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Protective Factors and Compensation in Resolving Dyslexia

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ABSTRACT

Two explanations for resolving dyslexia were investigated, one assuming resolving underlying deficits and another assuming compensatory mechanisms based on cognitive strengths. Thirty-six Dutch gifted secondary-school students with either persistent ($n = 18$) or resolving ($n = 18$) dyslexia participated. Groups, matched on IQ, were assessed on dyslexia- and intelligence-related cognitive risk and protective factors. Findings for the risk factors showed support for both the resolving-deficit and compensatory-mechanism theories: Resolving and persistent groups were comparable on phoneme deletion and nonalphanumeric rapid automatized naming, but resolvers outperformed students with persistent dyslexia on spoonerisms and alphanumeric rapid automatized naming. For the protective factors, resolvers consistently showed more pronounced cognitive strengths in verbal areas relevant for literacy development, which is in line with the compensatory-mechanism theory. We conclude that, besides underlying deficits resolving to some extent, compensation is a plausible explanation for resolving literacy difficulties in gifted students.

Across languages, studies have shown that dyslexia may be persistent, late-emerging, or resolving (Catts, Compton, Tomblin, & Bridges, 2012; Leach, Scarborough, & Rescorla, 2003; Torppa, Eklund, van Bergen, & Lyytinen, 2015). Students' literacy performance may even continue to float around the clinical threshold throughout development in both late-emerging and resolving cases. Mechanisms behind resolving literacy difficulties remain unknown, however. One explanation is that underlying cognitive deficits associated with dyslexia (phonological awareness [PA], rapid automatized naming [RAN], and verbal short-term memory [VSTM]; Vellutino, Fletcher, Snowling, & Scanlon, 2004) partly resolve during development. An alternative explanation is that cognitive deficits remain present but are compensated during development by strategies or processes associated with cognitive strengths. In this study, we test and compare these explanations for resolving dyslexia.

Compensation as an explanation for resolving literacy difficulties might best be tested in a population of resolvers where specific strengths are expected to occur, such as gifted students with high IQs (> 130; Winner, 1997). Cognitive profiles of gifted students with dyslexia consist of both dyslexia-related weaknesses and giftedness-related strengths relevant for literacy development (Berninger & Abbott, 2013; van Viersen, Kroesbergen, Slot, & de Bree, 2016). Consequently, their underlying profiles may allow for development of compensatory mechanisms that positively influence their literacy levels throughout development, and more so than in other populations with dyslexia (Brody & Mills, 1997; Foley Nicpon, Allmon, Sieck, & Stinson, 2011). Therefore, we examined differences in underlying cognitive strengths and weaknesses between gifted/dyslexic students with and without current literacy impairments. Specific hypotheses of resolving underlying deficits versus compensation through cognitive strengths were tested to investigate why dyslexia resolves in some students.

Proposed mechanisms for resolving dyslexia

Two distinct theoretical views exist on the relative contributions of underlying cognitive strengths and weaknesses to reading and the development of dyslexia (van Viersen, de Bree, Kroesbergen, Slot, & de Jong, 2015). The dominant *core-deficit view* (Stanovich & Siegel, 1994) assumes that a child's reading level is mainly influenced by the underlying cognitive risk factors associated with dyslexia. As the core deficits in phonological processing associated with dyslexia are unaffected by intelligence, students of high and low intelligence do not show differences in the core cognitive processes underlying their word-reading disability (Stanovich, 1996; Stanovich & Siegel, 1994). Skills that are more general and strongly associated with intelligence (e.g., vocabulary and language comprehension) are more distant form the phonological core. Differences on these skills between students that vary in intelligence will be observed. According to the core-deficit view, more general skills cannot compensate for deficits in the phonological processes underlying word reading, although they are probably beneficial for reading comprehension (Stanovich & Siegel, 1994). The main idea of the core-deficit view is thus that the word-reading level is in line with the underlying risk factors; higher word-reading levels are essentially the result of less severe underlying deficits in phonological processing, not of variable difference in underlying strengths affecting the dyslexia.

The *twice-exceptionality view* (Assouline, Foley Nicpon, & Whiteman, 2010; Brody & Mills, 1997; Foley Nicpon et al., 2011) assumes that underlying cognitive strengths and weaknesses both influence word-level reading. Twice-
exceptional refers to the combination of very low word reading and (exceptionally) high intelligence. According to the twice-exceptionality view, presence of an intelligence-related cognitive strength relevant for literacy (e.g., language; Snowling & Melby-Lervåg, 2016) can provoke or stimulate the emergence of a compensatory mechanism during development (Reis, McGuire, & Neu, 2000). This compensatory mechanism could help *circumvent* the specific dyslexia-related underlying deficit or *subdue* its negative effect on literacy development. In other words, dyslexia resolves not because cognitive strengths decrease the severity of underlying deficits but because cognitive strengths function as protective factors that decrease the *impact* of a risk factor by altering the reading process through a compensatory mechanism (van Viersen, de Bree, Kroesbergen, Kalee, & de Jong, 2017; Haft, Myers, & Hoeft, 2016 for a review).

Yet, clear evidence for the existence of compensatory mechanisms in dyslexia is lacking. There has been some empirical research on gifted primary school children with dyslexia (following low-achievement criteria) and borderline-dyslexic children (children with literacy difficulties relative to their high IQ but no low literacy achievement). This research supported the core-deficit view; higher literacy levels resulted from less severe underlying deficits, not from more pronounced cognitive strengths (van Viersen et al., 2015). Some evidence for compensation was found by van Viersen et al. (2017), who assessed foreign language word-reading and spelling profiles of Dutch gifted students with dyslexia in early secondary education. Their results showed that evidence for compensatory mechanisms explaining higher literacy levels in gifted students with dyslexia compared to averagely intelligent students with dyslexia (both based on low-achievement criteria) was limited to English as a second language. There were no indications for compensatory mechanisms in French or German. Overall, compensation has not been attested extensively. Studying the cognitive profiles of gifted students whose severe literacy difficulties have resolved may provide insight into the role of protective factors in resolving dyslexia, as these students moved across the diagnostic threshold of low achievement, contrary to the participants in the previously mentioned studies.

