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Dyslexia and early delayed motor development:
A study on co-occurring problems in at-risk children

Dyslexics have been found to have multiple co-occurring problems, of which language, motor and attention problems are among the most frequently named. This thesis examines the relationship between dyslexia and its possible precursors, with a specific aim to investigate claims about motor development. Infants with a familial risk of dyslexia were compared with a group of control infants. A parental questionnaire provided information about the medical history and development, speech and language development, motor development and attention. Additionally, language production and comprehension skills were assessed with the MacArthur Communicative Development Inventories. As dyslexic children have shown impaired language, motor and attention abilities, the development of the at-risk group was expected to be delayed. Furthermore, correlations between the performance in language, motor and attention skills are examined. The at-risk children indeed obtained lower scores on measures of receptive vocabulary. No difference was found between the two groups on any of the motor development measures. Overall motor development was associated with vocabulary scores for both groups, but a relationship between oral motor development and vocabulary was only present for the at-risk group. Similarly, whereas overall motor development was associated with attention for both groups, a correlation between oral motor development and attention was only present for the at-

risk group. This suggests that oral motor skills and attention need to be taken into account when studying precursors of dyslexia.

Keywords: motor development, precursors of dyslexia, phonological deficit, attention

Dyslexia is a specific language-based disorder characterized by difficulties in reading and/or spelling that are unexpected in relation to cognitive abilities and age (Lyon, 1995). The problems seem to be manifest themselves mainly in the phonological module of the language system, as evidenced by difficulties with phonological awareness, non-word repetition and converting graphemes to phonemes (Nicolson & Fawcett, 2008; Snowling, 2000; Ramus et al., 2003; Heilman et al., 1996). Further studies using different phonological tasks, e.g. speech production, word stress production and non-word repetition suggest a delay in acquisition in children with a familial risk of dyslexia (i.e. having at least one dyslexic parent) (e.g. de Bree, 2007). Other language related symptoms range from impairments in lexical retrieval, rapid automatic naming, verbal short term memory, (auditory) temporal processing and visual processing (e.g. Vellutino, Fletcher, Snowling & Scanlon, 2004).

Poor motor skills are known to frequently co-occur with dyslexia (Snowling, 2000). This idea dates from the 1930's, when dyslexics were first characterized as being clumsy (Geschwind, 1982). Dyslexia was regarded to be related to problems with motor development and coordination. Nowadays, the terms that are used to describe general motor problems are 'dyspraxia' or 'developmental coordination disorder' (DCD). The problems are characterized by *"a difficulty with gross and fine motor movements that is out of line with age and stage of development"* (Snowling 2000:211). Previous research gave rise to the estimation that 60% of children with reading disability had a developmental coordination disorder or other problems with motor skills (Johansson et al., 1995; Kaplan et al. 1998). This led to the question whether poor motor skills and developmental dyslexia are just co-morbid problems or whether both developmental disorders are caused by a more general learning problem. The present study sets out to research the relationship between motor skills and dyslexia by comparing performance in early motor milestones between children with a familial risk of dyslexia and developing children. Furthermore, it examines connections between motor development, attention, and language development.

Language problems

Although dyslexic children frequently exhibit problems in motor skills and attention, the primary attributes associated with dyslexia are problems in the area of language. Language difficulties (apart from difficulties in reading and writing) have been found in populations diagnosed with dyslexia (McArthur et al., 2000; Rispens & Been, 2007). Language difficulties during childhood is a known precursor of dyslexia, as differences in language development prior to the onset of reading instruction have been found in children that have a dyslexic parent or sibling (Lyytinen, Poikkeus, Laakso, Eklund & Lyytinen, 2001; Scarborough, 1990; Snowling, Gallagher & Frith, 2003; Van Alphen et al., 2004). These children are said to be at 'familial risk' of dyslexia, as it is a hereditary disorder. Approximately 35 to 40 percent of at-risk children are known to have reading-related skill deficits (e.g. word reading, orthographic coding, phonological decoding and phoneme awareness) later in life (Molfese et al., 2008), therefore studies with children that are at familial risk allow for insight into the developmental trajectory of dyslexia.

The Finnish Jyväskylä Longitudinal Study of Dyslexia (JLD; Lyytinen et al., 2001; Viholainen et al., 2002; Lyytinen et al., 2004; Viholainen et al., 2006) is one such study. The authors followed 88 children with and 88 children without a familial risk of dyslexia from birth up to 10 years of age. They found that at two years of age at-risk children produced shorter utterances as measured by the mean number of morphemes than control children. Furthermore, the onset of talking was found to be the most consistent predictor of dyslexia, as two year-old at-risk children that were identified as late-talkers showed a delay in object naming and inflectional morphology when they reached 3.5 years-old. Additionally, the JLD study found a high association between measures of receptive and expressive vocabulary and grammar at 2 and 2.5 years old and later reading and spelling accuracy at the end of the first grade (Lyytinen et al., 2005). Assessments of phonological skills in at-risk children frequently show a phonological deficit (e.g. de Bree, 2007), which is a hypothesized cause of developmental dyslexia in many leading studies (e.g. Goswami, 2000; Ramus & Szenkovits, 2008).

These studies account for the co-occurring symptoms of dyslexics by proposing that dyslexia is a multifactorial disorder (e.g. Pennington, 2009; Snowling, 2000), with a core deficit in (access to) phonological representations (e.g. Ramus & Szenkovits, 2008; Snowling, 2000).

Articulatory skill, a skill that involves motor abilities as well as phonological abilities, has been the subject of many studies on dyslexia. A child who has poor motor skills might develop delays in articulation, which in turn might lead to a delay in language. Proponents of a motor-articulatory feedback hypothesis of dyslexia believe that dyslexic children are unaware of the position of their articulators during speech, i.e. dyslexic children suffer from an inability to associate the position of their articulators with speech sounds. This would be the cause of an impaired development of phonological awareness and an impaired ability to convert graphemes to phonemes (Heilman et al., 1996). However, a study involving rapid automatic naming tasks (which are, among other things, used as a direct measure of articulatory skill), phonological awareness tasks (rhyme, spoonerisms, non-word reading, alliteration fluency, rhyme fluency) and motor tasks (balance, finger-to-thumb, bead threading, time estimation) found there was no correlation between motor skill, articulatory skill and phonological awareness (Ramus et al., 2003b).

