Executive functioning and developmental dyslexia: Comparing three-year-old children with low familial risk and high familial risk of dyslexia

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Abstract

This study compared the language proficiency and executive functioning of three-year-old children with high (N = 72) and low (N = 427) familial risk of developmental dyslexia. The language tests measured phoneme identification, vocabulary, non-word repletion and grammar. For executive functioning, tasks examining visual attention, inhibition and visuo-spatial working memory were used. Results did not show any significant differences between the groups on any of the tasks. This study was evaluated in order to formulate suggestions for future research on family risk.

Introduction

Most studies involving children with developmental dyslexia (DD) have focused on linguistic deficits. However, a number of recent studies have offered evidence for a correlation between executive functions (EF) and DD (e.g. Varvara, Varuzza, Sorrentino, Vicari & Menghini, 2014; Reiter, Tucha & Lange, 2005). Executive functions are a collective term used for multiple cognitive processes that regulate behaviour. These processes include attention, decision making, reasoning, planning, inhibition (self-control), working memory and cognitive or mental flexibility. The little amount of available data involving pre-schoolers and DD and executive functioning calls for more research. Because this demographic is quite young, none of the participants has been diagnosed with DD. Instead, studies involving re-schoolers (e.g. Snowling, Muter & Carroll, 2007) usually divide the children into two groups (high or low familial risk, henceforth referred to as high or low FR) based on whether or not at least one of the parents themselves had any history of reading and/or spelling problems.

Linguistic deficits of Developmental Dyslexia

DD is most commonly described as a cognitive reading disorder. It is a specific learning disability that stems from neurobiological causes (Lyon, Shaywitz, Shaywitz, 2003). Children with DD typically have trouble acquiring reading and spelling skills. They also struggle with phonological awareness (e.g. Bruck, 1992; de Jong & van der Leij, 2003; Swan & Goswami, 1997b), and lexical retrieval (e.g. Faust, Dimitrovsky, & Shacht, 2003; Swan & Goswami, 1997a; Wolf, 1991) and have less well-developed verbal short-term memory skills than children without DD (Tijms, 2004).

First of all, phonological awareness refers to a person's understanding of the sound structure (or the phoneme sequences) of words. This includes, for example, the ability to tell apart two different phonemes that distinguish the difference between two otherwise similar sounding words, such as *pin* and *bin*. Other instances include awareness of the structures of syllables (e.g. the first syllable *can-* in *can*dy sounds the same as *can*cel) and within syllables (e.g. identical rimes in *cat* and *hat*). Comprehension of phonemes is necessary to decode and encode speech or text. Without an adequate proficiency of this skill, one can have trouble understanding, repeating, pronouncing, remembering, spelling and differentiating words. Studies have pointed out that good readers seem to have better phonological awareness skills than poor readers (Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh & Shanahan, 2001; Torgesen, Wagner & Rashotte, 1994). In addition, adults and children with DD have poor phonological awareness (Bruck, 1992; Swan & Goswami, 1997). Bruck (1992) tested both children and adults with and without DD by running tasks involving syllable counting, phoneme counting and phoneme deletion. Results from two sessions showed that dyslexic subjects were not able to improve their phoneme awareness to a level comparable to the non-dyslexic age- and reading-matched control groups. However, the DD subjects did not have poor onset-rime awareness. Likewise, Swan and Goswami (1997) tested 15 children with DD and 15 reading age-matched controls and 15 chronological age-matched (CA) controls using syllable tapping, onset-rhyme judgment, initial phoneme-final phoneme judgment and phoneme tapping tasks. The results showed that the children with DD scored significantly lower than the control children on the phoneme judgment and the phoneme counting tasks. However, the scores on the syllable tapping and onset-rhyme judgment tasks did not show any differences between the groups. These studies suggest that the problem in DD lies on a phoneme level and not on a syllable or onset-rhyme level.

Another mechanism that seems to be related to DD is verbal short-term memory, also referred to as the phonological loop or articulatory loop. According to the well-known working memory model proposed by Baddeley (Baddeley & Hitch, 1974), verbal short-term memory is an aspect of working memory. It preserves memory of verbal information for up to 2 seconds before it decays (Baddeley, Gathercole & Papagno, 1998). Verbal short-term memory is required for reading and listening; it helps keeping strings of phonemes and words together in one’s mind (short-term memory), so that one can properly decipher the meaning of an utterance. Research has looked into deficits in verbal short-term memory as a possible explanation for DD alongside phonological awareness. Tijms (2004), for example, examined whether these two are linked or separate deficits. Using a principal-component factor analysis, Tijms (2004) compared the performance of children with DD aged 10-14 years in list-learning (verbal short-term memory), multiple tasks involving phonological processing and some basic reading and spelling tests. His results showed relationships between verbal memory, phonological processing and phonological memory, which led Tijms to conclude that both an impaired verbal short-term memory and phonological awareness are caused by an inability to accurately encode the phonological characteristics of verbal information.

