Language development in children with and without a familial risk of dyslexia: The relation with early speech perception

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Abstract

Language development of Dutch monolingual children aged 3½ to 4½ years old with a familial risk of dyslexia was compared to that of low-risk age-matched children. Their language development was assessed with a battery of tests. Both groups had been previously assessed on their perception of native and non-native phoneme contrasts (6-8 months of age) and their vocabulary size and use of gestures (10-29 months of age). Their current language development and executive functioning was correlated with their scores on early speech contrast perception. The analysis revealed that children who showed less sensitivity to a non-native speech sound contrast at infant age performed better on a rapid naming test at 3½ to 4½ years of age. Additionally, a positive correlation between decrease of sensitivity to non-native speech sound contrasts and the number of gestures used indicated that infants who focused more on their native language at 6 and 8 months of age knew and used more gestures at 10 and 14 months of age. No significant group differences were found on the language development tests. These results show that early speech perception is related to later language development. However, although it has been suggested that there is a relation of early speech perception and vocabulary size, a significant relation was only found with speed of processing (rapid retrieval) while no significant relation was found with vocabulary size.

Introduction

Reading and writing are crucial skills that children learn in elementary school. While most of them do not encounter any problems while acquiring these skills, a subset of school-going children, approximately 5 to 10 percent (Boets, Wouters, van Wieringen & Ghesquière, 2007), experiences difficulties attaining proficiency in reading and writing. It has been estimated that approximately 4 percent are diagnosed with a disorder that is commonly referred to as developmental dyslexia (Blomert, 2004). According to Lyon, Shaywitz and Shaywitz (2003) developmental dyslexia (henceforth referred to as dyslexia) is a specific neurobiological learning deficiency. This disorder typically manifests in impaired written word recognition and in poor spelling. The language deficit that dyslexics suffer from is independent of their cognitive and intellectual abilities. Aside of difficulties with processing written language, dyslexic adults and children, both school-going and pre-schoolers, typically show a wide range of co-morbid impairments, among others in rapid retrieval of familiar words (Wolf, Goldberg O'Rourke, Gidney, Lovett, Cirino & Morris, 2002), phonological awareness (Joanisse, Manis, Keating & Seidenberg, 2000; Manis et al., 1997), inflectional morphology (Joanisse, Manis, Keating & Seidenberg, 2000) and verbal short-term memory (Goulandris, Snowling & Walker, 2000). In addition to the impairments that are typical for dyslexia, a series of co-morbidities have been observed between dyslexia and a number of other developmental disorders, e.g. specific language impairment (SLI), attention deficit hyperactivity disorder (ADHD) and developmental coordination disorder (DCD) (Chaix, Albaret, Brassard, Cheuret, de Castelnau, Benesteau, Karsenty & Démonet, 2007; McArthur, Hogben, Edwards, Heath & Mengler, 2000; Willcutt & Pennington, 2000).

Dyslexia as a disorder has been established since as early as the 19th century (Snowling, 1996), yet the underlying cause remains unclear. Many theories have attempted to explain the source of dyslexia. A cognitive explanation that has been widely acknowledged is the phonological deficit hypothesis. This hypothesis (hereafter PDH) posits that the underlying cause of dyslexia is a deficit in the coding, storage and retrieval of phonological representations (Ramus & Szenkovits, 2008; Snowling, 1981). This deficit is considered to be the ‘core’ deficit, whereas the other impairments are considered to be co-morbidities. According to the PDH, the phonological representations of dyslexics are poor (otherwise described as holistic, underspecified, weak, fuzzy), which results in less efficient coding of phonological information. This in turn leads to problems with word retrieval, phonological awareness, verbal short-term memory and phonological learning of new verbal information (De Bree, 2007). Phonological representations are of immense importance for reading and writing, as a relation between phonemes and graphemes must be made in order to read and write. When these representations are poorly coded or retrieved, literacy and spelling problems appear (Shaywitz & Shaywitz, 2003, 2005). This becomes apparent in tasks that require an individual to segment words into their phonological elements. The inability to segment words suggests that the relation between phonemes and graphemes has not been established properly, which ultimately leads to poorer reading and writing skills (Shaywitz & Shaywitz, 2005). This is exactly what is observed in child and adult dyslexic individuals (Bruck, 1992). Altogether, poorly specified phonological representations result in delayed literacy development, poor spelling. It also results in a poor generalisation of word reading skills to non-word reading skills (Snowling, 2001). The claim made by the PDH that the problem lies in poor phonological representations, can therefore account for many of the difficulties dyslexics experience.

As Snowling (1998) points out, the PDH has two important advantages. First, the assumption of a *phonological* deficit, rather than only reading or writing problem per se, accounts for the results found in studies by Bradley and Bryant (1983) and Lundberg (1994) (as cited in Snowling, 1998) that revealed phonological awareness measured in pre-schoolers to be a predictor of later reading proficiency (see Snowling, 1998 for review). Second, the PDH is able to explain the different manifestations of dyslexia at different ages. Not only does the phonological deficit account for the link between phonological difficulties and reading difficulties in school-going children, it also accounts for the manifestations of dyslexia in adults. Difficulties in reading and writing typically persist through adulthood and adult dyslexics usually do not overcome their problems with spelling. However, the reading/decoding abilities of experienced dyslexic readers do seem to improve. It seems that training reading skills compensates for poor word decoding ability. Nevertheless, when faced with non-words, even experienced dyslexic readers exhibit decoding difficulties. This shows that the underlying phonological impairment remains unsolved (see Snowling, 1998 for review).

It must be noted that the PDH does not explain what the underlying cause of the phonological deficit is; neither does it explain the associated motoric and attention problems. It is beyond the scope of this paper to describe the neurobiological basis of dyslexia, which might explain all these findings. For the purposes of this research, the relevant issue is that the difficulties in various phonologically related areas have been observed and pose a problem for dyslexics.

In an attempt to approach the research on dyslexia from a different perspective, researchers have started to direct their attention to predictors of dyslexia. Knowing how to distinguish dyslexics from typically developing children at an early age has great clinical and educational relevance. It will allow for an earlier diagnosis as well as relevant adjustments to therapies, which will be able to anticipate the reading and writing problems instead of having to handle them after they have started to occur. Due to a large body of evidence revealing that dyslexia is hereditary, it is possible to investigate phonological difficulties in children who are at a familial risk of dyslexia before they learn to read and write. Children are considered at familial risk of dyslexia when they have at least one dyslexic parent; these “at-risk” children have a 32 to 66 percent chance of developing dyslexia. This is a very high percentage compared to the 2 to 13 percent estimated chance of developing dyslexia in children who do not have dyslexic parents (De Bree, 2007).

Scarborough (e.g. 1989, 1990, 1991) pioneered in this field of research by investigating the language abilities of toddlers who were at risk of dyslexia and assessing their reading development when they were eight years old. In retrospect, she concluded that the at-risk children who later developed dyslexia, produced shorter and less complex utterances and mispronounced words more often than controls at 2½ years of age (Scarborough, 1990). In addition, their syntactic knowledge was delayed by roughly six months at 2½ to 4 years of age (Scarborough, 1991), and their letter identification skills, ability to match letters to sounds, phoneme awareness and expressive naming were poorer at 5 years old compared to the typically developing peers (Scarborough, 1989). A study by Wilsenach (2006) has shown that compared to typically developing children, 3½ years old children at risk of dyslexia produce fewer instances of a complete past participle construction in a sentence completion task. After having children watch a cartoon movie, the experimenter elicited past participles by saying: *"What happened? I remember the frog has jumped and the rabbit…";* a correct use of the past participle meant that the child completed the sentence with *has* + the correct form of the main verb.

