representations (also see Share, 2004). Apparently, providing the disabled readers with the complete phonological representation of the words, instead of allowing them to decode the words for themselves, had a negative effect on remembering the orthographic details of the target words.

The necessary role of active involvement in the recoding process can also be inferred from a study by Shahar-Yames and Share (2008), in which they demonstrated that spelling words even had a larger effect on orthographic learning than reading words because of the greater processing demands involved in spelling (Bosman & Van Orden, 1997). In spelling, the writer is obliged to process each and every letter, actively retrieving the orthographic representation of the word, whereas reading requires only recognition (Perfetti, 1997).

As text-to-speech software might discourage such an active engagement in real reading activities, we suggest that this kind of software should be exclusively used for its original purpose, that is, to compensate for poor reading skills. Based on the current empirical results and theoretical insights, we certainly would not recommend text-to-speech software for poor readers in primary school because they need to engage in active reading as much as possible to advance their reading skills, instead of listening rather passively to a spoken text.

Appendix

Target and Homophone Spellings Used in the Three Dependent Measures.

A	B
Snauwtje	Snouwtje
Targ	Tarch
Krijminie	Kreiminie
Knoepsik	Knoepzik
Weildo	Wijldo
Kowand	Kowant
Adenap	Adenab
Blot	Blod

Acknowledgments

It is a pleasure to thank those who made this study possible. We thank Nore Hamers, Sophie De Vylder, and Cleor de Rosen for their assistance with collecting the data. We also thank Sensotec n.v. for providing us with text-to-speech software Kurzweil 3000. We extend our gratitude to Astrid Geudens for her helpful and interesting comments on the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Note

1. In this article we use the construct of orthographic learning exclusively as referring to the acquisition of word-specific knowledge, both at the subword level (e.g., knowing that "knight" is written with "kn-") as well as at the whole word level (e.g., knowing the complete spelling of the word "knight"), and not in the sense of getting knowledge about general aspects of the writing system such as sequential dependencies, structural redundancies, sensitivity to bigram frequencies, and so on (Castles & Nation, 2006; Geudens & Sandra, 2002; Vellutino, Scanlon, & Tanzman, 1994).

References

Baayen, H., Piepenbrock, R., & van Rijn, H. (1995). *The CELEX Lexical Database, Release 2* (CD-ROM). Philadelphia: University of Pennsylvania, Linguistic Data Consortium.

Bosman, A. M. T., & Van Orden, G. C. (1997). Why spelling is more difficult than reading. In C. A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: Research, theory, and practice across languages* (pp. 173–194). Hillsdale, NJ: Lawrence Erlbaum.

Bowey, J. A., & Miller, R. (2007). Correlates of orthographic learning in third-grade children's silent reading. *Journal of Research in Reading*, *30*, 115–128. doi:10.1111/j.1467-9817.2007.00335.x

Bowey, J. A., & Muller, D. (2005). Phonological recoding and rapid orthographic learning in third-graders' silent reading: A critical test of the self-teaching hypothesis. *Journal of Experimental Child Psychology*, *92*, 203–219. doi:10.1016/j.jecp.2005.06.005

Brooks, L. (1977). Visual pattern in fluent word identification. In A. S. Reber & D. L. Scarborough (Eds.), *Toward a psychology of reading* (pp. 143–181). Hillsdale, NJ: Lawrence Erlbaum.

Brus, B. T., & Voeten, M. J. M. (1973). *Eén-minuut-test* [One-Minute Test]. Nijmegen, Netherlands: Berkhout.

Cambium Learning Group. (2005). *Kurzweil 3000. Solutions for Struggling Readers* (Resource document). Natick, MA: Kurzweil Educational Systems. Retrieved from http://www.kurzweiledu.com/kurz3000.html

Castles, A., Coltheart, M., Larsen, L., Jones, P., Saunders, S., & McArthur, G. (2009). Assessing the basic components of reading: A revision of the Castles and Coltheart test with new norms. *Australian Journal of Learning Difficulties*, *14*, 67–88. doi:10.1080/19404150902783435

Castles, A., & Nation, K. (2006). How does orthographic learning happen? In S. Andrews (Ed.), *From inkmarks to ideas: Challenges and controversies about word recognition and reading* (pp. 151–179). London, UK: Psychology Press.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151–216). London, UK: Academic Press.