Lexical retrieval is the final impaired mechanism to be discussed here. As explained by

Friedmann, Biran and Dotan (2013), lexical retrieval refers to the process of turning a concept (of a word) that is stored inside the mental lexicon into a spoken word. For example, when one sees a picture of a dog, the word for *dog* is retrieved from their memory. Children with DD have been found to score lower on tasks that involve lexical retrieval, such as picture and object naming tasks (i.e. Faust et al., 2003; Swan & Goswami, 1997; Wolf, 1991;). Dimitrovsky and Shacht (2003) and Swan and Goswami (1997) both claim that difficulties with lexical retrieval stem from an impaired ability to find the right phonological word form.

Familial risk of Developmental Dyslexia

The studies reviewed above suggest that the language difficulties found in individuals with DD are caused by a phonological deficit, which is suggested to be manifested in problems with phonological awareness, lexical retrieval, and verbal short-term memory. These deficits can also be found in infants that have one or two parents with DD, and thus have a higher familial risk of DD. Snowling et al. (2007) conducted a follow-up study on children aged 12 and 13 years who were first tested on their reading and spelling abilities when they were 8 years old. Snowling et al. (2007) found that 42% of the high-FR children still had problems with reading and spelling 4 years later. Pennington and Lefly (2001) followed two groups (high and low FR) of children longitudinally from aged 5 to 8, and examined their phonological processing and literacy skills. 34% of the children with high FR developed dyslexia, as opposed to only 12% of the group with low FR. In a study conducted by Gallagher, Frith and Snowling (2000), 57% of the high-FR children aged 6 years had a literacy deficit, contrary to 12% to the group with low FR. This suggests that the inheritable high FR status does enlarge the risk of developing dyslexia as opposed to having a low FR. Van Bergen, de Jong, Regtvoort, Oort, Van Otterloo & Van der Leij (2011) examined this hypothesis by following the children's language development from kindergarten till the fifth grade using several tasks focussed on intelligence, phonological awareness, letter-knowledge, rapid naming, and (pseudo)word-reading. The children were divided into three groups during fifth grade: one with FR and dyslexia, one with FR and without dyslexia and one control group without both FR and dyslexia. The results showed that the FR non-dyslectic group first showed mild impairments in reading skills as they scored lower than the control group but higher than the FR dyslectic group. However, later on in fifth grade these non-dyslectic FR children had the same reading skill level as the control children. Regtvoort et al. (2011) concluded that 67% of children with FR ultimately do not end up with a reading impairment and they stress that the differences in genetic liability of the children may account for this divergence.

For studies that involve pre-schoolers with FR, it is not possible to test on literacy. However, (predictors of) spelling and reading can be measured through a number of other methods. One option is to assess the receptive vocabulary. The receptive vocabulary comprises the words a person is capable of understanding and responding to, whether or not that person is capable of using these words themselves. Receptive vocabulary was found to be a predictive of literacy proficiency at a current and later age (Lee, 2011; Ricketts, Nation, & Bishop 2007). Tasks to measure receptive vocabulary can include picture naming tasks in which the participants has to name known or unknown objects (e.g. Peabody Picture Vocabulary Test). A possible method to assess the children's understanding of inflectional and morphological rules is to run a grammar task that lets children decide which the grammaticality of short utterances provided to them auditorily.

Executive Functions and FR of Developmental Dyslexia

Executive functioning may affect reading and writing acquisition as it is suggested to support the processing of visual and linguistic input and lexical retrieval. Borella, Ghisletta & De Ribaupierre (2011) confirmed that the working memory capacity is related to text processing skills in adults and that inhibition skills have influence over differences in working memory. Inhibition refers to the cognitive mechanism that filters out irrelevant stimuli, suppresses undesired impulses and reflexes (de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012), which can include irrelevant linguistic information, and facilitates the processing of relevant linguistic input. A study by Gooch, Hulme, Nash and Snowling (2014) compared, amongst others, inhibition skills of children at FR with and without a language impairment and a control group. The children were tested at the age 3 ½ years and again a year later. Overall, the FR children without a language impairment scored lower on inhibition and other executive functions than the control group, but higher than the high FR group that did have language impairment. Gooch et al. (2014) concluded there that FR children are likely to have less well-developed executive functions, if they have an language impairment.

As for working memory, it is the part of short-term memory that supports temporary memory and the processing of information. Stored data can be swiftly changed or added into working memory (e.g. re-reading a (part of a) sentence, after misreading it, and then only using the right version to continue reading) and is transient. Visuo-spatial working memory concerns the storage and processing of visuo-spatial input such as locations. As for children and adults with DD, studies have shown poorer performance on tasks involving visuo-spatial working memory as compared to the control groups without DD (e.g. Bacon, Parmentier & Barr, 2013; Poblano, Valadéz-Tepec, de Lourdes Arias & García-Pedroza, 2000). The aforementioned study by Gooch et al. (2014) following FR children included a visuo-spatial memory task, and found overall lower scores for children with language impairments and FR than for the FR group without language impairments and the control group. This suggests a link between a working memory deficit and language impairment, but not necessarily FR.