Differences between typically developing and at-risk children have also been found in infants at a phonological and morpho-syntactic level. Wilsenach (2006) has reported that compared to their typically developing peers, 19 month old infants with familial risk of dyslexia do not show the same sensitivity that enables discrimination of ungrammatical sentences from grammatical ones. Results by Kerkhoff, Erkelens and De Bree (in prep.) revealed that Dutch 16 month old at-risk children, unlike 16 month old controls, are not able to categorize words into nouns and verbs by using the morphological information that frames the target word (e.g. An example of a Dutch verb frame: *hij X-t* (*he X-s*); and a noun frame: *een X-je* (*an X-DIM*)). Furthermore, a difference in word production has been found in 17 month old children at risk of dyslexia in the verbal and closed-class categories (Koster, Been, Krikhaar, Zwarts, Diepstra & van Leeuwen, 2005); the children at risk of dyslexia produced significantly fewer words in these categories than their age-matched normally developing peers.

Whereas several studies have been conducted to investigate differences between typically developing children and at-risk children on knowledge of grammar (such as the studies mentioned above), less is known about the earlier stages of language development, the developmental pattern of forming speech sound categories. Many studies have researched speech perception in typically developing children and in school-going and adult dyslexics, but only a few studies have explored speech perception in at-risk infants. Until recently, the few existing studies have focused mostly on phoneme duration (e.g. Richardson, Leppänen, Leiwo & Lyytinen, 2003) rather than the ability to discriminate between speech sounds. This is surprising, considering that speech discrimination has been hypothesized to play an important role in language acquisition.

During the first year of life, infants learn to categorize speech sounds (consonants and vowels) into phonemic categories that are meaningful components of their native language (Werker & Tees, 1984). They learn which contrasts are meaningful contrasts in their mother tongue and which are not. In Dutch, for instance, the voiced plosive /d/ and the voiceless plosive /t/ account for a meaningful contrast (/dak/ has a different meaning than /tak/), whereas the aspirated /$t^{h/}$ does not differ in meaning from the non-aspirated /t/ (Ernestus, 2000). Dutch infants have to learn that the difference between /$t^{h/}$ and /t/ is not more than an allophonic difference (a variation in pronunciation that is not meaningful), while the difference between /d/ and /t/ is. This is not a universal contrast; in Thai, for instance, the difference between /t/ and /$t^{h/}$ is meaningful (Tantibundhit, et al., 2011), and is therefore a contrast that Thai infants should be sensitive to. Forming these categories can help infants immensely with their language acquisition. In particular, word learning becomes a whole lot easier if the infant knows when to differentiate between allophonic differences. This ability in turn has a beneficial effect on their later vocabulary size. Comparing the results of a visual choice task (a screen displaying two items of which only one is named) to assess word learning of minimal pairs (/bin/ vs /din/) and results of the MacArthur Communicative Development Inventory, Yoshida, Fennell, Swingley and Werker (2009) found that 14 month old typically developing infants whose discriminating abilities were better and therefore used more phonetic detail in word learning tasks have a larger vocabulary size (both comprehension and production) at that age.

It has been hypothesized that a decline in phonetic sensitivity to non-native speech contrasts is associated with native language learning (Kuhl, Conboy, Padden, Nelson & Pruitt, 2005). This hypothesis poses that the better infant's "perceptual tuning" towards the native language is (and therefore the worse his/her sensitivity to non-native speech contrasts) the more advanced the language development will be. Exploring the influence of early speech perception on vocabulary size, a relation between them has been demonstrated in typically developing infants in a longitudinal study by Tsao, Liu and Kuhl (2004, see also Kuhl and colleagues, 2005). In their study, the infant's speech discrimination of a non-native vowel contrast was investigated at 6 months using a conditioned head-turn task. The results of this experiment were analysed on trials needed to meet the conditioning criteria (2 correct consecutive head-turn responses with the help of an intensity cue in the auditory stimuli, followed by three additional correct consecutive head-turn responses without the help of the intensity cue, all within 60 seconds after the conditioning phase had started) and correct identification of change trials (trials in which alternating non-native speech contrasts were presented). When the infants were 13, 16 and 24 months of age their language development was assessed by their results on the MacArthur Communicative Development Inventory (CDI). Significant correlations between speech perception at 6 months and word understanding, word production and phrase understanding at a later age, led Tsao, Liu and Kuhl (2004) to argue that early speech perception and later language development are somehow related.

It has been found that typically developing children lose the sensitivity to non-native consonant contrasts when they are between 6 and 8 months old (e.g. Werker & Tees, 1984). Until recently no research examined the speech discrimination abilities of infants who are at risk of dyslexia. Given that a phonological deficit is a core feature of dyslexia, it is surprising that this important part of language acquisition had never been studied until recently. However, in the past years De Klerk, De Bree, Kerkhoff & Wijnen (in prep.) brought about a change to this situation. They studied the speech perception of typically developing children and children at familial risk of dyslexia at the age of 4-5, 6, 8 and 10 months. They investigated the discrimination of a Dutch native vowel contrast (/aa-ee/) embedded in the non-words *faap* and *feep* and a non-native vowel contrast (/ae-E/) embedded in the non-words *saen* and *sEn*. The discrimination abilities of the infants were tested using a hybrid visual fixation paradigm (based on Houston, Horn, Qi, Ting & Gao, 2007). The results showed that at 4-5 and 6 months of age infants in both the control and the at-risk group were still able to phonetically discriminate the non-native vowel contrast, whereas they had lost this ability at 8 months of age. Interestingly, infants in both groups regained the skill to discriminate between the non-native vowels at the age of 10 months. Possibly this reversal takes place because children temporarily focus more on phonetic details when they begin to learn words. De Klerk and colleagues (in prep.) did not find differences between the groups; for each group they reported a change of the non-native speech contrast in discrimination between 6 and 8 month olds, which is in correspondence to the results of other studies investigating the decline of phonetic sensitivity in typically developing infants.

A second gap in the knowledge of early speech perception is the relation between speech perception at an early age and later language development in at-risk children. A longitudinal study by Guttorm, Leppänen, Poikkeus, Eklund, Lyytinen & Lyytinen (2008), using ERP to determine speech perception in newborns, investigated whether the discrimination of /ba/, /da/ and /ga/ in newborns could function as a predictor of later language and verbal memory skill in infants at risk of dyslexia. They detected a relation between the response pattern in the right hemisphere in at-risk children and their receptive language skills. The receptive language skills were significantly poorer when the at-risk children were 2½ years old and showed a tendency towards poorer receptive language skills at 5 years of age. The response pattern of at-risk children in the left hemisphere was associated with poorer verbal memory skills when they reached the age of 5 years. The study by Guttorm and colleagues (2008) indicates that at-risks can be distinguished at an early age from their typically developing peers on the basis of their ERP pattern. Despite these results, it is the only published study to this date that has looked into the relation between early speech perception and later language development in children at risk of dyslexia.

In this study, the relation between early speech perception and later language development in children with and without a risk of dyslexia will be further investigated as part of a follow-up study of the speech discrimination experiment by De Klerk, De Bree, Kerkhoff and Wijnen (in prep.) that was mentioned above. The speech discrimination data that was obtained in the experiment by De Klerk and colleagues (in prep.) will be used. To compare this early speech perception data to later language development, children who participated in the experiments of De Klerk and colleagues (in prep.) have been asked to come back to the lab when they reached the age of 3½ - 4½ years to participate in this study. Their current language development was examined and related to their performance on the discrimination experiments when they were infants. Therefore, the first research question that is asked is the following:

> *(1a) Does the speech discrimination ability at 6 to 8 months of age correlate with the language development at 3½ to 4½ years of age?*

The ability to discriminate speech contrasts is shown by the difference in looking time between trials that consist of alternating speech sounds (e.g. saen, sEn, saen, sEn) and non-alternating speech sounds (e.g. saen, saen, saen, saen). When infants start focusing on their native language, they will show a smaller difference in looking time between alternating and non-alternating trials of the non-native contrast as they will perceive these speech sounds as belonging to the same category. No difference in looking times is therefore associated with a more advanced perceptual tuning. Consequently, it is hypothesized that infants who show more focus to the native language, as indicated by a decrease in looking times to alternating trials in the non-native condition, will have a more advanced language development at the age of 3½ to 4½ years old than children with a larger looking time difference. Considering the results of the speech sound discrimination-based word learning task and the relation to vocabulary size in the experiment by Yoshida and colleagues (2009) and the relation between speech sound discrimination and vocabulary size that was found by Tsao, Liu and Kuhl (2004), it is expected that the more advanced language development will (at least) be shown by a larger vocabulary size.

