A possible relationship between early speech perception and later language development in Dutch children with and without a familial risk of dyslexia

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Abstract

Developmental dyslexia is a disorder that manifests itself by severe problems with reading and writing. It has been hypothesized that early speech perception is impaired in individuals with dyslexia. It has also been found that children with a familial risk of dyslexia show delays in their early language development, which might be precursors of dyslexia. In this study, the language development at toddler age of children with and without a familial risk of dyslexia is investigated, as well as the possibility of a relationship between early speech discrimination abilities at infant age and language development at toddler age. 48 Dutch monolingual children with and without a familial risk of dyslexia at the ages of 3;6 tot 4;6 were tested on receptive vocabulary size, verbal short-term memory, morpho-syntactic production, word retrieval speed and cognitive control of selective attention. These children had participated in a speech sound discrimination experiment (De Klerk et al., in prep) at the ages of 6 to 8 months. They were tested on their abilities to discriminate between alternating and non-alternating trials of native and non-native sound contrasts. No group differences in performance on the tasks at toddler age were found. In de speech discrimination experiment, the sample of infants of this study showed sensitivity to the native sound contrast at the ages of 6 and 8 months. They did not show sensitivity to the non-native sound contrast at the ages of 6 and 8 months. A negative correlation was found between looking time difference on the native sound contrast at the age of 6 months and the performance on the PPVT, which measures receptive vocabulary size. A positive correlation was found between looking time difference on the non-native sound contrast at the age of 8 months and the performance on the non-word repetition task. No other correlations between performance at infant age and performance at toddler age were found. This resulted in the conclusion that, for this sample of children, there is no reliable evidence for a relationship between early speech perception and later language development.

Introduction

Reading and writing skills are normally acquired during the first years of elementary school. A small percentage of school-age children, however, show problems with learning to read and write. It is estimated that approximately 4 percent of these children are diagnosed with developmental dyslexia (Grigorenko, 2001). Developmental dyslexia (henceforth dyslexia) manifests itself as severe reading and spelling problems, despite normal levels of intelligence and cognitive abilities (Vellutino, Fletcher, Snowling & Scanlon, 2004). Furthermore, children and adults with dyslexia typically show impairments in other language-related capacities as well, namely phonological processing, including phonological awareness (Joanisse, Manis, Keating & Seitenberg, 2000; Fawcett & Nicolson, 1995; Fletcher, Shaywitz, Shankweiler, Katz, Liberman, Stuebing, Francis, Fowler & Shaywitz, 1994) and verbal short-term memory (Beneventi, Tønnessen, & Ersland, 2009). It is also found that individuals with dyslexia have a deficit in naming speed, which is shown by a poor performance on rapid naming of familiar words (Wolf, Goldberg O'Rourke, Gidney, Lovett, Cirino & Morris, 2002; Fawcett & Nicolson, 1994). However, other problems have also been reported in individuals with dyslexia, such as grammatical morphology (Desroches, Newman & Robertson, 2013; Joanisse, Manis, Keating & Seitenberg, 2000), and visual attention (Bosse, Tainturier & Valdois, 2007). Dyslexia is a heritable and familial disorder (see for an overview Grigorenko, 2001) and it has been established that children born in families in which dyslexia occurs have approximately a 32 to 66 per cent chance of becoming dyslexic (see for an overview Vellutino et al., 2004; Van Bergen, Jong, Regtvoort, Oort, Otterloo & Van der Leij, 2001). Because of the fact that dyslexia is heritable and familial, children who have at least one dyslexic parent are referred to as being *at familial risk* of dyslexia.

Many studies have demonstrated that these children with a familial risk of dyslexia (henceforth FR children) show a delay in their language development compared to typically developing children (henceforth TD children), for example on their letter knowledge (Torppa, Lyytinen, Erskine, Eklund, & Lyytinen, 2010; Scarborough, 1989); word naming (Scarborough, 1989) and word production in the verbal and closed-class categories (Koster, Been, Krikhaar, Zwarts, Diepstra & van Leeuwen, 2005). Studies have also found that FR children have a delay in morpho-syntactic knowledge (Wilsenach, 2006; Lyytinen, Poikkeus, Laakso, Eklund & Lyytinen, 2001; Scarborough, 1991) and morpho-synctactic production (Van Alphen, De Bree, Gerrits, De Jong, Wilsenach & Wijnen, 2004). Other studies have also investigated complex phonology abilities of FR children. These studies have found that FR children have problems with phonological processing (Van Alphen et al., 2004) and with detecting mispronunciation of words (Carroll & Snowling, 2004; Van Alphen et al., 2004). FR children thus tend to show broad language problems, which could be precursors of dyslexia.

In addition to a delay in language development, it is also possible that FR children show attention deficits, since it is hypothesized that attention is related to language acquisition (Ribeiro, Zachrisson, Schjolberg, Aase, Rhorer-Baumgartner & Magnus, 2011) and dyslexia is known to be co-morbid with ADHD (see for an overview Knivsberg, Reichelt & Nødland, 1999). It is therefore possible that FR children have poorer attention skills than TD children. Unfortunately, we are aware of only one published study on the visual attention abilities of children with a familial risk of dyslexia. McBride-Chang, Lam, Lam, Chan, Fong, Wong & Wong (2011) tested FR children and TD children at the age of 3.5 years, to investigate whether children with a familial risk of dyslexia also show problems with visual attention. This was tested with a visual skill test, in which the participants were presented with 5 objects. One of these objects had a different quality than the other 4 objects. The participants were repeatedly asked to select this particular object that was different from the other objects. The results revealed no difference in performance on this task between the TD and FR children, indicating that this group of FR children had no deficit in visual attention found. More research is needed to see whether this is generally the case in FR children.

Many theories have been developed in an attempt to explain the source of the language impairments dyslexics, and thus also FR children who later develop dyslexia, face. However, there is not yet a consensus about the cause of dyslexia. The most widely accepted cognitive explanation is the phonological deficit hypothesis (henceforth PDH). This hypothesis states that individuals with dyslexia have problems with constructing, maintaining and retrieving phonological representations (Wagner & Torgesen, 1987), which results in an impairment in the processing of phonological information. It is established that individuals with dyslexia have poor phonological awareness, poor verbal short-term memory and slow lexical retrieval; all skills for which phonological representations are of importance (Ramus & Szenkovits, 2008). However, there is still much debate on whether individuals with dyslexia have 'weak' phonological representations, or that the access to the phonological representations is impaired. One explanation for the idea that individuals with dyslexia have problems with phonology is that they have poorer speech perception abilities. Phonological representations are of great importance for learning to read and write. In order to learn how to read, a child must learn the relation between orthography and the spoken language. In other words, he or she has to gain insight into the fact that the graphemes in a written word are the representation of sounds, the phonemes, a spoken word consists of. If the underlying phonological elements are poorly represented, a reader will experience difficulties in the segmentation of words into their phonological elements. A less developed ability to segment words suggests an instable representation of phonemes, which results in a less fully or properly acquisition of the connection between phonemes and graphemes. This in turn might lead to difficulty with reading and spelling (Shaywitz & Shaywitz, 2005; Shaywitz & Shaywitz, 2003). If it is the case that individuals with dyslexia have indeed 'weak' or 'unstable' phonological representations, this implies that they might also have a deficit in categorical speech perception.