Attention, another executive function linked with inhibition and working memory, is also often found impaired in individuals with DD. In order to able to read a text properly, one needs to be able to focus, shift and orientate their visual attention. Some studies have shown evidence of a considerable or even high co-morbidity between DD and Attention Deficit Hyperactivity Disorder (ADHD) (i.e. Gilger, Pennington & DeFries, 1992; Gillberg, Gillberg, Rasmussin, Kadesjo, Soderstrom, Rastam, et al., 2004). To examine attention and reading proficiency, visuo-spatial attention and visual search tasks have been used (e.g. Facoetti, Corradi, Ruffino, Gori & Zorzi, 2010; Facoetti, Paganoni, Turatto, Marzola & Mascetti, 2000). Facoetti et al. (2010) investigated the skills of pre-schoolers with and without high FR in visuospatial attention and auditory speech segmentation. The high-FR children scored significantly lower on both type of tasks than the control children. This suggests that a deficit in visuospatial attention is indeed related to DD.

Together with the other results from Gooch et al. (2014) that were discussed earlier, it can be hypothesised that any deficiencies in executive functioning should perhaps not be directly linked to an FR-status, but to language impairments. A deficit in executive functioning might be the cause of a further cognitive deficit that impairs a person's ability to acquire and improve their spelling and reading skills.

Current study

Decades of research have contributed to our understanding of DD. As was explained earlier in this paper, some studies point towards a link with executive functioning deficits, though we do not know whether this link is causal or correlational. As DD and executive functioning deficits are developmental disorders, examining preschool aged children (who are at earlier stages of the development of language and executive functions than studies with children with confirmed DD) could tell us important clues about how DD comes to be and what DD precisely is. If there is indeed a link between executive functioning and DD and it can be already found in individuals as young as pre-schoolers, assessing executive functioning could perhaps be used as an early predictor of a DD, alongside language screening, to enable earlier diagnosis of DD. As of yet, the amount of research involving infants is small. The current study contributes by comparing language and executive functioning in three-year-old children at high FR of DD and children at low FR. Two questions were addressed: 1) Do children at higher FR of DD perform more poorly on language tasks than control children at low FR?; and 2) Do children at higher FR of DD score lower on executive functioning tasks than the control children at low FR?

Method

Participants

A subset of the data from the pre-Cool project (Mulder, Hoofs, Verhagen, van der Veen & Leseman, 2014) was used. Specifically, the data of the three-year-old children who participated at the second measurement wave of the pre-COOL study were included. Children recruited through schools, institutions such as kindergartens, and letters to families. A smaller sample was selected from the total group of participating children. This selection was made on the basis of the following criteria: (i) the first and only language spoken by children's parents at home was Dutch, (ii) children had no missing data on the biographic variables gender and age and the educational levels of their parents, and (iii) parental questionnaire was available on children's FR status. More specifically, the latter criterion held that parents should have filled out a questionnaire containing two questions: (i) did one or both parents have a history of reading and/or spelling problems? (ii) did one or both parents have a diagnosis of DD? The high-FR group contained children of whom at least one parent had answered 'yes' to either one or both of these questions. The low-FR group contained children whose parents had answered 'no' to both questions. The high-FR group contained 72 children (*M* age = 3.51 years, *SD* = 0.24). In this high-FR group, there were 37 boys and 35 girls. The mean level of education of the parents for this groups was 3.22 on a scale from 1 ('vocational training as highest attained educational level of both parents') to 4 ('university degree as highest attained educational level') (*SD* = 0.75). The control group at low FR consisted out of 427 children (*M* age = 3.50 years, *SD* = 0.23). This control group contained 218 boys and 209 girls and the average of the parents' education was 3.46 (*SD* = 0.58). Age and gender were equal between the two groups ($p > .05$ for both). However, the level of parents' education was significantly higher in the low FR group than in the high FR group [t (86.039) = 2.514, $p = .014$].

Language tasks

Phoneme identification task. A phoneme identification was used to measure how well children could perceive and distinguish phonemes, which has been shown to be predictive of later reading proficiency (Maassen, Groenen & Crul, 2001). The design of this task was based on Gerrits (2003) and Kuijpers (1996). Children were shown multiple sets of two pictures at a time on a laptop. The pictures consisted of images of objects that had similar sounding words also known as minimal pairs (e.g. *peer-beer:* 'pear', 'beer'). The children were asked, for instance, which of the images represented a pear (*Kijk, een peer! Waar is een peer?:* 'Look, a pear? Where is a pear?). Then, the children had to point out the right option. Their answers were scored as 'correct', 'incorrect' or 'no response'. Before the children were offered the real stimuli, they were first presented with a couple of practise items consisting out of sets that sounded clearly distinct (*stoel -schoen, tas-muis*: 'chair-shoe', 'bag-mouse'). The real testing phase comprised 12 sets of minimal pairs that only differed in the initial consonant (*peer-beer*), the vowels (*bos-bus*: 'forest-bus'), the final consonants (*pot-pop*, 'pot-doll') or the initial or final consonant clusters (*brood-boot, mand-man*: 'bread-boat, 'basket-man'). The sets were constructed in a way that they covered as much of the different Dutch phonemes as possible while only containing highly frequent words from the Lexilijst ((Schlichting & Lutje Spelberg, 2002) or N-CDI (Zink & Lejaegere, 2001). Scores were calculated as the percentage of correct responses out of all responses for children who had completed at least half of the task.

