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Predicting responsiveness to intervention in dyslexia using dynamic assessment

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ABSTRACT

In the current study we examined the value of a dynamic test for predicting responsiveness to reading intervention for children diagnosed with dyslexia. The test consisted of a 20-minute training aimed at learning eight basic letter–speech sound correspondences within an artificial orthography, followed by a short assessment of both mastery of these correspondences and word reading ability in this unfamiliar script. Fifty-five (7- to 11-year-old) children diagnosed with dyslexia engaged in specialized intervention during approximately 10 months and their reading and spelling abilities were assessed before and after. Our results indicated that the dynamic test predicted variance in reading skills at posttest, over and above traditional static measures, such as phonological awareness and rapid naming. These findings indicate that responsiveness to learning new letter–speech sound correspondences has a prognostic value for the success of specialized reading intervention.

1. Introduction

Developmental dyslexia, henceforth referred to as dyslexia, is characterized by a specific and significant impairment in the automatic recognition of written words (Fletcher & Lyon, 2008; Peterson & Pennington, 2012; Snowling, 2012). There is ample evidence that specialized intervention is effective in ameliorating reading and spelling proficiency of children with dyslexia (see Galuschka, Ise, Krick, & Schulte-Körne, 2014 for an overview). Unfortunately, not all dyslexic readers benefit to the same extent and there is a substantial amount of non-responders as well (Galuschka et al., 2014; Singleton, 2009; Torgesen, 2005). Gaining more insight into factors that can predict responsiveness to intervention in dyslexia would be very welcome as it could help us to identify nonresponders at an early stage and, by doing so, to prevent wasting time, effort, and resources on interventions that are not effective.

A framework that is particularly important in this context is response to intervention (RTI), which is a common practice in educational settings across the United States and several European countries nowadays. RTI is an approach in which a tutor provides a pupil with progressively intense and individualized tiers of instruction with the aim of finding the best possible way to educate children and of identifying children with learning disabilities (Fuchs & Fuchs, 2006; Grigorenko, 2009; Gustafson, Svensson, & Fälth, 2014). Pupils who do not respond to Tier 1 receive more intensive and individualized instruction within Tier 2, and those who are unresponsive to Tier 2 proceed with even more rigorous instruction within Tier 3. Depending on the educational system, the framework is sometimes complemented by a fourth tier, which consists of placement in special education or referral to assessment and therapy within the health care system.

Although many pupils benefit from RTI as they receive high-quality instruction as soon as learning difficulties arise, the notion that intervention should initially be of modest intensity has been questioned (Denton et al., 2011; Vaughn, Denton, & Fletcher, 2010). Especially the value of Tier 2 intervention for the most learning disabled continues to be a subject to debate (Compton et al., 2012; Fuchs, Fuchs, & Compton, 2010). Indeed, there is evidence that engaging in less intensive tiers of intervention may not be effective for addressing the reading difficulties of children with dyslexia (Vaughn et al., 2010). Early identification of nonresponders could thus potentially improve their chance to benefit from intervention by intensifying initial intervention.

A convenient starting point for identifying factors predicting intervention success would be to focus on the standard assessment of dyslexia, which typically consists of a combination of reading and writing tasks along with a set of phonology-related tasks, such as phonological awareness, rapid naming, and verbal short-term memory, as well as some general cognitive measures. Indeed, several studies indicate that some of these factors, among which poor phonological awareness in

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particular, can predict unresponsiveness to early literacy intervention within children at risk for dyslexia (see Al Otaiba & Fuchs, 2002 and Nelson, Benner, & Gonzalez, 2003 for an overview), but it is far less clear whether these findings hold for children diagnosed with dyslexia (Frijters et al., 2011; Hatcher & Hulme, 1999; Morris et al., 2012; Tijms, 2011). For this group there is a paucity in our knowledge of factors moderating responsiveness to intervention (Démonet, Taylor, & Chaix, 2004; Frijters et al., 2011; Hoeft et al., 2011; Shaywitz, Morris, & Shaywitz, 2008; Tijms, 2011). A recent meta-analysis including twenty-two randomized controlled trial studies of reading disabled children failed to identify subject-related moderators of responsiveness to intervention (Galuschka et al., 2014).