Additionally, as many data points are gathered per child on the language development tests, a (sub-)question that will be looked into is:

> *(1b) How do the performances on the individual language development tests correlate with each other?*

It is not the aim of this study to get into the underlying processes and implications of this study very extensively, but as the data points are available it will be interesting to look at how the development of a certain language aspect correlates to another.

Since previous research has shown, group differences (typically developing vs. at-risk) can be found at this age on several language-related aspects. The tasks that will be administered in this study are tasks that dyslexics and at-risk children are known to be outperformed on by their typically developing peers. This leads to the second research question:

> *(2) Can the at-risk group be distinguished from the control group on the basis of discrepancies in their language development at 3½ to 4½ years of age?*

Based on current knowledge, it is hypothesized that the at-risk group will be outperformed by the control group on receptive vocabulary size; verbal short-term memory; rapid retrieval of familiar words and morpho-syntactic (inflection) abilities (Goswami, 2000; Goulandris, Snowling & Walker, 2000; Joanisse, Manis, Keating & Seidenberg, 2000; Manis et al., 1997; Scarborough, 1990; Wolf, Goldberg O'Rourke, Gidney, Lovett, Cirino & Morris, 2002). In addition to the language-related skills that are tested, the participant's cognitive control, the ability to block irrelevant information, will be examined. To block irrelevant information (under time pressure) and approach a task with a goal-directed attitude selective attention is necessary (See Lavie, Hirst, De Fockert & Viding, 2004 for more information about selective attention and cognitive control). Dyslexia is known to be co-morbid with ADHD (Willcutt &

Pennington, 2000) and it is therefore expected that the at-risk children will show a poorer attention span and will thus perform more poorly on the cognitive control tasks.

Method

Participants

19 of 20 monolingual Dutch children that were tested were included. Before attending the experiment, parents were asked to fill in a questionnaire that provides information about (indications of) sensory and/or mental problems (autism, AD(H)D), which could lead to exclusion. Due to visual problems that could not be corrected with glasses (one eye was covered) and hearing problems, one participant was excluded from further analysis. Another participant had limited vision but his sight was corrected-to-normal with glasses and was therefore included in the experiment. None of the parents reported indications of any mental problems. The sample consisted of 11 females and 8 males whose ages ranged from 3;8 (years;months) to 4;3 (*M* age = 3;10). Half of the participants (*N*=10; 5 female; *M* age = 3;10) had a familial risk of dyslexia due to having at least one dyslexic parent (inclusion criteria are reported below). The remaining children were considered typically developing controls (*M* age= 3;10). All the children had participated in the speech discrimination experiment that was conducted in the Babylab Utrecht (Utrecht University), at the age of 6 and/or 8 months (for recruiting details of the infants see De Klerk, et al., in prep.), and had successfully completed the two contrasts, both the native contrast (Dutch /aa-ee/ embedded in the non-words *faap* and *feep*) and the non-native contrast (English /ae-E/ embedded in the non-words *saen* and *sEn*).

The at-risk group is formed on the basis of parental reading difficulties. The parent, who may or may not have received an official dyslexia diagnosis, is presented with two standardized reading tests to confirm the reading problems and a verbal competence test to measure verbal intelligence. The reading tests are 1) the Een-Minuut-Test (EMT; Brus & Voeten, 1972), in which words have to be read out loud correctly and as quickly as possible within one minute, and 2) De Klepel (Van den Bos, Lutje Spelberg, Scheepstra & De Vries, 1994), in which non-words have to be read out loud correctly and as quickly as possible within two minutes. In addition, a verbal competence test (Analogies) was taken from the Wechsler Adult Intelligence Scale (WAIS, Uterwijk, 2000) to confirm that the impairment was in fact a reading one, rather than a generally decreased language competence due to a low intelligence. As dyslexia is characterized by a discrepancy between intelligence (including verbal competence) and reading (and writing) abilities, a child was included in the at-risk group when the dyslexic parent scored poorly on the reading tests but not on the verbal competence test. In three situations a child was included to the at-risk group: 1) the parent performed on or below the 20th percentile on both reading tests, or 2) the parent performed on or below the 10th percentile on either one of the reading tests, or 3) the parent's performance revealed a discrepancy of at least 60% between the performance on the verbal competence test and the performance on both reading tests.

N-CDI

On each visit to the Babylab Utrecht with their infants, parents were given the Dutch version of the MacArthur-Bates Communicative Development Inventory (N-CDI; Zink & Lejaegere, 2002) and were asked to fill it in and return it. The N-CDI is a standardized parent report that comes in two versions: *Words and Gestures* and *Words and Sentences*. In both forms word comprehension and word production are measured. The *Words and Gestures* form also measures the number of (communicative) gestures (e.g. pointing, shaking head, wiping hands and face) the infant uses. The raw scores can be translated in to a percentile score, which is based on age and gender. Between 10 and 16 months of age, the communicative development of children is measured by using the *Woorden en Gebaren* (Words and Gestures) version of the N-CDI; for older infants (16-30 months old) the *Woorden en Zinnen* (Words and Sentences) version is used. Unfortunately, for some children only one N-CDI had been filled out or even none at all. In the analysis, the percentile scores were used of the N-CDI's that were available: 13x *Words and Gestures* (age range: 10-14 months) and 10x *Words and Sentences* (age range: 18-29 months).

Apparatus and materials

The test battery consisted of the following tasks: (1) *Peabody Picture Vocabulary Test-III-NL* (PPVT; Schlichting, 2009); (2) Visual Search task (Pre-COOL, under development); (3) Non-word repetition task (NWR; Pre-COOL, under development); (4) *Continu Benoemen & Woorden Leren* (CB&WL, 'rapid naming'; Van den Bos & Lutje Spelberg, 2010); (5) Inflectional task (as put together by Van Alphen, De Bree, De Jong, Gerrits, Wilsenach & Wijnen, 2004). The visual search task and the non-word repetition (NWR) task were presented on a computer (Samsung R610) with a 16" screen. The auditory stimuli of the NWR task were improved and enhanced by using a Fostex 6301B loudspeaker as the sound quality and volume level of the Samsung laptop did not suffice. Children's answers during the NWR task were recorded on an *Ipad* using the application '*Audio Memos*'. A stopwatch was used to measure the response time during the rapid naming tasks (colours and pictures).

Assessing receptive vocabulary size

The PPVT is a standardized test that measures receptive vocabulary. The procedure is as follows: the participant looks at a sheet with four pictures, while the experimenter names an item or action (the target word can be either a noun or a verb) that is displayed on one of the four pictures. Then the participant is asked to point to the picture on which he or she thinks the noun or verb is displayed. The test material consists of multiple sets of 12 words (and accompanying picture-sheets), ranging from easy to difficult. The age of the participants determines at which set it is recommended to start with. Participants of a particular age should be able to perform well on the starting set (max. 4 errors out of the 12 words in the set). If the set appears to be too hard for the participant, the experimenter can continue with an easier set. Generally though, the participant will be able to complete the first set with four or fewer errors. Then the experimenter continues with the next set, which is slightly more difficult. This procedure is repeated until the participant makes nine or more mistakes in one set. That particular set will always be completed, even when the participant has already reached the limit of nine mistakes. The number of overall errors is subtracted from the number of correct answers to obtain the raw score. As it is a standardized test, the raw scores of the number of correct answers result in quotient scores for each individual child taking age into account, which are used in the data analysis. The full test took approximately 15 minutes to complete.