Research on resolving dyslexia

Few studies have focused on differences in cognitive profiles as a possible means to explain why dyslexia resolves in some children but persists in others. Torppa et al. (2015) assessed resolving dyslexia (based on low-achievement criteria) in Finnish-speaking secondary-school students with

average intelligence. Their findings showed deficits in dyslexia-related cognitive skills (PA, RAN, letter knowledge, and VSTM) at preschool age in both persistent and resolving students with dyslexia. However, early dyslexia-related deficits decreased in severity over time in the resolving group, pointing toward a developmental delay rather than a persistent deficit. Surprisingly, vocabulary deficits were found in the resolving group but not in the persisting group. The groups did not differ on general IQ. No clear protective factors were found. These findings provide support for the core-deficit view and disagree with compensation as the underlying mechanism of resolving dyslexia. Yet, the number of cognitive areas covered by Torppa et al. (2015) that could function as a strength was limited (vocabulary and general IQ). Inclusion of more complex language measures, such as verbal reasoning, or executive functions might have yielded different results, as these skills have been associated with resilience in children with reading disabilities (Haft et al., 2016).

A study on English-speaking secondary-school students by Catts et al. (2012) showed deficits in dyslexia-related cognitive skills at preschool age in both persistent and resolving groups. Whereas the persistent group showed deficits in vocabulary, average vocabulary skills and strong grammar were attested in the resolving group. Both the persistent and resolving group had lower nonverbal intelligence than typical readers. This pattern of findings differs from that of Torppa et al. (2015). One reason might be that the definition of reading disability used by Catts et al. includes deficits in word reading *and/or* reading comprehension. This is substantially different from the definition applied by Torppa et al. and the current study, which rely on word-level literacy deficits. Including reading comprehension renders intact language skills essential for resolving literacy difficulties (Lonigan, Burgess, & Schatschneider, 2018). Another difference is that Finnish and English differ in orthographic depth and the accompanying demands on reading-related skills: Vocabulary has a more prominent role in English at the word level as well (Ricketts, Nation, & Bishop, 2007; Seymour, Aro, & Erskine, 2003). Nevertheless, the findings by Catts et al. suggest that differences in literacy levels between students with persistent and resolving dyslexia not necessarily only originate from dyslexia-related underlying cognitive deficits. Literacy- and intelligence-related skills, such as vocabulary, grammar, and nonverbal abilities, could also be relevant.

Research on adults with compensated dyslexia, generally high-functioning university students with dyslexia, has focused more explicitly on the combination of cognitive strengths and weaknesses and possible areas of compensation to explain resolved literacy difficulties. These studies showed that, at later ages, resolvers have persistent deficits in phonological and/or orthographic processing (Cavalli, Duncan, Elbro, El Ahmadi, & Colé, 2017; Law, Wouters, & Ghesquière, 2015; Miller-Shaul, 2005; Parilla, Georgiou, & Corkett, 2007), RAN, verbal memory and speed of processing (Miller-Shaul, 2005; Parilla et al., 2007). Compensation of reading difficulties is linked to strengths in morphological knowledge (Cavalli et al., 2017; Law et al., 2015), vocabulary (Law et al., 2015; Miller-Shaul, 2005), and orthographic knowledge (Bekebrede, van der Leij, Plakas, Share, & Morfidi, 2010; Miller-Shaul, 2005). As a result, literacy skills of students with compensated dyslexia are characterized by continuously low (non)word reading and spelling (Miller-Shaul, 2005; Parilla et al., 2007), but often with levels above those of students with uncompensated dyslexia (Birch & Chase, 2004; Cavalli et al., 2017), and sometimes with word-reading levels within the normal range (Law et al., 2015). Reading comprehension is generally not or no longer impaired (Birch & Chase, 2004; Miller-Shaul, 2005; Parilla et al., 2007). These findings indicate that underlying deficits remain detectable at later ages despite higher literacy levels and that pronounced cognitive strengths, especially those related to language subskills, are present. These results suggest that the presence of protective factors accompanied by dyslexia-related deficits is indicative of compensatory mechanisms that can explain the resolved literacy difficulties of these high-functioning adults (Parilla et al., 2007), agreeing with the twice-exceptionality view. Yet, the studies do not provide an account of how these compensatory mechanisms may work.

Current study

We investigated whether compensation is a plausible explanation for resolving dyslexia in Dutch gifted secondary-school students with a dyslexia diagnosis. The possible explanations for resolving dyslexia, resolving underlying deficits versus compensation, were tested by comparing profiles of

underlying dyslexia-related risk factors and giftedness-related protective factors relevant for literacy development in gifted students with and without current literacy impairments. Groups were matched on general IQ, as we were not interested in overall effects of intelligence. Children who go on to become dyslexic already show differences in, for example, language skills from those who do not succumb to severe reading problems (van Viersen et al., 2017; Snowling & Melby-Lervåg, 2016). Matching on general intelligence still allows for the presence of underlying differences between verbal and performance IQ or associated subskills.

We hypothesize that, in the core-deficit view, gifted students with resolving dyslexia show higher performance on dyslexia-related risk factors than students with persistent dyslexia—in line with the differences in their literacy levels. Significant differences on possible protective factors were not expected following this view. In the twice-exceptionality view, the two groups would show equally low performance on dyslexia-related risk factors, whereas the resolving group would show *higher* performance on (a subset of) giftedness-related protective factors than the persistent group. Using case series, we also investigated numbers and combinations of strengths and deficits within students of both groups. In the core-deficit view, students with resolving dyslexia would show lower numbers and fewer combinations of deficits than students with persistent dyslexia, combined with comparable numbers and combinations of strengths. In the twice-exceptionality view, students in both groups would be comparable in their numbers and combinations of deficits but with higher numbers and more combinations of strengths in students with resolving dyslexia.