Dynamic assessment (DA) might be a viable approach for examining potential moderators of responsiveness to intervention. The focus of DA is on learning potential rather than learning outcome (Grigorenko, 2009; Gustafson et al., 2014). A typical DA procedure requires the pupil to engage in a training in which feedback is provided. The effect of training is then used to estimate the pupils' learning potential. There is ample evidence that this kind of process-oriented testing better predicts future learning than conventional testing within various academic domains, including reading skill (Caffrey, Fuchs, & Fuchs, 2008; Fuchs, Compton, Fuchs, Bouton, & Caffrey, 2011; Grigorenko & Sternberg, 1998; Gustafson et al., 2014; Jeltova et al., 2007; Spector, 1992). However, other studies have shown little advantage of dynamic testing over static testing (Caffrey et al., 2008). In a recent study Petersen, Allen, and Spencer (2014) compared the utility to predict reading difficulty at first grade of two DA reading measures and two commonly used one-point-in-time pre-reading measures administered to 600 kindergarten children and found both DA measures to be superior to the common static measures. DA has also been used to examine moderators of responsiveness to intervention recently. Cho, Compton, Fuchs, Fuchs, and Bouton (2014) showed that DA predicted the responsiveness to a validated reading intervention program. In this study, first-grade students received Tier 2 reading intervention within small groups during 14 weeks. DA of decoding was found to be a significant predictor of the growth in word identification fluency and the final level attained.

In the current study, we applied DA to children diagnosed with dyslexia in order to predict the success of subsequent specialized Tier 4 intervention. The DA we developed consists of a 20-minute training aimed at learning eight new basic letter–speech sound correspondences, followed by a short assessment of both mastery of the correspondences and word reading ability in this unfamiliar script. Letter–speech sound learning is the central focus of the training, because recent research suggests that a fundamental letter–speech sound learning deficit is a key factor in dyslexia (Blomert, 2011; Kronschnabel, Brem, Maurer, & Brandeis, 2014; McNorgan, Randazzo-Wagner, & Booth, 2013; Mittag, Thesleff, Laasonen, & Kujala, 2013; Peterson & Pennington, 2015; van Atteveldt & Ansari, 2014; Žarić et al., 2014). The advantage of adopting an artificial script is that differences in previous exposure to experimental stimuli can be ruled out, allaying concerns about noncontrolled factors influencing performance. In a previous study we demonstrated that our DA procedure differentiates between dyslexic readers and normal readers and predicts individual differences in reading and spelling ability (Aravena, Tijms, Snellings, & van der Molen, 2015). In the current study we examined whether, in addition to its diagnostic value, the DA procedure has prognostic value as well. The participating children engaged in specialized Tier 4 intervention during approximately 10 months. We tested their reading and spelling abilities before and after intervention and related these to the scores on our DA, as well as to the scores on two conventional static measures frequently used for the assessment of dyslexia, namely a phonological awareness task and an alphanumeric rapid naming task. Unlike most approaches to DA (Grigorenko, 2009; Grigorenko & Sternberg, 1998), our assessment did not involve instruction but just associative learning from exposure and implicit feedback. The 20-minute training consisted of a computer game in which children had to match speech sounds to unfamiliar letters. As correct responses led to success in the game and incorrect responses were penalized, children learned the letter–speech sound correspondences just by playing the game, without being aware of learning. Instructions were only related to the specifics of the game and did not reveal the underlying learning objective. This approach was chosen to approximate letter–speech sound learning as it naturally occurs and to measure the capacity to master new letter–speech sound correspondences, without interference from more general factors related to instruction, such as intelligence, verbal comprehension, or attention.

In brief, in the current study we examined whether a new DA procedure predicted the success of a subsequent specialized intervention within a group of children diagnosed with dyslexia. We expected this procedure to be an adequate candidate for this purpose for two reasons. First, because it focuses on the formation of letter–speech sound correspondences, a process that appears to be disrupted in children with dyslexia. Second, because it focuses on learning rate rather than on learning outcome.