Peabody Picture Vocabulary Test (PPVT). The Dutch version of the Peabody Picture Vocabulary test (PPVT-III-NL, Dunn, Dunn & Schlichting, 2005) was used to assess receptive vocabulary. The children were presented four images of objects (e.g. a spoon, ball, banana and dog) on a laptop screen. Then, the children were asked to point to one of the images in response to the assessor's uttering of questions like 'Waar is: hond'?' (Where is: dog?). of one of the objects (e.g. *Where is the dog?*). Their answers were scored as 'correct', 'incorrect' or 'no response'. Then, scores were calculated as the percentage of correct responses out of all responses for children who had completed at least half of the task. The pre-COOL project used an abbreviated version of the Peabody Picture Vocabulary Test with only 8 items (instead of 12) per set and 24 items in total plus one practise item (see also Mulder et al., 2014; Verhagen et al., 2016).

Non-word Repetition task. A Non-word Repetition Task (Veen, A., Veen, I. van der, Heurter, A.M.H., Ledoux, G., Mulder, L., Paas, T., Leseman, P., Mulder, H., Verhagen, J. & Slot, P., 2012) was used to evaluate verbal short-term memory. The task is to repeat non-existing words after they were presented auditorily to the participants. The twelve testing items were preceded by two exercise items with existing words. Short clips of objects appearing of a box were shown on a laptop screen. A pre-recorded female voice would utter sentences about the objects (e.g. *Look, a peun! Say peun)*, urging the children to repeat the target words. Their answers were scored as 'correct' (all phonemes pronounced correctly, regardless of intonation), 'incorrect', 'no answer' or 'unclear' (the test leader could not determine whether a phoneme was correct or incorrect). Scores were calculated as the percentage of correct responses out of all responses children who had completed at least half of the task.

Grammar task. A picture selection task was used to assess children's grammatical proficiency, which was modelled after similar tasks used with young children (Johnson, de Villiers & Seymour, 2005; Sekerina, Stromswold & Hestvik, 2004). In this task, children were presented with two pictures on a laptop screen, each depicting an action that marked a grammatical contrast involving personal pronouns (he vs. she), plural marking (the man washes vs. the men wash), auxiliaries (he washes vs. he has washed), and word order . The task was to point out the picture that matched the description the most. For example, the respective pictures with the target sentence 'she washes the pear' involved one on which a boy washed a pear and one on which a girl washed a pear. There were three practise items and twelve target items. Children's answers were scored as 'correct', 'incorrect', 'both pictures' (the child chose both pictures instead of one) or 'no response'. Scores were calculated as the percentage of correct responses out of all responses children who had completed at least half of the task.

Executive functions

Attention task: visual search. A visual search task (modelled after Gerhardstein & Rovee-Collier, 2002; Scerif, Cornish, Wilding, Driver & Karmiloff-Smith, 2004) was used to assess selective attention. In this task, the children were presented with a display containing 8 targets and 40 distractors on a laptop screen in a grid of 8 by 6 stimuli. The targets (elephants) and distractors (bears, horses) were highly similar in colour and shape. For each column, there was one target (the elephant) and seven distractors. The children's task was to find as many targets as possible in 40 seconds time. The test had three test items and an extensive practise phase in which children were acquainted with the test procedure. Children's scores were computed as the mean number of located targets per item for children who had completed at least two out of three test items.

Visuo-spatial working memory task: six boxes. To assess visuospatial working memory, the Six Boxes Task was used (after Diamond, Prevor, Callender & Druin, 1997). This type of task examines the amount of information a child can store in short-term memory while they manipulate the information being stored. Children were presented with six boxes. Every box contained a toy and the children were given six attempts to open up all six boxes. Every time a box was opened, a screen was put in between the child and the boxes and the child was distracted away from the boxes for six seconds by the research assistant. If a child did not open a box, but only touched or moved one around, the research assistant would open the box and scored this as a search attempt. The goal of this task was to see how well the children could remember which boxes they had already opened without opening the same box twice. Each time the children checked a box, their attempt was marked as 'correct or 'incorrect. The final score involved the percentage of correct trials out of all six search trials (i.e., search attempts).

Inhibition task. The inhibition task was adapted from the *Silly Sounds Stroop* task by Willoughby, Blair, Wirth, Greenberg, and Family Life Project Investigators (2010). A cat or a dog would be depicted on a laptop screen and the children had to make animal sound according to the picture as fast as possible. However, during the critical trials, they were told to swap the sounds a cat and a dog make. For example, if they were shown a dog, they were instructed to make the sound of a cat. During the practise phase, the children had to make to sound of a dog and subsequently that of a cat. Then, they were told that this was a 'silly game' in which the cat says 'woof'. To make sure that the children understood this rule, the research assistant asked them the following during two trials: "This is a game with silly animals. In this game, the cat says 'woof'. What does the cat say in this game?". If the children did not provide the right answer to one of the trials, then the trials were repeated. The tested would be stopped if a child that was still not able to correctly answer both trials. For the other children, the test continued with four test trials of two pictures of a cat and two of a dog. The score was calculated as the sum of correct answers.