Assessing verbal short-term memory

To assess the verbal short-term memory of the participants, a non-word repetition task was used. This NWR task consisted of 18 words that do not exist in Dutch, but could exist according to the phonotactic rules of the language. The stimuli were monosyllabic, disyllabic and trisyllabic, six of each type and half of them (n=3 per type) were words with a high phonotactic probability, whereas the other half had a low phonotactic probability (see appendix A for a list of all non-words). Each (auditory) stimulus was presented with a ‘new’ visual stimulus (a drawn picture of a non-existing item). The stimuli were embedded in sentences like: *“Kijk, een soot! Zeg eens: soot”* (“Look, a soot! Please say: soot”), recorded by a female speaker using child directed speech. Whenever the child had answered, or had refused to answer after listening to the stimulus three times and encouragement of the experimenter to repeat the (non-)word, the next item was presented. It took approximately five minutes to complete the task. Out of the 19 participants, three participants felt uncomfortable doing this task. They were shy and refused to repeat the words even after plenty of encouragement by the experimenter. All three participants have been excluded from the analysis as there was no data to analyse.

The answers per item were scored ‘correct’, ‘false’ or ‘no answer’ immediately. All sessions were recorded on an *Ipad* for offline analysis. The offline analysis created the possibility of a more fine-grained analysis of the utterances, as well as an opportunity to correct for any mistakes that the experimenter might have made during online scoring. For all participants, each non-word was transcribed and then further analysed on number of correct vowels and number of correct consonants, resulting in a percentage of correct phonemes per participant. Both the quantitative scores (correct/false) and the qualitative scores (percentage of correct phonemes) were used in the analysis.

Assessing word retrieval speed

A third aspect of language that was investigated is processing speed. Processing speed in language-related settings is typically measured with a rapid naming test, which examines the rapid retrieval of familiar words, e.g. colours, digits or familiar objects. The CB&WL is a standardized rapid naming test for children aged 5;10 (years;months) and older. It is used to screen for language and reading disorders like dyslexia. Due to this age restriction, only the raw scores can be used in the analysis of this test. As some parts of the CB&WL are too difficult for children aged 3½ to 4½ years old, only the rapid naming of colours and familiar objects (pictures of a pair of scissors; a tree; a bicycle; a duck and a chair) was measured in that particular order. A test sheet of this test consists of ten rows and five columns (resulting in 50 words per sheet in total).

After having been instructed that the task was to name all the words as quickly as possible, each participant was offered a practice round. First the experimenter showed the child how to do the test by naming the ten colours in the last column ‘as quickly as possible’[1] while covering the remaining colours with a second sheet. Then the participant was asked to show the experimenter how fast he could name the same column as the experimenter just did. In the exceptional case that the practice did not go well, it was repeated until the experimenter was confident that the participant understood the task. When the practice run went well, the covering sheet was removed, then the experimenter pointed out for the participant where to begin and the participant was instructed to name the colours as quickly as he could. As soon

[1] Although the experimenter said to do it as quickly as possible, the speed was adjusted to the age of the participants. For children the naming speed of the experimenter seemed very fast but from an adult point of view the experimenter in fact held back.

as the participant started, the time was recorded in seconds using a stopwatch. For each colour the experimenter noted whether the target a) was named correctly, or b) was skipped, or c) was named incorrectly but was self-corrected by the participant, or d) was named incorrectly without correction. When errors were made, the experimenter also wrote down the response that was given. After the rapid naming of colours, the same procedure was repeated with the familiar objects sheet. It took approximately ten minutes to complete both parts of the test.

The results of each participant were translated to a number representing the 'correct answers per second', averaged over both rapid naming tasks. As one of the participants was not familiar with the colours (revealed during practice and confirmed by the parent) and one other participant did not want to cooperate during the colour part of the test, the scores for these children was calculated using only the results of the object-naming part. Furthermore, one of the colours (red) was rather ambiguous and could be perceived as orange as well. When a participant consistently named this colour 'orange' it was calculated as a correct answer. However, when the participants used more than one name per colour, only the intended name of the colour (red in this case) was considered correct.

Assessing morpho-syntactic knowledge

An elicitation task was used to measure morpho-syntactic knowledge of nouns and verbs. The task was split up in two parts: nouns and verbs. In both parts the participant was shown two pictures simultaneously. The experimenter fully described the first picture but in the description of the second picture, the last word was omitted to elicit a response from the participant. When examining the inflectional knowledge of nouns, on the left side of the page a single exemplar of a target object was displayed (e.g. chair) whereas the right side displayed two or three of the target objects. The experimenter then said: *"Kijk, dit is een stoel en dit zijn twee…?"* ("Look, this is a chair and these are two…?"), stressing the numeral *twee* (two) to elicit the plural form *stoelen* (chairs). Ten plural forms of nouns that are familiar to children of their age were elicited in this manner in a fixed order. Two of the nouns had an irregular plural form. The participant's response was written down by the experimenter for later analysis.

Since participants were far from consistent in their responses, a proper way to analyse the results had to be come up with. After ample consideration it was decided that only the use of inflections would be analysed. That is, when the child said "tigers" instead of "cats" it was marked as a correct response due to correct use of the plural marker. Moreover, the use of the Dutch diminutive (plural) marker "-jes" was also regarded as a correct use of inflectional information. The only exception to the latter rule was when it was used for irregular nouns. In this case, it was categorised as a simplified plural form. Simplified plural forms were also marked when a child used the regular plural marker for irregular nouns. Lastly, all responses that contained a singular form instead of a plural form were calculated. This resulted in three data points per child (proper use of the plural marker, simplified form for irregular nouns and use of singular form). A fourth category was made for null responses and utterances that were not related to the task. However, none of the responses given were eligible for this category.

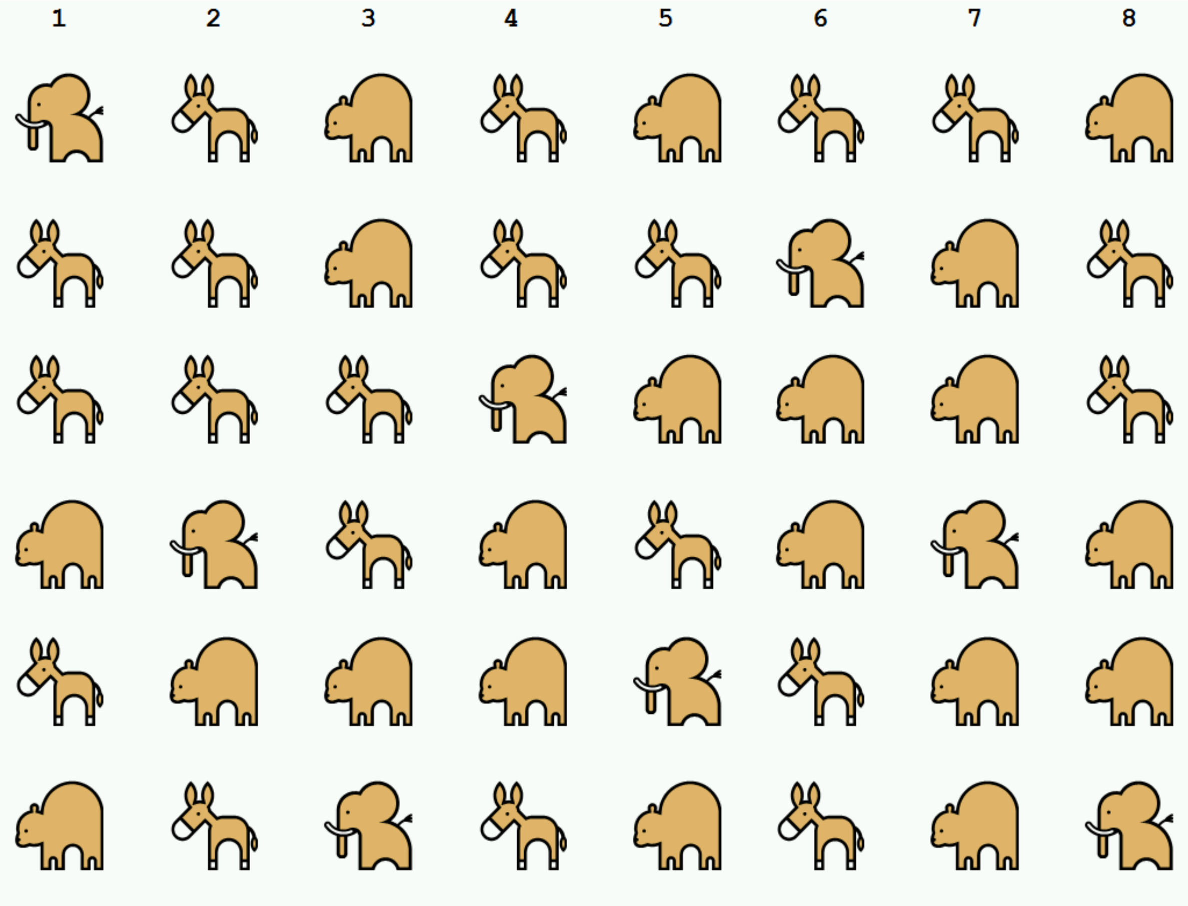
After eliciting ten nouns, the task continued as a verb agreement task. In Dutch the third person singular form of verbs is formed with stem+*t*. The stem and infinite form of a verb are not the same in Dutch, unlike English. Dutch has the infinitive marker *–en*. In independent sentences, the use of the infinitive form can only be grammatical when it is accompanied by an auxiliary verb. Before acquiring third person singular inflectional markers, children often use an auxiliary verb + infinitive construction by using an ‘empty’ verb like *gaan* (go) (van Alphen, de Bree, Gerrits, de Jong, Wilsenach & Wijnen, 2004). Although this latter form is grammatically correct, the goal was to elicit a third person singular inflection. On the left a picture was displayed of a person (or animal) performing one action (e.g. dancing) and on the right the same person was seen performing another action (e.g. reading). The experimenter enounced: *“Kijk, deze beer danst en deze beer…?”* (“Look, this bear dances and this bear…?”). Again, the responses were written down for later analysis.