Method

Participants

The sample included 36 Dutch native-speaker Grade 7 and 8 students. Participants came from a larger sample that was recruited through contacts with regular secondary schools, clinicians, (remedial) teachers, and calls on educational blogs and websites for parents and/or professionals. Active written informed consent was obtained from students and parents. Students were considered gifted when full IQ-score was 120 or higher or fell within the 95% reliability interval around a score of 125 (116–131) in case of a short form (see the Instruments section). In addition, students had been diagnosed with dyslexia at some point during their school career by a licensed educational psychologist following a response-to-intervention protocol, established in 2008 (Kleijnen et al., 2008; SDN, 2016), matching the criteria for dyslexia used in the current study (see next). Current reading and spelling levels were assessed to determine whether the literacy impairments persisted or were resolved. Criteria for dyslexia were (a) a word-reading score below the 10th percentile (standard score ≤ 6) or (b) a word-reading score below the 15th percentile (standard score ≤ 7) *and* a spelling score below the 10th percentile (stanine ≤ 2). Subsequently, two groups (resolved, *n* = 18, 77.8% boys; persistent, *n* = 18, 55.6% boys) were formed and matched on total IQ-score and age so that both groups were comparable on these variables (*p* = .28 and *p* = .54) but differed significantly in word-reading and spelling levels (Table 1).

Instruments

Intelligence
Intelligence was assessed using four subtests of the *Wechsler Intelligence Scale for Children NL–Third Edition* (Kort et al., 2005; Wechsler, 1991): vocabulary and similarities (verbal abilities) and block design and picture arrangement (performance abilities). Total IQ-scores were computed using Kaufman, Kaufman, Balgopal, and McLean (1996)'s formula for this short form. Reliability and validity quotients are all reported to be greater than .83 (Kaufman et al., 1996). Giftedness was established using the reliability interval around an IQ-score of 125 (i.e., 116–131) instead of a single cutoff score for the short form, because the short form covers fewer cognitive areas. Students'

Table 1. Descriptives for age, IQ score, literacy measures, and risk and protective factors per group.

	Persistent				Resolving						
Variable	M	SD	Min	Max	M	SD	Min	Max	t	df	p
Age (months)	156.39	7.37	142.00	169.00	154.61	9.82	134.00	170.00	0.62	34	.543
IQ (total)[a]	130.22	5.84	121.00	144.00	132.39	6.11	121.00	142.00	−1.09	34	.284
Verbal IQ[b]	14.12	1.96	9.50	18.00	16.00	1.71	11.50	18.00	−2.98	32	*.006*
Nonverbal IQ[b]	14.47	1.43	12.00	17.00	13.82	1.06	11.50	15.50	1.50	32	.144
Literacy											
Word reading[b]	6.28	3.16	1.00	12.00	9.89	1.64	7.00	14.00	−4.30	25.55	*< .001*
Nonword reading[b]	5.00	2.45	1.00	10.00	9.06	1.16	7.00	11.00	−6.35	24.28	*< .001*
Spelling[c]	2.72	1.91	1.00	6.00	4.56	1.58	2.00	7.00	−3.14	34	*.003*
Text reading[d]	123.03	32.40	65.24	192.19	137.19	16.68	108.54	171.69	−1.65	34	.108
Risk factors											
PA deletion[b]	6.71	2.16	3.70	10.30	6.73	2.45	3.90	11.20	−0.03	34	.977
PA spoonerism[b]	8.32	3.30	1.00	13.90	9.87	2.27	7.50	15.80	−1.64	34	.110
Nonalphanumeric RAN[b]	8.56	2.22	4.00	12.50	9.78	3.56	2.00	16.50	1.24	34	.225
Alphanumeric RAN[b]	6.94	1.79	4.00	11.50	8.08	2.68	3.00	13.00	−1.50	34	.143
VSTM[a]	98.44	12.64	82.00	127.00	104.61	10.91	88.00	136.00	−1.57	34	.126
Protective factors											
Verbal WM[a]	102.22	13.10	84.00	124.00	117.11	12.41	80.00	136.00	−3.50	34	*.001*
Visuospatial STM[a]	123.61	16.42	100.00	144.00	131.61	12.54	100.00	144.00	−1.64	34	.110
Visuospatial WM[a]	115.50	16.62	86.00	139.00	118.44	19.85	86.00	149.00	0.48	34	.633
Grammar[b]	9.67	3.09	1.00	14.00	12.56	2.46	6.00	16.00	−3.11	34	*.004*
Vocabulary[b]	112.33	11.40	95.00	138.00	117.39	10.13	93.00	136.00	−1.14	34	.169

Note. n = 34 (17;17) for the verbal and nonverbal IQ scores because for one participant only full-scale scores instead of separate subtest scores were available. The p values in italics are significant at α = .05. Degrees of freedom less than 34 indicate adjustment for unequal variances. PA = phonological awareness; RAN = rapid automatized naming; VSTM = verbal short-term memory; WM = working memory; STM = short-term memory.
[a]Standard score (M = 100, SD = 15). [b]Standard score (M = 10, SD = 3). [c]Stanine score on a scale from 1 to 9. [d]Number of words read correctly per minute.

cognitive abilities were not reassessed if complete test results (10 subtests) not older than 2 years were available. If so, the cutoff for giftedness was set at a full IQ-score at 120 or higher.

Literacy

(Non)word-reading fluency was assessed using *Eén Minuut Test* (Brus & Voeten, 1999) and *Klepel* (van den Bos, lutje Spelberg, Scheepstra, & de Vries, 1994). Students had 1 (words) and 2 (nonwords) min to read as many (non)words as possible. Item length increased from one to four syllables for both tests. Raw scores were the number of (non)words read correctly within the time constraint, with a maximum of 116 for each test. Raw scores are also transformed into norm-based standard scores (M = 10, SD = 3). Internal consistency is .90 for Eén Minuut Test and .92 for Klepel (Evers et al., 2009-2012).

Spelling ability was assessed using a sentence dictation (Henneman & Kleijnen, 2005). The dictation includes 10 sentences of increasing length and difficulty about the "Dutch weather." Raw scores are the number of words spelled correctly, which were also transformed into norm-based stanine scores (scale 1–9).

Text-reading fluency was measured using an informative text of 1023 words about the dangers of a tick bite (Henneman & Kleijnen, 2005). Students were asked to read the text out loud. Reading time and number of errors were recorded and transformed into number of correctly read words per minute.