In recent years, it has been suggested that children with dyslexia indeed have a deficit in categorical speech perception (Bogliotti, Serniclaes, Messaoud-Galusi, & Sprenger-Charolles, 2008; Serniclaes, Sprenger-Charolles, Carre, & Demonet, 2001). The organization of phonetic categories is important for speech perception. Normal development of phonetic categorization results in the ability to make distinctions between sounds categorically. Acoustic differences between tokens within the same category are not perceived as different sounds, while acoustic differences, with the same phonetic distance, that cross a phoneme boundary result in perception of two different sounds (for example, a switch in perception from 'da' to 'ta'). It is not yet determined whether a deficit in categorical speech perception in children with dyslexia is caused by too much sensitivity to sounds that fall within the same category, or by poor discrimination abilities. Godfrey, Syrdal-Kasky, Millay and Knox (1981) first proposed the idea that the speech perception in children with dyslexia was less categorical than the speech perception of age-matched controls. They tested children with dyslexia at the age of 10 years. The results showed that these children were less consistent in the identification of stimuli consisting of three different synthesized stop consonants (/b/-/d/-/g/) than their age-matched controls. In addition, the dyslexic children showed poorer phoneme boundary discrimination. Serniclaes et al. (2001) also found a difference in performance on speech and non-speech analogues discrimination tasks of dyslexic and TD children at the age of 13 years, using sine wave analogues of voiced stop consonants +/a/ syllables between the continuum of /ba/ and /da/. Moreover, their results showed that the discrimination abilities of the children with dyslexia were less categorical in the speech condition but not in the non-speech condition. This implies that a specific deficit in categorical speech sound perception, and not a general auditory deficit. The dyslexic children were better at discriminating acoustic difference between stimuli *within* the same category. This led to their conclusion that a categorical deficit in children with dyslexia may come from an increased perceptibility of within-category difference (Serniclaes et al., 2001). In addition, Bogliotti et al. (2008) tested children with dyslexia at the age of 10 years on their skills to identify and discriminate /do/-/to/ syllables along a voice onset time continuum. They tested this using a categorical perception task, in which the participants heard sequences of two stimuli along the continuum of /do/-/to/. The pairs consisted of either identical stimuli or different stimuli, and the participants were asked to identify the pairs of stimuli as identical or different. The results of their study showed that the children with dyslexia were less accurate in discriminating between the different stimuli (/do/ versus /to/) than the typically developing controls. These findings support the idea that a deficit in categorical perception is an aspect of dyslexia (Bogliotti et al., 2008). Altogether, these studies thus show that children with dyslexia may have a less categorical speech perception, and that this is manifested by less accurate discrimination between phonemes that fall in different categories and too much discrimination between phonemes that fall within the same category.

The idea that children with dyslexia have impaired speech perception abilities is not supported by all studies. Messoud-Galusi, Hazan & Rozen (2011) tested dyslexic children and typically developing children at the ages of 6.5 to 13.5 years old on their categorical perception, using a synthesized /bi/-/pi/ continuum. This was tested with identification tasks and discrimination tasks. The results showed that the dyslexic children did not consistently performed poorer on the tasks than the typically developing children (Messoud-Galusi et al., 2011), which undermines the claim of a speech perception deficit in children with dyslexia. There is thus still much unknown about the possible categorization problems and a possible deficit in the speech perception of children with dyslexia. It is therefore of importance to investigate this possible deficit in children with a familial risk of dyslexia.

Some studies on speech perception in children with a familial risk of dyslexia have found evidence of a deficit in their performance on speech perception. Gerrits & De Bree (2009) found that the speech perception of native Dutch FR children at the age of 3 to 4 years was poorer than that of typically developing controls. This was tested with a categorization task, using stimuli from a stop-consonant continuum between the Dutch word /pɔp/ ('doll') and the Dutch word /kɔp/ ('cup'). The participants had to point at a picture of either a doll or a cup each time a stimulus was presented. The results showed that the FR children were less accurate in pointing at the picture that represented the stimulus than the TD children, which suggests that their categorical perception may be weaker than that of TD children. However, results of some other studies on speech perception are in contrast with the assumption that there is a speech perception deficit in children with a familial risk of dyslexia. Scarborough (1990) tested FR children at the age of 30 and 36 months on speech discrimination skills, using a phoneme discrimination task. In this task, 24 trials were used consisting of minimal pairs (e.g.

bear/pear). The results showed no significant difference between the performance of the FR children and TD children on the task, suggesting that the FR children did not have poorer speech discrimination abilities than the TD children. Furthermore, Boets, Ghesquière, Van Wiering & Wouters, (2006) found no difference in word identification skills and only a marginally significant difference in speech discrimination skills of FR children at the age of 5 years compared to age-matched TD children. These skills were tested with an identification task and a discrimination task. The stimuli consisted of a stop-consonant continuum ranging from the meaningful word /bɑk/ to /dɑk/ (the Dutch words for 'box' and 'roof' respectively). The FR children and TD children performed equally on the identification task, but the performance of the FR children on the discrimination task was slightly poorer. Still, it is important to note that this field of research is very complex, and that the choice of tasks and stimuli, as well as the age of the children are all of influence on the outcomes of the study. Altogether, the outcomes of different studies show a mixed picture of a possible impairment in the speech perception skills of children with a familial risk of dyslexia.

Whereas many studies have investigated different aspects of the language development, including the speech perception, of children with a familial risk of dyslexia, only a few studies have looked at the early stages of speech perception development in infants with a familial risk of dyslexia. The few studies concerning FR infants and speech perception have focused on phoneme duration abilities of Finnish FR infants (e.g. Richardson, Leppänen, Leiwo, and Lyytinen, 2003). Phoneme duration is of importance in Finnish, since a longer or shorter duration of a phoneme in this language can change the meaning of a word. However, little research had been conducted on speech sound categorization in FR children. This is a surprising gap in the literature, since it is hypothesized that the problems FR children and individuals with dyslexia have, might be caused by impaired categorical speech perception. During the first year of life, infants start with the development of speech sound categories. They learn to organize speech sounds into phonemic categories and to discriminate between sound contrasts that are meaningful in their native language, and sound contrasts that are not (Werker & Tees, 1984). It has been suggested that the formation of these phonemic categories is important for the language acquisition of infants. In their study, Yoshida, Fennell, Swingley & Werker (2009) found that there is a relationship between sensitivity to phonetic detail and vocabulary size in typically developing infants at the age of 14 months. The infants were tested with a visual choice task, using the non-words /bɪn/ and /dɪn/. The non-words were introduced to the infants and labeled on non-existent objects, displayed on a screen, during the habituation phase. In the test phase, both non-existent objects were displayed on the screen, but only one non-word was named. They compared the looking times of these infants with receptive and productive vocabulary reported in the completed MacArthur Communicative Development Inventory's. They found that infants who looked at the picture that represented the non-word, and thus showed high sensitivity to the phonetic difference between the minimal pairs /bɪn/ and /dɪn/, had a larger vocabulary size at that age. This suggests that there might be a link between phonetic sensitivity, which is important for the formation of speech sound categories, and receptive and productive vocabulary.