2. Method

2.1. Participants

Participants were 55 primary education pupils (30 boys and 25 girls) diagnosed with dyslexia recruited from a nation-wide center for dyslexia in the Netherlands. The children had a mean age of 9 years and 3 months ($SD = 12.39$ months, age range = 7.33–11.08 years). An estimate of general intelligence was obtained by averaging the standardized *C*-scores (M = 5, SD = 2) of the subtest Analogies from the SON-R (Laros & Tellegen, 1991), a non-verbal reasoning-by-analogy task in which the child had to extract a principle and to apply it to a new situation ($r = 0.79$, test–retest), and the subtest Vocabulary from the WISC-III (Kort et al., 2005), a measure of expressive vocabulary requiring the child to describe the meaning of words of increasing complexity ($r = 0.90$, test–retest). The IQ estimates ranged from 3 to 8.5 ($M = 5.57$, $SD = 1.37$). Informed consent was obtained from the parents of each child.

Consistent with standard norms for severe dyslexia in the Dutch health care system (Blomert, 2006), children were diagnosed with dyslexia when they met all of the following three inclusion criteria: (1) either word reading speed was 1.5 standard deviation (SD) or more below average or, word reading speed was at least 1 SD below average together with a spelling skill of 1.5 SD or more below average; (2) performance on at least two out of six administered phonology-related tasks was at least 1.5 SD below average; and (3) the child had shown a poor response to intervention provided at school. Exclusionary criteria were uncorrected sensory disabilities, broad neurological deficits, low IQ (<80), poor school attendance, and ADHD. Because we incorporated Hebrew graphemes in our assessment, previous experience with Hebrew script was also an exclusionary criterion. All participants were native speakers of Dutch. The study was approved by the University's Ethics Committee.

2.2. Dynamic assessment

The dynamic assessment (DA), which had a total duration of approximately 30 min, consisted of a 20-minute training dedicated to learning non-existent letter–speech sound correspondences followed by a short assessment of both mastery of the newly learned correspondences and word reading ability in the artificial script. A summary of the different components of the DA is provided below.

2.2.1. The letter–speech sound training

The training consisted of a computer game in which the child had to match speech sounds to their corresponding orthographic representations (Aravena et al., 2015). Correct associations were rewarded while incorrect associations were penalized. Fast playing was reinforced by progressive time restrictions and by providing bonuses for fast playing. More specific, children operated a cannon at the bottom of the screen, moving it horizontally. The upper part of the screen was composed of columns of balloons containing single graphemes. Children were required to act on speech sounds that were presented repeatedly in the game. The response consisted of releasing bullets from the cannon and associating them to their corresponding grapheme. When children managed to clear a field of balloons, a new field was presented. As the amount of distractor graphemes increased during the game, fields became gradually more complex. Fig. 1 depicts some screenshots from the game.

The goal of the training was to learn a set of letter–speech sound correspondences from an artificial orthography. At the start of the game the child was presented with a standardized instruction that was integrated in the software. This instruction provided information regarding the specifics of the game but did not reveal the underlying learning objective. After the instruction, children received a short practice trial to become familiar with the set-up and the controls of the game. During the training session children were wearing headphones.

2.2.2. The artificial orthography

The artificial orthography consisted of eight Hebrew graphemes, which were randomly matched to highly frequent Dutch phonemes, thereby providing eight basic non-existing letter–speech sound pairs. We adopted Hebrew script to capture the characteristics of graphemes as they naturally occur. Evidence exists that letter shapes are not an arbitrary cultural choice but rather a product of our neural architecture (Dehaene, 2009, p. 173). The phonemes, three vowels and five consonants, were selected based on their high frequency and their ability to, by combining, create a large corpus of words. Combinations of phonemes producing strong coarticulation effects were avoided. Table 1 presents the letter–speech sound correspondences that were used. The directionality of the script was left-to-right.