Motor problems

The phonological deficit hypothesis opposes the idea of a general learning problem. However, there is a theory that does hypothesize a general learning deficit as a cause of dyslexia and by doing so, unites the range of its co-morbid symptoms into one theory. This is the cerebellar deficit hypothesis (Nicolson and Fawcett, 2008; Fawcett et al., 1996; Nicolson et al., 1995). The cerebellum, situated at the rear of the brain, is the part held responsible for the control of fine motor coordination and body movement, posture, muscle tone and balance (Krog, 2010). Furthermore, the cerebellum is known to play a role in the ability to automatize tasks, such as driving, typing and reading (Ramus et al., 2003a). According to the cerebellar deficit hypothesis, a mildly dysfunctional cerebellum results in problems with automatized tasks. This causes motor problems, as well as dysfunctional speech articulation. This is said to lead to language related problems, such as deficient phonological representations. Moreover, it is said to result in problems with the learning of grapheme-phoneme correspondences (Ramus et al., 2003a). Hence, it was proposed that dyslexia could be caused by a general learning deficit.

The basis of this theoretical framework would later change to what is now known as the procedural deficit hypothesis (Ullman, 2001; 2004). Research has shown there are two kinds of learning, namely declarative and procedural learning, of which procedural learning is the result of implicit, incidental learning. Neuro-anatomically, the procedural system is located in the inferior frontal cerebral cortex, the basal ganglia, the cerebellum and its interconnected structures. This system is thought to be responsible for the learning and execution of motor skills, in which rule learning and cognitive skills are included (Kerkhoff et al., 2011; to appear). The procedural deficit hypothesis states that *"[...] a significant proportion of individuals with dyslexia and SLI suffer from abnormalities of this brain network, leading to impairments of the linguistic (e.g. implicit phonological rules) and non-linguistic (e.g. motor) functions that depend on it"* (Kerkhoff et al., 2011; to appear).

One of the best known studies in support of the cerebellar hypothesis uses the balance test. In this test, 13-year-old children were asked to balance on a beam (Nicolson and Fawcett, 1990; Stoodley et al., 2005) under two conditions. In the first condition, participants merely had to balance while performing several tasks (using two feet, one foot, walking up and down the beam). In the second condition, another, non-motor, task was added, namely counting backwards and a choice reaction task. There was no difference between the dyslexic group and the control group in the first condition, however the dyslexic children performed significantly worse in the second condition. This outcome was thought to be the effect of the failure to fully automatize skills.

Other motor tasks in which dyslexic teenagers are known to perform worse than controls include the bead threading task (in which participants we asked to thread 18 large beads onto a string as quickly as possible; Nicolson & Fawcett, 1995), the finger-to-thumb task (perform a certain sequence of movements with the top of the index fingers and the thumb as quickly as possible; Fawcett et al., 1996) and the bimanual finger-tapping task (where participants had to reproduce the rhythm of a metronome and in which dyslexics were unable to keep pace from a certain speed threshold; Wolff et al., 1990).

However, these findings are questioned by Ramus et al. (2003a) and White et al. (2006). White et al. (2006) examined the association between dyslexia and auditory, visual and motor disorders (to which the authors referred as 'sensorimotor impairments'). They tested dyslexic children's performance on the motor tasks bead threading, finger-to-thumb, stork balance (stand on one foot as long as possible and place the other foot on the supporting knee) and heel-to-toe (walk along a line as many steps as possible). The results showed one or more sensorimotor impairments in 14 out of 23 dyslexic children. However, when they compared the literacy performance of the dyslexics with sensorimotor impairments to those without, no differences were found. Ramus et al. (2003a) used Nicolson and Fawcett's (1990) concurrent balance/dual task, along with bead threading, finger-to-thumb and bimanual finger-tapping and several other tasks, but the results showed no significant group differences. Furthermore, no evidence was found that motor/cerebellar performance is linked to phonology or literacy. However, it should be noted that in the study of Ramus et al. (2003a), all participants were university students. As highly educated dyslexics are known to perform better on literacy test than the average dyslexic, the selection of participants might have influenced the results.

The set of studies that are discussed so far show that the nature of the relationship between dyslexia and motor abilities is still unresolved. A study that contributed to the body of research from a different angle is the previously mentioned JLD study. Besides language development, it also investigated links between dyslexia and motor skills prior to the onset of reading education. Motor skills were assessed by means of a structured parental questionnaire during the first two years of life. Language skills were assessed from as young as 18 months old to 10 years of age. Reading skills were assessed multiple times between 7 and 10 years of age. Delays in both gross and fine motor development were found only among children of the at-risk group. Moreover, a delay in reaching motor milestones was linked to slower word, pseudo-word and text reading at the end of first grade (age 7-8). As the method is similar to the current study, the JLD-study will be described in detail in the section 'Statistical analysis'.

Shapiro et al. (1990) also investigated whether children with dyslexia had difficulties with motor development in the first years of life. They found no evidence for a relation between delayed motor development and delayed reading.

Attention problems

Another developmental disorder frequently associated with dyslexia is attention deficit. According to Snowling (2000) parents and teachers complain frequently about the lack of concentration of children with dyslexia. Adams et al. (1999) found that 12.5 percent of young poor readers were rated by their teachers as having a significant problem with attention. Pennington et al. (1993) tested the relationship between attention deficit and dyslexia with three groups of participants: a group of dyslexic readers without attention problems, a group of children diagnosed with ADHD and a group of children that were both diagnosed with dyslexia as well as ADHD. The diagnosis of ADHD was based on three types of ratings by the parents including severity of hyperactivity, pervasiveness of the problems and the age of onset of the problems. The performance on two tasks was measured. The first assessment consisted of phonological tasks, the second task set measured executive function. The first is thought to be the core deficit in dyslexia, the latter is thought of as the core deficit in ADHD. The dyslexic group performed poorly on tests of phonological processing, but they had no difficulty with the executive function tasks. The ADHD group showed the opposite in performance, as those children were found to have executive deficits and normal phonological processing skills. This was all in line with expectation. The third group that was diagnosed with dyslexia and ADHD turned out to perform like the dyslexics, because they showed phonological but not executive deficits. These findings suggested that in the case of co-occurring disorders with dyslexia, the development of one disorder is the consequence of another, as the children of the co-morbid group performed very differently from the ADHD group.