Cunningham, A. E. (2006). Accounting for children's orthographic learning while reading text: Do children self-teach? *Journal of Experimental Child Psychology*, *95*, 56–77. doi:10.1016/j.jecp.2006.03.008

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.doi:10.1016/S0022-0965(02)00008-5
de Jong, P. F. (2006). Units and routes of reading in Dutch. *Developmental Science*, *9*, 441–442. doi:10.1111/j.1467-7687.2006.00524.x
de Jong, P. F., Bitter, D. J. L., van Setten, M., & Marinus, E. (2009). Does phonological recoding occur during silent reading and is it necessary for orthographic learning? *Journal of Experimental Child Psychology*, *104*, 267–282. doi:10.1016/j.jecp.2009.06.002
de Jong, P. F., & Share, D. L. (2007). Orthographic learning during oral and silent reading. *Scientific Studies of Reading*, *11*, 55–71. doi:10.1207/s1532799xssr1101_4
Dimmitt, S., Hodapp, J., Judas, C., Munn, C., & Rachow, C. (2006). Iowa Text Reader Project impacts student achievement. *Closing the Gap*, *24*(6), 12–13.
Duñabeitia, J. A., & Vidal-Abarca, E. (2008). Children like dense neighborhoods: Orthographic neighborhood density effects in novel readers. *Spanish Journal of Psychology*, *11*, 26–35.
Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107–144). Mahwah, NJ: Lawrence Erlbaum.
Ehri, L. C., & Saltmarsh, J. (1995). Beginning readers outperform older disabled readers in learning to read words by sight. *Reading and Writing*, *7*, 295–326. doi:10.1007/BF03162082
Elkind, J. (1998). Computer reading machines for poor readers. *Perspectives*, *24*(2), 4–6.
Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds.), *New approaches to language mechanisms* (pp. 257–287). Amsterdam, Netherlands: North-Holland.
Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology: Human Perception and Performance*, *13*, 104–115. doi:10.1037/0096-1523.13.1.104
Geudens, A., & Sandra, D. (2002). The role of orthographic onset-rime units in Dutch beginning readers. In L. Verhoeven, P. Reitsma, & C. Elbro (Eds.), *Precursors of functional literacy* (pp. 49–67). Amsterdam, Netherlands: John Benjamins.
Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review*, *103*, 518–565. doi:10.1037/0033-295X.103.3.518
Higgins, E. L., & Raskind, M. H. (2004). Speech recognition-based and automaticity programs to help students with severe reading and spelling problems. *Annals of Dyslexia*, *54*(2), 365–392. doi:10.1007/s11881-004-0017-9
Higgins, E. L., & Raskind, M. H. (2005). The compensatory effectiveness of the quicktionary reading pen II on the reading comprehension of students with learning disabilities. *Journal of Special Education Technology*, *20*(1). Retrieved from http://www.tamcec.org
Hogaboam, T. W., & Perfetti, C. A. (1978). Reading skill and the role of verbal experience in decoding. *Journal of Educational Psychology*, *70*, 717–729. doi:10.1037/0022-0663.70.5.717
Jorm, A., & Share, D. (1983). Phonological recoding and reading acquisition. *Applied Psycholinguistics*, *4*, 103–147. doi:10.1017/S0142716400004380
Kleijnen, R., Bosman, A., De Jong, P., Henneman, K., Pasman, J., Paternotte, A., . . . Wijnen, F. (2008). Diagnose en behandeling van dyslexie [Diagnosis and treatment of dyslexia]. *Brochure van de Stichting Dyslexie Nederland (geheel herziene versie)*. Bilthoven: Stichting Dyslexie Nederland.
Kyte, C. S., & Johnson, C. J. (2006). The role of phonological recoding in orthographic learning. *Journal of Experimental Child Psychology*, *93*, 166–185. doi:10.1016/j.jecp.2005.09.003
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. doi:10.1037/0022-0663.100.1.150
Manis, F. R. (1985). Acquisition of word identification skills in normal and disabled readers. *Journal of Educational Psychology*, *77*, 78–90. doi:10.1037/0022-0663.77.1.78
Maxwell, S. E., & Delaney, H. D. (2004). *Designing experiments and analyzing data: A model comparison perspective* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.
McKague, M. (2005). *The development of orthographic representations in skilled readers* (Unpublished doctoral dissertation). University of Melbourne, Melbourne, Australia.
Paulesu, E. (2006). On the advantage of "shallow" orthographies: Number and grain size of the orthographic units or consistency per se? *Developmental Science*, *9*, 443–444. doi:10.1111/j.1467-7687.2006.00525.x
Perfetti, C. A. (1985). *Reading ability*. New York, NY: Oxford University press.
Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 145–174). Hillsdale, NJ: Lawrence Erlbaum.
Perfetti, C. A. (1997). The psycholinguistics of spelling and reading. In C. A. Perfetti, L. Rieben & M. Fayol (Eds.), *Learning to spell: Research, theory, and practice across languages* (pp. 21–38). Mahwah, NJ: Lawrence Erlbaum.
Raskind, M. H., & Higgins, E. L. (1999). Speaking to read: The effects of speech recognition technology on the reading and spelling performance of children with learning disabilities. *Annals of Dyslexia*, *49*, 251–281. doi:10.1007/s11881-999-0026-9
Reitsma, P. (1983a). Printed word learning in beginning readers. *Journal of Experimental Child Psychology*, *36*, 321–339. doi:10.1016/0022-0965(83)90036-X
Reitsma, P. (1983b). Word-specific knowledge in beginning reading. *Journal of Research in Reading*, *6*, 41–56. doi:10.1111/j.1467-9817.1983.tb00237.x
Rogosa, D. R., & Willett, J. B. (1985). Understanding correlates of change by modeling individual differences in growth. *Psychometrika*, *50*, 203–228. doi:10.1007/BF02294247
Salthouse, T. A., & Hedden, T. (2002). Interpreting reaction time measures in between-group comparisons. *Journal of Clinical and Experimental Neuropsychology*, *24*, 858–872. doi:10.1076/jcen.24.7.858.8392
Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime version 1.0*. Pittsburgh, PA: Psychology Software Tools.
Shahar-Yames, D., & Share, D. L. (2008). Spelling as a self-teaching mechanism in orthographic learning. *Journal of*