General procedure

The tests were administered by trained assistants in individual sessions in a quiet room at either the children's home or their day-care centre. Each session was about 45 minutes long. Tasks were administered in a fixed order, intermixed with other tasks that are not reported on in this study, as follows: Phoneme identification, Peabody Picture Vocabulary, Visual Search, Peabody Picture Vocabulary Test, Silly Sounds Stroop, Grammar task, Six Boxes, and Gift Delay. Breaks were taken as often as needed for the children to stay focussed.

Analyses

A MANCOVA was ran to compare the two groups on their skills in language and executive functioning. The scores of the tasks were taken as the dependent variables and low/high FR as the independent variable. Because there was a significant difference in children's parents' educational level across the two groups, this variable was taken as a covariate. All tasks were checked for equal error variances using Levene's Test for Equality of Error Variances. The variances did not differ significantly, expect for the phoneme identification task [F (1, 497) = 4.184, p = .044]. However, as all other language and EF variables met the Levene's test, MANCOVAs were carried out.

Results

Language proficiency

Table 1 shows the mean and the standard deviations for each task language task per test group. The MANCOVA showed no overall effect of group [*Wilk's* λ = .993, F (4, 493) = 0.888, p = .471, multivariate η^2 = .007]. Separate ANOVAs showed no significant differences between the groups: phoneme identification [F (1, 496) = 0.382, p = .537, η^2 = .001], vocabulary [F (1, 496) = 0.827, p = .364, η^2 = .002], non-word repetition [F (1, 496) = 3.279, p = .071, η^2 = .007] and grammar [F (1, 496) = 0.125, p = .724, η^2 < .001].

SES was a significant covariate [*Wilk's λ* = .993, *F* (3, 494) = 0.972, *p* = .006, multivariate η^2 = .028]. In separate ANOVAs significant effects of SES were found on the scores of the vocabulary, non-word repetition and the grammar tasks (*p*s ≤ .005). SES did not affect the phoneme task (*p* = .198).

Executive functioning

In Table 2, mean scores and standard deviations for the executive functioning tests are presented. A MANCOVA on all task scores with low/high FR as the independent variable showed an effect of group [*Wilk's λ* = .982, *F* (3, 494) = 3.081, *p* = .027, multivariate η^2 = .018]. Separate ANOVAs showed that there was a trend for the high FR group to score lower on selective attention than the low FR group [*F* (1, 496) = 3.714, *p* = .055, η^2 = .007]. No trends or effects were found for inhibition [*F* (1, 496) = 0.207, *p* = .649, η^2 < .001] and working memory [*F* (1, 496) = 2.893, *p* = .097, η^2 = .005]. Thus, the control children did not score significantly better than the FR children on any of the tasks, and on the selective attention task, the high-FR children tended to have slightly lower scores than the low-FR children.

The educational levels of the parents appeared to have influence on the scores [*Wilk's λ* = .980, *F* (3, 494) = 3.330, *p* = .019, multivariate η^2 = .020]. Separate ANOVAs indicated that the parents' education had significant effects on the inhibition and working memory tasks (*p*s < .05), but not on the attention task (*p* = .909).

Table 1

Mean scores (in % correct) and standard deviations (SD in %) for the language tasks per FR group

	High risk		Low risk	
Task	M	SD	M	SD
Phoneme identification	83.07	14.04	84.23	10.99
Vocabulary	67.79	17.67	70.32	15.58
Non-word repetition	44.81	21.07	50.96	22.58
Grammar	52.25	23.63	54.51	24.46

Table 2

Mean (M) scores and standard deviations (SD) of the executive functioning task per FR group

	High risk		Low risk	
Task	M	SD	M	SD
Attention	5.86	1.04	6.10	0.97
Inhibition	2.10	1.61	2.25	1.62
Working memory	85.56	13.10	83.01	15.12

Discussion

Previous studies have shown that children diagnosed with DD score lower at language tests and executive functioning tests than children without DD (e.g. Bacon et al., 2013; Bruck, 1992; Faust et al., 2003; Swan & Goswami, 1997; Wolf, 1991; Tijms, 2004). Little research has been done with pre-schoolers, who are in the earlier stage of language development. To fill up this gap, study was designed to find evidence that children with high FR have lower language and executive functioning than children with low FR. If such evidence is found, it would contribute to a more accurate understanding of the causes and symptoms of DD. Executive functioning could then be also used as an early predictor of DD, allowing earlier intervention to limit or prevent deficiencies. To this end, the current study compared the test results of three-year old children divided into low or high FR groups. Children that had at least one parents with a history reading/spelling difficulties was marked as high FR. The aim of this study was to answer the question whether children with high FR of DD preform worse on tasks involving language and executive functioning than those with low FR. The results showed no significant differences in performance on a series of language tasks (phoneme identification, vocabulary, non-word repetition and grammar) and executive functioning tasks (visual attention, inhibition and working memory) between children with higher FR of DD and control children at low familial risks. However, there was a trend for the high FR children to score slightly lower on the attention task and the non-word repetition task than the low FR controls. Overall, the current findings provide no indications that children with high FR of DD have a language or executive functioning impairment.