If not properly controlled for, attention disorders can confound results in dyslexia studies. Such influence can be seen in the balancing study of Nicholson & Fawcett (1990). Wimmer et al. (1999) reproduced the study and found that only children with high ADHD ratings performed poorly in dual-task balancing and children without remarkable attention problems performed no different from control children. In response, Nicolson & Fawcett (2001) have pointed out that since this study, all participants in their later studies were additionally screened for co-occurring attention problems. Chaix et al. (2007) studied the influence of attention disorders on motor deficits in dyslexia as well. They examined the frequency of motor impairments in a population of children with dyslexia and specified links with attention deficit. A higher rate of motor deficiencies was found in the group of dyslexics with attention deficit compared to the dyslexic group without attention deficit (77% compared to 44%). These results support the hypothesis that the role of attention problems should be taken into account when studying motor skills in dyslexics.

The developmental trajectory of at-risk infants

From the previous sections it became clear that dyslexia is associated with problems in certain motor tasks, including anecdotal evidence for clumsiness. However, little is known about the developmental trajectory of motor skills, i.e. reaching motor milestones. The Jyväskylä Longitudinal Study of Dyslexia (JLD; Lyytinen et al., 2001; Viholainen et al., 2002; Lyytinen et al., 2004; Viholainen et al., 2006) is one of the very few studies that researched the early motor development prior to the onset of reading education. This study indeed found evidence for a link between language skills and early motor development. Longitudinal studies of dyslexia are scarce; studies with children who have a familial risk of dyslexia followed from infancy, even more. The current study aims at filling this gap by comparing the age in which motor milestones are reached by children who are at familial risk of dyslexia and by typically developing children. Furthermore, correlation between language and speech development, motor development, attention and language skills are examined in children who are at familial risk of dyslexia.

In order to assess the full spectrum of the trajectory of motor development, the JLD study researched milestones of gross motor development and fine motor development. The current study slightly differs in this aspect, as it researches milestones of oral motor development instead of fine motor development, next to gross motor developmental milestones. Oral motor abilities (performance in imitation of single oral movements of different complexity, depending on how many muscles were involved) have been found to correlate with language production (vocabulary as well as grammatical complexity) in typically developing 21-month-old children (Alcock & Krawczyk, 2009). However, studies on oral motor development and connections with dyslexia are relatively scarce. Eckert et al. (2003) examined mouth movements during oral reading and graphomotor skills for hand movements during spelling. The authors found that 11-year old dyslexics had problems in learning to read, whereas they had no problems in any motor skill associated with learning to write. Nevertheless, oral motor skills have not been studied in children who are at familial risk of dyslexia. This is surprising, especially in the light of the motor articulatory feedback hypothesis and the established connections between dyslexia, motor deficit and phonological deficit.

The research question is twofold. Firstly, do children who are at familial risk of dyslexia perform worse than typically developing children on measures of 1) vocabulary and language development, 2) motor development and 3) attention? Secondly, this study examines whether there is a connection between these three areas of early development. Following the theoretical framework outlined in the introduction, children who have a familial risk of dyslexia are expected to differ from typically developing children in these three aspects. First of all, the at-risk group is expected to perform less well on measures of language and speech development and in language production and comprehension. Secondly, the at-risk group is expected to have a delayed motor development, i.e. reach important (gross and oral) motor milestones at a later age than the typically developing group. Thirdly, attention skills might be poorer in children who are at-risk of dyslexia. With regard to the second question, the expectation is that language development, production and comprehension, motor development and attention are more strongly (as a continuum is to be expected) linked to one another in the at-risk group than in the control group.

The current study is closely related to a study on implicit learning (Kerkhoff et al., 2011; to appear), which found that infants at familial risk of dyslexia are impaired on the implicit learning of non-adjacent dependencies in an artificial language. At the Utrecht Babylab, participants are screened with a parental questionnaire and a measurement of language skills. The current study analyzed background data from the same participants of Kerkhoff et al.'s study, for which questionnaires were completed by July, 2011. Some of these children would later be excluded from the original study due to unwanted behavior (excessive crying or fussiness, parental interference, etc.) during the experiment.

However, as these factors were not applicable to the parental questionnaire and the measurement of language skills, these children were still included in the current study.

The current study is the first to collect the raw data of the Babylab's parental questionnaires, to examine the relationships between aspects of the child's development, performance on language tests and familial risk of developmental dyslexia in such detail. A previous study (Deelstra, 2006) also compared motor development between at-risk children and control children. However, the aim of the current study is different, as in the previous study motor development was compared to the performance on a behavioral experiment, whereas this study provides an analysis of parental questionnaire data and its relations with a familial risk of dyslexia. Furthermore, all the items on motor development and additional speech and attention items are currently under study, whereas Deelstra (2006) only analyzed the questions on gross motor development and the mean age of first word production. No evidence for a link between any of the motor development items (age of first steps, progress in motor development, way of crawling) and the language development item (age of first word utterance) and group was found in that study.

Method

Participants

The participants are citizens of Utrecht and its surrounding communities in The Netherlands. The recruitment method involved written requests to parents of newborns, whose addresses had been provided by the local municipality. All children were Dutch native language speakers, two children had additionally come into contact with a Dutch dialect. In this study, data are reported from 62 children, of whom 34 were males and 28 females. The children met the requirements in order to participate in the experiments of the study of Kerkhoff et al. (2011; to appear). However, as previously noted, not all of these children were included in that study due to their behavior during the experiments. The two groups that are compared are children with a familial risk of dyslexia (i.e., with at least one dyslexic parent) and typically developing children. Parent's dyslexia was confirmed with either a prior formal diagnosis or three screening tests. These tests were:

1. the ‘Een-Minuut-Test’ (EMT; Brus & Voeten, 1972), a test in which as many existing words as possible have to be read correctly in the time span of one minute,
2. ‘De Klepel’ (Van den Bos, Lutje Spelberg, Scheepstra & De Vries, 1994), a pseudo-word reading test with a two minute time limit, and
3. the verbal competence test (Analogies), taken from the Dutch version of the Wechsler Adult Intelligence Scale (WAIS; Uterwijk, 2000).

