Dyslexia Action
Training and Professional Development

Copyright Notice

Course Name: DACPD85 Developing Writing Skills in Learners with Dyslexia

Name of Designated Person authorising scanning: Kathryn Benzine, Head of Training

Title of source (~~book or~~ journal): Dyslexia: An International Journal of Research and Practice, V19

Year of publication: 2013

~~Chapter or~~ article name: Writing in Dyslexia: Product and Process

Page number(s): 131-148

Name of Book Editor(s) or Author(s): n/a

Chapter or article Author(s): Froydis Morken and Turid Helland

Name of Publisher: Wiley

Place of Publication: Chichester

Internal use

~~A~~	~~From Paper original owned by Institution~~
B	From Digital original licensed to institution
~~C~~	~~From copyright fee paid copy~~

DYSLEXIA
Published online 29 May 2013 in Wiley Online Library
(wileyonlinelibrary.com). DOI: 10.1002/dys.1455

Writing in Dyslexia: Product and Process

Frøydis Morken* and Turid Helland

Department of Biological and Medical Psychology, University of Bergen, Norway

Research on dyslexia has largely centred on reading. The aim of this study was to assess the writing of 13 children with and 28 without dyslexia at age 11 years. A programme for keystroke logging was used to allow recording of typing activity as the children performed a sentence dictation task. Five sentences were read aloud twice each. The task was to type the sentence as correctly as possible, with no time constraints. The data were analysed from a product (spelling, grammar and semantics) and process (transcription fluency and revisions) perspective, using repeated measures ANOVA and *t*-tests to investigate group differences. Furthermore, the data were correlated with measures of rapid automatic naming and working memory. Results showed that the group with dyslexia revised their texts as much as the typical group, but they used more time, and the result was poorer. Moreover, rapid automatic naming correlated with transcription fluency, and working memory correlated with the number of semantic errors. This shows that dyslexia is generally not an issue of effort and that cognitive skills that are known to be important for reading also affect writing. Copyright © 2013 John Wiley & Sons, Ltd.

Keywords: dyslexia; writing; product; process

The main symptoms of dyslexia are problems with reading and writing. Additionally, modern definitions highlight its neurobiological origin (Lyon, Shaywitz & Shaywitz, 2003) and underlying cognitive factors such as deficits in phonological awareness, verbal memory and verbal processing speed (Rose, 2009). Furthermore, dyslexia is generally resistant to conventional classroom instruction, and not related to global IQ levels (Lyon *et al*., 2003; Tanaka *et al*., 2011). In recent years, the field has moved towards a view of dyslexia as a multifactorial disorder (Snowling & Hulme, 2012) or a part of a continuum or dimensional space (Bishop & Snowling, 2004). In research, focus has mainly been on the reading problems of persons with dyslexia. Less attention has been given to writing, especially at the sentence and text levels. This is particularly unfortunate, considering indications that problems with writing often persist even after reading problems have been remedied or compensated (Berninger, 2006). Understanding the nature of the writing problems associated with dyslexia is of great importance to facilitate effective support in the acquisition of functional writing skills, which are vital for professional opportunities and participation in society.

The study of writing can take two main perspectives; a product perspective or a process perspective. A product perspective is concerned with the final text, whereas a process perspective examines how that text came about

*Correspondence to: Frøydis Morken, Department of Biological and Medical Psychology, BB-bygget, Jonas Lies vei 91, 5009 Bergen, Norway. E-mail: froydis.morken@psybp.uib.no

(Berninger, Fuller & Whitaker, 1996). The present study sought to combine the two perspectives in a sentence dictation task. From a product perspective, we looked at spelling and semantics (omissions, additions and substitutions of words). From a process perspective, we investigated transcription fluency, as well as the number of revisions made by the participants during typing. In line with Berninger and Swanson (1994), we distinguished between revisions that were made online and locally, and those that were made *post-hoc* and globally. Finally, we correlated these measures with data on working memory (WM) and verbal processing speed, to investigate how these underlying cognitive skills relate to the written product and the writing process.

Writing is a complex activity. Hayes and Flower (1980) identified three main components of composition tasks; planning, translating and revising. They also suggested subprocesses of planning and revising. The whole process takes place under the influence of long-term memory and the task environment. This model has been highly influential in the field of writing research. However, originally a model of the writing process in skilled adult writers, it has shortcomings when it comes to describing how younger less apt writers produce text. Revisions of the model have been suggested in an attempt to incorporate developmental writing. Berninger and Swanson (1994) argued that the translation process should be divided into two subprocesses; text generation (the process of converting ideas into language) and transcription (conversion of language into written symbols).

In light of the modern definitions of dyslexia, we would expect the main challenge for writers with dyslexia to lie within the transcription domain. However, higher level processes would likely be influenced by these transcription challenges. One could speculate that with large resources going into transcription, less may be left for planning and text generation. Connelly, Campbell, MacLean and Barnes (2006) examined a sample of college students with and without dyslexia. They found that the written compositions did not differ in ideas or organization, but at the level of transcription.

Revision takes an intermediate position between the higher order processes associated with text generation and the lower order processes associated with transcription. Online revision focuses on single words and spelling, whereas *post-hoc* revision in its nature will also include larger textual elements such as semantic coherence and text flow. As such, online revision could be viewed as lower order, and *post-hoc* revision as higher order processes. It is a common understanding among many teachers and parents that children with dyslexia revise their written products less than children with typical literacy skills. It is, however, unclear if this conception is justified or not.

The aim of the present study was to investigate processes related to the more mechanic aspects of text production separated from the higher level processes of idea generation and text generation. Dictation tasks allow bypassing planning and text generation to focus on transcription and revision. Moreover, dictation tasks can help ensure that the output between groups is comparable. The written output from children with dyslexia can often differ from that of typical children both in terms of the length of the product and in terms of the words chosen. A dictation has the advantage of allowing the researcher to guide which and how many words the child is to write.

Poor spelling compared with peers is a well-known symptom of dyslexia (Coleman, Gregg, McLain & Bellair, 2009; Helland, 2007), and the problems tend to persist into adulthood (Maughan *et al*., 2009). Richards *et al*. (2009) used fMRI to show that the WM networks of the brain show different activation in typical and poor spellers. On a 0/2-back task, the group of poor spellers showed higher activations than the typical group in areas of the brain that are associated with cognition, executive functions and WM.

Even though there might be a common biological and cognitive basis for dyslexia, the disorder may manifest in different ways in different cultures. Paulesu *et al*. (2001) concluded that there is a common neurocognitive basis for dyslexia, but that differing orthographies lead to different performance in readers. The present study was conducted in Norway. The Norwegian language has a semi-transparent orthography, with 29 letters and 36 graphemes representing around 40 phonemes (Helland & Kaasa, 2005); the latter is subject to dialectal variation. In comparison, English has 26 letters and 561 graphemes, representing 44 phonemes (Dewey, 1971). Elley (1992) classified different languages on a scale from 1 to 5 where 1 indicated the most opaque orthographies and 5 the most transparent. In this classification, English scored 1 and Norwegian scored 3 along with Swedish, Dutch, Icelandic, German and Greek.