Similar to the nouns, different categories were used for the analysis of the responses in which only the use of inflectional markers was considered. The first category consisted of responses that properly used the third person singular form (stem+*t*), independent of whether the verb used was the target verb. The use of the (empty) auxiliary verb + infinitive formed the second category. When only an infinitive had been uttered it was categorised in the third category and lastly, the fourth category consisted of null responses and utterances that did not include a verb or were not related to the task. The responses in the last category were not taken into the analysis. To complete the two parts approximately five minutes were needed.

Assessing cognitive control

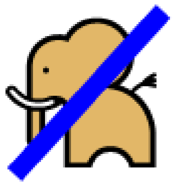
In addition to assessing language development, children’s ability to block irrelevant information was assessed. In a visual search task, two sessions with 48 pictures and one session with 72 drawn pictures of animals (elephants, horses and bears) were presented on a computer screen (see Figure 1). Per session, eight of them were pictures of elephants. The other pictures existed of two other types of animals that were similar to the elephants in colour and size. As soon as the animals were presented, the participant got 40 seconds to point out as many elephants as he could before the test disappeared and a bonus image (a large picture of an elephant with a hat, balloon or flower) appeared.

Figure 1 – The visual search task



The participant was instructed to point out all elephants and was continuously encouraged to search for the elephants as quickly as he could. When the participant pointed out an elephant, it was struck through with a thick blue diagonal line to point out that that particular elephant had been found (see figure 2). When a participant pointed to another type of animal or to an elephant that had been struck through, it was verbally corrected (*"No, in this game we only search for elephants"* or *"Can you find another elephant?"*) and the experimenter reported it as an error. After a practice session, in which the child was familiarized with the animals that were displayed and could practise the task of finding elephants and blocking the other pictures, three sessions of searching for eight elephants were completed. The first two sessions were equally difficult, 48 pictures were shown, consisting of eight targets (elephants) and 40 distracters. The third session was more difficult, this time 72 pictures were shown, 64 of which were distracters while the number of targets (eight) and the time given to find them remained the same. The whole task took approximately five minutes to complete.

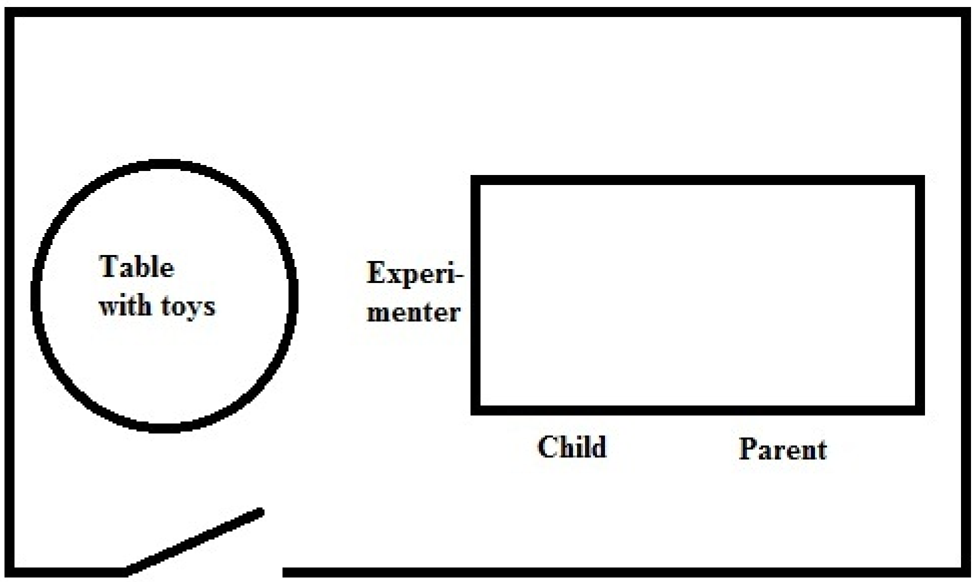
Figure 2 – Elephants that had been found, were struck through



General procedure

Parents were asked to fill out an online questionnaire concerning their child's development. Questions were asked regarding the motor-, language-, speech-, social- and emotional development as well as questions regarding the general health of the child. Parents also received an instruction per e-mail asking them not to get involved during the experiment and not to disturb the child in any way (e.g. asking questions to the experimenter, bringing siblings, etc.). This instruction was given per e-mail to prepare parents and to avoid a situation in which the child could hear the instruction. The latter situation could be unfavourable because it contained the instruction not to help the child or show him whether or not his answer was correct.

Figure 3 – The test room and setup



The tests were administered in a room where a rectangular table with six seats was positioned. The parent and child sat next to each other at the long end and the experimenter sat next to the child at the short end (see Figure 3 on the previous page). In this setup the parent could keep distance while the experimenter was interacting with the child. It also gave the experimenter the possibility to talk directly to the child (as opposed to when the experimenter had sat next to the child) and look at the tasks from the child's perspective (as opposed to when the experimenter had sat on the opposite side of the table).

For each participant the order in which the tests were administered was the same, starting with the PPVT, secondly the visual search task, followed by the non-word repetition task, then the rapid naming tasks (CB&WL) and finally the inflection task. As this is quite an intensive test battery, a short break (approx. 5 minutes) between tasks was offered when the child was losing attention (interest) or when the child started to show resistance. Afterwards the child was allowed to play for a while, while the experimenter sat down with the parent to discuss the session. The parent was asked to comment on the child's performance and concentration span, taking into account the typical and expected performance and concentration span for his/her child. If a child scores poorly on a test, it is important to know the reason for their performance. The parent can give valuable insight in these matters. Overall, most parents stated that their child performed in line with their expectations or even better. In some cases, concentration issues had decreased the performance. It rarely happened that a parent thought that the child had not performed to its abilities. However, on one occasion a participant had very clearly underperformed on the PPVT. The parent and the experimenter had concluded this independently from each other and agreed that the data did not represent the abilities of the child. This conclusion was drawn with the N-CDI results and the verbal ability of the child (using long, complex sentences) in mind. Because the underperformance was very obvious and the data was not representative, the child's data on the PPVT has not been included in the analysis. Generally, the experimenter's impression of the child and the comments of the parent were similar. The total visit usually took between 50 and 75 minutes and the child received two small presents for participating.