The at-risk group and the control group contained 33 and 29 children respectively. Age at the time of completion of the questionnaire ranged from 6 up to 20 months (some were 55 months old, as they participated at the beginning of the project and parents filled out the current version of the questionnaire later). The children were 18 months old when they participated in aforementioned study (Kerkhoff et al., 2011; to appear). However, the questionnaire was not always completed at the age of 18 months, as the children might have participated in experiments at the research institute as early as the age of 6 months. It is therefore necessary to control for age. Language skills were assessed when children were aged between 16 to 32 months. Social economic status was determined on the basis of the education of the parents. Maternal education was measured on a scale ranging from 1 (primary school) to 6 (university). Level 5 and 6 were regarded as ‘highly educated’, which applied to 103 out of 124 parents. As there was no difference found between the educational level of the parents of the two groups (fathers: $t(58) = 1.525$, $p = 0.133$; mothers: $t(59) = 1.856$, $p = 0.069$), social economic status has not been controlled for in the analysis. All the children had normal hearing and vision and no known neurological problems. One control child was born pre-term with a low birth weight (2020 grammes) and one at-risk child was post-term with a normal birth weight (3738 grammes). All other children were born within 36-42 weeks and had a normal birth weight (2500-4500 grammes). Additional background information on the medical history and development is summarized in Figure 1. There is no significant group effect on any of these medical items (all $p > .05$).

Figure 1: Medical background of the participants

Medical items	**Control**	**At-risk**
Child has had recurring ear infections	8/24 (33%)	9/29 (31%)
Difficulties during pregnancy or labour	12/29 (41%)	13/33 (39%)
Health issues (colds, hospital visits, etc.)	5/29 (17%)	7/33 (21%)
Family history of hyperactivity	0/29 (0%)	3/33 (9%)
Family history of sensitivity to colds	3/29 (10%)	2/33 (6%)
Family history of hearing problems	7/29 (24%)	5/33 (15%)
Family history of neurological problems	3/29 (10%)	3/33 (9%)
Family history of psychological problems	9/28 (32%)	11/33 (33%)
Child takes prescription drugs	1/29 (3%)	0/33 (0%)

PROCEDURE

CDI

The language measurement that is used in the present study is the Dutch version of the MacArthur Communicative Development Inventories (N-CDI; Zink and Lejaegere, 2002). It is a measure of receptive and productive vocabulary. It was assessed at the age of 16 (*n* = 8), 18 (*n* = 47) or more than 18 months (19-32, *n* = 4) in 60 children. To take this age range into account, percentile scores instead of raw scores were used in the analysis.

Anamnesis

In order to get data on the development and background of the children, a parental questionnaire (see appendix) was used. The inquiry contains data on social-economic status (as described above in 'Participants'), medical background (Figure 1), language and speech development, motor development and attention (Table 1). Additionally, it provided data on communication and social skills. However, as these variables were not part of this study's priority and there was no difference between the two subject groups, communication and social skills were not taken into account. Table 1 lists all the items of the questionnaire that are currently under study.

Table 1: Questionnaire items per subject

Gross motor development	*General motor development*
- Sitting without support (age in months)	- Progress in motor development
- Crawling (age in months)	- All gross and oral motor development items
- Walking without support (age in months)	
- Crawling on hands and knees (creeping)	*Language- and speech development*
	- First word (age in months)
Oral motor development	- Able to use two-word sentences
- Drinking: is able to drink from a regular cup / mug	- Able to use three-word sentences
- Chocking: chokes while drinking	*Attention*
- Chewing: is able to chew	- Play: engaged in the game s/he is playing
- Sucking: is able to drink with a straw	- Change: changes toys quickly
- Licking: is able to lick ice cream	- Distracted: is easily distracted while playing
- Blowing: is able to blow out a candle	- Reading: likes to be read to
	- Book: flick through books by themselves

STATISTICAL ANALYSIS

Measurements of motor development contained missing data, since parents sometimes failed to remember at what age their child had reached a certain motor milestone and/or whether their child was able to perform a particular milestone at the moment of completing the questionnaire. In other cases a particular milestone did not apply to the child yet, because s/he was too young. The average percentage missing values per motor item is 8% of the controls (minimum: 0%; maximum: 28%) and 14% of the at-risk group (minimum: 0%; maximum: 39%). The same reasons account for missing data in the speech items (controls: average: 36%, minimum: 28%, maximum: 48%; at-risk: average: 36%, minimum: 30%, maximum: 49%) and attention items (controls: average: 6%, minimum: 3%, maximum: 7%; at-risk: average: 15%, minimum: 12%, maximum: 18%). In the case of the N-CDI language measurements, data is missing for two children.

A group difference in the mean age in months of when a gross motor milestone is reached shows whether the motor development of one group is faster than the motor development of the other group. However, it remains unclear whether a certain group's motor development can be regarded as 'delayed', as great variance in motor development from child to child is expected. Therefore, a different approach, based on the norm of when a certain motor milestone should be reached, is used. Figure 2 shows the norms that the current study uses. On this basis it was decided whether the subjects were either regarded as ‘early to normal’ or ‘late’ in their motor development. Infants are expected to have mastered a specific skill when it has been mastered by 50-90% of their peers. Every age that falls within this range is regarded as ‘normal’, younger than 50% as ‘early’ and later than 90% as ‘late’. For example, a child that would sit at 6 months is regarded as having a ‘normal’ motor development with regard to *Sitting without support*, whereas the child that would sit at 8.5 months is ‘late’ in reaching that motor milestone. Milestones reached within norm (‘early’ to ‘normal’) were marked as zero, above the norm (‘late’) were scored as 1. Hence, a higher (mean) score indicates a poorer performance. In this way, gross motor milestone variables were dichotomized. The oral motor milestone variables and the attention items were already binominal, as they were posed as closed 'yes/no' questions in the questionnaire. Again, a positive answer (the child is able to drink from a mug, is able to chew, etc.) was marked as a 0 and a negative answer as 1. This also applies to the questions on two- and three-word sentences of the language and speech items. The age of when the child's first word was uttered is also dichotomized according to the normal range, namely from 12 to 18 months old (Schaerlaekens, 2000). Therefore, an age ranging from 0 to 18 months is marked as ‘early to normal’, above 18 months the child is considered ‘late’ in reaching this milestone. Dichotomizing the variables was done in order to compute composite variables.

One of the main advantages of using composite variables in the current study is that missing data are less problematic. Furthermore, every variable has more power as part of a composite variable.

Lastly, the index scores are scale numbers and performing powerful statistical tests such as the t-test for independent means then becomes possible.

Figure 2: Gross motor development age in months according to norm (from Shaffer, 2002).