Spelling and orthography are not the only obstacles for a person with dyslexia. There are also reports of impaired semantic processing, which could influence the process of generating a coherent text and developing arguments. Rüsseler, Becker, Johannes and Münte (2007) presented high-achieving dyslexic and non-dyslexic university students with semantic, rhyme and gender judgement tasks in German. They concluded that in addition to a phonological deficit, the dyslexics also displayed signs of more effortful semantic and syntactic processing. Furthermore, semantic priming has been shown to be impaired in both at-risk toddlers (Torkildsen, Syversen, Simonsen, Moen & Lindgren, 2007) and older reading impaired children (Betjemann & Keenan, 2008). However, Hanly and Vandenberg (2010) reported no impairment in the semantic stage of word retrieval in their study of tip-of-the-tongue states in children between 8 and 10 years old with and without dyslexia.

Revision processes could also be affected by semantic processing, making the monitoring of text more effortful for the writer. Also, revision necessitates skilful reading. To see his or her own mistakes, the writer has to read what he or she has produced. She or he must process the word visually, analyse it phonologically and match it to an item in the semantic lexicon (Seidenberg & McClelland, 1989). Moreover, the mismatch between the target and the item on the page has to be detected. This process would be disturbed by, for example, poorly specified phonological representations. Horowitz-Kraus and Breznitz (2011) reported a smaller error-related negativity in an event-related potential study of a group of university students with dyslexia. They hypothesized that this could be related to an underspecified or impaired mental lexicon. An important question in this regard is whether this implies that a person with dyslexia monitors the text less or less well.

Working memory could also affect both verbal and visual processing, and has repeatedly been shown to be impaired in dyslexia (Beneventi, Tønnessen, Ersland & Hugdahl, 2010; Helland & Asbjørnsen, 2003, 2004; Jeffries & Everatt, 2004; Menghini, Finzi, Carlesimo & Vicari, 2011; Smith-Spark & Fisk, 2007). In its current form, Baddeley's model of WM consists of a control system termed the central executive coordinating two slave systems; the phonological loop and the visuo-spatial sketchpad, as well as the episodic buffer that aids storage (Baddeley, 2000, 2003; Baddeley & Hitch, 1974; Baddeley & Logie, 1999).

The distinction between short-term memory and WM has been subject to controversy. Some researchers distinguish clearly between the two concepts (e.g. Conway *et al*., 2005), whereas others rather consider them overlapping, distinguishing between long-term memory and WM only (Baddeley & Hitch, 1974; Goswami, 2008). This also has consequences for the discussion on how to measure these constructs. Engle, Tuholski, Laughlin and Conway (1999) found that traditional span tasks, which are widely used to measure WM, looked more like short-term memory tasks than WM tasks, even in the backward condition. Cowan (2008), on the other hand, argued that span tasks may be sufficiently complex to tap into WM in young children seeing as they do correlate with cognitive aptitudes. Also, administering complex WM tasks to very young subjects might not be feasible. Hence, span tasks such as digit span should be appropriate measures of verbal WM in this group.

It has been pointed out that increased processing load tends to increase forgetting, the causes of which are discussed by Jarrold, Tam, Baddeley and Harvey (2011). An increase in processing demands in sentences could consist of an increasing number of words (longer sentences). Another way to increase the load would be to increase the orthographic complexity and the number of phonemes in the dictated words. Consequently, one could hypothesize that longer sentences with longer and more complex words would mean more errors, in particular on the word (semantic) level, related to verbal WM.

Rapid automatic naming (RAN) deficits in dyslexia are well documented (Clarke, Hulme & Snowling, 2005; Georgiou, Papadopoulos, Zarouna & Parrila, 2012; Norton & Wolf, 2012; Warmington & Hulme, 2012) and could imply slower general language processing. The bulk of this research has discussed RAN in relation to reading rather than writing. However, by using a letter naming task, Berninger, Nielsen, Abott, Wijsman and Raskind (2008) showed that rapid automatic letter writing and RAN are associated. Furthermore, they suggested that rapid automatic letter writing and RAN together may comprise a general automaticity factor affecting spelling skills. Thus, one could hypothesize that RAN influences transcription fluency, which is often measured in terms of the number of words typed within a given time unit (Berninger, 2000). There are indications that dyslexia may affect motor and automatization skills through a deficit in cerebellar function (Nicolson, Fawcett & Dean, 2001). Such impairments could be expected to influence typing speed in children with dyslexia as compared with typical children. On the other hand, Irannejad and Savage (2012) failed to find evidence of motor-cerebellar impairment in their recent study of children with atypical reading development. However, the children in their study were identified with dyslexia purely on the basis of deficits in word identification. This would include children with dyslexia, but possibly also children with reading impairment stemming from other aetiologies. Furthermore, Berninger, Abbott, Augsburger and Garcia (2009) investigated the relationship between writing by pen and paper and by keyboard in children with and without learning disabilities in handwriting and spelling. They found no difference between the two transcription modes at the single sentence level.

The main aim of this study was to assess the writing of children with dyslexia from both a product and a process angle. In line with previous research, we expected the final product to be poorer than that of typical children. The writing process, however, has been much less explored. Still, we did expect the process to differ between the dyslexia group and the typical group. Furthermore, we expected the differences in product and process to be mirrored in WM and RAN results, these being known benchmarks in dyslexia.

METHOD

Participants

The participants were part of The Bergen Longitudinal Dyslexia Study (also called The Speak Up Project), run from our lab. The original sample comprised 109 five-year-old children from all four counties in Western Norway, with both urban and rural communities represented. On the basis of a questionnaire developed for this purpose, a group of children at-risk of developmental dyslexia was identified. The questionnaires were completed by parents and teachers, and included questions on a variety of aspects that research has shown to be related to dyslexia; familial risk (Torppa, Eklund, van Bergen & Lyytinen, 2011), early language development (Snowling, Bishop & Stothard, 2000) and motor development (Nicolson *et al.*, 2001) among others. Hence, the project used an endophenotyping approach, rather than the more common genetic approach, to select participants for the at-risk and control groups (Helland, Plante, & Hugdahl, 2011).