Phonology

PA, the ability to quickly analyze and manipulate phonemes in spoken words, was assessed using two subtests from the *Fonemische Analyse Test* (van den Bos, lutje Spelberg, & de Groot, 2011). Both covered 12 items. In the deletion task, students had to remove a target phoneme from a spoken word and say the resulting (non)word (e.g., *kraal* "bead" without /k/ is *raal*). In the spoonerism task, students had to transpose the onset phonemes of two words (e.g., *Kees Bos* to *Bees Kos*). Raw response times in seconds and accuracy scores were recorded and norm-based standard scores were

computed per subtest ($M = 10$, $SD = 3$). Number of correct answers per minute was used for the analyses. Internal consistency of the test is .93 (Evers et al., 2009–2012).

Naming speed was assessed with *Continu Benoemen & Woorden Lezen* (van den Bos & lutje Spelberg, 2007). In four subtests (colors, digits, pictures, and letters), students had to correctly name 50 items as quickly as possible. Each subtest had five items (e.g., red, yellow, blue, green, and black). Outcomes were naming times in seconds per subtest and norm-based standard scores ($M = 10$, $SD = 3$). Raw naming scores were combined into a mean alphanumeric RAN (digits and letters) and nonalphanumeric RAN (colors and objects) score. Internal consistency of the subtests varies between .79 and .87 (Evers et al., 2009-2012).

VSTM was measured with the digit recall subtest of the *Automated Working Memory Assessment* battery (Alloway, 2007). Students had to recall digits in series of increasing length in the correct order. Subtests in this test battery are discontinued after three incorrect answers. Number of correctly recalled series of digits was the raw score used in the analyses. Age-referenced norm scores were available ($M = 100$, $SD = 15$) for the case series. Test–retest reliability of this subtest is .89 (Alloway, Gathercole, Kirkwood, & Elliot, 2009).

Working memory

Visuospatial short-term memory (VSSTM) and verbal and visuospatial working memory (VSWM) were assessed with the *Automated Working Memory Assessment* battery (Alloway, 2007). Verbal working memory (WM) was measured using backward digit recall. Students had to recall increasing series of digits backward. VSSTM was assessed using the dot matrix subtest. Students had to recall the position of increasingly difficult series of red dots in an empty matrix. VSWM was measured using odd-one-out. Students had to indicate the odd figure in increasingly complex sequences of three figures and then recall the sequences of odd figures in an empty matrix in the right order. Raw scores were the number of correct items per subtest and used in the analyses. Norm-based standard scores ($M = 100$, $SD = 15$) were derived for the case series. Test–retest reliabilities of the subtests were .86, .85, and .88, respectively (Alloway et al., 2009).

Language

Grammar skills were assessed using the formulated sentences subtest of the *Clinical Evaluation of Language Fundamentals-4 NL* (Kort, Schittekatte, & Compaan, 2010). Students had to formulate grammatically correct sentences about actions or situations displayed in drawn pictures using a target word or phrase. Raw accuracy scores were used in the analyses and could also be transformed into norm-based standard scores ($M = 10$, $SD = 3$). Internal consistency of the subtest is .78 (Evers et al., 2009–2012).

Receptive vocabulary was measured with the *Peabody Picture Vocabulary Test NL* (Dunn & Dunn, 1997; Schlichting, 2005). Stimulus words were presented verbally. Students had to choose the picture showing the right meaning of the word out of four alternatives. The test consists of 17 sets of 12 words. The test starts with the entry set that corresponds to the student's age. The test is terminated after nine or more incorrect answers within one set. Raw scores were also transformed into norm-based standard scores ($M = 100$, $SD = 15$). Reliability has been evaluated as good (Egberink, Holly-Middelkamp, & Vermeulen, 2017).

Procedure

Students were assessed by trained and supervised (under)graduate students. Students were tested in the first half of the school year during a 2- to 3-hr session at school, home, or in a clinic. Ample breaks were provided between tests, both scheduled and on request. Test results were combined into a short report, evaluated by a licensed educational psychologist, and provided to the parents of the students. The study was conducted following the ethical principles of the Faculty of Social and Behavioral Sciences of Utrecht University, adhering to international standards.

Analyses

Group comparisons

We compared the gifted/dyslexic students with and without current literacy impairments on their phonological, WM, and language skills, using Bayesian model selection (the Bayesian alternative for frequentist multivariate analysis of covariance). Benefits of this approach compared to traditional methods have been reported before (van Viersen et al., 2015, 2017). In short, informative hypotheses using (in)equality constraints between group means were used to test and compare the competing hypotheses formulated earlier (Klugkist, Laudy, & Hoijtink, 2005; Table 2). Each informative hypothesis is tested against the alternative hypothesis, resulting in a Bayes Factor (BF). A BF represents the amount of evidence favoring one hypothesis compared to another (Kass & Raftery, 1995). A BF smaller than one represents evidence in favor of the alternative hypothesis. A BF larger than one indicates support for the informative hypothesis. A BF can also be interpreted as a measure of effect size (1–3 = small, 3–10 = medium, > 10 = large; Kass & Raftery, 1995). Competing hypotheses can be compared using the posterior model probability (PMP) for each hypothesis. The PMP indicates the relative amount of support for a specific hypothesis within a set of hypotheses (Klugkist, van Wesel, & Bullens, 2011). A difference of .05 or smaller between PMPs will not be interpreted and treated as equal support for both hypotheses in this study.

The BIEMS software package (Mulder, Hoijtink, & de Leeuw, 2012; Mulder, Hoijtink, & Klugkist, 2010; Mulder et al., 2009) was used for the analyses. Analyses were run using uninformative flat priors, as there is insufficient prior information available about the characteristics of our specific population to determine specific prior distributions (van de Schoot & Depaoli, 2014). All available knowledge was used to establish (in)equality constraints between group means and formulate informative hypotheses. Prior probabilities were thus assumed to be equal for all models under investigation. The Markov chain Monte Carlo sampling rate was set at the default of 20.000 iterations. After model specification, an unconstrained default prior (i.e., conjugate expected-constrained posterior prior (CECPP); Mulder et al., 2012) was generated and prior means of beta and prior covariance matrix were inspected before calculating the BFs and PMPs for the specific models.[1] Age and IQ were included as covariates.