Gross motor items	**Norm**	
	50% of infants have mastered skill	**90% of infants have mastered skill**
Sitting without support	5.5	7.8
Crawling	7.0	9.0
Walking without support	12.1	14.3

This data analysis method is inspired by the previously mentioned JLD study (Viholainen et al., 2002; Viholainen et al., 2006). In this study, motor development was also observed and recorded by parents. There were 26 motor milestones, of which 12 were on gross motor development (such as Raising head, Rolling from prone to supine, Moving around by holding onto furniture) and 14 on fine motor development (Palmar grasp: holding finger tightly, Bringing toy to mouth, Transferring an object from hand to hand, etc.). The 12 gross motor items involved five skills related to motor development, e.g. ‘raising head’ was one of the two milestones related to head control and ‘moving around by holding onto furniture’ was one of the two milestones for walking ability. The 14 fine motor items involved four motor skills, e.g. the ‘palmar grasp’ was related to fist coordination and ‘bringing toy to mouth’ was one of the three fine motor items that had to do with reaching. Results showed no significant differences between the groups on any of the 26 separate motor variables. Subsequently, the motor items were grouped together into nine composite variables according to their developmental function, which ensured maximum sample size. Through cluster analysis the at-risk group could be further divided into a slow motor development subgroup and a fast motor development subgroup. The control group could be split into three subgroups, namely a fast motor development, a slow gross motor development and a slow fine motor development subgroup. Of all these five subgroups, only the slow motor development at-risk subgroup turned out to perform significantly less well than the other four subgroups on measures of vocabulary and expressive language, where the language differences manifested themselves especially in smaller vocabulary and shorter sentences. At the age of 7, reading speed was assessed. For the statistical analysis, the same five clusters as found in the previous study were used. The results showed that children who had a familial risk and a slow early motor development read fewer words than the control children in the text reading task and that they read slower in comparison to the other subgroups.

Figure 3: Cronbach's α by test measurement

Test items		**number of items**	**Cronbach's α**
Gross motor development items	Continuous	3	0.595
	Dichotomized (according to norm)	4	0.251
Oral motor development items		6	0.787
Attention items		5	0.533
Language and speech development items		3	0.530
N-CDI percentile score items		2	0.767

The composite variable clusters of the current study are based on developmental function as well. Integrity of these clusters is measured with a reliability analysis (Figure 3), as was done in the JLD study. Interestingly, Cronbach's α shows a relatively poor internal consistency in the data of gross motor milestones. Apparently, reaching a certain milestone at a younger age than peers does not guarantee that the next milestone will be reached at an earlier age as well. When the age in months was dichotomized according to the norm (Figure 2), this had a negative effect on the reliability of data. However, this was to be expected, as the gross motor development trajectory is known to differ greatly from child to child. Therefore, the gross motor items are included in the analysis. All the oral motor development items have an acceptable reliability. The variable *Choking: chokes while drinking* is not included in the oral development cluster, as Cronbach's $\alpha(5) = 0.855$ when the item was left out. The reliability of the attention items is poor. Due to this, in composing the attention index cluster the items *Play: engaged in the game s/he is playing* and *Books: flick through books by themselves* were left out. By doing so, Cronbach's α rose to 0.667. The N-CDI percentile score items have an acceptable reliability. The language and speech development items, however, did not meet the minimal requirement of reliability as Cronbach's $\alpha \leq 0.6$. As the variable *First word* is an interval variable, no composite variable of language and speech development items was computed.

Results

COMPOSITE SCORES

Firstly the index scores per subject, except for the language and speech items, were computed. This entails that the dichotomized numbers were added and divided by the total number of variables. By doing so, composite variables were formed. Out of the motor development items, a gross motor (*Sitting without support, Crawling, Walking without support, Crawling on hands and knees*), an oral motor (*Drinking, Chewing, Sucking, Licking, Blowing*) and a general motor (*Sitting without support, Crawling, Walking without support, Crawling on hands and knees, Drinking, Chewing, Sucking, Licking, Blowing, Progress in motor development*) composite variable was formed. The gross motor development index score is the outcome of the addition of the values of the dichotomized gross motor variables, divided by 4 if all the gross motor questions were answered or less than 4 in the case of missing variables. The oral motor development index score is the outcome of the added oral motor values, again divided by the maximum possible number of points (5 if all oral motor questions were answered, less than 5 in the case of missing variables). The same method was used for calculating the attention index score, which was composed of 3 items (*Change, Distracted, Reading)*. The general motor development index score is composed of all the gross motor items (4) and all the oral motor items (5) that are used in the clusters. Additionally, the *Progress in motor development* item ('fast to normal' = 0, 'slow' = 1) is a part of the general motor development index score, which is thus composed of 10 motor items in total. The results of the tests performed with these four composite variables are discussed later in this section.

LANGUAGE- AND SPEECH DEVELOPMENT

Vocabulary size

Receptive and productive vocabulary size was assessed with the Dutch version of the MacArthur Communicative Development Inventory (N-CDI; Zink & Lejaegere, 2002), which was completed by parents. A strong correlation (Pearson's $r(60) = 0.624$, $p < 0.000$) between the two measures implied that the values are reliable. Results of a t-test are shown in Figure 4. The at-risk group performed more poorly than the control group on mean receptive vocabulary ($t(60) = 2.123$, $p = 0.041$).

Figure 4: Percentile scores of the N-CDI by group.

Percentile scores	**Control**		**At-risk**		**t**	**df**	***p***
	Mean	**SE**	**Mean**	**SE**			
Receptive vocabulary percentile score	60.46	5.675	45.63	4.258	2.123	51.692	0.041*
Productive vocabulary percentile score	51.82	5.582	50.63	3.958	0.178	58	0.859

*result is significant (p<0.05)

Language- and speech development

First, data for the age of the child in months when s/he uttered his/her first word were analyzed. The Shapiro-Wilk analysis showed the distribution was normal ($p = 0.426$), therefore a t-test is performed. The difference in mean age is shown in Figure 5. Children who are at-risk of dyslexia tend to be more than a month older than control children on average when they said their first word.

Figure 5: Mean age in months of uttering the first word by group.