Results

As many tests that were administered, a lot of data points were gathered per participant. In the tables below a summary is given (including the measures that were used for analysis) of the children that had successfully completed the task (table 1) and an overview of the descriptive statistics is displayed (tables 2, 3 and 4)

Table 1 – The measures used in the analysis per task

Task	Measure	*N*
PPVT	*Percentile score	18
Visual Search	*Number of elephants pointed out	19
Non-word repetition task	*Total correct (quantitative scoring) *Percentage of phonemes correct in total (qualitative scoring)	16 16
CB&WL rapid naming test	*Average correctly named items per second *Average time needed in the rapid naming test *Average number of self corrections	19 19 19
Inflection task nouns	*Correct plural forms used *Simplified plural forms used for irregular nouns *Singular forms used where plural forms were required	19 19 19
Inflection task verbs	*Correct third person singular forms (stem+*t*) used *Auxiliary+infinitive forms used *Infinitives used where third person singular forms were required	19 19 19
N-CDI	*Words and Gestures *Words and Sentences	13 10
Speech perception[a]	*Difference score in looking time between alternating and non-alternating trials in the non-native condition *Difference score in looking time between alternating and non-alternating trials in the native condition	19 19

[a] *This data was gathered in the experiment by De Klerk and colleagues (in prep.). See their paper for details.*

Table 2 – Descriptive statistics of the speech perception data (non-native condition)

	Control		At-risk		Both groups	
	M	***SD***	***M***	***SD***	***M***	***SD***
Looking times Alternating trials (sec.)	7,96	4,09	6,31	2,95	7,17	3,61
Looking times Non-alternating trials (sec.)	7,47	3,42	6,33	3,95	6,92	3,65

Table 3 – Descriptive statistics of the language development data

	Control			At-risk		
	N	***Mean***	***SD***	***N***	***Mean***	***SD***
PPVT - Percentile score	8	69,00	15,09	10	72,40	18,64
Visual Search task – Number of elephants pointed out	9	19,56	3,58	10	18,70	2,21
NWR task – Total correct	7	11,71	2,36	9	11,22	2,73
NWR task – Percentage of phonemes correct	7	90,19	3,41	9	90,56	5,24
Rapid naming test – Average correctly named items per sec.	9	0,40	0,12	10	0,42	0,18
Rapid naming test – Average time needed (sec.)	9	132,00	39,30	10	130,75	54,38
Rapid naming test – Average number of self corrections	9	0,78	0,67	10	1,15	1,47
Inflection task nouns – Correct plural forms	9	8,67	1,66	10	9,20	0,63
Inflection task nouns – Simplified plural forms	9	0.44	0,53	10	0.80	0,63
Inflection task nouns – Singular forms	9	0,89	1,27	10	0,00	0,00
Inflection task verbs – Correct third person sing. forms	9	6,56	2,30	10	6,20	3,88
Inflection task verbs – Aux. verb + infinitive constructions	9	0,89	1,05	10	2,60	3,50
Inflection task verbs - Infinitives	9	2,22	2,49	10	0,90	1,45

Table 4 – Descriptive statistics of the N-CDI data

	Control			At-risk		
	N	***Mean***	***SD***	***N***	***Mean***	***SD***
N-CDI Words and Gestures – Word comprehension percentile	5	55,80	36,17	8	63,88	27,89
N-CDI Words and Gestures – Word production percentile	5	51,80	33,86	8	55,25	30,33
N-CDI Words and Gestures – Gestures percentile	5	60,40	26,19	8	74,13	19,90
N-CDI Words and Sentences – Word comprehension percentile	4	63,75	31,46	6	66,67	24,43
N-CDI Words and Sentences – Word production percentile	4	56,25	34,25	6	59,17	20,10

In order to explore the relation between early speech perception and later language development, the difference in looking time between alternating and non-alternating trials in the non-native condition of the infant study was correlated with the scores on the tests that were administered in this study. A negative correlation between the difference in looking times and the average correctly named items per second in the CB&WL rapid naming test (r=-.404, p=.045) indicated that the more sensitive the infants were to the irrelevant contrast the fewer items they named per second, averaged over both rapid naming tests (colours and pictures). Additionally, a positive correlation was found between the difference in looking times and the average time needed in the rapid naming test (r=.458, p=.021); children who were less focused towards their native language at the age of 6 to 8 months needed more time in the rapid naming test. No other significant results were found in correlations between the difference in looking time and the tasks administered at this time. However, a negative correlation (r=-.480, p=.044) between the difference in looking time and gestures (as recorded in the NCDI *Words and Gestures* form) showed that a more advanced speech discrimination ability has a positive relation to the number of gestures used between 10 and 14 months of age. These results are summarised in table 5.

Table 5 – Correlations found between early speech perception and language development

		1	2	3
Difference in looking time (infant study)	**Pearson's Correlation**	-.404	.458	-.480
	***p*-value**	.045	.021	.044
	N	19	19	13

1: Average correctly named items per second (Rapid naming)

2: Average time needed to complete the test (Rapid naming)

3: Number of gestures used (N-CDI Words & Gestures)

A second analysis was conducted to investigate correlations between performances between the tests that were administered. The percentage of correct phonemes in the non-word repetition task was found to be positively correlated with the average correctly named items per second in the rapid naming test (r=.509, p=.044) and negatively correlated with the average time needed in the rapid naming test (r=-.576, p=.020). A better performance on the non-word repetition task was thus related to a better performance on the rapid naming test as indicated by naming more items per second and needing less time overall.

As for the relation between verbal short-term memory and morpho-syntactic knowledge, a better performance on the non-word repetition task was related to a decreased use of simplified plural forms of irregular nouns; as indicated by the negative correlations between the percentage of correct phonemes in the non-word repetition task and the use of simplified plural versions (as explained in the method section) of irregular nouns (r=-.620, p=.010). Confirming these results, a positive correlation was observed between the percentage of correct phonemes in the non-word repetition task and the correct use of plural forms (r=.534, p=.033). Quantitative scoring (correct/false) of the non-word repetition data led to the same significant correlations with the inflection tasks.

In addition to the correlations mentioned above, significant correlations between rapid retrieval of words and morpho-syntactic knowledge were also observed. A higher average of correctly named items per second in the rapid naming test was positively correlated to a frequent correct use of third person singular forms (r=.478, p=.039) and negatively correlated to using an (empty) auxiliary verb + infinitive construction (r=-.522, p=.022). That is, when a participant performed better on the rapid naming test (as indicated by the number of correctly named items per second), the use of more advanced verbal inflection increased.

Furthermore, a positive correlation was found between the performance on the PPVT and the correct use of the third person singular marker in the inflection task (*r*=.382, *p*=.007). This was accompanied by a negative correlation between the receptive vocabulary size and the use of the (empty) auxiliary verb + infinitive construction (*r*=-.337, *p*=.019). This construction is considered less advanced than using the third person singular on the main verb. The two correlations that were found were thus an indication that a larger receptive vocabulary is related to more advanced knowledge of morpho-syntactic information. Furthermore, a larger receptive vocabulary size was related to a faster completion of the rapid naming task, as indicated by the negative correlation that was found between the performance on the PPVT and the time needed for the rapid naming test (*r*=-.355, *p*=.013).

Lastly, only one significant correlation was found between the visual search task (cognitive control) and the language tests. Better cognitive control is related to more advanced morpho-syntactic knowledge, as indicated by the negative correlation between the performance on the visual search and the use of simplified plural markers for irregular nouns (*r*=-.589, *p*=.008). An overview is given of the correlations between the language development tests in table 6 below.