2.2.3. Letter–speech sound identification task within the artificial orthography

In this task a phoneme was presented over headphones, while simultaneously two graphemes from the artificial orthography were displayed at the screen. One of these graphemes corresponded with the presented phoneme, while the other was as a distractor. By striking the corresponding button the child had to decide, as fast as possible, which of the graphemes belonged to the presented phoneme. The task consisted of 56 items. Response speed and accuracy were recorded automatically by the software. The score for response speed was the median speed of correct responses and the score for accuracy was the number of correct responses (respectively $r = 0.96$ and $r = 0.90$, split-half).

Table 1
Letter–speech sound correspondences within the artificial orthography.

Letter	ט	כ	ם	ף	פ	צ	ך	ש
Speech sound (IPA)	[u]	[ɛ]	[α] [a]	[k]	[r]	[l]	[t]	[n]

Note. IPA, International Phonetic Alphabet.

2.2.4. Reading task within the artificial orthography

We administered a time-limited test (3MAST) consisting of a list of 22 high-frequent Dutch words written within the artificial orthography. The words were presented in lowercase Arial typeface, font size 24, and arranged in two columns of equal length. The child had to read (column-wise) as many words as possible within 3 min. The score consisted of the number of words read correctly per second.

2.3. Traditional measures used for the assessment of dyslexia

2.3.1. Phonological awareness

We assessed phonological awareness with a phoneme deletion task from the 3DM, a standardized and computerized battery for assessing dyslexia (Blomert & Vaessen, 2009). In this task the child had to delete consonants from aurally presented pseudowords (CVC or CCVCC structure) as fast as possible (for example /FOT/ minus /F/ makes /OT/). The score consisted of the percentage of correct responses ($r = 0.85$, internal consistency).

2.3.2. Rapid naming

We assessed both rapid naming of letters and digits with a rapid naming task from the 3DM (Blomert & Vaessen, 2009). The child had to name aloud items presented on the computer screen as fast and accurate as possible. Within both domains sheets containing 15 items each were presented two times. The score per subtask was the mean response time of the two sheets ($r = 0.80$ for letters and $r = 0.83$ for digits, split-half reliability). In the current study we used a composite measure of alphanumeric rapid naming consisting of the scores of both the rapid naming of letters and digits.

2.4. Reading and spelling measures

2.4.1. Word reading

We assessed word reading with a time-limited task from the 3DM (Blomert & Vaessen, 2009). This word-reading task included three different levels comprising high-frequency words, low-frequency words and pseudo-words. Each level contained 75 words, displayed on 5 sheets with 15 items each. The difficulty of each level increased systematically from monosyllabic words without consonant clusters to 3 or 4 syllabic words with consonant clusters in the fifth sheet. The child was instructed to read as many words as possible while maintaining accuracy within a time-limit of 30 s per level. Both accuracy (percentage of

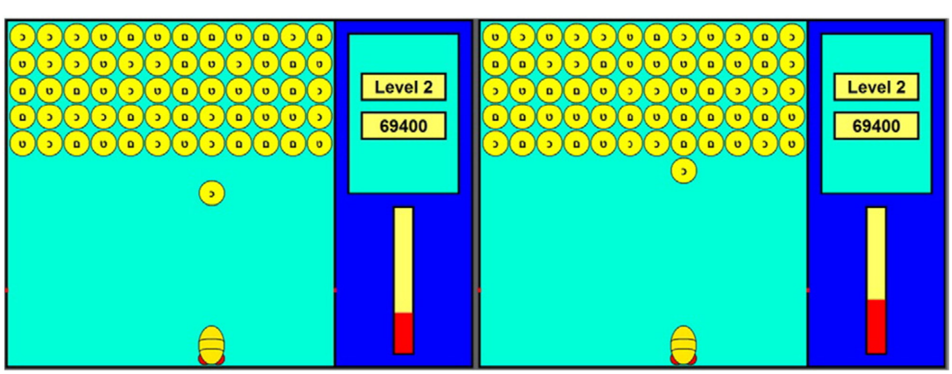

Fig. 1. Screenshots from the training.

correctly read words) and speed (number of words read correctly) were measured (respectively $r = 0.73$ and $r = 0.95$, test–retest).