Twenty-six children (13 boys, 13 girls) were identified as at-risk, and 26 matched controls were selected from the remaining group. As this was a population-based rather than a clinically referred sample, it was expected that around 10% of the original sample (~11 children) would develop dyslexia. Prevalence estimates range from around 5 to around 17% in the general population (Gabrieli, 2009). The children were followed regularly from age 5 to 8 years. After 3 years, a follow-up study was conducted, of which the present study is part. For this study, 42 (22 boys, 20 girls) of the original 52 participants agreed to participate. Thirteen children (five boys, all from the original at-risk group, and eight girls, six from the original at-risk group) children were identified with dyslexia. The remaining 29 (17 boys, 12 girls) were identified with typical literacy skills. Of these, one girl from the typical group did not complete the full assessment. Thus, for the purposes of this paper, there were 41 participants in total, 13 in the dyslexia group and 28 in the typical group. The age range in the dyslexia group at the time of testing was from 10:8 to 11:6 years with a mean of 11:1.5 (SD 3.66 months). The age range in the typical group was from 10:8 to 11:8 years with a mean of 11:2 (SD 3.28 months). A *t*-test with the design groups (2: dyslexia, typical) by age did not yield significant age differences. Dyslexia assessment was based on four standard Norwegian literacy assessment tests: three subtests from Standardisert Test i Avkoding og Staving [Standardized Test of Decoding and Spelling] (STAS) (Klinkenberg & Skaar, 2001), namely non-word reading, real word reading and real word spelling, were used together with the text reading test Carlsten Reading Test Grade 6 (Carlsten, 2002), which is a cloze test measuring silent reading fluency and comprehension. Details on these tests and the scoring procedures are presented by Helland, Plante *et al.* (2011).

There were significant differences between the groups on all four literacy measures. *T*-tests with the design groups (2: dyslexia, typical) by test scores showed a p-value of 0.0006 ($d = -1.420$) for non-word reading, $p < 0.0000$ ($d = -1.724$) for real word reading, $p < 0.0003$ ($d = -1.462$) for word spelling and $p < 0.0000$ ($d = -2.280$) for text reading and. This is only marginally different from what was reported by Helland, Plante, *et al.* (2011) and Helland, Tjus, Hovden, Ofte and Heimann (2011), who had one more child in the typical group.

IQ scores as measured with the Wechsler Preschool and Primary Scale of Intelligence-R (Wechsler, 2002) were also in line with what was reported by Helland, Plante *et al.* (2011), and were within the normal range at age 5 years. On the full scale IQ, a composite of the verbal and performance scales, the typical group had a mean score of 105.68 (SD 11.10), and the dyslexia group had a mean score of 100.15 (SD 17.95). A two-tailed t-test with the design groups (2: dyslexia vs. typical) by test scores did not yield significant differences between groups, and the effect size was $d = -0.371$.

Details on group comparisons of Digit Span and RAN can be found in Table 1. In general, the typical group scored better than the dyslexia group on both measures (Helland, 2011, August).

It should be pointed out that Norway has a relatively homogenous population, with a large middle class. Socioeconomic factors are not as prominent as in many other countries. The vast majority of schools is public and follows a common curriculum (Utdannings- og forskningsdepartementet [Ministry of Education and Research], 2006).

All parents provided informed consent forms on behalf of their child. Both The Bergen Longitudinal Dyslexia Study and the follow-up study were approved by the Regional Committee for Research Ethics in Western Norway and by the Norwegian Social Science Data Services.

Assessment

Assessment was carried out in the local communities, either in schools or in the offices of the Educational and Psychological Counselling Services. The tests were administered by trained professionals from the local Educational and Psychological

Table 1. Group comparisons. Working memory and rapid automatic naming (RAN)

Cognitive variables	Dyslexia mean (SD)	Typical mean (SD)	t-value	p-value	Cohen's d
Digit span					
5 years	4.8 (1.6)	7.2 (2.4)	−3.241	0.01	−1.176
7 years	8.4 (1.3)	10.1 (2.1)	−2.615	0.01	−0.973
8 years	9.1 (1.6)	10.9 (1.8)	−2.938	0.01	−1.057
11 years	11.7 (2.0)	13.0 (2.8)	−1.557	n.s.	−0.534
RAN colours					
5 years	103.7 (39.6)	81.0 (22.1)	2.380	0.02	0.708
6 years	82.0 (24.6)	71.1 (19.8)	1.534	n.s.	2.0
7 years	65.2 (16.6)	54.7 (19.4)	1.679	n.s.	0.582
11 years	36.1 (10.3)	34.0 (9.9)	0.623	n.s.	0.208
RAN letters and digits					
8 years	37.6 (9.7)	48.2 (9.5)	−3.332	0.002	−1.104
11 years	54.3 (9.5)	62.7 (11.6)	−2.295	0.03	−0.792

Counselling Services, through speech and language therapists, special needs, teachers or psychologists.

Controlled sentence dictations

A sentence dictation task was developed to allow focus on transcription and revision as previously discussed. The stimuli were constructed using high-frequency lexical items. Words with regular as well as irregular spelling were included to represent the variation in Norwegian orthography. Also, words representing known pitfalls in the spelling of Norwegian were included. The sentences were ordered such that the sentence presumed to be the easiest came first, and the most difficult came last. They were also ordered by the number of words (6–12), from shortest to longest (see Table 2 for details on the sentences). Each sentence was read aloud twice to the child by the test administrator. The child was instructed to type the sentence as correctly as possible on a computer, and press enter when he or she had finished each sentence. There were no time constraints.

The dictations were collected using the software TextPilot Research (Include A/S, 2009) based on the spell-checker TextPilot to build a system for keystroke logging especially developed for this project. Essentially, the programme records all typing behaviour, allowing the researcher to replay and analyse events on-screen at a later point. The programme has a built-in timer, providing the opportunity to log time usage. Furthermore, this method allows analyses of how the child makes revisions in the text during writing. TextPilot Research runs

Table 2. Dictation sentences

	Words	Letters	Phonemes
Sentence 1			
Kjell blir elleve år i morgen. Kjell become + pres eleven year + Ø(pl.) in morning Kjell will be eleven years old tomorrow.	6	24	~19
Sentence 2			
Han samler på mange sjeldne sommerfugler. He collect + pres on many rare + pl butterfly + pl. He collects many rare butterflies.	6	35	~32
Sentence 3			
Om vinteren går han ofte langt på ski. In winter + def go + pres he often long + adj on ski. In winter he often skis far.	8	30	~28
Sentence 4			
Han reiser alltid på fjelltur til en liten rød hytte. He travel + pres always on mountaintrip to a (masc) little + masc red + Ø (masc) cabin. He always goes on mountain trips to a small red cabin.	10	43	~36
Sentence 5			
I mars i år fikk han en fin sjokoladebrun og grå kattunge. In March in year get(past) he a (masc) nice + Ø (masc) chocolatebrown + Ø (masc) and grey + Ø (masc) kitten In March this year he got a nice chocolate brown and grey kitten.	12	46	~40

The number of phonemes is subject to slight dialectal variation.

on top of the regular word processor, so to the typing child, it appears as an ordinary Microsoft Word document.