Speech development item	**Control**		**At-risk**		**t**	**df**	***p***
	Mean	**SE**	**Mean**	**SE**			
First word	10.67	1.022	11.76	0.627	-0.916	23.607	0.369

None of the control children reached this milestone at an later age than the norm, whereas 2 at-risk children did ($\chi^2(1, n = 32) = 1.882$, $p = 0.170$; Figure 6). When the child was 16 months or older, parents were asked whether their child used two- and/or three-word sentences. These lingual phases normally do not start before the age of 18 months (Schaerlaekens, 2000), so the majority of the children is expected not to be able to do this, but a between group difference would still be meaningful. Yet, a Pearson Chi Square analysis shows that there is no significant effect of group on these two variables (*Two-word sentences*: $\chi^2(1, n = 44) = 0.287$, $p = 0.592$; *Three-word sentence*s: $\chi^2(1, n = 43) = 0.953$, $p = 0.329$; Figure 6).

Figure 6: Early/normal speech development by group.

Speech development item	**Control**	**At-risk**
First word (according to norm)	15/15 (100%)	15/17 (88%)
Able to use two-word sentences	8/21 (38%)	7/23 (30%)
Able to use three-word sentences	6/20 (30%)	4/23 (17%)

MOTOR DEVELOPMENT

Gross motor development

Of all the motor development items the gross motor items in the questionnaire are discussed first. The questionnaire contained questions on the age of the child when it could first sit, crawl, and walk. A goodness-of-fit test is performed in order to check for a normal distribution. The Shapiro-Wilk test of normality shows no significant deviance for the gross motor items (*Sitting without support*: $p = 0.103$; *Crawling*: $p = 0.225$; *Walking without support*: $p = 0.277$). Therefore, a t-test for independent means is used in order to test for differences in motor development between the typically developing control group and the at-risk group (see Figure 7). The groups did not differ on any of the three motor items.

Figure 7: Mean age in months for reaching gross motor development milestones by group.

Gross motor items	Control (n =26)		At-risk (n =24)		t	*p*
	Mean	SE	Mean	SE		
Sitting without support	7.07 (n =23)	0.2521	7.40 (n =22)	0.3317	-0.825	0.414
Crawling	9.78 (n =25)	0.3404	8.97 (n =22)	0.3266	1.726	0.091
Walking without support	14.91 (n =21)	0.4332	13.95 (n =20)	0.4197	1.583	0.122

In the next step, the age in months of reaching a gross motor development milestone was compared to the norm (Figure 2). The gross motor development of the subjects according to the norm is shown in Figure 8. The mean age in months suggests that control children were later than the at-risk children with *Crawling* and *Walking*. When compared to the norm, it looks like more control children than at-risk children have a delayed development with regard to these motor items. Nevertheless, these differences were not significant (*Crawling*: $\chi^2(1, n = 47) = 1.066, p = 0.302$; *Walking without support*: $\chi^2(1, n =41) = 1.967, p = 0.161$). Interestingly, the mean age in months of *Sitting without support* showed that at-risk children were slightly later in reaching this motor milestone, but when compared to the norm, it turns out that almost just as many control as at-risk children were considered 'late' in reaching this milestone. An analysis with Pearson's Chi-Square shows that the groups do not differ with respect to *Sitting without support* (according to the norm): $\chi^2(1, n = 45) = 0.015, p = 0.903$.

Figure 8: Early/normal gross motor development according to norm in months by group

Gross motor items	Control	At-risk
Sitting without support	14/23 (61%)	13/22 (59%)
Crawling	11/25 (44%)	13/22 (59%)
Walking without support	8/21 (38%)	12/20 (60%)
Crawling on hands and knees (creeping)	22/29 (76%)	20/32 (63%)

The specific way of crawling, namely whether the child has crawled on hands and knees (also known as 'creeping'), is analyzed and listed in Figure 8 as well. This way of crawling is regarded as the most common way of crawling and it is therefore interesting to investigate whether more control than at-risk children crawl this way. The numbers do indicate that at-risk children were more likely to crawl in a way that differed from creeping as did their controls, however this was not significant: $\chi^2(1, n = 61) = 1.267$, $p = 0.260$.

Oral motor development

The questionnaire also contained questions regarding oral motor development, which is a specific kind of fine motor development. The questions were about:

the ways of drinking the child uses (from either a bottle, sippy cup or a regular cup),

whether s/he chokes sometimes while drinking ('never', 'occasionally' or 'often'),

whether s/he is able to chew ('yes' or 'no'),

whether s/he is able to drink with straw ('yes' or 'no'),

whether s/he is able to lick ice cream ('yes' or 'no') and

whether s/he is able to blow out a candle ('yes' or 'no').

Kerkhoff et al. (2011; to appear) report between group differences in drinking from cup and straw. The analysis in the current study is more conservative, as age is controlled for as a factor. This is because this type of questions has a high age-sensitive nature, e.g. whether a typically developing child is already able to drink from a regular cup mostly depends on age. The age of 14 months was chosen because at this age, all these motor items should have been acquired. All questionnaires that were filled in when the child was younger than 14 months were thus excluded in the analysis of oral motor development ($n = 17$). This brought the control group down to 24 children and the at-risk group to 21 children. Figure 9 presents the results. An analysis with Pearson's Chi-Square shows there were no significant differences between the two groups on any of these variables (all $p>0.05$).

Figure 9: Oral motor development by group

Oral motor items	**Control**	**At-risk**
Drinking: is able to drink from a regular cup / mug	21/23 (91%)	17/20 (85%)
Choking: chokes while drinking	10/24 (42%)	8/21 (38%)
Chewing: is able to chew	22/24 (92%)	21/21 (100%)
Sucking: is able to drink with straw	21/21 (100%)	18/19 (95%)
Licking: is able to lick ice cream	16/22 (73%)	14/18 (78%)
Blowing: is able to blow out a candle	12/20 (60%)	8/15 (53%)

General motor development

In this section the relationship between general motor development and familial risk of dyslexia is examined. Furthermore, the results of the analysis with the motor composite scores are discussed. The last item of the parental questionnaire is on the progress in the child's motor development. Parents were asked to judge it either as 'slow', 'normal' or 'fast'. Not one of the parents of the at-risk children regarded their child's motor development as 'slow', which is significant compared to 4 control children who were marked as 'slow' ($\chi^2(1, n = 60) = 4.581, p = 0.032$; Figure 10).