2.4.2. Spelling

We assessed spelling with a task from the 3DM (Blomert & Vaessen, 2009). In this task a word was presented over headphones while it was also visible on the screen. In the visually presented word a letter or letter combination was missing. By striking a key the child had to decide as fast as possible which of four different letters or letter combinations represented the missing part. Word frequencies varied systematically and words were either phonetically transparent (18 items) or needed the application of a Dutch spelling rule (36 items). Scores consisted of the percentage of accurate responses ($r = 0.80$, internal consistency).

2.5. Specialized intervention

The Dutch educational system utilizes a three-tier approach to reading instruction. Children who do not respond to intensive Tier 3 intervention are assessed for their reading deficiency and those diagnosed with dyslexia receive specialized intervention within the health care system, which in the Netherlands represents the fourth tier. The intervention used in this study was a Dutch computer-based Tier 4 intervention program for treating dyslexia (LEXY).

Intervention was provided by speech therapists and psychologists, on a one-to-one basis in weekly 45-min sessions. Sessions took place in a dyslexia center in the child's neighborhood. Besides these sessions at the center, participants were required to practice at home three times a week for 15 min.

LEXY provides insight into the way written language transcribes the characteristics of the spoken language system by clarifying the phonological and morphological structure, and by explicitly training the rule-systems that are essential for the graphic representation of spoken language, using step-by-step algorithmic plans. All elements within the learning environment (like phonemic and orthographic units and mapping operations) are graphically represented on the computer screen (see Tijms & Hoeks, 2005 for a more detailed review of LEXY). The LEXY program aims at achieving a mastery level for each element of the program, which implies that participants do not pass through it at a fixed pace. On average the duration of the intervention program is 48 to 60 sessions, but in the current study the posttest was administered before the end of intervention, at 39 weeks. The program is in line with guidelines regarding effective intervention for children with dyslexia (Galuschka et al., 2014; Singleton, 2009) and its efficacy has been demonstrated repeatedly (Tijms, 2011; Tijms & Hoeks, 2005).

2.6. Design and procedure

The DA was administered as part of a standard diagnostic assessment consisting of two 3.5 hour-sessions within one week interval. A trained psychologist administered the DA on a one-to-one basis during the second session. The assessment took place in a silent room in the dyslexia center. Children started with the intervention program approximately four months after the assessment. The pretest consisted of the word reading and the spelling task and took place during the first session of the intervention. The posttest, which included the same tasks, took place during the 39th session, which was after approximately 10 months ($M = 43.0$ weeks, $SD = 1.9$ weeks), depending on the amount of cancelled sessions due to illness or holidays. In total, 33 sessions were used for intervention and 6 sessions were used for assessment purposes.

2.7. Analyses

In order to understand the predictive potential of the pertinent variables, we first had a look at the overall effect of the intervention. Gain values were calculated by subtracting the standardized T-scores ($M = 50$, $SD = 10$) obtained at pretest from those obtained at posttest for each individual. A one-sample t-test was then conducted to determine whether the mean of these gain values was significantly different from zero.

To determine whether the three dynamic assessment (DA) variables predict the improvement in reading and spelling skills during intervention we conducted a series of two-step fixed-entry multiple regression analyses with the posttest scores of reading and spelling measures as the dependent variables. In each of the analyses we entered the pretest score in the first step to filter out variance due to differences at the start of intervention. The three DA measures as well as phonological awareness (PA) and alphanumeric rapid naming (RAN) were added alternately in the second step to determine their individual contribution. In an additional series of multiple regression analyses we compared the predictive potential of the combined DA measures to the combined traditional measures by entering both phonological awareness and rapid naming in the second step and the three DA measures in the third step and vice versa.

