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DOI
10.1177/0022219414538517

Publication date
2016

Document Version
Final published version

Published in
Journal of Learning Disabilities

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J Learn Disabil published online 16 June 2014
DOI: 10.1177/0022219414538517

Hammill Institute on Disabilities

Journal of Learning Disabilities
1–11

DOI: 10.1177/0022219414538517
journaloflearningdisabilities.sagepub.com
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High Reading Skills Mask Dyslexia in Gifted Children

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Abstract

This study investigated how gifted children with dyslexia might be able to mask literacy problems and the role of possible compensatory mechanisms. The sample consisted of 121 Dutch primary school children that were divided over four groups (typically developing [TD] children, children with dyslexia, gifted children, gifted children with dyslexia). The test battery included measures of literacy (reading/spelling) and cognitive abilities related to literacy and language (phonological awareness [PA], rapid automatized naming [RAN], verbal short-term memory [VSTM], working memory [WM], grammar, and vocabulary). It was hypothesized that gifted children with dyslexia would outperform children with dyslexia on literacy tests. In addition, a core-deficit model including dyslexia-related weaknesses and a compensational model involving giftedness-related strengths were tested using Bayesian statistics to explain their reading/spelling performance. Gifted children with dyslexia performed on all literacy tests in between children with dyslexia and TD children. Their cognitive profile showed signs of weaknesses in PA and RAN and strengths in VSTM, WM, and language skills. Findings indicate that phonology is a risk factor for gifted children with dyslexia, but this is moderated by other skills such as WM, grammar, and vocabulary, providing opportunities for compensation of a cognitive deficit and masking of literacy difficulties.

Keywords

giftedness, dyslexia, twice-exceptionality, Bayesian statistics, working memory, literacy

Within the field of giftedness, there is increasing interest in understanding twice-exceptionality, the concomitant occurrence of giftedness and a learning disability (LD) within an individual (Brody & Mills, 1997). As the field of twice-exceptionality still heavily relies on anecdotal information, it is in need of empirical research to support evidence-based practices regarding the identification and education of gifted students with LD (Lovett & Lewandowski, 2006; Nielsen, 2002), and more information on individual exceptionalities is required (Foley, Allmon, Sieck, & Stinson, 2011). The present study aims to provide empirical data on the achievement and cognitive characteristics of gifted children with dyslexia, an LD characterized by severe reading and/or spelling difficulties (Vellutino, Fletcher, Snowling, & Scanlon, 2004). These empirical data will increase our understanding of both giftedness and dyslexia, as well as shed more light on the possibilities to mask underachievement and to compensate a cognitive deficit. These insights may provide a new step toward better identification and service of twice-exceptional children.

Although empirical data are not available, the estimates for the prevalence of giftedness and LD range from 1% to 5% of the total population of children with learning disabilities (McCoach, Kehle, Bray, & Siegle, 2004; Nielsen, 2002; Silverman, 1989), which is comparable to the prevalence in the general population. However, these estimates are based on a wide variety of definitions of giftedness and LD as well as twice-exceptionality and can be considered rather conservative (Nielsen, 2002). Moreover, many twice-exceptional children might remain undetected as they may not positively or negatively stand out compared to the general population (Nielsen, 2002). A lack of a concrete definition, underachievement, underestimation of intellectual abilities, and masking effects are considered as the main reasons for the problems with adequate identification and early intervention of twice-exceptionality (Brody & Mills, 1997; Foley et al., 2011; McCoach, Kehle, Bray, & Siegle, 2001).

In the present study the definition of McCoach et al. (2001) was used for twice-exceptionality: "Gifted/learning

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disabled students are students of superior intellectual ability who exhibit a significant discrepancy in their level of performance in a particular academic area" (p. 405). In addition, giftedness was defined as "high intelligence" or academic giftedness, which is typically classified with an IQ score greater than 130 (Winner, 1997). However, since the achievement–ability discrepancy has been heavily debated (e.g., Lovett & Lewandowski, 2006), it was used only to nominate children for participation in the study, as it is the only definition that leaves room for the possibility of masking or compensation of LD in a high IQ population (see Assouline, Foley, & Whiteman, 2010, for an elaborate discussion). Further inclusion was based on a comprehensive evaluation of a child's academic *and* cognitive strengths and weaknesses, integrating multiple sources of information, which may unveil specific underlying deficits needed for correct identification of LD, here dyslexia, in gifted children (Assouline et al., 2010; Brody & Mills, 1997; Lovett & Lewandowski, 2006; McCoach et al., 2001; Nielsen, 2002). Prior to focusing on the combination of giftedness and dyslexia, both elements will be introduced in more detail.