Case series

Individual data on profiles of cognitive risk and protective factors within the gifted students with persistent and resolving dyslexia was investigated using case-series analysis. The cutoff for cognitive risk factors was set at 1 SD below the norm-based mean, indicating weak performance. This criterion has been applied in other case-series studies (Nag & Snowling, 2011; Ramus et al., 2003; van Viersen et al., 2015). The cutoff for

Table 2. Investigated models, statistical hypotheses, and translation for Bayesian analyses.

Model	Statistical Hypothesis	Translation
Risk factors		
Model 0	μ_R, μ_P	Alternative hypothesis or unconstrained model
Model 1	$\mu_R > \mu_P$	Core-deficit view: Gifted students with resolving dyslexia have higher scores on the cognitive risk factors than the gifted students with persistent dyslexia, indicating less severe deficits in the non-impaired group.
Model 2	$\mu_R = \mu_P$	Twice-exceptionality view: Both groups have approximately equal scores on the cognitive risk factors, indicating that the groups have equally severe underlying deficits.
Protective factors		
Model 0	μ_R, μ_P	Alternative hypothesis or unconstrained model
Model 1	$\mu_R > \mu_P$	Twice-exceptionality view: Gifted students with resolving dyslexia have higher scores on the cognitive protective factors than the gifted students with persistent dyslexia, indicating more pronounced strengths in the non-impaired group.
Model 2	$\mu_R = \mu_P$	Core-deficit view: Both groups have approximately equal scores on the cognitive protective factors, indicating that the groups are comparable in their underlying strengths.

Note. μ represents the group mean. P = persistent dyslexia; R = resolving dyslexia.

cognitive protective factors was set at 1 *SD* above the norm-based mean, indicating strong performance (van Viersen et al., 2015). In addition, broader strengths and weaknesses in dyslexia- and giftedness-related cognitive domains were mapped by combining information on individual factors. Consequently, below-average performance on either or both the deletion and spoonerism tasks was considered a weakness in PA, whereas below-average performance on either or both alphanumeric RAN and nonalphanumeric RAN was counted as a weakness in RAN. In contrast to PA and RAN, VSTM could be mapped both as a risk or a protective factor, as VSTM might not be impaired in gifted students (van Viersen et al., 2015). Above-average performance, indicating a protective factor, on either or both VSTM and verbal WM represented a strength in verbal WM-abilities, whereas above-average performance on either or both VSSTM and VSWM indicated a strength in visual WM-abilities. Above-average performance on either or both grammar and vocabulary was considered a strength in language. Proportions of risk and protective factors, as well as broader strengths and weaknesses, were compared between groups using chi-square tests adjusted for small samples.

Results

Group comparisons

For the *risk factors*,[2] the results of the multivariate analyses show that Model 1 (resolving > persistent) received most support from the data, about 3 times more than the alternative model (no constraints; see Table 3). These findings are supported by univariate results for the spoonerism task and for alphanumeric RAN (PMPs = .52 and .44). The posterior means of the unconstrained model indicate higher performance on these tasks for the resolving group than for the persistent dyslexia group. For VSTM, Model 1 and 2 (resolving = persistent) were both equally supported by the data (ΔPMP < .05). The posterior means show a small difference in favor of the gifted students with resolving dyslexia. However, Model 2 received most support from the data for the deletion task and nonalphanumeric RAN (PMPs = .46 and .42), with the posterior means showing that both groups obtained comparable scores on these risk factors. Overall, the gifted students with persistent and resolving dyslexia are comparable on some but not all risk factors associated with dyslexia.

Table 3. PMs and PSDs adjusted for age and IQ and BFs and PMPs of the three models for the cognitive risk and protective factors of the gifted/dyslexic students with and without literacy impairments.

Skill/Component	Persistent[a]		Resolving[b]		Model 0 (μ_R, μ_P)		Model 1 $(\mu_R > \mu_P)$[c]		Model 2 $(\mu_R = \mu_P)$	
	PM	PSD	PM	PSD	BF	PMP	BF	PMP	BF	PMP
Risk factors										
Multivariate					1.00	.25	**3.27**	.56	0.80	.19
Univariate										
PA deletion	29.27	8.38	30.80	8.45	1.00	.23	1.32	.31	**1.95**	.46
PA spoonerism	9.09	1.76	11.48	1.81	1.00	.28	**1.83**	.52	0.70	.20
RAN alphanumeric[c]	24.78	0.64	23.73	0.64	1.00	.26	**1.68**	.44	1.10	.29
RAN nonalphanumeric[c]	38.51	2.44	37.71	2.41	1.00	.25	1.31	.33	**1.68**	.42
VSTM	28.79	0.85	29.61	0.86	1.00	.25	**1.51**	.38	**1.51**	.37
Protective factors										
Multivariate					1.00	.25	**4.76**	.74	0.07	.01
Univariate										
Verbal WM	14.94	0.48	18.10	0.48	1.00	.33	**2.00**	.66	0.02	.01
Visuospatial STM	30.06	1.32	30.62	1.31	1.00	.24	1.29	.31	**1.87**	.45
Visuospatial WM	24.65	1.99	24.73	2.02	1.00	.24	1.03	.25	**2.05**	.50
Grammar	32.23	1.03	35.15	1.05	1.00	.32	**1.96**	.62	0.20	.06
Vocabulary	152.01	7.29	155.09	7.35	1.00	.25	**1.60**	.40	1.36	.34

Note. μ represents the group mean. Boldface indicates BFs of models that received most support from the data. See Table 1 for the risk and protective factors' mean standard scores. PM = posterior mean; PSD = posterior standard deviation; BF = Bayes factor; PMP = posterior model probability; R = resolving dyslexia; P = persistent dyslexia; PA = phonological awareness; RAN = rapid automatized naming; VSTM = verbal short-term memory; WM = working memory; STM = short-term memory.
[a]$n = 18$. [b]$n = 18$. [c]$\mu_R < \mu_P$ for both RAN variables, because higher scores indicate slower naming speed.