When speech sound categories are formed, infants have learned which sounds are meaningful in their native language and loose their sensitivity to non-native sound contrasts. It has been demonstrated that a decline of perception of non-native consonant contrasts takes place between 6-8 and 10-12 months of age (Werker & Tees, 1984). In their study, Werker and Tees (1984) tested the ability of English infants between the ages of 6 to 12 months to discriminate between non-native sound contrasts, using the Hindi /t.a/-/ta/ contrast and the Thompson /`ki/-/`qi/ contrast. The results showed that most English infants were able to discriminate between both non-native sound contrasts at the ages of 6 to 8 months, but had lost this ability at the ages of 10 to 12 months. Werker and Tees thus suggested that a perceptual reorganization of consonants towards the native language occurs around the ages of 8 to 12 months. Due to this perceptual reorganization, infants loose their sensitivity to non-native sound contrasts.

It has been hypothesized that this decline of sensitivity to non-native sound contrasts is related to native language learning (Kuhl, Conboy, Padden, Nelson & Pruitt, 2005). This hypothesis states that infants who 'tune in' better to their mother tongue, and consequently show less sensitivity towards non-native speech contrasts, are further ahead in their language development. This hypothesis is supported by a longitudinal study of Tsao, Liu and Kuhl (2004). In this study, English infants at the age of 6 months were tested on their speech discrimination abilities of non-native contrasts, using a conditioned head-turn task. The vowel contrast consisted of two Finnish vowels, the Finnish high-back vowel /u/ versus the Finnish high-front /y/. Importantly, these vowels are perceived by English adults as non-prototypical tokens of the English /u/

and /i/ vowels and the ability to discriminate between these sound contrasts will therefore reflect the ability to discriminate between native sound contrasts. Parents completed the MacArthur Communicative Development Inventory when their children were at the age of 13, 16 and 24 months, which determined the receptive and productive vocabulary. The results of the study showed that the infants' ability to discriminate between the vowels in the head-turn task positively correlated with their later language abilities in word comprehension, word production and sentence comprehension. This suggests that there might be a relationship between speech discrimination abilities and later language development.

Until recently, only a few studies that we are aware of have investigated FR children very early in their language development on their ability to discriminate between speech sounds. However, in the past years De Klerk, De Bree, Kerkhoff & Wijnen (in prep.) have conducted a study to fill this gap in the research on the development of early speech perception in children with a familial risk of dyslexia. They investigated the developmental pathway of a Dutch native vowel contrast, /a-e/ and the (partly) non-native vowel contrast, /æ-ɛ/, in infants (both TD and FR) aged 4-5, 6, 8 and 10 months. The native and non-native vowel contrasts were embedded in the non-words *fap* and *fep*, and in *sæn* and *sɛn*. Infants' abilities to discriminate between these speech sounds were tested using a hybrid visual fixation paradigm (based on Houston, Horn, Qi, Ting & Gao, 2007). The results of the study showed that at the age of 4-5 and 6 months, both groups (TD and FR) were able to discriminate the native as well as the non-native vowel contrast, whereas both groups (TD and FR) had lost this sensitivity for the non-native contrast at 8 months of age. This is in line with the literature (Kuhl et al., 2005; Werker & Tees, 1984). Interestingly, both groups seem to have regained sensitivity for the non-native vowels at the age of 10 months. This dip at the age of 8 months could be evidence for the perceptual reorganization: before the age of 8 months, infants discriminate the contrast based on acoustic or perceptual differences and after reorganization they discriminate the contrast based on the knowledge they have about the categories (and thus notice that one of the pair does not belong to their native category, /sæn/ in this case). On the other hand this dip could be explained by the temporarily increased focus on phonetic details when they seriously begin to learn words, which happens typically around the age of 10 months (De Klerk et al., in prep). In De Klerk and colleagues' (in prep.) study, no differences were found between TD and FR infants: in both groups a change was reported in the ability to discriminate non-native speech contrasts between 6 and 8 months. This suggests that the FR infants might not differ from the TD infants in their development of speech sound categories.

Since it is hypothesized that the development of speech sound categories is important for language acquisition, it is of importance to investigate the relationship between speech sound discrimination abilities and later language development in at-risk children. Guttorm, Leppänen, Poikkeus, Eklund, Lyytinen & Lyytinen (2008) conducted a longitudinal study on the relationship between brain responses to tones varying in pitch, hemispheric ERP patterns, and later reading accuracy in children with a familial risk of dyslexia. Brain responses and hemispheric ERP patterns were measured when the participants were 40 weeks old infants. The brain responses of the FR infants showed no differentiation between the tones. The infants showed a different hemispheric ERP pattern than did the control group of TD infants. Moreover, the FR children showed significantly poorer receptive language skills at 2.5 years of age, and a tendency towards delayed receptive language skills at 5 years of age. Consequently, Guttorm et al (2008) argued that there is a relationship between response patterns in the right hemisphere and later receptive language performance in children with a familial risk of dyslexia. These results indicate that response pattern to tones of infants as young as 40 weeks may be predictors of later language development. Moreover, this study shows that there is already a difference between FR infants and TD infants in a very early stage of their language development. Until recently, no other longitudinal studies have been published on the possible relationship between early speech perception at infant age and later language development in children with a familial risk of dyslexia.

The aim of the present study is to further investigate the relation between early speech perception and later language development in children with and without a risk of dyslexia. This study is a part of a follow-up study of the speech discrimination experiment by De Klerk et al. (in prep.) as mentioned above. The speech discrimination data of the experiment by De Klerk and colleagues (in prep.) will be used in this study and will therefore briefly be discussed before the results of this study will be presented. In order to investigate a possible relationship between speech discrimination and later language development, infants that were tested by De Klerk and colleagues (in prep.) have been asked to visit the lab again, between the ages of 3.5 to 4.5 years. Their current language development (measured through vocabulary size and morpho-syntactic knowledge), phonology skills and attention were tested and were compared with their performance on the discrimination experiments when they were infants. To see whether there are differences in language development between the FR children and TD children, the first research question that will be examined in this study is as follows: *to what extent do the FR children differ from the TD children in their language abilities, phonological abilities and attention at toddler age?* Since there is evidence that TD children perform poorly on tasks that measure language and phonology skills (Carroll & Snowling, 2004; Van Alphen, 2004) it is expected that the FR children show a poorer performance on the tasks administered in this study than the TD children. Since dyslexia is known to be co-morbid with ADHD and it is hypothesized that attention is related to language acquisition, it is expected that the FR children in this study might also show a poorer performance on the task that measures cognitive control of visual attention than the TD children.

With regard to the possible link between early speech perception and later language development, the second research question that will be investigated in this study is: *how do the performances on the tasks of the FR children and TD children at toddler age relate to their early speech discrimination abilities on native and non-native sound contrasts at the age of 6 and at the age of 8 months?* The ability to discriminate speech contrasts is shown by the difference in looking time between alternating (e.g. sæn-sɛn, sæn-sɛn) and non-alternating (e.g. sæn-sæn, sæn-sæn) speech sound trials. The hypothesis (Kuhl et al., 2005) that infants show less sensitivity to non-native speech sounds as soon as they start to focus on their native language, suggest that no difference in looking times between the non-alternating and alternating trials of the non-native contrast is associated with further developed perceptual tuning. This in turn could result in the fact that infants who show more focus to their mother tongue may have more developed language skills at the age of 3.5 to 4.5 years old, and vice versa: infants who do show a looking time difference between the non-alternating and alternating trials of the non-native sound contrast may show less advanced language skills at this age. Regarding the native contrast, it is thus expected that higher difference in looking time between the alternating and non-alternating trials at the ages of 6 and 8 months is related to better performances on the tasks at toddler age. Since a decline in sensitivity to the non-native contrast occurs at the age of 8 months, regarding this contrast it is expected that a lower difference in looking time between the alternating and non-alternating trials at the age of 8 months, is related to better performance on the tasks at toddler age. Considering the relationship that has been found between early speech perception and later vocabulary size (Yoshida et al., 2009, Tsao, Liu & Kuhl, 2004), it is expected that more developed language skills will be at least reflected by a larger vocabulary size and is hypothesized to be reflected in better morpho-syntactic knowledge.