Dyslexia is defined as an LD characterized by severe reading and/or spelling difficulties at word level (Snowling, 2000). Depending on the transparency of a language's orthography, reading difficulties are marked by either poor accuracy or slowness in naming of words (Frith, Wimmer, & Landerl, 1998). Nonword reading is particularly impaired and often seen as the first indicator of broader underlying decoding problems (Griffiths & Snowling, 2002; Van den Bos & Scheepstra, 1993). One of the main cognitive deficits proposed to underlie dyslexia is a phonological deficit leading to difficulties in connecting sounds to letters (Vellutino et al., 2004), but the breadth/range of phonological areas involved is still under investigation. According to Snowling (2000), phonological awareness (PA), verbal short-term memory (VSTM), and rapid automatized naming (RAN) tasks are a reflection of the phonological skills demanded for successful literacy acquisition. Although it is still a matter of debate whether RAN should be viewed as part of the phonological deficit, there is convincing evidence showing that RAN is related to reading skills (e.g., Vaessen, Gerretsen, & Blomert, 2009; Warmington & Hulme, 2012).

Gifted children often show specific academic and cognitive strengths that are relevant in relation to the weaknesses associated with dyslexia described above. Even though the relation between IQ and reading achievement is not perfect (Naglieri, 2001; Vellutino, Scanlon, & Lyon, 2000), research on the literacy skills of gifted children has shown that most of them learn to read earlier than their peers do and have been reported to read at least two grade levels above their chronological grade (Kaplan, 1999). In addition, gifted children have been described as having textual information understanding capacities that are well above the level of their age-matched peers (Reis et al., 2004), as they use their advanced vocabulary and grammar to enhance understanding and accelerate their literacy development (Hoh, 2005). Gifted children rely on metacognitive skills, such as analysis, synthesis, and evaluation, while reading and automatically integrate prior knowledge and experience into their reading, allowing an intuitive development of reading skills (Catron & Wingenbach, 1986). Furthermore, gifted children display more efficient working memory (WM) and higher speed of processing than typically developing (TD) children (Alloway & Elsworth, 2012; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Dark & Benbow, 1991; Johnson, Im-Bolter, & Pascual-Leone, 2003). Several studies have shown that intelligence and WM are (highly) correlated, but they also form separate cognitive skills with unique contributions to learning outcomes (Ackerman, Beier, & Boyle, 2005; Alloway & Alloway, 2010; Conway, Kane, & Engle, 2003). WM was found to be the stronger predictor for academic progress in literacy (Alloway, 2009) and can therefore, besides general language abilities, be an important compensatory factor in the literacy development of gifted children with dyslexia. For gifted children, these precocious abilities allow them to make associations between words faster and more frequently and recall language facts from their memory faster, resulting in better performance on speeded tasks, such as timed word reading tests as well as RAN tasks (Dark & Benbow, 1991; Johnson et al., 2003).

It is as yet unknown how the combination of giftedness and dyslexia manifests itself within one child. However, we do know that dyslexia is an LD that can be found across intelligence levels, including high IQ children (Snowling & Hulme, 2012; see, e.g., Hatcher & Hulme, 1999; Vellutino et al., 2004, on the role of IQ in dyslexia). Moreover, previous research has shown that children displaying positive indicators for dyslexia such as academic underachievement, slow literacy development, and poor phonological skills need not necessarily have literacy problems that are severe enough to reach the diagnostic threshold (Miles, Wheeler, & Haslum, 2003; Snowling, 2008). This identification problem specifically arises with gifted or high-functioning children, whose reading deficits are proposed to be mild or compensated (Snowling & Hulme, 2012). Research on gifted children with LD in general has shown that the academic achievement of these students might not be as low as that of other students with LD; *average* achievement may be sufficient to suspect an underlying deficit (Assouline et al., 2010; Bireley, Languis, & Williamson, 1992; Brody & Mills, 1997). In addition, a student's giftedness and learning disabilities can both lie in related academic areas. For example, a student can show reading levels well above grade level but experience great difficulty with spelling and writing (Bireley et al., 1992; Brody & Mills, 1997).

At the cognitive level, it can be expected that both the underlying deficit(s) associated with dyslexia and the precocious abilities of gifted children that were described

above also occur in the cognitive profile of gifted children with dyslexia. Yet it is unknown how these specific strengths and weaknesses affect each other. Empirical research on cognitive characteristics of gifted children with LD in general has indicated that they show underlying perceptual and memory deficits in visual and auditory discrimination, sequencing, decoding skills, short-term auditory memory, and spatial abilities (Waldron & Saphire, 1990, 1992). In contrast, they show more advanced verbal abilities than nonverbal abilities, show high metacognitive skills, and rely more on verbal comprehension, reasoning, and abstract thinking (Assouline et al., 2010; Hannah & Shore, 2008; Waldron & Saphire, 1990). Generally, their WM and processing speed abilities are similar to those of their age mates (Assouline et al., 2010). However, these studies do not provide any information about the implications of certain patterns of cognitive strengths and weaknesses for the behavioral expression of a specific LD or possible compensatory mechanisms.