The sentences were scored on both product (spelling and semantic errors) and processing (transcription fluency and revisions) variables. Each sentence was scored for: (a) spelling errors: the number of misspelled words; (b) semantic errors: the number of words added, omitted or substituted; and (c) total errors: spelling and semantic errors combined. This measure is only reported for all five sentences together; (d) transcription fluency: to compensate for differences in the number of words each child typed, the time used from typing the first character to typing the last character was divided by the number of words actually typed, resulting in a measure of seconds/word; (e) revisions: the number of online revisions (corrections made to the word the child was currently working on); the number of *post-hoc* revisions (corrections made to any other word in the sentence); and the total number of revisions (online and *post-hoc* revisions together). To investigate the pattern of revisions in further detail, the texts were scored for; (f) the number of online and *post-hoc* revisions correcting spelling, semantics and other factors (generally punctuation and capitalisation); and (g) the number of misspelled words that were never subjected to attempts of revision. (f) and (g) were only scored on text level, not on sentence level.

Scoring was performed by the researchers. Principles for scoring were predetermined, and cases of doubt were discussed in the team and agreed upon.

Cognitive measures

Two of the cognitive measures collected in the course of the Bergen Longitudinal Dyslexia Study were used in the present study, namely Digit Span and RAN.

Digit span

To assess verbal WM capacity, the Digit Span task from the Wechsler Intelligence Scale for Children – Third Edition (Wechsler, 1974) was used. The task was administered and scored according to test instructions. Raw scores were used because standardized scores were only available from 6 years. The data collection points were at the ages of 5, 7, 8 and 11 years.

Rapid automatic naming

Two tests were used to assess RAN skills. First, the baseline condition of a Stroop paradigm (Golden, 1987) was administered when the children were 5, 6, 7 and 11 years old. In this test, the participants were shown a sheet with $6 \times 8 = 48$ dots in different colours. The task was to name the colours as quickly and accurately as possible. This test was scored by timing how long the child took to name the colour of all the dots. Timing was performed using a stopwatch.

Second, the RAN task from the STAS test battery (Klinkenberg & Skaar, 2001) was used when the children were 8 and 11 years old. This task involves naming of digits and letters in scrambled order. Scoring was performed by timing how many items the child was able to name correctly within a 40 s limit.

Data Analyses

Between-group differences were investigated through two-tailed *t*-tests with the design groups (2: dyslexia vs. typical) by task score. Because of relatively small group size and within-group variance, Mann–Whitney *U*-test was also computed, to secure the reliability of the results. Cronbach's alpha was computed for the total number of errors. Cohen's *d* was calculated as a measure of effect size. Finally, the process and product variables were correlated with longitudinal data on digit span and RAN with casewise deletion of missing data. The sum scores for spelling errors, semantic errors, transcription fluency and revisions were also correlated with literacy data. One participant had missing data for transcription fluency and revisions on three sentences, due to technical failure. The α-level was set at $p < 0.05$.

RESULTS

Product Variables

For spelling errors, *t*-tests were significant for Sentence 2, Sentence 5 and Total (see Table 3 for details), with the typical group producing consistently fewer errors than the dyslexia group.

T-tests for semantic errors were significant for Sentence 3, Sentence 4, Sentence 5 and Total (details are reported in Table 3). Again, the typical group made fewer errors than the dyslexia group.

The *t*-test for the overall number of errors showed that the dyslexia group made significantly more errors than the typical group ($p < 0.0001$, $d = 1.628$). Cronbach's alpha was 0.62.

Process Variables

T-tests of transcription fluency showed significant group differences on Sentence 2, Sentence 3, Sentence 4, Sentence 5 and Total (see Table 3 for details). The typical group used less time per word than did the dyslexia group.

For revisions, *t*-tests did not show significance. Moreover, when examining the revision patterns in detail, separating revisions to spelling from semantic revisions and revisions to other factors, only the number of online revisions correcting spelling came out with a significant group difference ($p < 0.05$, $d = 0.681$). On this measure, the dyslexia group had a mean of 4.9 spelling revisions (SD 2.3), and the typical group had a mean of 3.3 (SD 2.4). There were no differences between the groups on *post-hoc* spelling revisions, on semantic revisions or on other types of revisions. Also, there were no significant differences as to how many misspelled words were ignored by the writers in the two groups.

Mann–Whitney *U*-test largely corroborated the results for both product and process variables.

Correlations

As can be seen from Table 4, the overall correlation pattern was one of semantic errors correlating with digit span and transcription fluency correlating with RAN. Spelling errors and revisions showed very little correlation with either measure.

Spelling errors only showed moderate negative correlations with Digit Span at 5 and 8 years. There were no significant correlations between spelling errors and RAN (see Table 4 for details).

Table 3. Group comparisons. Product and process

	Dyslexia mean (SD)	Typical mean (SD)	*t*-value	*p*-value	Cohen's *d*
Product variables					
Spelling errors					
Sentence 1	0.8 (0.8)	0.6 (0.6)	0.732	n.s.	0.283
Sentence 2	1.6 (1.0)	1.0 (0.8)	2.210	0.03	0.663
Sentence 3	0.3 (0.5)	0.2 (0.4)	0.635	n.s.	0.220
Sentence 4	1.4 (1.3)	0.9 (0.9)	1.326	n.s.	0.447
Sentence 5	1.7 (0.9)	0.9 (0.8)	2.741	0.01	0.940
Total (sum)	5.8 (2.9)	3.6 (1.9)	2.866	0.01	0.897
Semantic errors					
Sentence 1	0.0 (0.0)	0.0 (0.2)	−0.677	n.s.	0
Sentence 2	0.4 (0.7)	0.1 (0.3)	1.854	n.s.	0.557
Sentence 3	0.5 (0.7)	0.1 (0.3)	2.854	0.01	0.743
Sentence 4	2.0 (1.0)	1.1 (1.2)	2.498	0.02	0.815
Sentence 5	2.8 (1.3)	1.6 (1.3)	2.197	0.03	0.923
Total (sum)	5.8 (2.5)	3.0 (2.2)	3.625	0.001	1.189
Total errors	11.6 (3.1)	6.6 (3.0)	4.898	0.0001	1.606
Process variables					
Transcription fluency (sec/word)					
Sentence 1	4.4 (2.0)	3.9 (2.2)	0.789	n.s.	0.238
Sentence 2	6.8 (3.9)	4.8 (1.8)	2.123	0.04	0.658
Sentence 3	4.6 (3.1)	2.8 (1.0)	2.850	0.01	0.782
Sentence 4	4.6 (2.2)	3.4 (1.5)	2.013	0.05	0.637
Sentence 5	6.0 (3.2)	4.2 (1.6)	2.519	0.02	0.712
Total (mean)	5.2 (2.5)	3.8 (1.2)	2.519	0.02	0.714
Revisions (online and *post-hoc*)					
Sentence 1	0.8 (0.9)	0.9 (1.0)	−0.244	n.s.	−0.105
Sentence 2	1.3 (1.5)	1.3 (1.4)	0.100	n.s.	0
Sentence 3	1.0 (1.1)	0.7 (0.8)	0.962	n.s.	0.312
Sentence 4	1.0 (0.9)	0.7 (0.8)	1.171	n.s.	0.352
Sentence 5	2.2 (1.1)	1.5 (1.5)	1.427	n.s.	0.532
Total (sum)	6.3 (2.8)	5.1 (3.0)	1.155	n.s.	0.414

Semantic errors showed significant correlations with Digit Span across all age groups, but there were more significant correlations when the children were younger (see Table 4 for details). Correlations with RAN were only significant for the first data point, when the children were 5 years old (see Table 4).