Method

Participants

For this study, 48 monolingual Dutch children were tested[1]. 28 of the participants were considered as typically developing controls (12 female, 16 male; *M* age=3;9, SD=2.2 months). 18 of the participants (10 female, 8 male; *M* age=3;9, SD=2.2 months) were considered to have a familial risk of dyslexia, due to having at least one dyslexic parent (inclusion criteria are reported below in this section). Children were selected on basis of their age (between 3;6 and 4;6) and their performance on the speech discrimination experiment: children were included when they had completed the native contrast (Dutch /a/-/e/) or the (partly) non-native contrast (English /æ/-/ɛ/), or both contrasts. All children had participated in the speech discrimination experiment of De Klerk et al. (in prep.) at the age of 6 and/or 8 months (see De Klerk et al., in prep., for information about the process used for recruiting the infants). In addition, parents were asked to fill in a questionnaire concerning (indications of) sensory and/or mental problems (such as autism and AD(H)D). One participant had been diagnosed with ADHD. Out of the 48 children, 46 were included for data-analysis. One participant was excluded due to visual impairments that could not be corrected with glasses, and hearing problems. Another participant was excluded because of social environmental circumstances that could have affected the participant's performance on the tasks.

Participants were included in the FR group on basis of the reading difficulties of their parent(s). Since not all parents with reading difficulties had officially been diagnosed with dyslexia, the parents were tested at the Babylab Utrecht (Utrecht University) on their reading abilities and verbal intelligence. The reading tests that were used are 1) the 'Een-Minuut-Test' (EMT; Brus & Voeten, 1972) in which the parent was presented with a wordlist and was asked to read the words out loud as accurately and as

[1] 20 children were tested by Lorijn Zaadnoordijk in 2012

quickly as possible within one minute and 2) 'De Klepel' (Van den Bosch, Lutje Spelberg, Scheepstra & De Vries, 1994), in which the parent was presented with a list consisting of 116 non-words and was asked to read the non-words out loud as accurately and as quickly as possible within two minutes. Since all parents were highly educated a third test was taken, the verbal intelligence test (Analogies) from the Wechsler Adult Intelligence Scale (WAIS, Uterwijk, 2000). Since dyslexia manifests itself as a discrepancy between reading (and writing) skills and intelligence (including verbal competence), a child was included in the FR group when the dyslexic parent performed poorly on the reading tests, but not on the verbal competence test, or showed a discrepancy between performance on the reading tests and the verbal competence test. A child was included in the FR group if 1) the parent scored within or below the 20th percentile in both reading tests, or 2) the parent scored within or below the 10th percentile in one of the reading tests, or 3) the parent's scores in the verbal competence test and the scores in both reading tests showed a discrepancy of at least 60 per cent (based on Kuijpers, Van der Leij, Been, Van Leeuwen, Ter Keurs, Schreuder & Van der Bosch, 2003).

Tasks and Materials

Vocabulary. To follow the language development of the infants, parents were asked to fill in the Dutch version of the MacArthur-Bates Communicative development Inventory (N-CDI; Zink & Lejaegere, 2002). The N-CDI is a standardized parent report on word comprehension and word production, consisting of two versions: *Woorden en Gebaren* ('Words and Gestures') and *Woorden en Zinnen* ('Words and Sentences)'. The *Woorden en Gebaren* version additionally measures the use of (communicative) gestures and the *Woorden en Zinnen* version also measures the early use of grammatical inflections and sentences. Each time a parent visited the lab with his or her child, the parent was asked to fill in the *Woorden en Gebaren* form, when their infant was between the ages of 10 and 16 months, or the *Woorden en Zinnen* form, when their infant was between the ages of 16 and 30 months.

Preschool/Toddler age

Receptive vocabulary size. The Peabody Picture Vocabulary Test (PPVT; Schlichting, 2009) is a standardized test to measure the receptive vocabulary size of children. The test consists of a number of cards with four different pictures. The cards are organized in age-adjusted sets, increasing in complexity. Each set consists of twelve target words. On each card, four different pictures are shown and the participant is presented with a target word by the experimenter. One of the four pictures represents this target word and the participant is instructed to point at the picture he or she thinks represents the spoken word. The target words can be either object names or actions, for example the object *trommel* ('drum') or the action *slapen* ('is sleeping'). In addition, the target words consist of both concrete and abstract objects and actions. Testing and scoring proceeded according to the manual. Raw scores were converted to calculate the quotient scores and percentile scores. These scores were used for further analysis.

Verbal short-term memory. The non-word repetition task (NWR; Pre-COOL, under development) was used to assess verbal short-term memory. The task consisted of eighteen non-words, following the phonotactic rules of Dutch. The eighteen non-words were divided into 1-syllabic, 2-syllabic and 3-syllabic items, each consisting of six items. Half of the eighteen items were non-words with a high phonotactic probability and the other half were non-words with a low phonotactic probability, equally distributed among the three groups. Each auditory stimulus, recorded by a female speaker using child directed speech, was presented with an accompanying visual stimulus. This stimulus was a non-existent object, displayed on the computer screen. The stimuli were embedded in sentences: *"Kijk, een peek! Zeg eens: peek* ("Look, a pek! Please say: pek"). The child was instructed to repeat the target word. Their answer was directly scored as 'correct' or 'incorrect' on the computer. If the child refused to repeat the word after having listened to the stimulus three times accompanied with encouragement of the experimenter, the next stimulus would be presented. Afterwards, the audio-file was used for more detailed off-line analysis. For all the stimuli, the total of correct phonemes were determined. The percentage of correct phonemes per participant was calculated, as were the percentage of correct phonemes in the high probability stimuli, the percentage of correct phonemes in the low probability stimuli and the percentage of correct phonemes in the 1-syllabic, 2-syllabic and 3-syllabic stimuli. Four of the participants were presented with a different version of this task, due to miscommunication in the lab. This version consisted of six 1-syllabic items and six 2-syllabic items. Half of these items were non-words with a high phonotactic probability and the other half were non-words with a low phonotactic probability. The data of these four participants thus resulted in a percentage of correct phonemes of only the 1-syllabic and 2-syllabic stimuli, since they had not been presented with the 3-syllabic stimuli.