3. Results

3.1. Overall effect of the intervention

Table 2 presents the standardized T-scores for the reading and spelling tasks at pretest and posttest. A one-sample t-test showed that the treatment had a significant beneficial effect on reading accuracy ($t(52) = 3.032$, $p = 0.004$, $d = 0.84$) and on reading speed ($t(52) = 7.071$, $p < 0.001$, $d = 1.96$) as well as on spelling ($t(52) = 5.937$, $p < 0.001$, $d = 1.65$). Note that the gains are expressed in standardized scores, and thus reflect a shift in position within the normal distribution. In other words, the reading disabled children that received intervention made significantly more progress than their peers (from the national norm) during the same period.

Despite the improvements that were made, the average accuracy and speed scores of reading were still below the normal range after 39 sessions of treatment. This was not surprising, however, given that the posttest was administered mid-term. The improvements found at the end of this treatment are typically more substantial (Tijms, 2011; Tijms & Hoeks, 2005).

3.2. Predicting reading and spelling gains during intervention

The results from the multiple regression analyses, presented in Table 3, indicate that neither PA nor RAN made a significant contribution to predicting the improvement in any of the reading and spelling skills during intervention. The same was true for the artificial orthography-related accuracy measure of the letter–speech sound identification task (LSIa). The speed measure of the letter–speech sound identification task (LSIs), however, accounted for 17% of the variance in reading accuracy and 6% of the variance in reading speed at posttest. The contribution to the variance in spelling at posttest was negligible. The amount of words read per second within the artificial orthography (WPS) accounted for 12% of variance in reading accuracy at posttest, but did not contribute to the variance of any of the other measures.

The results from the additional analyses, which are shown in Table 4, indicate that the three DA measures combined accounted for 23% of

Table 2
The development of standardized t-scores for reading and spelling during intervention.

	t-Score at pretest	*t-Score at posttest*	*Gain values (t-score)*
	M (SD)	M (SD)	M (SD)
Reading accuracy	32.44 (11.37)	37.25 (11.64)	5.11 (12.28)**
Reading speed	29.60 (5.09)	34.94 (7.39)	5.45 (5.61)**
Spelling	37.07 (7.28)	44.49 (8.69)	7.75 (9.51)**

** Significant at the 0.01 level.

Table 3
Regression models predicting reading and spelling measures at posttest.

Steps		Reading accuracy R^2	Reading accuracy ΔR^2	Reading speed R^2	Reading speed ΔR^2	Spelling R^2	Spelling ΔR^2
1	Pretest	0.19	0.19**	0.42	0.42**	0.09	0.09*
2	PA	0.21	0.02	0.43	0.01	0.09	0.00
2	RAN	0.21	0.02	0.42	0.00	0.09	0.00
2	LSIa	0.19	0.00	0.42	0.00	0.10	0.01
2	LSIs	0.36	0.17**	0.48	0.06*	0.10	0.01
2	WPS	0.31	0.12**	0.43	0.01	0.10	0.01

Note. PA, phonological awareness; RAN, rapid naming of alphanumeric items; LSIa, letter–speech sound identification accuracy; LSIs, letter–speech sound identification speed; WPS, number of words read per second.
** Significant at the 0.01 level.
* Significant at the 0.05 level.

variance in reading accuracy at posttest when entered in the second step and for 19% of additional variance when entered in the third step. The three DA measures thus predicted variance in reading accuracy at posttest, over and above traditional static measures, such as PA and RAN.

4. Discussion

In the current study we used dynamic assessment (DA) for children diagnosed with dyslexia to examine whether it would predict the success of a subsequent specialized intervention. In a previous study we demonstrated that our DA predicts individual differences in reading and spelling ability and differentiates between dyslexic readers and normal readers (Aravena et al., 2015). The results from the current study indicate that in addition to its diagnostic value our DA has prognostic value as well. More specifically we found that the speed measure from the letter–speech sound identification task (LSIs) made a significant contribution to explaining variance in response to intervention on reading accuracy and speed and that the amount of words read per second within the artificial orthography (WPS) accounted for another significant portion of variance in reading accuracy at posttest.