The total number of errors showed moderate negative correlation with digit span across all measuring points (see Table 4 for details). RAN, on the other hand, did not show the same pattern. The only significant correlation between RAN and total errors was a moderate positive correlation at 5 years.

Transcription fluency showed moderate correlations with RAN at 5, 6 and 7 years, but no significant correlation at 11 years. There were also a few significant correlations with Digit Span, but substantially less than with RAN (see Table 4 for details).

Neither RAN nor Digit Span correlated with either measure of revisions.

As to the background literacy data, there was significant correlation with both product and process variables. Product: spelling errors correlated with STAS spelling ($r = -0.68$, $p < 0.000$), and semantic errors correlated with text reading ($r = -0.36$, $p < 0.02$). Process: transcription fluency correlated with text reading

Table 4. Correlations

	Digit span total (years)				RAN colours (years)				RAN letters and digits(years)	
	5	7	8	11	5	6	7	11	8	11
Product										
Spelling errors										
Sentence 1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 2	−0.32	n.s.	−0.48	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 3	n.s.	n.s.	−0.40	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 4	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 5	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Overall	n.s.	n.s.	−0.35	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Semantic errors										
Sentence 1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 2	−0.32	n.s.	n.s.	n.s.	0.32	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 3	−0.41	−0.42	−0.52	−0.38	0.35	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 4	−0.55	−0.52	−0.50	−0.45	0.34	n.s.	n.s.	n.s.	−0.34	n.s.
Sentence 5	−0.38	−0.35	−0.27	−0.26	0.32	n.s.	n.s.	n.s.	−0.35	n.s.
Overall	−0.58	−0.53	−0.50	−0.42	0.44	n.s.	n.s.	n.s.	n.s.	n.s.
Total errors	−0.54	−0.51	−0.57	−0.42	0.35	n.s.	n.s.	n.s.	n.s.	n.s.
Process										
Transcription fluency (sec/word)										
Sentence 1	n.s.	n.s.	n.s.	−0.39	0.41	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 2	n.s.	n.s.	n.s.	n.s.	0.59	n.s.	0.36	n.s.	−0.46	n.s.
Sentence 3	n.s.	−0.34	−0.34	−0.39	0.55	0.37	0.32	n.s.	−0.39	n.s.
Sentence 4	n.s.	n.s.	n.s.	n.s.	0.59	0.42	0.52	n.s.	−0.60	n.s.
Sentence 5	n.s.	n.s.	n.s.	n.s.	0.44	0.33	n.s.	n.s.	−0.39	n.s.
Overall	n.s.	n.s.	n.s.	−0.33	0.61	0.38	0.42	n.s.	−0.49	n.s.
Revisions (online and *post-hoc*)										
Sentence 1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 3	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Sentence 4	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	−0.33	n.s.
Sentence 5	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Overall	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

($r = -0.37$, $p < 0.02$). The number of revisions did not correlate with scores from the literacy tests.

DISCUSSION

The main findings in this study were that even though the dyslexia group revised their texts as much, and largely in the same manner, as the typical group, they ended up with a final product of poorer quality, and they needed more time to produce their texts. Furthermore, transcription fluency correlated with measures of rapid naming, and the number of semantic errors correlated with verbal WM.

The product variables showed differences between the groups as expected. For spelling errors, *t*-tests showed significant group differences on two sentences and the total, due to a higher number of errors by the children with dyslexia. Three sentences (1, 3 and 4) did not show group differences.

Spelling deficits are well known in dyslexia. As pointed out, this has been related to different factors of explanation, for example WM (Richards *et al*., 2009) and orthography (Paulesu *et al*., 2001). Of the two sentences that stand out as more difficult for the dyslexia group than for the typical group, Sentence 2 has only six elements, and as such, should not be very taxing for WM. On the other hand, three of the six elements have irregular or challenging spelling, and one is a compound. In comparison, Sentence 3 has eight items, but these are of a more regular type (2 irregular, no compounds). Also, Sentence 3 has fewer letters and fewer phonemes than Sentence 2. Hence, Sentence 2 appears more challenging than Sentence 3 orthographically, even though it has fewer words. On Sentence 3, there was no group difference indicated by the *t*-test. This suggests that for spelling, orthographic transparency may be more important than WM load. However, Sentence 5 was also difficult for the dyslexia group. This was the most challenging sentence WM wise. Orthographically, most elements are relatively transparent, but there are two complicated irregular compounds in addition to two shorter irregular words. The group differences on this sentence could be due to WM load, orthography or, most probably, both. Hence, there seems to be interplay between the two factors orthographic transparency and WM load in the spelling accuracy of children with dyslexia. The sentences were ordered with the intention of going from easy to more difficult. In retrospect, we see that Sentences 2 and 3 could have been reordered so that Sentence 3 came before Sentence 2.

For semantic errors, *t*-tests were significant for Sentences 3, 4 and 5 and for the total. The sentences were ordered so as to go from less to more taxing for WM. As the sentences became longer and more difficult to remember, the dyslexia group seems to have struggled more than the typical group. This is in line with a number of studies showing a WM deficit in dyslexia (Beneventi, Tønnessen & Ersland, 2009; Beneventi *et al*., 2010; Helland & Asbjørnsen, 2004; Jeffries & Everatt, 2004; Smith-Spark & Fisk, 2007). The results for spelling and semantics were not correlated ($r = 0.09$ for the total), indicating that these are independent of each other. Cronbach's alpha showed moderate internal consistency, which is not unexpected, because the sentences were constructed to challenge the writers to different degrees.

As to the process variables, there were group differences on transcription fluency, but less so on revisions. On transcription fluency, the typical group was faster than the dyslexia group. This could be due to slower general language processing in the dyslexia group. The dyslexia group did score significantly lower than the typical group on RAN digits/letters, indicating that there could be some kind of processing deficit. The findings are also in line with Berninger *et al*.'s (2008) data showing an association between RAN and letter writing.

One concern is the question of keyboard knowledge. It would have been ideal to have carried out a formal test of typing proficiency, but as the test load on the children was already rather high, this was not performed. However, all these children were trained regularly with computer-based educational programmes from age 5 years (Helland, Tjus, *et al*., 2011). Moreover, the emphasis on Information and Communications Technology in Norwegian schools is rather high, and computers are an integral part of teaching in many classes. Hence, the children should all be familiar with the use of a computer and keyboard. However, another issue complicating the matter is the time used over the revisions themselves. Even though the number of revisions was largely the same between the two groups, there is at present no way of separating language processing *per se* from the time each child has used working on detected spelling errors. It is conceivable that, spelling being a difficult issue for children with dyslexia, the dyslexia group would also need more time to reach a way of spelling a given word that they would be willing to accept. Hence, the results should be interpreted with care. Rather, identifying the cause(s) of the group difference could be a topic for further research.