These outcomes are not in line with those of similar studies involving FR. In earlier work, deficits were found in phoneme identification/awareness (Pennington & Lefly, 2001), vocabulary and morphology (Lyytinen & Lyytinen, 2004), non-word repetition (De Bree, Rispens & Gerrits, 2007), attention (Facoetti et al., 2010), inhibition (Gooch et al., 2014), working memory (Gooch et al., 2014). However, the trends for non-word repetition and attention found in the current study do match earlier studies (e.g. De Bree, Rispens & Gerrits, 2007; Facoetti et al., 2010) to a certain degree. This means that, although the trends were not significant, they still provide confidence for the reliability of the data and the two tasks in question.

A couple of factors could have affected the results of the current study. First of all, the parents' education appeared to have an influence on the task scores of the children. Several studies have offered evidence that SES does indeed affect early vocabulary development of two-year-olds (Hoff, 2003), phonological sensitivity and reading skills of 5-year-olds (Bowey, 1995) alerting, orienting, and executive attention and of seven-year-olds (Mezzacappa, 2004). The current study did, however, not focus on the SES of the children during selection. A proxy of SES, parental education levels were used instead, but the distribution was far from equal as more children with parents with higher levels of education were included in the testing than ones with lower levels (e.g. 7 children with category 1 and 184 with category 4). Because children with higher parental education were overrepresented, the overall results in both FR groups might have been relatively high, causing between group differences and impairments to not appear. In future work, it would be good to compare the high and low FR groups in relation to SES or parental education (e.g. compare groups with high SES and high FR, high SES and low FR etc.). This will tell more about whether executive functioning and language impairments is linked to only children with high FR and low SES or parental education and not those with high FR and high SES or parental education.

Second, the current participants were not matched on age nor gender. Although the overall distribution of these two variables did not differ between the groups, matching each high FR child with someone from the low FR group based on age, gender and also SES may have made the comparison more fair.

A third note to keep in mind is that FR children only have a higher chance of developing dyslexia later on. As previous research (e.g. Gallagher, Frith & Snowling, 2000) has shown, not all children with high FR keep on having problems with language or even had them in the first place. High-FR children just seem to have a statistically larger chance to develop language or executive functioning deficiencies. Future research could first test for the presence of language impairments in the participants using a (standardised) test. Then the high-FR children can be classified into two groups, one group with and one without language impairments. This should make it clearer whether a link between an executive functioning deficit and language impairment exists.

The fourth factor that might be responsible for the lack of differences in executive functioning between the FR groups is age. Very little is known about executive functioning in children at such a young age as this study. Perhaps, at the age of three years, executive functions have not yet developed to a point were high FR children show impairments when compared to their low FR peers.

A final limitation is that the current measurements involved only one point in time. Measurements were only taken at one point in time. Perhaps the results would have been different for some children if they had been tested a couple of months later as they can improve a lot over a short span of time at this age or they could have just had a bad day. Especially since DD is a developmental disorder, the results would be more meaningful with longitudinal research that has frequent testing sessions, allowing for a clear picture of the potentially different developmental pathways in EF development of children with high FR of DD.

In conclusion, no differences in language skills nor executive functioning was found between three-year old pre-schoolers with high and low FR of DD. However, the current study was able to provide some points of attention that may be helpful for future research on FR of DD.

Literature

Adams, A., & Gathercole, S. (2000). Limitations in working memory: Implications for language development. *International Journal of Language Communication Disorders*, 35, 95-116.

Altemeier, L. E., Abbott, R. D., & Berninger, V. W. (2008). Executive functions for reading and writing in typical literacy development and dyslexia. *Journal of clinical and experimental neuropsychology*, *30*(5), 588-606.

Bacon, A. M., Parmentier, F. B., & Barr, P. (2013). Visuospatial memory in dyslexia: Evidence for strategic deficits. *Memory*, *21*(2), 189-209.

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological review*, *105*(1), 158.

van Bergen, E., de Jong, P.F., Regtvoort, A., Oort, F., van Otterloo, S., & van der Leij, A. (2011). Dutch children at family risk of dyslexia: Precursors, reading development, and parental effects. *Dyslexia*, *17*, 2–18.

Berninger, V., Abbott, R., Cook, C. R., & Nagy, W. (2016). Relationships of Attention and Executive Functions to Oral Language, Reading, and Writing Skills and Systems in Middle Childhood and Early Adolescence. *Journal of learning disabilities*, 1-16

Bishop, D. V., Adams, C. V., & Norbury, C. F. (2006). Distinct genetic influences on grammar and phonological short-term memory deficits: evidence from 6-year-old twins. *Genes, Brain and Behavior*, *5*(2), 158-169.