The present study tested the performance differences between groups to answer the question what the achievement and cognitive characteristics of gifted children with dyslexia are compared to children with dyslexia, TD children, and gifted children. The assessment battery used to measure performance covered five domains, that is, literacy, phonology, verbal and visuospatial WM, and language skills. Based on previous research, it was hypothesized that gifted children with dyslexia would show higher reading and spelling performance overall than the children with dyslexia, but lower performance than TD children and considerably lower than gifted children. In addition, a "core-deficit" model of dyslexia and a "compensational" model of giftedness were tested to explain group differences in reading and spelling performance. These models serve to illustrate that gifted children with dyslexia may have specific cognitive weaknesses that are related to their dyslexia, but also possess strongly developed skills that are related to their giftedness, which might form a compensatory mechanism for a cognitive deficit. Therefore, mapping the behavioral and cognitive profile of gifted children with dyslexia will shed more light on the possibility to compensate a phonological deficit and mask literacy difficulties. The data were analyzed using Bayesian statistics. This relatively novel method, described in more detail within the Main Analyses section, allows formulation and evaluation of informative hypotheses and has not been applied extensively in the area of special education yet (but see Kolkman, Hoijtink, Kroesbergen, & Leseman, 2013; see Klugkist, Laudy, & Hoijtink, 2005, for worked examples of Bayesian analyses).

Method

Participants

The sample consisted of 121 Dutch primary school children from Grades 2 to 4. Informed consent was obtained from all participants and their parents. The study consisted of four groups: (a) children with dyslexia (D; $n = 33$), (b) gifted children with dyslexia (GD; $n = 26$), (c) typically developing children (TD; $n = 31$), and (d) gifted children (G; $n = 31$). To be able to include as many twice-exceptional children as possible, children were first nominated for the gifted and dyslexia group based on a significant discrepancy between their IQ and reading and/or spelling ability of at least two standard deviations (Snowling, 1998). Subsequently, the three inclusion criteria for *both* dyslexia groups were in line with the criteria for an official diagnosis in the Netherlands (Kleijnen et al., 2008). Children had to show (a) at most average scores on both reading *and* spelling (standard score ≤ 12), (b) below average scores on reading *or* spelling (lowest 10–15%), and (c) below average performance on at least one of the three cognitive factors that have been proposed to underlie dyslexia: PA, RAN, and VSTM (standard score ≤ 7; Snowling, 2000). Of the 43 twice-exceptional children who were nominated based on a significant discrepancy, 26 children met the inclusion criteria for the GD group and 17 children turned out to be borderline cases (i.e., Criteria a and c were met, but they failed to meet Criterion b). The borderline cases were excluded from further analyses. Giftedness was defined as a high IQ score on a validated intelligence test (see Lovett & Lewandowski, 2006). The cutoff value was set at a full IQ score greater than 125 or a 95% reliability interval tapping at least 130 in case of a short form. Table 1 shows the age, intelligence, and sex in the four groups.

Table 1. Sample Size, Percentage of Boys, and Means and Standard Deviations for Age and IQ Score per Group.

			Age (Months)*		IQ (Total)*	
Group	*n*	% Boys	*M*	*SD*	*M*	*SD*
Dyslexia	33	48.5	113.85	12.39	98.70	11.41
Gifted + Dyslexia	26	65.4	108.77	8.14	132.50	8.05
Typically Developing	31	29.0	103.45	8.92	108.23	9.41
Gifted	31	41.9	100.58	10.43	134.10	8.95

*$p < .001$.

Out of the 33 children in the dyslexia group, 20 had an official diagnosis of dyslexia (60.6%); for the gifted and dyslexia group this was 13 of the 26 children (50.0%). This relatively low percentage is due to the fact that Dutch children at primary school are eligible for reimbursed treatment of dyslexia only if they meet strict criteria, including poor performance on nonword reading as well as an extensive period of remedial instruction prior to a possible diagnosis (Blomert, 2006). The latter criterion is most influential on the number of diagnoses in the current study because of the young age of the children in the sample. To address this issue, the children without a diagnosis all had to be referred

by their teachers based on relative academic underachievement and persistent and continuous problems with reading and/or spelling, and should have been *at least* in the process of being tested for dyslexia.

Instruments

Intelligence. To estimate the general cognitive abilities of the participants, a short form of the *Wechsler Intelligence Scale for Children III-NL* (Kort et al., 2005) was used, consisting of the similarities and vocabulary verbal subtests and the picture completion and block design performance subtests. The reliability and validity quotients are all reported to be greater than .83 (Kaufman, Kaufman, Balgopal, & McLean, 1996).