As mentioned, our data showed no differences in the overall number of revisions. Rather, the dyslexia group and the typical group made a comparable number of revisions across all sentences. As previously pointed out, Horowitz-Kraus and Breznitz (2011) suggested that persons with dyslexia have a deficit in the error-detection mechanism. In a sense, it is therefore surprising to find that the group with dyslexia corrected the texts to the same extent as the typical group. However, given an uncorrected product containing more errors than that of typical writers, the dyslexia group would need to successfully revise more words than their peers to reach a final product of comparable quality. Their failure to do so could at least in part be attributed to a defect error-detection mechanism as proposed by Horowitz-Kraus and Breznitz. Still, when examining the data in further detail, we found that the dyslexia group and the typical group ignored a comparable number of spelling mistakes. And even more surprisingly, the dyslexia group actually attempted to revise even more misspellings online than the typical group.

There were no differences in the number of semantic revisions or the *post-hoc* spelling revisions between the groups. This should imply that the group with dyslexia is aware of at least as many mistakes as the typical writers, but that they are less successful at revising them. This is not in line with what could be expected building on the results of Horowitz-Kraus and Breznitz (2011). It should be noted that the lack of significant differences in the number of revisions extends to both local and global revisions. It is especially interesting to note that in both groups, very little revision was performed *post-hoc* (total mean 1.15 revisions *post-hoc* vs. 5.15 revisions online in the dyslexia group, and 1.21 revisions *post-hoc* vs. 3.96 revisions online in the typical group). In fact, around half of the subjects did not make any *post-hoc* revisions. These subjects were proportionately distributed between the two groups. This is in line with Berninger and Swanson's (1994) finding that post-translation revision is emerging, but not yet fully operational, in intermediate grade students. This seems to hold for students both with and without dyslexia, and the better product of the typical writers does not seem to be the direct result of different revision strategies or monitoring capacity. Moreover, there were only four cases of online and *post-hoc* revisions being made to the same word. Of the three children making this type of revision, one was from the dyslexia group and two were from the typical group. Three instances resulted in the end product being a correctly spelled word, and one instance resulted in a misspelled word. The misspelling was performed by a child from the typical group. There were also only three cases of a correctly spelled word being revised with a misspelling as the result. Two of these cases were from the typical group, and one was from the dyslexia group. Altogether, the children with dyslexia did not revise their texts less, but they did revise them less well.

Finally, we wanted to investigate whether the benchmark cognitive deficits in WM and rapid naming were reflected in the product and process variables. For the product, there was significant correlation between semantic errors and the WM task. Furthermore, semantic errors clearly increased with increasing memory load, with the three latter sentences (8, 10 and 12 words) showing significant group differences on *t*-tests. It should also be noted that Sentences 1 to 3 (6, 6 and 8 items) came out with a similar error proportion, although it is slightly higher in the 8-item sentence. Sentences 4 (10 items) and 5 (12 items), on the other hand, show a much larger proportion of errors. This is in line with the general idea that the WM capacity of most people is around 7 items +/−2 (Miller, 1956). Still, some children recall Sentence 5 (12 words) perfectly. This is probably due to different factors. First, grammatical clues are likely to ease the process of remembering. Second, sentences allow chunking of words into semantically meaningful episodes. This is also supported by the observation that in the cases where the children substituted one word for another, the two words were often semantically related (e.g. 'green' for 'red' or 'cat' for 'kitten'). In the terms of Baddeley's (Baddeley, 2000, 2003; Baddeley, Gathercole & Papagno, 1998; Baddeley & Hitch, 1974) model of WM, this could indicate a well-functioning episodic buffer together with poorly specified lexical items resulting from a deficit in the phonological buffer. This is consistent with the results of Hanly and Vandenberg (2010) who pointed to deficits in the phonological phase of word retrieval, but not in the semantic phase. Hence, the meaning of the word or sentence is remembered more or less accurately, but its phonological expression is not. Furthermore, semantic errors correlated with text reading. The test that was used to assess text reading here is designed to test both reading fluency and reading comprehension. The latter is also likely to be dependent upon WM capacity, and as such, the connection between the two is not surprising.

The number of spelling errors did not correlate with rapid naming and only showed correlation with digit span at 8 years. It did, however, correlate with the spelling test from the STAS battery (Klinkenberg & Skaar, 2001). Because both tasks measure spelling abilities, this was expected.

As to the process variables, transcription fluency showed correlation with rapid naming measures. This could indicate that slower general language processing in the dyslexia group influences transcription fluency. This is in line with Berninger *et al.*'s (2008) findings, indicating a connection between rapid naming and rapid automatic letter writing. Even though their study concerned handwriting, parallels could be drawn to keyboarding (Berninger *et al.*, 2009). Berninger *et al.*'s (2008) RAN task was based on letter naming. In this study, we had one task with colour naming, and one with naming of digits and letters. The colour naming task was chosen to accommodate the children who still did not know their letters. Hence, this task was used across the whole data collection. At the data collection points when the children were 8 and 11 years old, we did, however, include the letter/digit naming RAN task. Correlation analyses with transcription fluency and the STAS RAN task supported the conclusions from the colour naming task as it showed significant correlation with transcription fluency at 8 years. We would therefore argue that the link between rapid naming and transcription fluency holds even when the specific RAN task in question does not involve letter naming.

It is important to note that, in our study, there was no correlation between rapid naming and transcription fluency at 11 years. Correlations are only evident for the earlier data points. Dehaene *et al.* (2010) showed that literacy acquisition itself can influence cortical organization. This could also have consequences for performance. Hence, it could be that learning to read and write in itself has affected the children's RAN scores, and that this has helped the children with dyslexia narrow the gap to their peers. Still, the earlier differences may have influenced the literacy acquisition process to a degree that has not been compensated for at later stages. Thus, there are still group differences in transcription fluency at 11 years. This is in line with other findings, showing that a number of cognitive factors seem to separate the groups at earlier stages in development, but not in this age group (Helland, 2011, August). Interestingly, transcription fluency showed correlation with text reading, which is also a fluency task. This strengthens the idea that there could be a connection between general language processing speed and reading on the one hand and writing on the other.

Due to small group sizes, one should be careful about drawing strong conclusions from this material. Still, there are three main points to be highlighted from the present study: (1) slower language processing in the oral domain may also break through to the written domain; (2) verbal WM seems to have consequences especially in the interface between semantics and phonology, but also in spelling and orthography with increasing load; and (3) when children with dyslexia present written text of poorer quality than their peers effort is not necessarily the problem, but rather the ability to detect and correct errors.

Clinical Implications and Future Prospects

Some still mistake dyslexia for lack of effort. This study indicates that this is not the case. According to our data, children with dyslexia put as much work into their text as other children. However, they still do not reach the same quality on the end product. Many persons with dyslexia may benefit from learning efficient techniques for reviewing their texts and discovering residual errors. Still, learning how to revise successfully may be the most pressing issue. Moreover, seeing that impaired WM may play an important role also in the writing process, one should pay special attention to study techniques and forms of intervention that could alleviate this.