Concerning *protective factors*,[3] the multivariate results show that Model 1 (resolving > persistent) received about 5 times more support than the alternative model (no constraints; see Table 3). The univariate results confirm that Model 1 received most support from the data for the verbal WM and language factors (PMPs = .40–.62). The posterior means indeed show higher scores for the resolved students on these protective factors than for the students with persistent dyslexia. In contrast, Model 2 (resolving = persistent) received most support from the data for both visuospatial memory factors, also about 2 times more than the alternative model (PMPs = .45 and .50). The posterior means show that both groups indeed obtained equal scores on VSSTM and VSWM. These results indicate that the gifted students with resolving dyslexia have specific and more pronounced strengths in language-related areas, including verbal WM, grammar, and vocabulary, than gifted students with persistent dyslexia.

Case series

The case-series analysis provides insight in the numbers of risk and protective factors and breadth/depth of strengths and weaknesses within students with persistent and resolving dyslexia (Tables 4 and 5). This analysis is based on the clinical cutoffs used in diagnostic assessment, shedding light on what profiles a diagnostician might encounter during assessment and thereby providing more information on the clinical characteristics of students with dyslexia.

For the *risk factors*, no significant differences appeared between groups in percentages of students with a PA-deficit (persistent = 83.3%; resolving = 66.7%, p = .26). In contrast, the group with persistent dyslexia had a higher percentage of students with a RAN-deficit (persistent = 94.4%; resolving = 61.1%, p = .02). This is largely in line with the group comparison results, indicating that both groups had equally severe deficits in some but not all dyslexia-related risk factors. An exception was alphanumeric RAN, on which the resolving group outperformed the students with persistent dyslexia. This finding corresponds to the somewhat lower percentage of students with a RAN-deficit in the resolving group. The results for VSTM show that percentages for both the number of deficits (persistent = 5.6%; resolving = 0.0%, *ns*) and the number of strengths (persistent = 11.1%; resolving = 11.1%, *ns*) are very low in both groups. The influence of VSTM as a risk factor over and above RAN and PA thus seems very limited in gifted students with dyslexia.

Regarding the total number of weaknesses in dyslexia-related cognitive areas, both groups showed equal percentages of students with zero (persistent = 5.6%; resolving = 5.6%, *ns*) or three weaknesses (persistent = 5.6%; resolving = 0.0%, *ns*). However, gifted students with persistent dyslexia less often had a weakness in only one area (persistent = 11.1%; resolving = 61.1%, p = .002) and were more likely to have two weaknesses compared to the gifted students with resolving dyslexia (persistent = 77.7%; resolving = 33.3%, p = .008).

For the *protective factors*, the results show a higher percentage of students with a strength in verbal WM-abilities in the resolving group than in the persistent group (persistent = 27.8%; resolving = 77.8%, p = .003). Percentages of students with a strength in visual WM-abilities (persistent = 66.7%; resolving = 83.3%, p = .26) and language skills (persistent = 55.6%; resolving = 77.8%, p = .16) were somewhat higher in the resolving group than in the persistent group, but differences were not significant.

Regarding the number of strengths in giftedness-related areas important for literacy development, both groups showed comparable percentages of students with zero (persistent = 5.6%; resolving = 0.0%, *ns*) or two strengths (persistent = 33.3%; resolving = 38.9%, *ns*). Yet, there were more students with a strength in only one area in the persistent group (persistent = 50.0%; resolving = 11.1%, p = .013), whereas the resolving-dyslexia group contained a higher percentage of students with strengths in three cognitive areas (persistent = 11.1%; resolving = 50.0%, p = .013). These findings correspond to the group-comparison results showing that gifted students with resolving dyslexia show more pronounced strengths in language-related areas, including verbal WM (See also Online Resource 1).

Table 4. Findings from the case series showing the cognitive risk and protective factors observed among gifted/dyslexic students with literacy impairments (persistent).

	Risk Factors					Protective Factors								
Case No.	PA Deletion SS < 8	PA Spoonerism SS < 8	RAN Alphanumeric SS < 8	RAN Nonalphanumeric SS < 8	VSTM SS < 85 / SS > 115	VWM SS > 115	VSSTM SS > 115	VSWM SS > 115	Grammar SS > 12	Vocabulary SS > 115	Literacy Composite[a]	IQ-Score	No. of weaknesses	No. of strengths
5							+	+		+	0.29	132	0	2
10	−		−		−		+	+			0.23	129	3	1
11	−		−				+			+	0.54	135	2	2
17	−		−								−0.47	132	2	0
36	−		−	−					+		0.26	130	2	1
39	−		−				+				0.47	124	2	1
40	−	−	−	−			+	+			0.03	126	2	1
42	−	−	−				+	+		+	−0.98	131	2	2
47	−		−							+	0.06	129	2	1
58	−	−	−	−			+		+		−1.40	122	2	2
79	−	−	−			+	+	+		+	0.09	131	2	2
86		−	−			+					0.29	134	2	1
87	−		−	−			+	+			−0.99	138	2	1
98	−		−	−			+			+	−0.34	135	2	2
121			−						+	+	0.07	127	1	2
127	−	−	−	−	+	+	+	+	+	+	0.51	124	2	3
137				−		+		+			0.38	121	1	1
153	−		−		+	+					0.98	144	2	1
Total	14	6	16	7	1/2	5	11	8	4	8	0.00	130.22	1.83	1.50

Note. A − (minus) indicates a standard score ≤ 1 SD below the mean (risk factor), whereas a + (plus) indicates a standard score ≥ 1 SD above the mean (protective factor). Empty cells indicate scores within 1 SD of the mean (neither risk nor protective factor). PA = phonological awareness; SS = standard score; RAN = rapid automatized naming; VSTM = verbal short-term memory; VWM = verbal working memory; VSSTM = visuospatial short-term memory; VSWM = visuospatial working memory.
[a]Literacy composite represents the average z-score of the Eén Minuut Test and Klepel standard scores and dictation stanine score.

Table 5. Findings from the case series showing the cognitive risk and protective factors observed among gifted/dyslexic students without literacy impairments (resolving).