Literacy. Timed word reading was measured using the *Eén-minuut-test* (EMT; Brus & Voeten, 1999) and decoding speed of nonwords was measured using *Klepel* (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994). In these tests, the child has 1 or 2 minutes, respectively, to accurately read as many words as possible. Word length increases from one to four syllables. Raw scores are the number of correctly read words or nonwords, with a maximum of 116 words. Internal consistency is .90 for EMT and .92 for *Klepel* (Evers et al., 2009–2012).

Timed text reading was measured using the *AVI* (Visser, Van Laarhoven, & Ter Beek, 1996). In this test, the child has to read several texts that correspond in difficulty to grade levels (i.e., middle of Grade 1 to end of Grade 6). Both the reading time (seconds) and the number of errors are recorded. Scores on the highest mastery text were transformed into a number correct per minute ratio for the analyses. Reliability is evaluated as "acceptable" (Evers et al., 2009–2012).

Spelling at word level was measured using a short form of the *PI-dictee* (Geelhoed & Reitsma, 2000). The short form contains eight blocks of seven words, with each block representing specific spelling categories (P. F. De Jong, personal communication, September 2012). The test continues until the child makes six or more errors in one block. The raw score is the total number of correctly written words. Internal consistency of the full version varies between .90 and .93 (Evers et al., 2009–2012).

Phonology. PA was assessed using the *Fonemische Analyse Test* (Van den Bos, Lutje Spelberg, & De Groot, 2011). This is a computerized test measuring the ability to analyze and manipulate phonemes. The first subtest targets phoneme deletion (e.g., *kraal* "bead" without /k/ is *raal*), and the second subtest targets phoneme transposition (e.g., transposing onset phonemes of *Kees Bos* to *Bees Kos*). Raw response time and accuracy scores were transformed into a number correct per second ratio score for the analyses. Internal consistency of the test is .93 (Evers et al., 2009–2012).

RAN was measured using the *Continu Benoemen & Woorden Lezen* (Van den Bos & Lutje Spelberg, 2007). This test includes four subtests (colors, digits, pictures, and letters) assessing the child's naming speed. Average raw scores for the colors and pictures subtests and the digits and letters subtests were computed for the analyses, resulting in a "non-alphanumeric" score and an "alphanumeric" score. Internal consistency of the test varies between .79 and .87 (Evers et al., 2009–2012).

VSTM was measured by the subtest digit recall of the *Automated Working Memory Assessment* (AWMA) battery (Alloway, 2007). The subtest consists of several series of digits of increasing length that were presented through the computer and recalled by the child. Raw scores were used for the analyses. Test–retest reliability is .89 (Alloway, Gathercole, Kirkwood, & Elliot, 2009).

Working memory. WM was measured using subtests of the AWMA (Alloway, 2007). All WM subtests were discontinued after three incorrect answers. Verbal WM was measured using backward digit recall, in which the child recalled increasing series of digits backward. Raw scores were used in the analyses. Test–retest reliability of this subtest is .86 (Alloway et al., 2009).

Visuospatial WM was measured by two subtests. Spatial span demands the child to evaluate figures by mental rotation, classify them as "the same" or "opposite," and recall the place of a red dot in an empty figure. Odd-one-out requires the child to indicate in increasingly complex sequences which figure out of three is odd, and recall the odd figures in a matrix. The raw scores of the visuospatial subtests were combined into a composite score for the analyses. Test–retest reliabilities are .79 and .88, respectively (Alloway et al., 2009).

Language. Grammar and vocabulary were measured using the *Clinical Evaluation of Language Fundamentals–4–NL* (Kort, Schittekatte, & Compaan, 2010). The child's grammar skills were assessed by the subtest formulated sentences of the language structure index, in which the child formulates a sentence about visual stimuli using a targeted word or phrase. The word classes 2 subtest of the language content index, in which the child chooses two related words and describes their relationship, measured vocabulary. Raw scores were used for the analyses. Internal consistency of the subtests is .78 and .87, respectively (Evers et al., 2009–2012).

Procedure

Participants were recruited through advertisements on the websites of educational magazines and clinical institutions and through contacts with school psychologists. Trained and supervised graduate students performed the assessments using the test battery described above. All children

were tested in a clinic, at school, or in their homes within one session that lasted for 2 to 3 hours. After the assessment, the test results were summarized in a short report and evaluated by a licensed school psychologist. Any diagnostic uncertainties were resolved during joint evaluation meetings.

Analyses

Data screening. Missing data analyses showed several missing data points (i.e., *AVI* [4], digit recall [1], backward digit recall [1], visuospatial WM [1], grammar [3], and vocabulary [3]). Since the software for the analysis does not allow missing data and only 0.8% of the total number of data points in the analyses were missing (equally distributed across groups), single imputation based on the series mean was applied. The data contained no univariate or multivariate outliers. Further data screening showed no violations of assumptions for multivariate analysis of variance. Finally, since the age of the children was not equally distributed across groups (see Table 1), this variable was centered and added to the analyses as a covariate.