This study has focused on differences between children with dyslexia and children with typical literacy skills in writing processing in sentence dictation. It has shown that, contrary to what many would think, children with dyslexia correct their own writing as much as typically writing children. Still, they write more slowly and there are more residual errors. However, sentence dictations are in many ways an artificial task, and the interaction between transcription and revision skills on one side, and idea and text generation on the other is not clear. It would therefore be of great interest to see if these results hold up also in a free composition task, and we see this as an important issue for future studies.

REFERENCES

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, *4*(11), 417–423.

Baddeley, A. (2003). Working memory and language: an overview. *Journal of Communication Disorders*, *36*, 189–208.

Baddeley, A., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), The psychology of learning and motivation (Vol. *8*). New York, NY: Academic Press.

Baddeley, A., & Logie, R. H. (1999). Working memory: the multiple-component model. In M. Akira, & P. Shah (Eds.), Models of working memory. Mechanisms of active maintenance and executive control (pp. 28–61). Cambridge: Cambridge University Press.

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review*, *105*(1), 158–173. DOI: 10.1037/0033-295X.105.1.158

Beneventi, H., TØnnessen, F. E., & Ersland, L. (2009). Dyslexic children show short-term memory deficits in phonological storage and serial rehearsal: an fMRI study. *International Journal of Neuroscience* (119), 2017–2043. DOI: 10.1080/00207450903139671

Beneventi, H., TØnnessen, F. E., Ersland, L., & Hugdahl, K. (2010). Executive working memory processes in dyslexia: behavioral and fMRI evidence. *Scandinavian Journal of Psychology*, *51*, 192–202. DOI: 10.1111/j.1467-9450-2010.00808.x

Berninger, V. W. (2000). Development of language by hand and its connections to language by ear, mouth and eye. *Topics in Language Disorders*, *20*(4), 65–83.

Berninger, V. W. (2006). A developmental approach to learning disabilities. In K. A. Renninger, & I. E. Siegel (Eds.), Handbook of child psychology (Vol. *4*: Child Psychology in Practice). Hoboken, NJ: John Wiley and Sons, Inc.

Berninger, V. W., & Swanson, H. L. (1994). Modifying Hayes and Flowers' model of skilled writing to explain beginning and developing writing. In E. C. Butterfield (Ed.), Children's writing: toward a process theory of the development of skilled writing (Vol. *2*, pp. 57–81), Hampton Hill, Middlesex, England: Jai Press Inc.

Berninger, V. W., Abbott, R., Augsburger, A., & Garcia, N. (2009). Comparison of pen and keyboard transcription modes in children with and without learning disabilities. *Learning Disability Quarterly*, *32*(3), 123–141.

Berninger, V. W., Fuller, F., & Whitaker, D. (1996). A process model of writing development across the life span. *Educational Psychology Review*, *8*(3), 193–218.

Berninger, V. W., Nielsen, K. H., Abott, R. D., Wijsman, E., & Raskind, W. (2008). Writing problems in developmental dyslexia: under-recognized and under-treated. *Journal of School Psychology*, *46*, 1–21. DOI: 10.1016/j.jsp.2006.11.008

Betjemann, R. S., & Keenan, J. M. (2008). Phonological and semantic priming in children with reading disability. *Child Development*, *79*(4), 1086–1102.

Bishop, D. V., & Snowling, M. J. (2004). Developmental dyslexia and specific language impairment: same or different? *Psychological Bulletin*, *130*(6), 858–886. DOI: 10.1037/0033-2909.130.6.858

Carlsten, C. T. (2002). LeseprØve 6. Klasse bokmål og nynorsk [reading test 6th grade bokmål And nynorsk]. Oslo: Damm & SØn AS.

Clarke, P., Hulme, C., & Snowling, M. J. (2005). Individual differences in RAN and reading: a response timing analysis. *Journal of Research in Reading*, *28*(2), 73–86.

Coleman, C., Gregg, N., McLain, L., & Bellair, L. W. (2009). A comparison of spelling performance across young adults with and without dyslexia. *Assessment for Effective Intervention*, *34*(2), 94–105. DOI: 10.1177/1534508408318808

Connelly, V., Campbell, S., MacLean, M., & Barnes, J. (2006). Contribution of lower order skills to the written composition of college students with and without dyslexia. *Developmental Neuropsychology*, *29*(1), 175–196.

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. (2005). Working memory span tasks: a methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 796–786.

Cowan, N. (2008). What are the differences between long-term, short-term and working memory? *Progress in Brain Research* (169), 323–338. DOI: 10.1016/S0079-6123(07)00020-9

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Filho, G. N., Jobert, A., . . . Cohen, L. (2010). How learning to read changes the cortical networks for vision and language. *Science*, *330*, 1359–1364. DOI: 10.1126/science.1194140

Dewey, G. (1971). English spelling: roadblock to reading. New York: Teachers College Press.

Elley, W. B. (1992). How in the world do students read? IEA study of student literacy. Hamburg: The International Association for the Evaluation of Educational Achievement.

Engle, R., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short term memory, and general fluid intelligence: a latent variable approach. *Journal of Experimental Psychology. General*, *128*(3), 309–331.

Gabrieli, J. D. E. (2009). Dyslexia: a new synergy between education and cognitive neuroscience. *Science*, *325*, 280–283. DOI: 10.1126/science.1171999

Georgiou, G. K., Papadopoulos, T. C., Zarouna, E., & Parrila, R. (2012). Are auditory and visual processing deficits related to developmental dyslexia? *Dyslexia*, *18*, 110–129. DOI: 10.1002/dys.1439

Golden, C. J. (1987). Manual for the Stroop Color and Word Test. Chicago:Stoelting Company. Norwegian translation by Hugdahl, K. (undated version). Bergen: University of Bergen.

Goswami, U. (2008). Cognitive development: the learning brain. Hove: Psychology Press.

Hanly, S., & Vandenberg, B. (2010). Tip-of-the-tongue and word retrieval deficits in dyslexia. *Journal of Learning Disabilities*, *43*(1), 15–23. DOI: 10.1177/0022219409338744

Hayes, J. R., & Flower, L. S. (1980). Identifying the organization of writing processes. In L. W. Gregg, & E. R. Sternberg (Eds.), Cognitive processes in writing (pp. 3–30). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Helland, T. (2007). Dyslexia at a behavioural and cognitive level. *Dyslexia*, *13*(1), 25–41. DOI: 10.1002/dys.325

Helland, T. (2011, August). Developmental cognitive benchmarks in dyslexia. Paper presented at the 15th European Conference on Developmental Psychology, Bergen, Norway.