	Risk Factors					Protective Factors									
Case No.	PA Deletion SS < 8	PA Spoonerism SS < 8	RAN Alphanumeric SS < 8	RAN Nonalphanumeric SS < 8	VSTM SS < 85	VSTM SS > 115	VWM SS > 115	VSSTM SS > 115	VSWM SS > 115	Grammar SS > 12	Vocabulary SS > 12	Literacy Composite[a]	IQ-Score	No. of Weaknesses	No. of Strengths
4	−						+	+	+	+		0.28	135	1	3
6			−	−			+	+	+	+	+	1.22	132	1	3
14								+		+	+	0.46	135	0	2
16	−		−	−			+	+	+			−0.32	138	2	3
18				−				+	+	+	+	0.40	121	1	2
65	−						+	+		+		−0.19	130	1	2
66	−		−	−				+		+	+	−0.39	132	2	2
71	−	−		−			+				+	1.00	132	2	3
95	−						+	+		+	+	0.02	132	1	2
104	−		−				+	+	+			−0.11	122	2	1
105	−		−				+		+		+	−0.31	132	2	2
107	−						+	+	+		+	−0.65	138	1	3
120			−				+	+	+	+	+	0.60	142	1	3
128			−			+	+	+	+	+		−0.59	122	1	3
139			−				+	+	+			−1.01	135	1	2
140	−											−1.10	129	1	1
141	−		−	−			+	+		+	+	0.24	142	2	3
170	−					+	+	+	+	+	+	0.46	134	1	3
	12	1	9	6	0/2		14	15	11	11	11	0.00	132.39	1.27	2.39

Note. A − (minus) indicates a standard score ≤ 1 SD below the mean (risk factor), whereas a + (plus) indicates a standard score ≥ 1 SD above the mean (protective factor). Empty cells indicate scores within 1 SD of the mean (neither risk nor protective factor). PA = phonological awareness; SS = standard score; RAN = rapid automatized naming; VSTM = verbal short-term memory; VWM = verbal working memory; VSSTM = visuospatial short-term memory; VSWM = visuospatial working memory.
[a]Literacy composite represents the average z-score of the *Eén Minuut Test* and *Klepel* standard scores and dictation stanine score.

Discussion

Two possible explanations for resolving dyslexia were investigated, one assuming resolving under-lying deficits (core-deficit view; Stanovich & Siegel, 1994) and the other compensation (twice-exceptionality view; Foley Nicpon et al., 2011). The participants of this study were seventh- and eighth-grade students with a dyslexia diagnosis and high IQ. The exceptional cognitive strengths of these students might allow for the development of compensatory mechanisms. Comparing cognitive strengths and weaknesses of gifted students with and without current literacy impairments thus provides a test case to assess why dyslexia resolves in some students. Following the core-deficit view, students with resolving dyslexia were hypothesized to have less severe, lower numbers, and fewer combinations of dyslexia-related deficits than students with persistent dyslexia. Both groups would be largely comparable on their profiles of intelligence-related cognitive strengths. In the twice-exceptionality view, both groups would have similar cognitive deficits, but the resolving group would have more pronounced, higher numbers, and more combinations of cognitive strengths relevant for literacy development than the persistent group.

The group comparisons indicated mixed results on the dyslexia-related risk factors. Gifted students with resolving dyslexia performed better on the spoonerism task, a measure of PA, and on alphanumeric RAN than gifted students with persistent dyslexia. Yet, the resolving and persistent groups showed comparably low performance on the other PA task and nonalphanumeric RAN. There were no differences between groups on VSTM, agreeing with other results on gifted samples (van Viersen et al., 2015). The risk-factor findings do not provide clear support for either the core-deficit view or the twice-exceptionality view: Both groups had equal scores on two tasks, in line with the twice-exceptionality view, but resolvers had higher scores on two other tasks, in line with the core-deficit view. Regarding alphanumeric RAN, the higher performance of resolvers is not surpris-ing. Alphanumeric RAN is more strongly related to reading than nonalphanumeric RAN (van den Bos, Zijlstra, & lutje Spelberg, 2002). The alphanumeric-RAN performance of the gifted students with resolving dyslexia is in line with their higher literacy levels, supporting the core-deficit view for this risk factor. However, why the results on the PA risk factors differ between tasks is less clear. Given that students can delete more phonemes correctly per minute than transpose phonemes, task difficulty could be an issue. Although the findings for the spoonerism task would fit the hypothesis of the core-deficit view, the mixed results for PA warrant caution.

For the protective factors, group comparisons favored the twice-exceptionality view. The gifted students with resolving dyslexia outperformed those with persistent dyslexia on verbal WM, vocabu-lary, and grammar. Both groups were comparable on visuospatial-memory components. Accordingly, gifted students with resolving dyslexia consistently show specific strengths in a verbal subset of protective factors relevant for literacy development. This finding is particularly noteworthy because both groups were gifted, implying that their language abilities were in the narrow upper range of the distribution. Despite this small ability range and group matching on general IQ, we did observe differences in literacy-related skills. These strengths have limited relevance for resolving of dyslexia according to the core-deficit view but provide support for the twice-exceptionality view. Overall, the group-level results showed that although some underlying deficits may resolve slightly over time, this does not hold for all deficits. Furthermore, the language-related strengths in students with resolving dyslexia support the possibility that compensation decreases their reading and spelling problems.

The case-series analysis largely confirmed the group-level findings for the risk factors, providing mixed support for the twice-exceptionality and core-deficit views. There were comparable percen-tages of PA deficits in the persistent and resolving groups. Similar to the group-level results, this number was primarily driven by low performance on the deletion task for most students. The lower percentage of students with RAN deficits in the resolving group is interesting. The individual profiles indicate that this is not driven by fewer deficits in alphanumeric RAN, as might be expected based on the group analyses, but by fewer deficits in nonalphanumeric RAN in the resolving group. Combinations of deficits were in accordance with the patterns for the separate deficits, with more

single deficits and fewer double deficits in the resolving group than in the persistent group. VSTM was a factor of no significance for profiles of cognitive weaknesses associated with dyslexia in gifted students (see also van Viersen et al., 2015, 2016). In all, dyslexia-related deficits largely remain present in students with resolving dyslexia, despite their higher literacy levels.