Morpho-syntactic production. To assess morpho-syntactic production, an elicitation task (Van Alphen et al., 2004) was used. The task consisted of two different parts, the inflection of the plural form of nouns and the inflection of the third person singular cojugation of verbs. Both parts were tested using ten sheets on which two pictures were shown. To test the inflection of nouns, a picture of one item of the target word was shown, for example a chair, and on the other picture two items of the target word were shown. The experimenter named the word that represented the first picture but omitted the target word represented the second picture: *Kijk, dit is een stoel, en dit zijn twee…?* ("Look, this is one chair, and these are two...?"), stressing the word *twee* (two) to elicit the plural form of the target word (in this case, *stoelen*). This procedure was repeated for the other nine target words. Two of the target words were words with an irregular plural form[2]. The participant's answer was written down on a scoring form. Correct scores were calculated. After the elicitation task concerning nouns, verb agreement was tested. This was again tested with ten sheets showing two pictures. On the first picture a person or animal was performing an action. On the second picture, the same person or animal was performing a different action. The experimenter named the action on the first picture but omitted the target word represented on the second picture: *Kijk, deze beer danst, en deze beer…?*[3] ("Look, this bear dances, and this bear…?"), stressing the word *this* to elicit the third person singular form. Again, the participant's was written down on the test form. Correct scores were calculated.

Word retrieval speed. To assess word retrieval speed a rapid naming test, a part of the CB&WL test (CB&WL, 'rapid naming'; Van den Bosch & Lutje Spelberg, 2010), was used, which examines the rapid retrieval of familiar words. The test consisted of two groups of familiar words, namely familiar[4] colors (red, yellow, green, blue and black) and familiar objects (a pair of scissors, a tree, a bicycle, a duck and a chair). Both the rapid naming of the familiar colors and the familiar objects was tested using a test sheet, consisting of

[2] In Dutch, the regular plural form of a noun is formed with the singular form *+en*. The two irregular forms in this test were 1) *koe – koeien* ('cow' – 'cows') and 2) *ei – eieren* ('egg' – 'eggs')

[3] In Dutch, the third person singular is formed with *stem+t*.

[4] For some of the participants, not all colors were familiar. This was checked with the parent. If this was the case, the rapid naming of the colors was not tested with this particular participant.

ten rows and five columns (50 words per sheet in total). First the rapid naming of the familiar colors was tested, followed by that of the familiar objects. The participant was instructed that he/she should name all the colors/pictures on the sheet as quickly as possible. Before starting the test, the participant could 'practice' the naming of the colors/pictures with the last column of the sheet. Prior to the participant carrying out these rapid naming tasks, the experimenter first named the colors/pictures 'as quickly as possible' (but adjusted the speed to the age of the participants) to show the participant how the task was done. Then the participant was asked to do the same. This 'practice round' was used to make sure the participant understood the task, and whether he or she was indeed familiar with the names of the colors. When the practice round went well, the participant was instructed to name the first column on the sheet as quickly as possible. The other columns were covered with a blank sheet. After finishing the first column, the participant was asked to go further with the second column (the other columns were covered with two blank sheets), until the participant had named all five columns of colors/pictures. The order of the presented tests was first the colors and then the pictures of objects. A stopwatch was used to measure the naming speed. Each participant's answers were directly scored on the test form, noting whether the target word was 1) named correctly, 2) was skipped, 3) was named incorrectly but directly self-corrected by the participant, or 4) was named incorrectly. For data analysis, the total of correct answers for each naming task was counted, which resulted in an average of correct answers for both naming tests. The number of correct answers per second was converted for the naming of the colors and the naming of the objects, as well as the average for both tests[5].

Cognitive control of selective attention. In addition to the tasks on language skills, a visual search task (Pre-COOL, under development) was used to measure cognitive control, that is to say, the participants' ability to block irrelevant information. In the visual search task, three different slides with pictures of animals (elephants, horses and bears) were shown to the participant on a computer screen. The first two slides consisted of 48 pictures and the third slide consisted of 72 pictures. On all three slides, eight of the pictures were elephants. The other pictures were pictures of horses and bears, which were similar to the pictures of the elephants in cooler (brown) and size. Before starting

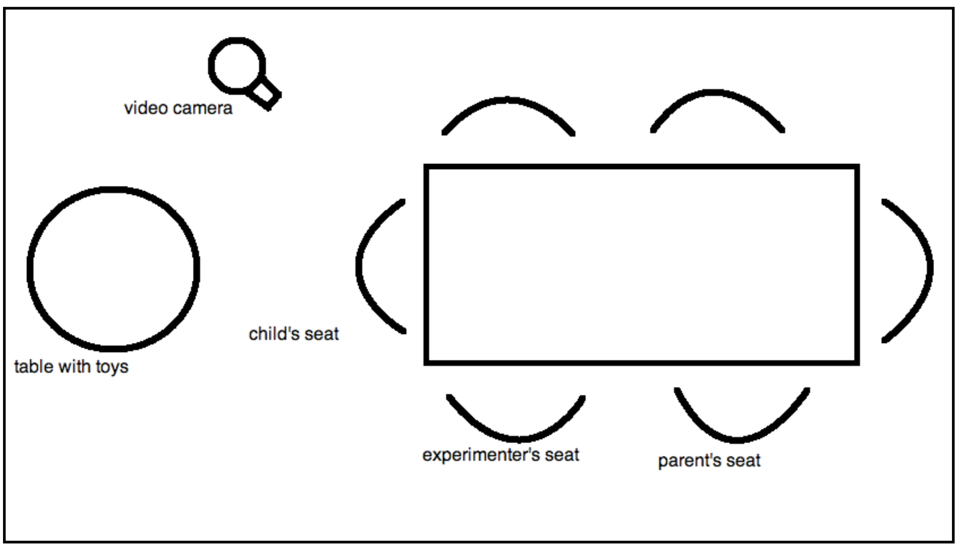
[5] The CB&WL test is a standardized test for children at the age of five years and ten months and older. Since the age-range of the participants in this study is three and a half to four and a half years old, only the raw scores were used.

with the test, the participant was familiarized with the different pictures of the three different animals, and was instructed to look for and point at *only* the elephants, and to do this as quickly as possible. The participant was given the opportunity to practice two times. Then the first slide appeared on the screen, and the participant had 40 seconds to point at as many elephants as possible, and was continuously encouraged by the experimenter to look for more elephants. When the participant pointed at an elephant, a blue line covered the elephant, so it was clear that this particular elephant was already found. If the participant pointed at a picture that did not represent the elephant, then the experimenter corrected the child by saying: "No, we only look for elephants! *Can you find another elephant?"*. The procedure was the same for the two following slides. After each slide, an image of a big elephant was shown (wearing a hat, holding a balloon, and holding a flower, respectively) as a minor reward for their effort. The experimenter and the participant looked together at the picture, in order to relax from the searching for elephants. For analysis, the total number of found elephants was converted, as well as the total number of other (incorrect) pictures of animals the participant had pointed at.

General procedure

The test session took place in a quiet room in the Utrecht Babylab. The video camera was placed behind the participant, skewed so that both the participant and the experimenter were recorded and the computer screen could be seen as well (see Figure 2.).

Figure 2. Test session setup



The test session started with the PPVT, which was followed by the non-word repetition task, then the visual search task, the rapid naming tasks, and finally the inflection task. To make the participant feel comfortable and less shy, the test session did not start immediately. Instead, the experimenter showed the participant a bowl containing brightly colored stickers of animals. After looking together at what kind of animals there were, the experimenter told the child that they were going to play five ‘games’, and that with each ‘game’ the child could earn a sticker. The experimenter then showed the child a bundle of brightly colored sheets, and asked the child to pick the color he or she liked best. The child was told that the sheet would be used to stick the earned stickers on. The experimenter wrote down the name of the child on the sheet (saying the name of the child out loud) and then the test session began. If the participant got tired or thirsty, a small break, in between the tests, of approximately five minutes was used to drink something and rest. Generally, no more than two breaks of five minutes were needed in a test session. After all the tests were administered, the participant was given a small present and could play with the toys on the other table in the room. While the child played, the experimenter and the parent talked the session through and the experimenter wrote down remarks. The parent was asked whether, according to him/her, the child had performed as expected, was concentrated during the tasks, etcetera. At the end of the session, the child also received a book to thank him or her and the parent was thanked as well.