Main analyses. Instead of using traditional frequentist analyses, Bayesian statistics were used to compare all four groups on literacy skills and cognitive components. Bayesian model selection offers the possibility to use prior knowledge to formulate and evaluate informative hypotheses using equality and inequality constraints between groups and compare competing hypotheses that are based on specific expectations (Klugkist et al., 2005). The outcome of the analysis is a Bayes factor (BF), representing the amount of evidence in favor of one hypothesis compared to another (Kass & Raftery, 1995). The Bayesian framework is a promising alternative for standard frequentist analyses. It offers solutions to important analytical problems concerning multiple testing, such as alpha inflation and loss of power after correcting the alpha level (Klugkist, Van Wesel, & Bullens, 2011). In addition, Bayesian analyses are not based on normality or asymptotic assumptions, making it a suitable approach for relatively small sample sizes (Gill, 2008). As such, Bayesian analyses were used to test informative hypotheses about the literacy skills and cognitive components and obtain parameter estimates to make further inferences. The analyses were performed using the BIEMS software package (Mulder et al., 2009; Mulder, Hoijtink, & De Leeuw, 2012; Mulder, Hoijtink, & Klugkist, 2010).

For *literacy*, we tested two competing hypotheses about the literacy skills of gifted children with dyslexia compared to children with dyslexia, TD children, and gifted children. Each hypothesis was translated into a statistical hypothesis with (in)equality constrained parameters (Klugkist et al., 2005). Here, the parameters were the group means on the word reading, nonword reading, text reading, and spelling tasks. Based on the inclusion criteria for dyslexia, the first hypothesis stated that gifted children with dyslexia would score about equally low on literacy skills as children with dyslexia and lower than TD children, and that gifted children would outperform all groups, that is, $\mu_D = \mu_{GD} < \mu_{TD} < \mu_G$ (Model 1). The second hypothesis stated that gifted children with dyslexia would score *higher* on literacy skills than children with dyslexia but lower than TD children, and that gifted children would outperform all groups, that is, $\mu_D < \mu_{GD} < \mu_{TD} < \mu_G$ (Model 2). These informative hypotheses were compared to the alternative hypothesis, or unconstrained model, that is, μ_D, μ_{GD}, μ_{TD}, μ_G (Model 0), to protect against incorrectly choosing a wrong or poorly formulated hypothesis (Van de Schoot et al., 2011).

For the underlying *cognitive components* (i.e., PA, RAN, VSTM, verbal and visuospatial WM, grammar, and vocabulary), two different sets of informative hypotheses were tested. First, we formulated two informative hypotheses about the phonology measures that would fit a core-deficit model of dyslexia, as proposed by Snowling (2000). The first hypothesis stated that gifted children with dyslexia would score about equally low on all phonology measures as the children with dyslexia and lower than the TD children, and that gifted children would outperform all groups, that is, $\mu_D = \mu_{GD} < \mu_{TD} < \mu_G$ (Model 1). The second hypothesis stated that gifted children with dyslexia would score higher on all phonology measures than children with dyslexia but lower than TD children, and that gifted children would outperform all groups, that is, $\mu_D < \mu_{GD} < \mu_{TD} < \mu_G$ (Model 2). For RAN, the informative hypotheses had to be formulated in the opposite direction, since low scores indicated high performance on these tasks. Second, a compensational model was used to formulate informative hypotheses about the cognitive components that were expected to be giftedness-related strengths. However, since previous research on these components in twice-exceptional children in general has showed very mixed results, not all group differences could be specified in the informative hypotheses. Consequently, the first hypothesis stated solely that gifted children would outperform all groups on the WM and language measures, that is, $\mu_G > \mu_{TD}$, μ_{GD}, μ_D (Model 1). The second hypothesis stated that both gifted children and gifted children with dyslexia would outperform the TD children as well as the children with dyslexia on the WM and language measures, that is, μ_G, $\mu_{GD} > \mu_{TD}$, μ_D (Model 2).

Generally, the first step of the analysis involves calculating the $BF_{i,u}$ for the informative hypothesis (H_i) versus the unconstrained alternative (H_u). When one of the informative hypotheses receives more support from the data than the unconstrained model ($BF_{i,u} > 1$), a second step could be to compare several models by dividing the $BF_{i,u}$ of each model by the sum of BFs of the other models of interest. Assuming prior probabilities to be equal for all models, this results in a posterior model probability (PMP), representing

Table 2. Bayes Factors (BFs) and Posterior Model Probabilities (PMPs) of the Three Models for the Literacy Skills and Cognitive Components.