Borella, E., Ghisletta, P., & De Ribaupierre, A. (2011). Age differences in text processing: The role of working memory, inhibition, and processing speed. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 1-10.

Bowey, J. A. (1995). Socioeconomic status differences in preschool phonological sensitivity and first-grade reading achievement. *Journal of Educational Psychology*, *87*(3), 476.

De Bree, E., Rispens, J., & Gerrits, E. (2007). Non-word repetition in Dutch children with (a risk of) dyslexia and SLI. *Clinical Linguistics & Phonetics*,*21*(11-12), 935-944.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental psychology*, *28*(5), 874.

Diamond, A., Prevor, M. B., Callender, G., & Druin, D. P. (1997). Prefrontal cortex cognitive deficits in children treated early and continuously for PKU. *Monographs of the Society for Research in Child Development*, 62(4), i.

Gerhardstein, P., & Rovee-Collier, C. (2002). The development of visual search in infants and very young children. *Journal of Experimental Child Psychology*, 81(2), 194-215.

Faust, M., Dimitrovsky, L., & Shacht, T. (2003). Naming Difficulties in Children with Dyslexia

Application of the Tip-of-the-Tongue Paradigm.*Journal of Learning Disabilities*, *36*(3), 203-215.

Duff, F. J., Nation, K., Plunkett, K., & Bishop, D. V. (2015). Early prediction of language and literacy problems: is 18 months too early?. *PeerJ*, *3*, e1098.

Ehri, L. C., Nunes, S. R., Willows, D. M., Schuster, B. V., Yaghoub-Zadeh, Z., & Shanahan, T. (2001). Phonemic awareness instruction helps children learn to read: Evidence from the National Reading Panel's meta-analysis. *Reading research quarterly*, *36*(3), 250-287.

Facoetti, A., Corradi, N., Ruffino, M., Gori, S., & Zorzi, M. (2010). Visual spatial attention and speech segmentation are both impaired in preschoolers at familial risk for developmental dyslexia. *Dyslexia*, *16*(3), 226-239.

Facoetti, A., Paganoni, P., Turatto, M., Marzola, V., & Mascetti, G. G. (2000). Visual-spatial attention in developmental dyslexia. *Cortex*, *36*(1), 109-123.

Faust, M., Dimitrovsky, L., & Shacht, T. (2003). Naming Difficulties in Children with Dyslexia Application of the Tip-of-the-Tongue Paradigm. *Journal of Learning Disabilities*, *36*(3), 203-215.

Friedmann, N., Biran, M., & Dotan, D. (2013). Lexical retrieval and its breakdown in aphasia and developmental language impairment. *The Cambridge handbook of biolinguistics*, 350-374.

Gathercole, S. E., & Baddeley, A. D. (2014). *Working memory and language*. Psychology Press.

Gerrits, E. (2003). Speech perception of young children at risk for dyslexia and children with specific language impairment. *Proceedings of the 15th International Conference of p a (ICPhS)*, Barcelona, Spain.

Gilger, J. W., Pennington, B. F., & DeFries, J. C. (1992). A twin study of the etiology of comorbidity: attention-deficit hyperactivity disorder and dyslexia. *Journal of the American Academy of Child & Adolescent Psychiatry*, *31*(2), 343-348.

Gillberg, C., Gillberg, I. C., Rasmussin, P., Kadesjo, B., Soderstrom, H., Rastam, M., et al. (2004). Co-existing disorders in ADHD—Implications for diagnosis and intervention. *European Child and Adolescent Psychiatry*, 13, 80–92.

Gooch, D., Hulme, C., Nash, H. M., & Snowling, M. J. (2014). Comorbidities in preschool children at family risk of dyslexia. *Journal of Child Psychology and Psychiatry*, *55*(3), 237-246.

Hoeft, F., McCandliss, B.D., Black, J.M., Gantman, A., Zakerani, N., Hulme, C., & Gabrieli, J.D.E. (2011). Neural systems predicting long-term outcome in dyslexia. *Proceedings of the National Academy of Sciences of the United States of America*, 108(1), 361–366.

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child development*, *74*(5), 1368-1378.

Hoff, E., Core, C., & Bridges, K. (2008). Non-word repetition assesses phonological memory and is related to vocabulary development in 20- to 24-month-olds. *Journal of Child and Language*, 35, 903-916.

Johnson, V. A., de Villiers, J. G., & Seymour, H. N. (2005). Agreement without understanding? The case of third person singular ⁄ s ⁄. *First Language*, 25, 317–330.

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, 36(2), 220-232.

Koster, C., Been, P.H., Krikhaar, E.M., Zwarts,F. (2004). Differences at 17 Months: Productive Language Patterns in Infants at Familial Risk for Dyslexia and Typically Developing Infants *Journal of Speech, Language, and Hearing Research*, April 2005, Vol. 48, 426-438.

Johnson, C. (1996). Perception of the voicing contrast by Dutch children and adults. *Journal of Phonetics*, 24, 367-382.