Data analysis

Before the TD group and the FR group could be compared on their performance on the different tasks, it was important to verify that there were no significant differences between those two groups in age, since a higher age can have a positive effect on performance. To test the age differences between the TD and FR group, an independent samples T-test was used, with the Age (in months) as the dependent variable and Group as independent variable. There was no significant difference according to Age found between the TD group (M=45.14, SD=2.20) and the FR group (M=44.94, SD=2.16) ($t(44)=0.30$, $p=0.77$). Despite this lack of significant difference, the age-range between the two groups was slightly different; with the FR group consisting of more participants below the mean than did the TD group. To filter out any possible age effects from the results, only for the standardized tasks independent samples T-tests could be used to investigate whether there were any group differences in performance on the tasks. For the N-CDI and the PPVT, standardized percentile scores are used, and thus group difference in performance between the TD and FR group on these tasks could be tested with independent samples T-tests, with the Measure of the task as the dependent variable and Group as the independent variable. All other tasks, namely the NWR task, the Inflection Task, the CB task and the VS task, are not standardized tasks and therefore Univariate ANOVA tests were used for the analysis of group differences in performance between the TD and FR group on these tasks, with the Measure of the task as the dependent variable, with Group as the independent variable, and with Age as covariate.

Results

Performance at toddler/preschool age

The statistics of the independent samples T-tests and Univariate ANOVA tests are listed in Table 1.

Table 1. Performances of the TD and FR group on the tasks at toddler age

Group	Test (dependent variable)				Age effect (covariate)	
	n=	M (SD)	*F* or *t*	*p*-value	*F*	*p*-value
N-CDI percentile score comprehension *at age 18-29 months*			0.64	0.53		
TD	18	59.0 (24.7)				
FR	13	52.7 (30.5)				
N-CDI percentile score production *at age 18-29months*			0.76	0.45		
TD	18	58.0 (27.3)				
FR	13	50.9 (23.3)				
PPVT percentile score			0.91	0.37		
TD	27	65.4 (16.9)				
FR	18	70.2 (17.5)				
NWR percentage of total correct phonemes			0.03	0.86	2.10	0.16
TD	24	89.0 (5.37)				
FR	16	89.5 (8.52)				
NWR percentage of correct phonemes in 1-syllabic stimuli			0.63	0.43	0.63	0.43

TD	26	93.2 (6.91)				
FR	17	94.8 (6.65)				
NWR percentage of correct phonemes in 2-syllabic stimuli			0.55	0.47	0.06	0.81
TD	26	91.9 (6.34)				
FR	17	90.2 (9.01)				
NWR percentage of correct phonemes in 3-syllabic stimuli			0.31	0.72	5.44	0.03
TD	24	81.9 (11.38)				
FR	16	83.3 (12.92)				
Infl. task total correct plural form – nouns			1.55	0.22	0.00	0.99
TD	28	7.7 (2.45)				
FR	18	8.5 (1.58)				
Inf. task total correct third person singular form –verbs			0.04	0.84	0.04	0.85
TD	28	6.6 (2.47)				
FR	18	6.4 (3.40)				
CB average correctly named items per second			1.52	0.22	1.39	0.25
TD	28	0.49 (0.14)				
FR	18	0.43 (0.16)				
VS Total found Elephants			3.10	0.09	3.38	0.08
TD	26	20.2 (2.89)				
FR	18	18.6 (2.55)				

Outcomes of the independent samples T-tests showed that there was no significant difference between the TD and FR groups on the percentile scores of comprehension and production of the N-CDI and on the percentile scores of the PPVT. Outcomes of the Univariate ANOVA tests showed that there were no significant differences in performance between the TD and FR group on the NWR task, the Inflection task, the CB task and the VS task.

Infant age: speech discrimination

Before investigating whether there are any correlations between the performances on the HVF experiment and the tasks administered in this study, the results of the HVF experiment are described for this sample of children. The statistics of the performance of the FR and the TD group on the native sound contrast can be found in Table 2. The performances of this sample of children at the ages of 6 and 8 months did not differ from the findings of the whole sample of children tested at these ages in the discrimination experiment of De Klerk et al. (in prep.).

Table 2. the native /a/ - /e/ contrast

Group	Age (months)	n=	Mean alt In ms (SD)	Mean non-alt in ms (SD)	Diff. score *M* alt – *M* non-alt (SD)	Pattern longer looking time for alt than non-alt (%)
TD	6	9	12.1 (6.9)	9.3 (3.3)	2.8 (5.5)	33.3
	8	7	8.4 (6.7)	7.7 (4.0)	0.7 (3.2)	57.1
FR	6	11	9.5 (5.5)	7.3 (4.5)	2.2 (2.9)	18.2
	8	8	8.7 (2.6)	6.6 (3.1)	2.1 (3.6)	25.0

Repeated Measures ANOVA tests were conducted; with Trial Type (Alternating vs. Non-alternating) as within-subject factor and with Group (TD and FR) and Age (6 months and 8 months) as between-subject factors. Outcomes showed that there was a main effect of Trial Type ($F(1,31)=8.5$, $p=0.007$, $n2p=0.21$). This means that this sample of children showed a significant difference in looking time between the alternating and non-alternating trial. The effect found on Trial Type was substantial. There were no interactions found between Trial Type and Age ($F(1,31)=0.63$, $p=0.44$), which means that at both ages (6 and 8 months) this sample of children showed a difference in looking time between the two trials. There were also no interactions between Trial Type and Group ($F(1,31)=0.09$, $p=0.76$), which means that both the TD and FR groups of this sample of children showed a difference in looking time between the two trials. There were also no interactions found between Age and Group ($F(1)=0.41$, $p=0.53$), which means that both the FR and TD group showed a difference in looking time between the two trials on both the age of 6 months and on the age of 8 months. Looking at the percentage of children that showed the pattern, it is found that 33.3 per cent of the TD group at the age of 6 months shows this pattern, and 57.1 per cent of the TD group at the age of 8 months shows this pattern. For the FR group it is found that 18.1 per cent of this group at the age of 6 months shows this pattern, and at the age of 8 months, 25.5 per cent of this group shows this pattern.

Moving on to the performances on the non-native sound contrast, the statistics of the performance of the FR and the TD group on the non-native sound contrast are listed in Table 3. The performances of this sample of children differed from the findings of the whole sample of children tested in the discrimination experiment by the De Klerk et al. (in prep.). The whole sample of children still showed sensitivity towards the non-native contrast at the age of 6 months. At the age of 8 months, they did not show this sensitivity. This sample of children however, showed to have already lost sensitivity towards the non-native sound contrast at the age of 6 months.