	Model 0		Model 1		Model 2	
Skill/component	BF	PMP	BF	PMP	BF	PMP
Literacy						
Word reading	1.00	.04	0.19	.01	23.94	.95
Nonword reading	1.00	.04	2.50	.09	23.15	.87
Text reading	1.00	.04	0.05	.00	24.19	.96
Spelling	1.00	.04	0.27	.01	23.87	.95
Core-deficit model						
Phoneme deletion	1.00	.04	0.02	.00	21.75	.96
Phoneme transposition	1.00	.04	1.18	.04	24.45	.92
RAN alphanumeric	1.00	.03	7.62	.25	22.01	.72
RAN non-alphanumeric	1.00	.04	4.81	.18	20.90	.78
VSTM	1.00	.26	0.22	.06	2.59	.68
Compensational model						
Verbal WM	1.00	.11	3.93	.44	4.05	.45
Visuospatial WM	1.00	.10	3.10	.31	5.90	.59
Grammar	1.00	.10	3.97	.38	5.43	.52
Vocabulary	1.00	.11	2.57	.29	5.26	.60

Note. RAN = rapid automatized naming; VSTM = verbal short-term memory; WM = working memory.

the relative support for a specific hypothesis within a set of hypotheses (Klugkist et al., 2011). It should be borne in mind that, in a Bayesian framework, *probability* is defined as a degree of belief. In the case of a PMP *probability* relates to the probability that a hypothesis is true (Klugkist et al., 2011). In addition to the BFs and PMPs, the obtained parameter estimates were used to make more detailed inferences about the group differences.

Results

Literacy

Table 2 shows the BFs and PMPs for all three models in the analysis, presenting the results for each literacy skill separately. Recall that in this approach Model 0 was the alternative hypothesis ($\mu_D, \mu_{GD}, \mu_{TD}, \mu_G$), Model 1 stated that gifted children with dyslexia would show literacy skills comparable to children with dyslexia ($\mu_D = \mu_{GD} < \mu_{TD} < \mu_G$), and Model 2 stated that gifted children with dyslexia would perform better than children with dyslexia but worse than TD children ($\mu_D < \mu_{GD} < \mu_{TD} < \mu_G$). Model 2 received most support from the data for all literacy skills, on average about 23 times more than the alternative hypothesis. The probabilities that the hypothesis under Model 2 is true vary between .87 and .96. As displayed in Table 3, the posterior means of the unconstrained model indeed indicate that gifted children with dyslexia scored higher than children with dyslexia on every aspect of literacy (reading and spelling) but lower than TD children, and that gifted children outperformed all groups.

Cognitive Components

Table 2 also shows the BFs and PMPs for the core-deficit model of dyslexia and the compensational model of giftedness-related strengths, presenting the results for each cognitive component separately. Recall that in the core-deficit approach, Model 1 stated that gifted children with dyslexia would show phonology levels comparable to children with dyslexia ($\mu_D = \mu_{GD} < \mu_{TD} < \mu_G$), and Model 2 stated that gifted children with dyslexia would show higher phonology levels than children with dyslexia but lower than TD children ($\mu_D < \mu_{GD} < \mu_{TD} < \mu_G$). For all phonology measures, Model 2 received most support from the data, about 22 times more than the alternative hypothesis. For the PA and RAN measures, the results are confirmed by the posterior means under the unconstrained model that are displayed in Table 3, showing that the gifted children with dyslexia scored higher on the phonology measures than the children with dyslexia but lower than the TD children, and that the gifted children showed the highest scores (PMPs = .72–.96). However, the BF and PMP of the second model are considerably lower for VSTM than for the PA and RAN measures. The posterior group means of VSTM indicate that one of the constraints in the second model was imposed incorrectly, explaining the lower BF. In contrast to PA and RAN, the gifted children with dyslexia outperformed not only the children with dyslexia, but also the TD children on the VSTM component. The gifted children outperformed all groups.

For the compensational model, recall that Model 1 stated that the gifted children would outperform all groups on WM and language skills ($\mu_G > \mu_{TD}, \mu_{GD}, \mu_D$) and that Model 2 stated that both the gifted children and the gifted children with dyslexia would outperform the TD children as well as the children with dyslexia on WM and language skills ($\mu_G, \mu_{GD} > \mu_{TD}, \mu_D$). Although for some measures the differences in BFs between Model 1 and Model 2 were relatively small, Model 2 received about 5 times more support for all components from the data than the alternative hypothesis (Table 2; PMPs = .45–.60). The posterior means in Table 3 show that gifted children with dyslexia outperformed children with dyslexia as well as TD children on both WM components, although there seems to be no difference between the gifted children with dyslexia and the TD children on verbal WM. All groups still scored lower than gifted children. Similarly, gifted children with dyslexia outperformed both children with dyslexia and TD children on the language component grammar, but the gifted children showed even higher scores. For vocabulary, however, the posterior means show that the gifted children with dyslexia not only outperformed the

Table 3. Posterior Means (*PM*) and Standard Deviations (*PSD*) of the Literacy Skills and Cognitive Components Adjusted for Age.