Table 6 – Correlations found between the language development tests

		1	2	3	4	5	6
Total correct (non-word repetition)	**Pearson's Correlation**			.567	-.655		
	***p*-value**			.022	.006		
	N			16	16		
Percentage of correct phonemes (non-word repetition)	**Pearson's Correlation**	.509	-.576	.534	-.620		
	***p*-value**	.044	.020	.033	.010		
	N	16	16	16	16		

Average correctly named items per second (rapid naming)	**Pearson's Correlation**					.478	-.522
	***p*-value**					.039	.022
	N					19	19
Percentile score on the PPVT	**Pearson's Correlation**		-.355			.382	-.337
	***p*-value**		.013			.007	.019
	N		18			18	18
Number of elephants found in the visual search task	**Pearson's Correlation**				-.589		
	***p*-value**				.008		
	N				19		

1: Average correctly named per second (Rapid naming)

2: Average time needed in the rapid naming test (Rapid naming)

3: Use of correct plural forms (Inflection task)

4: Use of simplified plural forms for irregular nouns (Inflection task)

5: Use of the correct third person singular marker (Inflection task)

6: Use of (empty) auxiliary verb + infinitive constructions (Inflection task)

Using the N-CDI data it was possible to investigate the relation between early language acquisition (word comprehension, word production and gestures) and later language development. Correlations were found between early language acquisition on the one hand, and receptive vocabulary, cognitive control, rapid retrieval of familiar words and morpho-syntactic knowledge on the other.

First, the N-CDI *Words and Gestures* results were analysed. At this age, word comprehension and word production were significantly correlated (*r*=.947, *p*=.000), meaning that children aged 10 to 14 months with a larger receptive vocabulary size also had a larger expressive vocabulary size. Word production was negatively correlated with frequency of the use of infinitives in situations where third person singular forms were required (*r*=-585, *p*=.036). That is, a larger receptive and expressive vocabulary size at the age of 10 to 14 months old meant using an inflected verb (a third person singular main verb or an inflected auxiliary verb combined with an infinitive) more often.

A positive correlation between the use of gestures before 16 months of age and word comprehension (*r*=.730, *p*=.005) and production (*r*=.717, *p*=.006) before 16 months of age, as also word comprehension (*r*=.717, *p*=.045) between 16 and 30 months of age, showed that a more extensive use of gestures is connected to a larger receptive and expressive vocabulary size. In addition, a positive correlation was observed between the use of gestures and the average correctly named items per second in the rapid naming test (*r*=.582, *p*=.037). A negative correlation was found between the average time needed to name the items in the rapid naming test and the use of gestures (*r*=-612, *p*=.026). A more extensive use of gestures at 10 to 14 months of age is thus related to rapid retrieval abilities at 3½ and 4½ years old.

Next off, the analysis was carried out with the N-CDI *Words and Sentences* percentile scores. Resembling the *Words and Gestures* results, word comprehension and word production between 18 and 29 months of age were positively correlated (*r*=.904, *p*=.000). Both word comprehension and word production were found to be positively correlated with the correct use of plural forms in nouns (*r*=.678, *p*=.031; *r*=.674, *p*=.032). This means that a larger receptive and expressive vocabulary size at the age of 18 to 29 months is connected to more frequently using plural markers correctly. In tables 7 and 8 all the significant correlations with the N-CDI results are recapped.

Table 7 – Correlations found between all N-CDI data

		1	2	3	4	5
Words and Gestures: Word comprehension	**Pearson's Correlation**		.947	.730		
	***p*-value**		.000	.005		
	N		13	13		
Words and Gestures: Word production	**Pearson's Correlation**	.947		.717		
	***p*-value**	.000		.006		
	N	13		13		
Words and Gestures: Gestures	**Pearson's Correlation**	.730	.717		.717	
	***p*-value**	.005	.006		.045	
	N	13	13		8	

Words and Sentences: Word comprehension	**Pearson's Correlation**			.717		.904
	***p*-value**			.045		.000
	N			8		10
Words and Sentences: Word production	**Pearson's Correlation**				.904	
	***p*-value**				.000	
	N				10	

1: Word comprehension at 10-14 months old (N-CDI Words and Gestures)

2: Word production at 10-14 months old (N-CDI Words and Gestures)

3: Gestures at 10-14 months old (N-CDI Words and Gestures)

4: Word comprehension at 18-29 months old (N-CDI Words and Sentences)

5: Word production at 18-29 months old (N-CDI Words and Sentences)

Table 8 – Correlations found between the N-CDI data and the language development tests

		1	2	3	4
Words and Gestures: Word production	**Pearson's Correlation**				-.585
	***p*-value**				.036
	N				13
Words and Gestures: Gestures	**Pearson's Correlation**	.582	-.612		
	***p*-value**	.037	.026		
	N	13	13		
Words and Sentences: Word comprehen-sion	**Pearson's Correlation**			.678	
	***p*-value**			.031	
	N			10	
Words and Sentences: Word production	**Pearson's Correlation**			.674	
	***p*-value**			.032	
	N			10	

1: Average correctly named items per second (Rapid naming)

2: Average time needed to complete the test (Rapid naming)

3: Correct use of plural markers (Inflection task)

4: Use of infinitives where third person singular forms were required (Inflection task)

Lastly, analyses were conducted in order to investigate group differences in the performance on the tasks that were administered in this study. Using group (typically developing versus at familial risk of dyslexia) as independent variable and performance as dependent variable, an independent t-test was performed for each test separately. Unexpectedly, no significant group differences were found.

Discussion

This follow up study was set up to investigate the relation between early speech perception and later language development in children with and without a familial risk of dyslexia. The first question that was examined was whether such a relation actually exists. It was hypothesized that a stronger focus to the native language, as indicated by a smaller looking time difference between alternating and non-alternating trials in the non-native condition, would result in a more advanced language development. Based on the results by Tsao, Liu and Kuhl (2004) and Yoshida, Fennell, Swingley and Werker (2009), a more advanced language development was expected to at least be noticeable through a larger vocabulary size. A relation between early speech perception and later language development was indeed found, although not regarding the vocabulary size. Instead, a better perceptual tuning to the native language at 6 to 8 months of age was found to be related to a better performance on a rapid naming test as well as to a more extensive use of gestures. Children whose looking times difference was smaller at infant age named more items correctly per second in the rapid naming test and were overall faster completing a part of this test. Therefore, it seems that focusing on the speech sound contrasts of the native language has beneficial effects on processing speed and rapid retrieval at a later age. The extent to which participants perform successfully on a rapid naming test depends on several factors, among which the retrieval of phonological information is found (Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993). Possibly the positive correlation between early speech perception and later rapid retrieval can be explained by better specified and thus stronger phonological representations.

Secondly, as mentioned, children who were less sensitive to the non-native speech contrast also knew more gestures at the age of 10 to 14 months as measured by the N-CDI. Although Tsao, Liu and Kuhl (2004) found a relation between sensitivity to speech sound contrasts and CDI results, they did not find significant correlations between early speech perception and gestures in 13 nor 16 month old infants. Nevertheless, a correlation between language development (early speech perception in this case) and gestures is not an unexpected finding. It has long been argued that language development and gestures go hand in hand (Bates & Dick, 2002). Usually studies that find a relation between language development and gestures explore them at the same moment in time (both assessments are done at the same age). In this study, however, the relation was found between language development at an earlier age and gestures at a later age, as well as a relation between both language development and gestures at a later age (details are given later). This shows that language development is related to gestures independent of the developmental stage and age of the individual.

Although we expected to find a relation between early speech perception and later language development, it was surprising to find no significant correlations between speech perception and vocabulary size on neither the N-CDI's (at 10 to 29 months old) nor the PPVT (at 3½ to 4½ years old). These results stand in contrast to the results found by Tsao and colleagues (2004) and Yoshida and colleagues (2009). Both of their experiments, however, used different tasks which might explain the different findings. Tsao and colleages (2004) used a head-turn task to establish sensitivity to non-native contrasts and used the number of correct identifications of change trials (trials in which alternating non-native speech contrasts were presented) to measure sensitivity. The word learning experiment by Yoshida and colleagues (2009) did not necessarily assess sensitivity to speech sound contrasts but rather whether a child would be able to discriminate /bin/ from /din/ in a word learning situation. This /b/-/d/ contrast is, unlike the critical (non-native) contrast in this study, a native contrast and although speech sound discrimination plays a crucial role, sensitivity is measured in a very different way. Furthermore, in this experiment the N-CDI's have not been filled in at the same age for all children, contrary to the experiments by Tsao and colleagues (2004), and Yoshida and colleagues (2009). Although a percentile score is used which takes age into account, the results would have been more stable if the scores were used of children of the same age. And lastly, in this study only 19 children were tested which is a lot less than in the other experiments. Despite these circumstances, finding relations between early speech perception on the one hand and rapid retrieval and non-linguistic communication on the other hand proves that there is a connection between early speech perception and later language development. It is worth testing more participants for this study to further explore this relation and possible other relations.