The case-series findings on protective factors are more mixed than those of the group comparisons. In the resolving group the percentage of students with a verbal WM strength was clearly higher and strengths in visual WM and language skills were somewhat higher. However, the indication from the group analyses that mainly language-related skills (verbal WM, vocabulary, and grammar) may function as a source for compensatory mechanisms is not fully supported by the case-series analysis and was not found previously (van Viersen et al., 2015). The groups are comparable in percentage of students with strengths in two areas, whereas the resolving group contains more students with a strength in visuospatial skills, as well as more students with strengths in all three areas. Yet, the findings generally point toward more pronounced cognitive strengths in students with resolving dyslexia, supporting the twice-exceptionality view.

The findings of previous studies on resolving dyslexia as well as compensation in gifted children with dyslexia were generally in line with the core-deficit view (Torppa et al., 2015; van Viersen et al., 2015). This study is one of the first to indicate some support for the twice-exceptionality view on compensation, across risk and protective factors and both at the group and individual level. Unlike Torppa et al. (2015), we found no indications that a resolving developmental delay in underlying skills was fully responsible for improved literacy levels of the students with resolving dyslexia. In our sample of gifted students, poorer literacy outcomes were associated with more severe deficits to some extent, providing some support for the core-deficit view. However, most students with resolving dyslexia still had persistent PA deficits, and more than half of the students in this group still showed RAN impairments. This is in line with the twice-exceptionality view (see also Table 1).

The results showed that gifted students with resolving dyslexia possess specific strengths relevant for literacy development. Although our findings on resolving dyslexia could be suggested to result *only* from the somewhat less severe underlying risk factors, particularly in alphanumeric RAN, we contend that *both* risk and protective factors matter in literacy development and dyslexia. Our findings on the specific language-related strengths suggest that compensation could be responsible for the resolving literacy difficulties, at least in gifted students. As this study was cross-sectional, it cannot be assessed whether the language skills of the resolvers were stronger from the beginning of reading instruction or whether they developed because these students became better readers with more reading experience. Especially reading experience could explain higher PA and vocabulary levels in the resolving students: It has been found that there are bidirectional relationships between reading and PA and reading and vocabulary. Nevertheless, the present findings are an important starting point for further research. The finding of language-related strengths in the resolvers calls for further experimental and longitudinal research on how such strengths can lead to higher (non)word reading ability, also including measures of literacy experience.

The finding that, unlike the results of other studies (Grades 7–8; van Viersen, 2017, Grades 2–4; van Viersen et al., 2015, 2016), students with resolving dyslexia might compensate could be due to the older age of the students involved in this study. Compensatory mechanisms most likely need to develop and may depend on effects of exposure or educational experience. Elbro (2010), for example, found that the relation between verbal IQ and word-reading fluency increases over time. Compensatory mechanisms based on protective factors in the verbal area may thus not start to develop up to a certain age or acquisition level, when there is an *opportunity* to compensate. The development of mechanisms based on these strengths might also depend on the current demands that are placed on reading processes. Compensation may become necessary only when the demands increase and exceed the level of skill of the students, when there is a *need* to compensate. More detailed insights in the way reading processes work in different age groups and the role of cognitive strengths in specific areas is needed to gain more knowledge about how compensatory mechanisms might influence literacy.

Our findings have implications for current practices in diagnosing dyslexia. Although (poor) reading ability tends to be highly stable over time (Landerl & Wimmer, 2008; van Viersen et al., 2018), the dyslexia diagnosis clearly is not. Torppa et al. (2015) raised the issue of missing a diagnosis when dyslexia is late-emerging and early identification is the norm, but our findings require us to also address the opposite. If early identification is the norm, and dyslexia could indeed be compensated in some cases, should the diagnosis remain valid indefinitely? This is an important question given the impact of a diagnosis and the availability of—and students' subsequent dependency on—services that come with a diagnosis. Periodically reassessing diagnosis and services provided may be considered best practice, but in reality this is rarely done. An alternative could be that the dyslexia diagnosis remains valid but the services that students require are reevaluated and updated periodically. Of course, it is important to follow students who seem to no longer need these services and check whether the dyslexia resurfaces, especially during crucial educational changes such as learning foreign languages.

Another implication is that the role of protective factors cannot be ignored during diagnosis and intervention. Currently, the main focus is on identifying underling deficits and remediating the difficulties at the word level. Yet, obtaining a comprehensive overview of the weaknesses and the strengths relevant to the literacy difficulties of the student is essential. Cavalli et al. (2017) found a dissociation between phonological and morphological awareness in students with dyslexia, indicating that morphological awareness is one of the factors that should be assessed as a possible compensatory factor. A protective-factor approach provides information not only about the specific underlying causes of the dyslexia but also about the student's resilience (Haft et al., 2016). The (possible) strengths a student possesses should be included in the dyslexia treatment, whether they are already present or still need to be developed. Including broader factors, such as language comprehension and grammar, also allows for focusing more on the literacy skills that students need in their future school career, such as text reading and writing.

A limitation of this study is the small size and restricted population used to investigate explanations for resolving dyslexia. Our findings on a possible role for protective factors in the development of compensatory mechanisms are based on a group of students with extraordinary talents and cognitive resources. Although targeting this special group is valuable, it is unclear whether these effects can also occur in other groups of students with dyslexia. Data on children with special strengths that are not necessarily gifted in general are thus important next steps. Future research should, for example, establish the level of strength that is required for a protective factor to be of use and further investigate their influence on reading processes. After all, the current study did not provide any insight into *how* the presence of cognitive strengths may lead to higher literacy levels, or how compensatory mechanisms come into play. Unraveling how compensatory mechanisms may work and develop might yield a new way of looking at treatment of dyslexia and aid intervention practices.

Notes

1. The high standardization of input (e.g., starting values) and the straightforward estimation procedure used in BIEMS assure easy convergence of the models under investigation. Therefore, provided output on prior and posterior distributions as well as convergence diagnostics is limited (see Mulder et al., 2012).
2. Model 1 is favored over Model 2 for the core-deficit view, whereas Model 2 is favored over Model 1 for the twice-exceptionality view (Table 2).
3. Model 1 is favored over Model 2 for the twice-exceptionality view, whereas Model 2 is favored over Model 1 for the core-deficit view (Table 2).

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Disclosure of potential conflicts of interest

The authors declare that they have no conflict of interest.

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