Table 3. the non-native /æ/ -/ɛ/ contrast

Group		Age (months) n=	Mean alt In ms (SD)	Mean non-alt in ms (SD)	Diff. score *M* alt – *M* non-alt (SD)	Pattern longer looking time for alt than non-alt (%)
TD	6	12	10.1 (4.2)	9.8 (5.4)	0.3 (6.0)	50.0
	8	16	8.0 (4.6)	7.4 (3.5)	0.6 (3.3)	50.0
FR	6	12	6.8 (3.3)	6.8 (3.8)	0.0 (3.1)	41.7
	8	10	8.2 (5.2)	6.9 (4.0)	1.3 (3.8)	40.0

Repeated Measures ANOVA tests were used, with Trial Type (Alternating vs. Non-alternating) as within-subject factor and with Group (TD and FR) and Age (6 months and 8 months) as between-subject factors. Outcomes showed that there was no main effect of Trial Type ($F(1,46)=0.74$, $p=0.39$). This means that this sample of children shows no significant difference in looking time between the non-alternating and alternating trial. There were no interactions found between Trial Type and Age ($F(1,46)=0.46$, $p=0.50$), which means that this sample of children at both the age of 6 months and the age of 8 months showed no difference in looking time between the two trials. Also no interactions between Trial Type and Group ($F(1,46)=0.03$, $p=0.87$) were found, which means that both the TD and FR group of this sample of children showed no difference in looking time between the two trials. There were also no interactions found between Age and Group ($F(1)=1.98$, $p=0.17$). This means that both the TD and FR groups showed no difference in looking time between the two trials at both the age of 6 months and the age of 8 months. Looking at the percentage of children in this sample that showed the pattern, it is found that the 50 per cent of the TD groups showed the pattern at the age of 6 months, and also 50 per cent of this group showed the pattern at the age of 8 months. In the FR group, 41.7 per cent of the children showed the pattern at the age of 6 months, and 40.0 per cent showed the pattern at the age of 8 months.

Correlations between the performance at infant age and at toddler/preschool age

In order to investigate whether there is a possible link between early speech perception and later language development, Pearson Correlations were conducted to determine the difference in looking time between the alternating and non-alternating trials of both contrasts and the performance at toddler age. For these correlations the absolute difference scores between the looking time to the alternating and non-alternating trial were used (for example a looking time on the alternating trial of 5 ms and a looking time on the non-alternating trial of -6 ms results in an absolute difference score of 1 ms). The outcomes of the correlations are listed in Table 4.

Table 4. Correlations between looking time difference and the performance on the tasks

	LT - 6 months						LT 8 months					
	native			non-native			native			non-native		
	overall	TD	FR	overall	TD	FR	overall	TD	FR	overall	TD	FR
PPVT perc. score	-.498*	-.723*	-.229	.196	.269	.475	.014	.718	-.397	-.107	.157	-.374
NWR total correct	-.175	-.347	.050	-.073	-.071	-.139	.029	-.129	.245	.445*	.252	.723*
NWR 1-syll. stimuli	-.158	-.302	.050	-.083	-.055	-.157	.021	-.129	.249	.456*	.274	.726*
NWR 2-syll. stimuli	-.158	-.302	.050	-.077	-.055	-.156	.021	-.129	.249	.456*	.274	.726*
NWR 3-syll. stimuli	-.212	-.302	-.101	-.077	-.055	.004	.021	-.129	.249	.351	.189	.726*
Infl. task total correct	.075	.204	-.081	-.064	.004	.230	.028	-.015	.060	.337	.241	.419
CB average correct per sec.	-.090	-.182	-.020	.053	.299	.138	.038	-.174	.114	-.152	-.188	-.105
VS total elephants found	-.071	-.020	-.151	.178	.238	.317	.111	-.496	-.048	-.041	.079	-.124

overall = both FR and TD; *p<0,05

Regarding the native sound contrast, it was expected that a more substantial difference between the looking time of the alternating trial and the looking time that of the non-alternating trial, would show a better performance on the tasks administered at toddler age. Outcomes of the Pearson Correlations showed that there was a negative correlation between the looking time difference on the native sound contrast at the age of 6 months and the percentile score on the PPVT. There were no other correlations found between the performance on the native sound contrast at the age of 6 months and the performance on the tasks at toddler age. There were also no correlations between the looking time difference on the native sound contrast at the age of 8 months and the performance on the tasks at toddler age. To see whether the negative correlation between looking time difference on the native sound contrast at the age of 6 months and the percentile score of the PPVT was the same for both the TD group and the FR group, the performances of each group were analyzed separately. It was found that for the TD group there was still a negative correlation between the looking time difference on the native sound contrast at the age of 6 months and the percentile score of the PPVT, but for the FR group this correlation was not found.

Regarding the non-native sound contrast, it was expected that a more substantial difference between the looking time of the alternating trial and that of the non-alternating trial at the age of 8 months, but not at the age of 6 months, would show a lower performance on the tasks administered at toddler age. Outcomes of the Pearson Correlations showed that there were no correlations between the looking time difference on the non-native sound contrast at the age of 6 months and the task performance at toddler age. A positive correlation was found between the looking time difference on the non-native sound contrast and the total correct syllables of the NWR task, the total correct syllables in the 1-syllabic stimuli of the NWR task, and the total correct syllables in the 2-syllabic stimuli of the NWR task. No other correlations between the looking time difference at the age of 8 months and the task performance at toddler age were found. The TD and FR groups' looking times and task performances were separated, to see whether the positive correlation between the looking time difference on the non-native sound contrast at the age of 8 months and the performance on the NWR task was found in both groups. It was found that only for the FR group was there a positive correlation between the looking time difference and the total number of correct syllables, the total number of correct syllables in the 1-syllabic, 2-syllabic and 3-syllabic stimuli. Half of the stimuli of the NWR task consisted of phonemes with low phonotactic probability in Dutch, and the other half of the stimuli consisted of phonemes with high phonotactic probability in Dutch. In order to investigate whether there was a difference in the correlation between the looking time difference on the non-native sound contrast of the FR group at the age of 8 months and the performance on the high probability stimuli and the low probability stimuli, a final Pearson Correlation was conducted. Outcomes showed that for the FR group there was a positive correlation between the looking time difference on the non-native contrast at the age of 8 months and the performance on the high probability stimuli as well as the performance on the low probability stimuli.

Discussion

The aim of this study was to investigate whether there is a relationship between early speech perception and later language development in children with and without a familial risk of dyslexia. The first research question was to what extent the FR children differed from the TD children in their language abilities, phonological abilities and attention at toddler age. Since it has been found that FR children are outperformed by TD children on most tasks that test these skills (Wilsenach, 2006; Carrol & Snowling, 2004; Van Alphen et al., 2004; Scarborough, 1991; Scarborough, 1989), it was expected that significant group differences would be found on the tasks administered in this study, and that the FR children would perform poorer on the tasks than the TD children. However, the results did not show any group differences, and thus the FR children did not show indications of any of the problems in the areas that were investigated in this study. This lack of evidence that the FR children have a delay in their language development could be caused by the fact that in this study no individual analyses of the participants' performances were made. It is possible that a sub-group of the FR children in this study in fact did show a poorer performance than the TD children on one or several of the tasks, but that this was not visible in the group results due to other FR children who had even a better performance than the TD children. This idea of a sub-group of the FR children who show indications of language problems is supported by the fact that children who have a familial risk of dyslexia have a 32 to 66 per cent chance of developing dyslexia (Van Bergen et al., 2001; Vellutino et al., 2004). It is also important to note that the sample size in this study was fairly small, with an FR group consisting of only 18 children. With regard to the 32 to 66 per cent chance of developing dyslexia, it is possible that none of the 18 FR children in this study will eventually show reading and writing problems, and are thus expected to show a similar performance on the tasks as the TD children. A larger sample size is thus necessary to gain more insight in the possible differences in performance on the tasks administered in this study. In addition, it would be of great interest to test these FR children again in a few years, to see whether they have or have not developed difficulties with reading and writing.