	Dyslexia		Gifted + Dyslexia		Typically Developing		Gifted	
Skill/component	*PM*	*PSD*	*PM*	*PSD*	*PM*	*PSD*	*PM*	*PSD*
Literacy								
Word reading	30.14	4.11	39.57	4.53	56.59	3.95	70.55	4.17
Nonword reading	19.16	4.98	26.31	5.62	47.74	4.75	58.85	5.12
Text reading	76.48	8.93	91.80	10.07	103.03	8.74	113.28	9.23
Spelling	16.76	1.90	22.80	2.10	30.67	1.82	36.42	1.93
Core-deficit model								
Phoneme deletion	0.16	0.0005	0.30	0.0006	0.35	0.0005	0.46	0.0005
Phoneme transposition	0.02	0.00009	0.05	0.0001	0.09	0.00008	0.14	0.00009
RAN alphanumeric	35.71	1.05	33.57	1.18	29.40	1.02	25.30	1.07
RAN non-alphanumeric	58.57	2.74	54.60	3.03	49.07	2.65	46.28	2.81
VSTM	22.57	0.68	25.89	0.77	24.56	0.66	26.54	0.70
Compensational model								
Verbal WM	9.79	0.42	12.54	0.48	12.09	0.42	14.68	0.44
Visuospatial WM	14.08	0.52	19.86	0.57	17.50	0.51	20.67	0.53
Grammar	24.68	0.83	26.87	0.93	25.00	0.80	30.76	0.86
Vocabulary	12.56	0.92	18.20	1.04	16.41	0.88	18.73	0.94

Note. Higher values indicate worse performance in the RAN alphanumeric and non-alphanumeric cognitive components. RAN = rapid automatized naming; VSTM = verbal short-term memory; WM = working memory.

children with dyslexia and the TD children, but also scored about equal to the gifted children.

Discussion

This study compared literacy skills and the cognitive profiles between gifted children with dyslexia, children with dyslexia, TD children, and gifted children. The hypothesis that gifted children with dyslexia would show higher reading and spelling performance overall than the children with dyslexia, but lower performance than TD children and considerably lower than gifted children, was accepted. Furthermore, the hypotheses that gifted children with dyslexia have a specific cognitive profile of dyslexia-related weaknesses (core-deficit model) and giftedness-related strengths (compensational model) that may provide possibilities for compensation of underlying deficits were largely confirmed.

Assumptions based on anecdotal information and previous research on twice-exceptionality were confirmed: The performance of gifted children with dyslexia on reading and spelling tests was in between that of children with dyslexia and TD children. Gifted children with dyslexia, as classified based on conventional behavioral and cognitive criteria, were not found to display literacy performance as poor as averagely intelligent children with dyslexia. This illustrates the difficulty of recognizing literacy difficulties in these children based on their achievement, as they might not seem to fulfill criteria for dyslexia. Consequently, they are not likely to be referred to diagnostic research. These results are also important for the borderline cases that were excluded from the analysis because they did not meet the diagnostic criteria for dyslexia. In fact, if these children would have been averagely intelligent, they might have reached the diagnostic threshold. We contend that for these children their intelligence must be taken into account and they should be assessed based on broader criteria to receive a diagnosis and/or an appropriate intervention. Although not all children in both dyslexia groups had received a diagnosis of dyslexia prior to the study, these children were all referred by their teachers because of serious concerns about literacy development and were in process of being tested. Limiting inclusion to children with a (double) diagnosis would have made it virtually impossible to conduct this study, especially because of the aforementioned difficulty of identification of gifted children with LD.

Furthermore, since nonword reading plays such an essential role in diagnosing dyslexia in the Netherlands, it is important to highlight that nonword reading performance of the gifted children with dyslexia was also better overall than of the children with dyslexia. Hence, nonword reading does not sufficiently differentiate children with dyslexia from typical readers in a gifted/high IQ population. This might be due to compensation that gifted children with dyslexia possess in skills related to nonword reading. For example, gifted children with dyslexia may show relatively better performance on the PA and RAN tasks because they perform better on speeded tasks (Catts, Gillispie, Leonard, Kail, & Miller, 2002; Johnson et al., 2003). In addition, recent research on the role of visual attention span in

reading development and dyslexia might shed more light on possibilities for compensation of a (non)word reading deficit (e.g., Valdois, Lassus-Sangosse, & Lobier, 2012; Van den Boer, De Jong, & Haentjens-Van Meeteren, 2013). Consequently, the finding that gifted children with dyslexia generally outperform children with dyslexia on a nonword reading test implies that nonword reading is not a suitable screening method for dyslexia in gifted children.