Although only few correlations were found between early speech perception and later language development, the analysis did reveal some interesting correlations between the language development tasks. The percentage of correctly repeated phonemes in the NWR task was found to be related to the number of items named correctly per second in the rapid naming test, namely the higher the scores were on the NWR task, the better the scores on the rapid naming test. In addition, the amount of time needed overall for the rapid naming test decreased when the performance on the non-word repetition task increased. In both tasks a processing and a retrieval component play a key role. These roles are rather obvious in the rapid naming test; this test is based on processing visual information and retrieving the matching words as fast as possible. The NWR task, however, also requires a form of processing and retrieval. In a NWR task, verbal short-term memory is tested. Verbal short-term memory is a part of the short-term memory that is also known as the *phonological loop.* This loop consists of two parts: It enables rehearsal of the phonological information and it offers a system for temporary storage (Baddeley, Eyseneck & Anderson, 2009). During the NWR task the auditory input (the phoneme string that is combined as a non-word) needs to be processed, rehearsed and retrieved in order to repeat the non-word. It appears that participants who perform better on one of the tests have an advantage on the other test as well. Possibly this is because of their processing and retrieval abilities.

Additionally, an increased performance on the non-word repetition task was also correlated with an increased correct use of inflection. As for nouns, participants whose verbal short-term memory was better, used the correct plural form more often. In addition, they used a simplified (incorrect) plural form of irregular nouns less often. Although these two findings are closely related, their underlying mechanisms are somewhat different. In the case of using the correct plural marker for nouns, children are required to pick up on the information they are given and hold on to it. They must realise that there is a difference between singular and plural versions of a word and that the experimenter wants them to use a plural marker. It requires a form of attention to notice this implicit request. When the plural form is elicited as the experimenter says: *"these are two...?"*, they must process this prime, hold on to the target word and retrieve the proper plural marker for it. In Dutch this can be either *–en* or *–s.* After they have retrieved it, they must program a phoneme string and pronounce the word. A lot of these processes are similar in the NWR task. In a NWR task, attention to detail and holding on to the target word is crucial. Furthermore, in order to successfully complete a NWR task, the participant must retrieve phonological information and create a phoneme string to be produced. Although a different approach is needed in successfully producing plural forms of irregular nouns, here attention and retrieval are of great importance as well. The participant must notice an irregular plural form is required. This takes attention as well as a developed language ability. Then the irregular form has to be retrieved from the mental lexicon. Lastly, the rapid retrieval performance and the morpho-syntactic knowledge of participants were found to be correlated as well. Participants who named more items correctly per second used fewer (empty) auxiliary verb + infinitive constructions and their use of the correct third person singular marker increased significantly. Altogether, attention, processing and retrieval are common mechanisms that are required in order to perform successfully on the NWR task, the rapid naming task and the inflection task. Therefore, it makes sense that correlations are found between the performances on these tasks. As attention was also measured in the visual search task, one would expect to find correlations between the attention task and the NWR task, rapid naming test and inflection tasks. Unfortunately, the analysis of the visual search task did not yield very promising results. Only one significant correlation was found: A better cognitive control was related to producing fewer instances of simplified plural forms of irregular nouns.

Although no significant correlations were found between early speech perception and vocabulary size, the performance on the PPVT did correlate with some of the other later language development tests. Participants whose receptive vocabulary size was larger showed more advanced knowledge of verbal inflections. This is in line with the correlations that were found by Lyytinen and Lyytinen (2004). Their results showed a correlation between the inflectional knowledge measured by the CDI and the receptive vocabulary measured by the Reynell Developmental Language Scales. Although participants who performed better on the PPVT did not necessarily perform better on the rapid naming test as they did not have a significantly higher number of correctly named items per second, they did completed the rapid naming test significantly faster. These results were strengthened by similar results that were gained by analysing the N-CDI's that parents had filled in when their children were between 10 and 29 months old. Language development at this age was also found to be in some ways related to the performance on the rapid naming test (rapid retrieval) as well as on the inflection tasks (morpho-syntactic knowledge). A more extensive use of gestures as well as a larger vocabulary size at 10 to 29 month old corresponded to a better performance on the rapid naming test and the inflection tasks, just like a larger vocabulary did at 3½ to 4½ years of age. The results of the *Words and Gestures* N-CDI's were in many cases found to be correlated to the results of the *Words and Sentences* N-CDI's. This shows that these parental reports function well as a longitudinal measure of language development.

. Altogether, morpho-syntactic (inflectional) knowledge correlates with all the aspects of later language development that were tested: receptive vocabulary size, verbal short-term memory, rapid retrieval and cognitive control. In addition, inflectional knowledge also correlates with the vocabulary size at a younger age. Furthermore, two 'triangles' were observed. Early speech perception, rapid retrieval and gestures all correlate with each other. As do verbal short-term memory, rapid retrieval and inflectional knowledge. Although the latter three all have an attentional component, no correlations were found with the cognitive control task. It therefore seems that either the attentional component is not the key factor that makes them correlate or that the attentional component in those three tests differs too much from the selective attention that is tested in the cognitive control task.

The second research question that was investigated was whether the at-risk group would perform significantly different on the language development tests compared to their typically developing peers. As the tests that were administered measured aspects of language that dyslexic individuals are known to be outperformed on (e.g. Goswami, 2000; Goulandris, Snowling & Walker, 2000; Joanisse, Manis, Keating & Seidenberg, 2000; Manis et al., 1997; Scarborough, 1989, 1990, 1991; Willcutt & Pennington, 2000; Wolf, Goldberg O'Rourke, Gidney, Lovett, Cirino & Morris, 2002), it was predicted that the at-risk group would perform worse than the controls. Contrary to the prediction, no significant results were found on any of the tests. The at-risk group performed equally well on all of them. The most likely explanation for these unexpected results lies in the size of the sample. Only 10 at-risk children were tested. Considering that 'only' 32 to 66 percent of these children develop dyslexia (De Bree, 2007), a group of 10 at-risk children is simply not large enough. It has been suggested that the familial risk of dyslexia is 'continuous'; that is, that children who are at risk of dyslexia in retrospect performed poorer on language tests even when they have not developed dyslexia later in life (Snowling, Gallagher & Frith, 2003). This cannot be confirmed with the results of this study. However, sample size again forms a problem here and no claims can be made based on these 10 at-risk children. More children will have to be tested in order to gain a more robust result.

In conclusion, the results of this study show the following: a relation between early speech perception and later language development exists. A stronger focus towards the native language results in a faster and more accurate retrieval of familiar words. In addition, vocabulary size (at different ages), verbal short-term memory, rapid retrieval of words and morpho-syntactic knowledge are in different ways related to each other. A potential relation between language and cognitive control was not found clearly in these results. And lastly, no significant group differences were found between typically developing children and children who are at a familial risk of dyslexia. This unexpected result should most likely be appointed to the small sample size.

Due to limited time these results are preliminary. More participants will be tested in the future in order to reach a representative sample size.

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Appendices

Appendix A - Words used in the non-word repetition task

	Monosyllabic	**Disyllabic**	**Trisyllabic**
High phonotactic probability	Jaat Loen	Holin Keepon	Liepoetaan Peelaanot

	Peek	Natep	Sietaalon
Low phonotactic probability	Jiek Luup Peun	Hiemup Keupun Nuipok	Luujeemuk Poekuijol Suitaajin