The second question investigated in this study was in which way the performances on the tasks of the FR children and TD children at toddler age were related to their early speech discrimination ability on native and non-native sound contrasts at the ages of 6 and 8 months. The sample of children of this study showed a difference in looking time between the two trials of native sound contrast at both the ages of 6 and 8 months and no difference in looking time between the two trials of the non-native sound contrast at the ages of 6 and 8 months. With regard to the native contrast, it is was expected that higher difference in looking time between the alternating and non-alternating trials at the ages of 6 and 8 months would be related to better performances on the tasks at toddler age. The analyses revealed a negative correlation between difference in looking time between the trials of the native sound contrast at the age of 6 months and the percentile scores on the PPVT, which measures receptive vocabulary size. This is in contrast with the expectations, because more perceptual tuning towards the native language suggests a better language development (Kuhl et al., 2005), and is thus expected to correlate with a better performance on the PPVT. When the performances on the native sound contrast at the age of 6 months and the PPVT at toddler age were analyzed for FR and TD group separately, it was found that only the TD group showed this negative correlation. This is again in contrast with the expectations, since other studies have found a relationship between early speech perception and later vocabulary size in TD children (Yoshida et al., 2009, Tsao, Liu & Kuhl, 2004). It is possible that a percentage of the TD children performed very poorly on the PPVT task, for instance because they were extremely shy, had performance anxiety or were very tired, and that their performance resulted in a very low mean performance on the PPVT task for the TD group. Unfortunately, individual performances were not analyzed in this study, and it is thus not possible to investigate whether the performances of a few TD children can account for this negative correlation between the performance on the native sound contrast and the PPVT task. It must also be noted that the amount of data obtained in this study is not sufficient to make generalizations about the findings in this study. No other correlations between the difference in looking time between the two trials of the native sound contrast at the ages of 6 to 8 months and the performances on the other tasks at toddler age were found.

With regard to the non-native sound contrast, it was expected that a lower difference in looking time between the alternating and non-alternating trials at the age of 8 months would relate to a better performance on the tasks at toddler age. This was expected because it has been established that a decline in sensitivity to the non-native sound contrast occurs at the age of 8 months (De Klerk at al., in prep; Werker & Tees, 1984). Analyses revealed a positive correlation between difference in looking time between the alternating and non-alternating trials of the non-native sound contrast at the age of 8 months and the performance on the NWR task at toddler age. This correlation was found between the difference in looking time and the total percentage of correctly repeated syllables, and the percentage of correctly repeated syllables in the 1-syllabic stimuli as well as in the 2-syllabic stimuli. This finding was the opposite of the expectations, since a decline in sensitivity to non-native sound contrasts suggests better perceptual tuning towards the native language and thus a further language development. To see whether this positive correlation was found in both the FR and TD group, the performances of these groups at infant age and at toddler age were analyzed separately. The analyses showed that this positive correlation between looking time difference on the non-native contrast and the performance on the NWR task was only found in the FR group. Since the stimuli in the NWR task consisted of both stimuli with high phonotactic probability in Dutch and low phonotactic probability in Dutch, it was interesting to see whether the positive correlation between the performance on the non-native sound contrast and the performance on the NWR task was found in both or only one of these categories of stimuli. If it was the case that it was only found in the low probability stimuli, the positive correlation might be explained by the idea that infants who show a higher sensitivity to non-native sound contrast, are at toddler age still more sensitive to sounds that are of low probability in their native language, and thus are better at repeating these sounds. Analyses revealed that there was a positive correlation between the difference in looking time and both the high probability and low probability stimuli of the NWR task. No other correlations were found between difference in looking time between the two trials of the non-native contrast and performances on the tasks at toddler age.

It must be noted however, that not all participants in this study had completed the native and non-native sound contrasts at infant age, and also that only a small part of the participants had participated on the HVF experiment at both the age of 6 and the age of 8 months. This results in very small sub-groups, with a sample of only 10 FR children who had completed the non-native sound contrast at the age of 8 months. It is therefore reasonable to suggest that the positive correlation between the difference in looking time between the trials of the non-native sound contrast at the age of 8 months and the performance on the NWR task of these FR children will not be found when a larger sample size is used. Results of this study would have been more reliable if the FR and TD children that were tested at toddler age had all participated in the HVF experiment at both the age of 6 months and the age of 8 months, and additionally had completed both the native and the non-native sound contrast. This would create the opportunity to investigate exactly which performances on infant age are correlated to which performances at toddler age. In this way, more insight could be gained in whether there are sub-groups in the FR group and/or TD group that differ in their performances on infant age and toddler age from the greater part of the group.

Another factor that could have been of influence on the results is that the sample of children tested in this study showed a slightly different pattern in the HVF experiment that the total sample of infants tested in this experiment by the Klerk et al. (in prep.). Neither the FR and TD group showed a difference in looking time between the alternating and non-alternating trials of the non-native sound contrast at the ages of 6 and 8 months, which means that both groups (TD and FR) had lost their sensitivity towards the non-native sound contrast at the age of 6 months. In De Klerk et al. study (in prep.) it was found that both the FR and TD group still showed a difference in looking times between the two trials of the non-native sound contrast at the age of 6 months, but at the age of 8 months had lost their sensitivity towards the non-native sound contrast. This decline in sensitivity towards the non-native sound contrast is hypothesized to be related to a better language development (Kuhl et al., 2005), and since both the FR group and TD group in this study showed to have already lost their sensitivity towards the non-native sound contrast at the age of 6 months, it is not surprising that there are no negative correlations found between the performance on the non-native contrast and the performance at toddler age. A second remark on the performances of this sample of children in the HVF experiment concerns the fact that conclusions cannot be drawn so easily from looking time data, since many factors can be of influence on the looking times infants show. As Aslin (2007) points out, absence of preference for one of the two trials (alternating or non-alternating), which is shown by a very small or no difference in looking time between the two trials, does not necessary mean that the infant is not able to discriminate between the two trials (Aslin, 2007). Additionally, it is possible that the FR group and TD group in fact show differences in their looking behavior, but that this is not visible, since only global looking time is measured, and no other measures are used, such as the number of looking and looking away and the durations of each look. (Aslin, 2007). It must also be noted that difference in looking time might not be an adequate measure for discrimination abilities of infants, since a larger looking time does not necessarily implies better discrimination abilities. This matter will need to be addressed further.

In conclusion, in this study no differences are found between the performances on the tasks of the FR children and the TD children. The tasks that were administered tested receptive vocabulary size, verbal short-term memory, morpho-syntactic production, word retrieval speed and cognitive control of selective attention. Since the FR children did not perform poorer on these tasks in comparison to the TD children, the FR children in this study show no indications of language problems, problems with phonology or problems with attention. The correlations between the performance at infant age and the performance at toddler age were not in line with the expectations, but might be due to the small sample size of this study and/or the fact that no analyses were made of individual performances on the tasks. The results of this study thus did not show a reliable indication of a relationship between early speech perception and later language development in children with and without a familial risk of dyslexia.

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