In line with the proposed core-deficit model of dyslexia, the gifted children with dyslexia showed weaknesses in PA and RAN. However, they performed better on the PA and RAN tasks than the children with dyslexia. Remarkably, the gifted children with dyslexia showed a strength in VSTM rather than a deficit. Concerning the compensational model of giftedness-related strengths, the gifted children with dyslexia indeed showed high performance on verbal and visuospatial WM tasks and language skills. The absence of a weakness in VSTM might be explained by compensation through their substantial WM capacity or outstanding language skills. It can be concluded that the high grammar scores and the exceptionally high scores on vocabulary indicate a major advantage compared to averagely intelligent children with dyslexia. General language skills may form an important area of compensation for gifted children with dyslexia. Although better language skills have been found a protective factor for all children with dyslexia (Nation & Snowling, 1998; Snowling, 2008), gifted children with dyslexia might benefit even more because they can rely on virtually excellent language skills.

To the best of our knowledge, this is the first study that has empirically examined the clinical expression and underlying cognitive profile of dyslexia in a gifted/high IQ population. It shows that masking of literacy difficulties can cause dyslexia to remain undetected in gifted children for a protracted time, despite achievement being lower than anticipated on the basis of the intellectual capacities of the child. In addition, it shows that phonology can be considered a risk factor for the development of possible reading and/or spelling difficulties, but is moderated by many other skills. In the case of gifted children with dyslexia, large WM capacity and excellent language skills can be considered important protective factors. These findings fit the ideas of a multiple-deficit model of developmental learning disabilities (Pennington, 2006). Overall, the emergence of a specific LD such as dyslexia depends on a complex interplay of risk and protective factors, which are unique to specific populations and even differ per individual child (Pennington, 2006).

An additional novelty was the use of Bayesian statistics instead of standard frequentist statistics. Bayesian statistics allow the integration of prior knowledge in the evaluation of hypotheses and are especially suitable for studies were small sample sizes are an issue (Gill, 2008; Klugkist et al., 2005). Although the sample size in this study cannot be considered particularly small, it might cause power problems in relation to multiple testing when taking into account the amount of skills and cognitive components under investigation. Consequently, Bayesian statistics are a perfect fit to our data compared to traditional frequentist statistics, providing important solutions to multiple testing problems (Klugkist et al., 2011).

Practical implications of the study mainly involve raising awareness about the ways in which dyslexia might occur in gifted children. Even though it is premature to derive new diagnostic criteria from these findings, it can be stated that teachers and diagnosticians should be more conscious about gifted children showing signs of underachievement, sudden deterioration in their school performance, or demotivation. Moreover, teachers have the responsibility to take action when they notice a child is falling behind in a specific domain, which is often neglected when dealing with twice-exceptional children (Assouline et al., 2010). More alertness will hopefully improve the possibility of early intervention and prevent increasing severity of the impairment in a child's future school career, as well as promote quicker referral to gifted programs. The aim of early recognition by teachers or diagnosticians should not be to provide a label for the child but to identify the child's strengths and weaknesses and utilize this knowledge for the purpose of mediation and better service.

Future research should focus on cross-linguistic studies as well as longitudinal or cross-sectional studies of gifted children with dyslexia to assess development and outcomes at adolescence and adulthood. Furthermore, case series analyses could provide more insight in the etiological differences between gifted children with dyslexia at the individual level, including the borderline cases that were excluded from the analyses in the current study. Using larger sample sizes, including more children with diagnoses, and adding more/other cognitive components (e.g., executive functions or processing speed) will extend knowledge of the behavioral and cognitive weaknesses and strengths of gifted children with dyslexia. In combination with the replication of findings, this will hopefully result in earlier identification of gifted children with dyslexia and improve intervention and programming practices.

In summary, this study showed that gifted children with dyslexia outperform children with dyslexia on literacy skills and that they have a unique cognitive profile characterized by both deficits related to dyslexia and strengths associated with giftedness. Weaknesses in phonology seem to be moderated by strengths in WM and general language ability. This renders reading and spelling ability levels that are not as low as in averagely intelligent children with dyslexia, which in turn frustrates early signaling and referral. The Bayesian statistics used for the analysis were a perfect fit to the data and provided detailed insight in the performance of gifted children with dyslexia compared to the other groups.

Overall, it can be stated that gifted children with dyslexia form a special group within the population of children with dyslexia as well as the population of gifted children with LD. They require their own broader diagnostic criteria that take into account their high intelligence, and effects of masking and compensation should not be underestimated.

Acknowledgments

We are grateful to the children and parents who participated in this study. We also thank Rens van de Schoot and Anouck Kluytmans (Utrecht University) for sharing their knowledge of Bayesian statistics and their helpful comments on the presented analyses in the article. Finally, we are indebted to the anonymous reviewers of the article for their helpful reviews.

Declaration of Conflicting Interests

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

Funding

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

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