Our findings are consistent with previous findings demonstrating the added value of DA in forecasting reading development (Caffrey et al., 2008; Fuchs et al., 2011; Grigorenko & Sternberg, 1998; Gustafson et al., 2014; Jeltova et al., 2007; Petersen et al., 2014; Spector, 1992) and, more importantly, in predicting responsiveness to reading intervention (Cho et al., 2014). The current study strengthens and extends available data by showing that DA has the potential to predict responsiveness to intervention beyond Tier 3 intervention within a sample of children diagnosed with dyslexia. This is of particular interest because so far the quest for predictors of responsiveness to intervention for this group has not been very fruitful (Frijters et al., 2011; Hoeft et al., 2011; Tijms, 2011). Our results indicate that a dynamic approach to assessment provides new opportunities to predict responsiveness to intervention even for the most reading disabled. From a clinical point of view early identification of potential non-responders is valuable because it may assist practitioners adapting their educational strategies at an initial stage or even start off a prompt deployment of alternative ways of accessing written information, such as computer-based readers.

A possible explanation for the current success of our DA approach is that it not only identifies an essential underlying factor, namely a letter–speech sound binding deficit, but that it also provides an index of the extent to which this underlying problem interferes with learning to read. This explanation is in line with findings from longitudinal studies indicating that deficits in the initial learning of letter–speech sound associations are an important risk factor for developing reading difficulties (Caravolas et al., 2012; Lyytinen, Ronimus, Alanko, Poikkeus, & Taanila, 2007). According to Lyytinen et al. (2007) it is a serious reason for concern when a child struggles storing grapheme–phoneme connections in memory in stable form. We think it is this 'struggle' that manifests itself within the 20 min of playing the DA game and, thus, it might provide a proxy for the responsiveness to reading intervention.

It is noteworthy that we did not find any moderating effect of phonological awareness or rapid naming on the responsiveness to intervention. Research has consistently demonstrated that these factors are important predictors of variance in reading skills (see Melby-Lervåg, Lyster, & Hulme, 2012 and Norton & Wolf, 2012 for reviews). Moreover, some studies did obtain evidence to suggest that these factors can predict responsiveness in children at risk for dyslexia (Al Otaiba & Fuchs, 2002; Nelson et al., 2003 for reviews). The current lack of an association between phonological awareness and rapid naming and response to intervention is in line with the notion that phonological factors may be less important than is often assumed (Byrne, 2011). Observations that, although phonological deficits are common in individuals with dyslexia, a single phonological deficit is not necessary or sufficient to cause the disorder, have led to the idea that poor phonological awareness and rapid naming are two of multiple factors that interact in causing dyslexia (Pennington, 2006; Peterson & Pennington, 2012; Snowling, 2008; Moll, Loff, & Snowling, 2013).

Although the current study did not focus on the effectivity of the intervention per se, but rather aimed at gaining insight into factors that can predict responsiveness to intervention, the intervention gains were derived from national normative data rather than from a direct comparison with a control group within a randomized control trial (RCT) design. Our study thus indicates that the DA procedure is able to predict changes between pretest and posttest, but cannot establish whether these changes result from the intervention. However, it is important to add that findings from a recent RCT-study on the effectivity of the LEXY program demonstrated that children with dyslexia showed substantial reading and spelling gains after the intervention and improved at a faster rate than both typical readers and waiting-list controls (Fraga González et al., 2015).

Although our findings indicate that our DA is able to significantly predict progress in reading and spelling skills during specialized intervention, with up to 19% of uniquely explained variance, its predictive power is modest from a clinical perspective. It should be noted, however, that, as we focused on Tier 4 intervention, all children within our sample were characterized by severe and persistent reading and spelling disabilities, limiting variability. Based on the results from other studies (for example Cho et al., 2014 and Petersen et al., 2014) it seems plausible that the predictive potential of the DA will increase when applied to Tier 3 or even Tier 2 intervention.

The findings of the current study raise a number of interesting questions. First, why is LSIs the best predictor among the three DA variables?

Table 4
Regression models predicting reading and spelling measures at posttest.