Maassen, B., P., Groenen, P., & Th. Crul (2001). Identification and discrimination of voicing and place-of-articulation in developmental dyslexia, *Clinical Linguistics and Phonetics,* 15, 319-339.

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child development*, *75*(5), 1373-1386.

Lee. J. (2011). Size matters: Early vocabulary as a predictor of language and literacy competence. *Applied Psycholinguistics* 32: 69–92.

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*(1), 59-80.

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of dyslexia*, *53*(1), 1-14.

Lyytinen, H., Ahonen, T., Eklund, K., Guttorm, T. K., Laakso, M. L., Leinonen, S., Leppanen, P.H.T., Lyytinen, P., Poikkeus, A.M., Puolakanaho, A., & Richardson, U. (2001). Developmental pathways of children with and without familial risk for dyslexia during the first years of life. *neuropsychology*, *20*(2), 535-554.

Lyytinen, P., & Lyytinen, H. (2004). Growth and predictive relations of vocabulary and inflectional morphology in children with and without familial risk for dyslexia. *Applied Psycholinguistics*, *25*(3), 397-411.

Mann, V. A., & Liberman, I. Y. (1984). Phonological awareness and verbal short-term memory. *Journal of learning disabilities*, *17*(10), 592-599.

Mulder, H., Hoofs, H., Verhagen, J., van der Veen, I., & Leseman, P. P. (2014). Psychometric properties and convergent and predictive validity of an executive function test battery for two-year-olds. *Frontiers in psychology*, *5*.

Pennington, B. F., & Lefly, D. L. (2001). Early reading development in children at family risk for dyslexia. *Child development*, *72*(3), 816-833.

Poblano, A., Valadéz-Tepec, T., de Lourdes Arias, M., & García-Pedroza, F. (2000). Phonological and visuo-spatial working memory alterations in dyslexic children. *Archives of Medical Research*, *31*(5), 493-496.

Reiter, A., Tucha, O., & Lange, K. W. (2005). Executive functions in children with dyslexia. *Dyslexia*, *11*(2), 116-131.

Scerif, G., Cornish, K., Wilding, J., Driver, J., & Karmiloff-Smith, A. (2004). Visual search in typically developing toddlers and toddlers with fragile X or williams syndrome. *Developmental Science*, 7(1), 116-130.

Smith-Spark, J.H., Henry, L.A., Messer, D J., Edvardsdottir, E., & Zięcik, A.P. (2016). Executive functions in adults with developmental dyslexia. *Research in developmental disabilities*, *53*, 323-341.

Ricketts, J., Nation, K., & Bishop, D.V.M. (2007). Vocabulary is important for some, but not all reading skills, *Scientific Studies of Reading*, 11, 235- 257.

de Ridder, D. T., Lensvelt-Mulders, G., Finkenauer, C., Stok, F. M., & Baumeister, R. F. (2012). Taking stock of self-control a meta-analysis of how trait self-control relates to a wide range of behaviors. *Personality and Social Psychology Review*, *16*(1), 76-99.

Diamond, A. (2013). Executive functions. *Annual review of psychology*, *64*, 135.

Schlichting, J. & Lutje Spelberg, H. (2002). *Lexilijst Nederlands: Een instrument om de taalontwikkeling te onderzoeken bij Nederlandstalige kinderenvan 15-27 maanden in het kader van de vroegonderkenning.* Lisse: Swets Test.

Sekerina, Irina, Karin Stromswold, & Arild Hestvik (2004). How do children and adults process referentially ambiguous pronouns? *Journal of Child Language*, 31, 123-152.

Snowling, M. J., Muter, V., & Carroll, J. (2007). Children at family risk of dyslexia: a follow-up in early adolescence. *Journal of Child Psychology and Psychiatry*, *48*(6), 609-618.

Swan, D., & Goswami, U. (1997a). Picture naming deficits in developmental dyslexia: The phonological representations hypothesis. *Brain and language*,*56*(3), 334-353.

Swan, D., & Goswami, U. (1997b). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *Journal of experimental child psychology*, *66*(1), 18-41.

Tijms, J. (2004). Verbal memory and phonological processing in dyslexia. *Journal of Research in Reading*, *27*(3), 300-310.

Torgesen, J.,Wagner, R., & Rashotte, C. (1994). Longitudinal studies of phonological processing and reading. *Journal of Learning Disabilities, 27*, 276–286.

Varvara, P., Varuzza, C., Sorrentino, A. C., Vicari, S., & Menghini, D. (2014). *Executive functions in developmental dyslexia*.

Veen, A., Veen, I. van der, Heurter, A.M.H., Ledoux, G., Mulder, L., Paas, T., Leseman, P., Mulder, H., Verhagen, J., Slot, & P. (2012). Pre-COOL-cohortonderzoek. *Technisch rapport twee-jarigencohort: tweede meting 2011-2012.* Amsterdam: Kohnstamm Instituut.

Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment*, 22, 306– 317.

Wolf, M. (1991). The word-retrieval deficit hypothesis and developmental dyslexia. *Learning and Individual Differences*, *3*(3), 205-223.