Research in Reading, *31*(1), 22–39. doi:10.1111/j.1467-9817.2007.00359.x

Share, D. L. (1995). Phonological recoding and self-teaching: sine qua non of reading acquisition. *Cognition*, *55*(2), 151–218. doi:10.1016/0010-0277(94)00645-2

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. doi:10.1006/jecp.1998.2481

Share, D. L. (2004). Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *Journal of Experimental Child Psychology*, *87*, 267–298. doi:10.1016/j.jecp.2004.01.001

Share, D. L. (2008). On the anglocentricities of current reading research and practice: The perils of overreliance on an "outlier" orthography. *Psychological Bulletin*, *134*(4), 584–615. doi:10.1037/0033-2909.134.4.584

Share, D. L., & Shalev, C. (2004). Self-teaching in normal and disabled readers. *Reading and Writing*, *17*, 1–31. doi:10.1007/s11145-004-2658-9

Stanovich, K. E. (1988). Explaining the differences between the dyslexic and the garden-variety poor reader: The phonological-core variable difference model. *Journal of Learning Disabilities*, *21*, 590–612. doi:10.1177/002221948802101003

Stanovich, K. E. (1991). Discrepancy definitions of reading disability: Has intelligence led us astray? *Reading Research Quarterly*, *26*, 1–29. doi:10.2307/747729

van Daal, V. P. H., & Reitsma, P. (1990). The use of speech feedback by normal and disabled readers in computer-based reading practice. *Reading and Writing*, *5*, 243–259. doi:10.1007/BF01027390

van Daal, V. P. H., & van der Leij, A. (1992). Computer-based reading and spelling practice for children with learning disabilities. *Journal of Learning Disabilities*, *25*(3), 186–195. doi:10.1177/002221949202500306

van den Bos, K. P., lutje Spelberg, H. C., Scheepstra, A. J. M., & de Vries, J. R. (1994). *De Klepel. Een test voor de leesvaardigheid van pseudo-woorden* [The Klepel: A test for the reading ability of pseudowords]. Nijmegen, Netherlands: Berkhout Testmateriaal.

Van den Broeck, W. (2002). The misconception of the regression-based discrepancy operationalization in the definition and research of learning disabilities. *Journal of Learning Disabilities*, *35*(3), 194–204. doi:10.1177/002221940203500301

Van den Broeck, W., & Geudens, A. (2012). Old and new ways to study characteristics of reading disability: The case of the nonword reading deficit. *Cognitive Psychology*, *65*, 414–456. http://dx.doi.org/10.1016/j.cogpsych.2012.06.003

Van den Broeck, W., Geudens, A., & van den Bos, K. P. (2010). The nonword-reading deficit of disabled readers: A developmental interpretation. *Developmental Psychology*, *46*, 717–734. doi:10.1037/a0019038

van der Leij, A., & van Daal, V. H. P. (1999). Automatization aspects of dyslexia: Speed limitations in word identification, sensitivity to increasing task demands, and orthographic compensation. *Journal of Learning Disabilities*, *32*(5), 417–428. doi:10.1177/002221949903200507

Vellutino, F. R., Scanlon, D. M., & Tanzman, M. S. (1994). Components of reading ability: Issues and problems in operationalizing word identification, phonological coding, and orthographic coding. In G. R. Lyon (Ed.), *Frames of reference for the assessment of learning disabilities: New views on measurement issues* (pp. 279–332). Baltimore, MD: Brookes.

Wang, H.-C., Castles, A., Nickels, L., & Nation, K. (2011). Context effects on orthographic learning of regular and irregular words. *Journal of Experimental Child Psychology*, *109*(1), 39–57. doi:10.1016/j.jecp.2010.11.005

Wechsler, D., Kort, W., Schittekatte, M., Bosmans, M., Compaan, E. L., Dekker, P. H., & Verhaeghe, P. (2005). *Wechsler Intelligence Scale for Children–Third Edition* (WISC-III-NL). Amsterdam, Netherlands: Pearson.

Wimmer, H. (2006). Don't neglect reading fluency! *Developmental Science*, *9*, 447–448. doi:10.1111/j.1467-7687.2006.00527.x

Wise, B. W., Ring, J., & Olson, R. K. (2000). Individual differences in gains from computer-assisted remedial reading. *Journal of Experimental Child Psychology*, *77*, 197–205. doi:10.1006/jecp.1999.2559

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, *131*, 3–29. doi:10.1037/0033-2909.131.1.3