Helland, T., & Asbjørnsen, A. E. (2003). Visual-sequential and visuo-spatial skills in dyslexia: variations according to language comprehension and mathematics skills. *Child Neuropsychology*, *9*(3), 208–220. DOI: 10.1076/chin.9.3.208.16456

Helland, T., & Asbjørnsen, A. E. (2004). Digit span in dyslexia: variations according to language comprehension and mathematics skills. *Journal of Clinical and Experimental Neuropsychology*, *26*(1), 31–42.

Helland, T., & Kaasa, R. (2005). Dyslexia in English as a second language. *Dyslexia*, *11*, 41–60. DOI: 10.1002/dys.286

Helland, T., Plante, E., & Hugdahl, K. (2011). Predicting dyslexia at age 11 from a risk index questionnaire at age five. *Dyslexia*, *17*, 207–226. DOI: 10.1002/dys.432

Helland, T., Tjus, T., Hovden, M., Ofte, S., & Heimann, M. (2011). Effects of bottom-up and top-down intervention principles in emergent literacy in children at risk of developmental dyslexia: a longitudinal study. *Journal of Learning Disabilities*, *44*(2), 105-122. DOI: 10.1177/0022219410391188

Horowitz-Kraus, T., & Breznitz, Z. (2011). Error detection mechanism for words and sentences: a comparison between readers with dyslexia and skilled readers. *International Journal of Disability, Development and Education*, *58*(1), 33–45. DOI: 10.1080/1034912x.2011.548466

Include A/S. (2009). TextPilot research. Bergen: Include A/S.

Irannejad, S., & Savage, R. (2012). Is a cerebellar deficit the underlying cause of reading disabilities? *Annals of Dyslexia*, *62*, 22–52. DOI: 10.1007/s11881-011-0060-2

Jarrold, C., Tam, H., Baddeley, A., & Harvey, C. E. (2011). How Does Processing Affect Storage in Working Memory Tasks? Evidence for Both Domain-General and Domain-Specific Effects. *Journal of Experimental Psychology*, *37*(3), 688–705. DOI: 10.1037/a0022527

Jeffries, S., & Everatt, J. (2004). Working memory: its role in dyslexia and other specific learning difficulties. *Dyslexia*, *10*, 196–214. DOI: 10.1002/dys.278

Klinkenberg, J. E., & Skaar, E. (2001). STAS. Standardisert test i avkoding og staving. [Standardised test in decoding and spelling]. Hønefoss: Pedagogisk-psykologisk tjeneste.

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). Part 1. Defining dyslexia, comorbidity, Teachers' knowledge of language and reading. A definition of dyslexia. *Annals of Dyslexia*, *53*, 1–14.

Maughan, B., Messer, J., Collishaw, S., Pickles, A., Snowling, M. J., Yule, W., & Rutter, M. (2009). Persistence of literacy problems: spelling in adolescence and at mid-life. *Journal of Child Psychology and Psychiatry*, *50*(8), 893–901. DOI: 10.1111/j.1469-7610.2009.02079.x

Menghini, D., Finzi, A., Carlesimo, G. A., & Vicari, S. (2011). Working memory impairment in children with developmental dyslexia: is it just a phonological deficit? *Developmental Neuropsychology*, *36*(2), 199–213. DOI: 10.1080/87565641.2010.549868

Miller, G. A. (1956). The magical number 7, plus or minus 2: some limits on Our capacity for processing information. *Psychological Review*, *63*, 81–97.

Nicolson, R. I., Fawcett, A. J., & Dean, P. (2001). Developmental dyslexia: the cerebellar deficit hypothesis. *Trends in Neurosciences*, *24*(9), 508–511.

Norton, E. S., & Wolf, M. (2012). Rapid automatized naming (RAN) and reading fluency: implications for understanding and treatment of reading disabilities. *Annual Review of Psychology*, *63*, 427–452. DOI: 10.1146/annurev-psych-120710-100431

Paulesu, E., Démonet, J.-F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N., . . . Frith, U. (2001). Dyslexia: cultural diversity and biological unity. *Science*, *291*(5511), 2165–2167.

Richards, T., Berninger, V. W., Winn, W., Swanson, H. L., Stock, P., Liang, O., & Abbott, R. (2009). Differences in fMRI activation between children with and without spelling disability on 2-back/0-back working memory contrast. *Journal of Writing Research*, *1*(2), 93–123.

Rose, J. (2009). Identifying and teaching children and young people with dyslexia and literacy difficulties: secretary of state for children, schools and families.

Rüsseler, J., Becker, P., Johannes, S., & Münte, T. F. (2007). Semantic, syntactic, and phonological processing of written words in adult developmental dyslexic readers: an event-related brain potential study. *BMC Neuroscience*, *8*(52). DOI: 10.1186/1471-2202-8-52

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*(4), 523–568.

Smith-Spark, J. H., & Fisk, J. E. (2007). Working memory functioning in developmental dyslexia. *Memory*, *15*(1), 34–56.

Snowling, M. J., & Hulme, C. (2012). Annual research review: the nature and classification of reading disorders – a commentary on proposals for DSM-5. *Journal of Child Psychology and Psychiatry*, *53*(5), 593–607. DOI: 10.1111/j.1469-7610.2011.02495.x

Snowling, M. J., Bishop, D. V., & Stothard, S. E. (2000). Is preschool language impairment a risk factor for dyslexia in adolescence? *Journal of Child Psychology and Psychiatry*, *41*(5), 587–600.

Tanaka, H., Black, J. M., Hulme, C., Stanley, L. M., Kesler, S. R., Whitfield-Gabrieli, S., . . . Hoeft, F. (2011). The brain basis of the phonological deficit in dyslexia is independent of IQ. *Psychological Science*, *22*, 1142–1451. DOI: 10.1177/0956797611419521

Torkildsen, J. v. K., Syversen, G., Simonsen, H. G., Moen, I., & Lindgren, M. (2007). Brain responses to lexical-semantic priming in children at-risk for dyslexia. *Brain and Language*, *102*, 243–261. DOI: 10.1016/j.bandl.2006.11.010

Torppa, M., Eklund, K., van Bergen, E., & Lyytinen, H. (2011). Parental literacy predicts children's literacy: a longitudinal family-risk study. *Dyslexia*, *17*, 339–355. DOI: 10.1002/dys.437

Utdannings- og forskningsdepartementet [Ministry of Education and Research]. (2006). Kunnskapsløftet. Læreplan for grunnskolen og videregående opplæring. Oslo: Utdannings- og forskningsdepartementet.

Warmington, M., & Hulme, C. (2012). Phoneme awareness, visual-verbal paired-associate learning, and rapid automatized naming as predictors of individual differences in reading ability. *Scientific Studies of Reading*, *16*(1), 45–62. DOI: 10.1080/10888438.2010.534832

Wechsler, D. (1974). Wechsler intelligence scale for children – revised (Norwegian edition by undheim, J. O. ed.). Jaren, Norway: Vigga-trykk.

Wechsler, D. (2002). Wechsler preschool and primary scale of intelligence–third edition. Upper Saddle River, NJ: Pearson.