Figure 10: Slow motor development by group

Motor item	**Control**	**At-risk**
Progress in motor development	4/29 (14%)	0/31 (0%)

The Shapiro-Wilk goodness-of-fits test showed that the composite variables did not all have a normal distribution (*Gross motor development index score*: p < 0.000; *Oral motor development index score*: $p < 0.000$; *General motor development index score*: $p = 0.097$). Therefore, the more conservative Mann-Whitney U test for nonparametric tests is used, of which the result is provided in Figure 8. Children younger than 14 months were excluded from the analysis of the oral motor composite variable and therefore from the general motor composite variable as well. The figure presents a higher, thus more negative mean score for the at-risk group on the gross motor and oral motor composite variables. However, the effect of group is not significant. Interestingly, the mean score of general motor development seems more positive now for the at-risk group than the control group (Figure 11), which is likely to be a consequence of including the *Progress in motor development*.

Figure 11: Composite motor development variables index scores by group.

Composite variables	**Control**		**At-risk**		**U**	***p***
	n	**Mean rank**	***n***	**Mean rank**		
General motor development index score	24	24.92	21	20.81	206.000	0.292
Gross motor development index score	29	30.66	32	31.31	454.000	0.883
Oral motor development index score	24	22.98	21	23.02	251.500	0.990

ATTENTION

Three of the 33 parents of at-risk children reported a history of hyperactivity in the family, whereas none of the control parents did (Figure 1). The actual measurement of attention is done by means of the parental questionnaire that contained questions on the attention span of the child, masked as questions on the child's play behavior. Children with ADHD are known to exhibit problems with sustained attention during play. In a study with 4- to 5-year-old ADHD children, this was found to relate to problems with listening to a story, more transitional play (moving from one activity to another) and less constructive play (learning to use materials, creating something) among other things (Alessandri, 1992). Differences in measures of interest in block play have even been reported for 7-month-old infants with a familial risk of ADHD (Auerbach et al., 2004).

Results of the attention questions are listed in Figure 12. A larger number of at-risk children does not like to flick through books by themselves compared to the control children: $\chi^2(1, n = 55) = 4.672$, $p = 0.031$. None of the other variables show a group effect.

Figure 12: Attention by group

Attention items	**Control**	**At-risk**
Play: engaged in the game s/he is playing	26/27 (96%)	28/29 (97%)
Change: changes toys quickly	14/27 (52%)	14/29 (48%)
Distracted: is easily distracted while playing	12/28 (43%)	11/18 (40%)
Reading: likes to be read to	20/27 (74%)	24/27 (89%)
Books: flick through books by themselves	26/28 (93%)	19/27 (70%)

The composite variable *Attention index score* was formed with three items (*Change, Distracted, Reading*). The Mann-Whitney U test is performed as the *Attention index score* did not meet the requirements of a normal distribution (Shapiro-Wilk: $p < 0.000$). Results are shown in Figure 13. The at-risk group is found to have a slightly lower, and therefore more positive, mean rank than the control group.

Figure 13: Composite attention variable index score by group.

Composite variable	**Control**		**At-risk**		**U**	***p***
	n	**Mean rank**	**n**	**Mean rank**		
Attention index score	28	30.91	30	28.18	380.500	0.514

ASSOCIATIONS BETWEEN LANGUAGE, MOTOR DEVELOPMENT AND ATTENTION

As most of the composite index scores did not have a normal distribution, a different measure than Pearson's correlation coefficient had to be used in order to research the connection between the different developmental functions and dyslexia. Another indicator of how well one variable can be predicted from another is the eta square statistic. This statistic is designed to compute the percentage of variance of the dependent variable that is explained by the independent variable. Figure 14 shows the results of an association analysis between language development (N-CDI percentile scores), motor development (*Gross motor development index, Oral motor development index, General motor* *development index*), attention (*Attention index*) and age when the first word was uttered (*First word*) analyzed separately for each group. As the eta statistic requires an interval and a binominal variable, the N-CDI percentile scores were dichotomized: scores ranging from 50 to 100 were marked as 'high' and a score <50 was marked as 'low'. The results should be interpreted with care, as the eta square statistic is highly sensitive to differences in sample size.

Figure 14: Eta squared coefficients between performance on vocabulary measurement and all motor development index variables, attention index variable and first word variable.

Composite variable	**Receptive vocabulary (dichotomized)**		**Productive vocabulary (dichotomized)**	
	Control	**At-risk**	**Control**	**At-risk**
Gross motor development index	0.175	0.142	0.417*	0.11
Oral motor development index	0.072	0.319*	0.176	0.348*
General motor development index	0.529**	0.475*	0.782**	0.714**
Attention index	0.149	0.064	0.142	0.226
First word	0.430*	0.373*	0.810**	0.390*

*moderate association (0.3 to 0.5), **high association (>0.5)

First, there was a moderate to high association found between the age when the first word is uttered and the receptive and productive vocabulary percentile scores in both groups. With respect to motor development, an interesting association is found when all motor variables are taken together (the *General motor development index*). General motor development explains a significant percentage of variability in both vocabulary measures, for both groups. The association is especially strong in productive vocabulary, regardless of group. Interestingly, 32% of the variance in receptive vocabulary and 35% of the variance in productive vocabulary is accounted for by oral motor development in the at-risk group, whereas such an effect is not found in the control group. Regarding gross motor development, however, no less than 42% of its variability can be explained by productive vocabulary in the control group. Lastly, the attention index score is a poor indicator of the variability in vocabulary percentile scores.

As dyslexic children with attention deficiencies are more prone to exhibit motor problems (e.g. Chaix et al., 2007), associations between attention and motor development are analyzed as well. In order to do this, the attention index score was dichotomized: an attention index score ranging from 0 to 0.5 was marked as 'good, little to no problems' and a score >0.5 was marked as 'poor, some problems'. The association between the attention index score and the variables relating to motor development (*Gross motor development index*, *Oral motor development index*, *General motor development index*), was analyzed separately for each group, see Figure 15. General motor development accounts for 45% of the variance in attention for the control group. This effect is even stronger in the at-risk group, where general motor development explains 94% of attention. Furthermore, the effect of oral motor development on attention was present for at-risk group only. This result begs for an analysis of the difference in motor development while controlling for poor attention, i.e. research whether there are between group differences in motor performance measures while excluding children with a poor attention performance. However, this would yield no reliable results in the current study, as the current sample size allows no room for reduction of the participant numbers.

Figure 15: Eta squared coefficients (significance two-tailed in brackets) between performance on attention and all motor development index variables.