Steps		Reading accuracy R^2	Reading accuracy ΔR^2	Reading speed R^2	Reading speed ΔR^2	Spelling R^2	Spelling ΔR^2
1	Pretest	0.19	0.19**	0.42	0.42**	0.09	0.09*
2	PA						
	RAN	0.23	0.04	0.43	0.01	0.09	0.00
3	LSIa						
	LSIs						
	WPS	0.42	0.19**	0.50	0.07	0.11	0.02
2	LSIa						
	LSIs						
	WPS	0.41	0.23**	0.48	0.06	0.11	0.02
3	PA						
	RAN	0.42	0.00	0.50	0.02	0.11	0.00

Note. PA, phonological awareness; RAN, rapid naming of alphanumeric items; LSIa, letter–speech sound identification accuracy; LSIs, letter–speech sound identification speed; WPS, number of words read per second.
** Significant at the 0.01 level.
* Significant at the 0.05 level.

One possible explanation is that, while LSIa is related to the understanding of the newly learned letter–speech sound correspondences, LSIs, in addition, provides an index of the ability to instrumentally use these correspondences. This interpretation is in line with the literature on dysfunctional letter–speech sound learning, suggesting that the amount of automation of the concerning units at a neuronal level and in identification latencies at a behavioral level, reflects the extent to which the quality of the learned association enables fluent reading (Aravena et al., 2015; Blomert, 2011; van Atteveldt & Ansari, 2014; Widmann, Schröger, Tervaniemi, Pakarinen, & Kujala, 2012). Within this context, LSIs seems to be the purest measure of one's ability to automate the learned associations and it is this ability that may to a large extent determine one's responsiveness to intervention.

A second interesting question is why progress in reading speed seems much more difficult to predict than progress in reading accuracy. A possible explanation centers on the duration of the intervention. The literature on skill acquisition clearly indicates that speeding up cognitive processes by obtaining automaticity requires extended amounts of training (Schneider & Chein, 2003; Siegler, 2005). Accordingly, several studies related to specialized reading intervention indicate that gains in reading accuracy largely precede gains in reading rate (Tijms, 2007; Žarić et al., 2014). It is therefore possible that the intervention in the current study is too short to exert a substantial influence on reading rate and that the variance in reading rate at posttest is only minimally related to disrupted letter–speech sound learning. This interpretation is supported by the fact that a substantial part of variance in reading rate at posttest is explained by variance at pretest, which is not the case for reading accuracy.

From a practical perspective it is interesting to reflect on our results in the context of response to intervention (RTI). There is a general concern that many children receive instruction within less intensive tiers only to show their failure in order to gain access to more appropriate instruction (Caffrey et al., 2008; Fuchs et al., 2011; Gustafson et al., 2014; Vaughn et al., 2010). It has been proposed to integrate DA within a RTI framework to overcome the apparent limitations of RTI (Compton et al., 2010; Gustafson et al., 2014; Kantor, Wagner, Torgesen, & Rashotte, 2011; Lidz & Peña, 2009). Compton et al. (2010), for example, reported that the addition of a decoding DA procedure to a base 1st-grade screening significantly improved classification accuracy of children at-risk for future reading difficulty within a RTI framework. Additionally, Gellert and Elbro (2015) demonstrated that language-neutral dynamic testing before the onset of reading instruction can predict reading difficulties at the end of Grade 1. The current result that DA predicts the response to intervention before the actual intervention commences adds to these findings and supports the utility of DA in RTI decision-making. It allows for skipping tiers of less intensive intervention or even for starting specialized intervention right away. Importantly, as the current DA procedure can be administered fully automatized with the aid of a computer, it is suitable for large scale implementation.

In conclusion, our findings demonstrate that a short DA procedure based on letter–speech sound learning has a predictive value in assessing child's susceptibility to long-term intervention. In this regard, the DA procedure may provide a useful tool in the assessment of dyslexia and may qualify as an alternative or supplement to RTI in future research and policy-making. From a theoretical perspective, our findings support the notion that a letter–speech sound learning deficit is a crucial factor within the etiological framework of dyslexia (Blomert, 2011; Kronschnabel et al., 2014; McNorgan et al., 2013; Mittag et al., 2013; van Atteveldt & Ansari, 2014; Žarić et al., 2014).

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