Composite variable	**Attention (dichotomized)**	
	Control	**At-risk**
Gross motor development index	0.257	0.061
Oral motor development index	0.028	0.405*
General motor development	0.451*	0.942**

*moderate association (0.3 to 0.5), **high association (>0.5)

Discussion

This study investigated language, motor, and attention skills as measured by a parental questionnaire, in children who are at familial risk of dyslexia and their typically developing peers. Children at familial risk of dyslexia were expected to perform worse than typically developing children on measures of vocabulary, language and speech development, motor development and attention. Considering the many co-occurring difficulties dyslexics have, performance on these different developmental skills was expected to show a stronger correlation in children who are at familial risk.

In line with the expectations, the at-risk children performed less well on measures of receptive vocabulary. Similar results in relation to receptive vocabulary have been obtained in the JLD study (Lyytinen et al., 2001; Viholainen et al., 2002; Lyytinen et al., 2004; Viholainen et al., 2006). Unlike this study, no difference in age of onset of talking is found in the present study.

The JLD study also found that part of the at-risk group had a delay in early motor development (Viholainen et al., 2002). In the present study a difference in the progress in motor development was found, but the direction was unexpected, as significantly more control than at-risk children were regarded as slow by their parents. Both groups performed equally well on measures of gross and oral motor development (e.g. sitting, crawling, or drinking from a cup), which, again, was not in line with expectation.

Interestingly, an association is found between some areas of motor development and vocabulary scores. Though there was no group difference in oral motor development, an association between (receptive and productive) vocabulary and oral motor development was found for at-risk children but not for control children. In line with the motor-articulatory feedback hypothesis (Heilman et al., 1996), a delay in oral motor development could be connected to a delay in phonological processing, which is a hypothesized cause of dyslexia. As the performance in vocabulary was poorer than that of the control children, this result suggests that vocabulary skills are linked to oral motor development in children with a familial risk of dyslexia. The JLD study had found a connection between motor and language delays in children at familial risk of dyslexia as well, as the at-risk children who showed motor delays had a smaller receptive vocabulary and produced shorter sentences than non-risk children at 18 and 24 months of age. This was found for both gross and fine motor development. Oral motor development has been reported in the literature in relation to language development (Alcock and Krawczyk, 2009), however this measurement was one of imitation performance and not an assessment of motor milestones, as done in the current study. Since oral motor milestones have not been previously studied in at-risk children, the result of the present study adds to the current literature about the importance of motor skills for language development, and suggests that such skills should be further subdivided. Between general motor development and vocabulary an association was found for both groups. However, the effect was not particularly higher in one of the groups. It is therefore unwise to draw strong conclusions, as the association results between oral motor development and vocabulary might be explained by the idea that motor development is interrelated with general cognitive development, as they both might be based on the shared neural systems of motor and cognitive functions (Ojeman, 1984; Diamond, 2000).

With respect to attention, the only measure for which a significant difference was found is that more at-risk children did not like to flick through books by themselves, which is obviously intriguing in the light of the possible reading problems that some of these children will be facing.

Furthermore, an association was found between attention (measured in the form of play behavior; e.g. whether the child becomes engaged in the game s/he is playing, whether s/he changes toys quickly, etc.) and general motor development for both groups of children. This suggests a possible connection between motor development and attention, which should be researched more thoroughly. General motor development accounted for a larger portion of variability in attention for the at-risk children than for the control children, which indicates that these skills are more interrelated for this group of children. Again, an association between oral motor development and attention was only present for the at-risk group. In sum, these results indicate that it is useful to consider general motor and oral motor skills separately. Oral motor skills and articulation should also be studied in connection to these children's performance on implicit (language) learning tasks, to further assess predictions of the procedural deficit hypothesis (Ullman, 2001; 2004).

The current study used a parental questionnaire in order to assess aspects of the developmental trajectory of infants at familial risk of dyslexia. This method is a limitation of the study, as parents might be prejudiced regarding their own children. The parents of the at-risk children were aware that the UIL-OTS researches early language development, therefore their answers to the questionnaire might not be entirely objective. However, parents were not informed on the subject of current study, the relationship between motor development and familial risk of dyslexia. It is therefore unlikely that they were more positive regarding the questions on motor milestones. It is therefore difficult to explain the difference in the question on the progress in the child's motor development, whereas more control children were regarded as slow by their parents.

A second limitation that should be considered is the number of participants in this study. As variance in motor development is to be expected from child to child and therefore within group as well, further studies on this subject should preferably have a large number (60 per group or more) of participants. A sufficient number of participants is especially important for the at-risk group, as only around half of the at-risk children will actually be diagnosed with dyslexia later in life.

More work on this subject is necessary, as there are still many questions and no adequate method yet for recognizing the precursors of developmental dyslexia. The role of attention in children who are at familial risk especially seems to be underestimated in the literature. Considering the high association with motor development in at-risk children, it would be interesting to do a follow-up study which assesses the reading and spelling abilities of these children after two years of reading education (age 8). Then the predictive value of this association as measured in infancy can be analyzed. Another fascinating starting point for future research is the association found between oral motor development and receptive and productive vocabulary in children with a familial risk of dyslexia. In what way will these results relate to the children's later reading and spelling abilities? Such research might shed more light on the nature of this developmental disorder and its possible precursors.

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List of abbreviations

ADHD	Attention Deficit/Hyperactivity Disorder
DCD	Developmental Coordination Disorder
EMT	Eén Minuut Test ('One Minute Test')
JLD	Jyväskylä Longitudinal Study of Dyslexia
M-CDI	MacArthur Communicative Development Inventories

N-CDI	Nederlandse ('Dutch version of the') MacArthur Communicative Development Inventories
UIL-OTS	Utrecht Institute of Linguistics OTS
WAIS	Wechsler Adult Intelligence Scale

Appendix

THE PARENTAL QUESTIONNAIRE

Algemene gegevens	***General information***
Naam kind	*Child's name*
Geslacht	*Gender*
Geboortedatum	*Date of birth*
Nationaliteit	*Nationality*
Datum van invullen	*Current date*
Eerste taal van het kind: Nederlands / dialect / anders, namelijk...	*The child's native language: Dutch / dialect / other...*
Andere talen die thuis worden gesproken	*Other languages that are spoken at home*

Naam vader	*Father's name*
Geboortedatum	*Date of birth*
Opleiding	*Educational level*

Naam moeder	*Mother's name*
Geboortedatum	*Date of birth*
Opleiding	*Educational level*

Medische gegevens	***Medical background***
1. Met hoeveel weken werd uw kind geboren?	*What was the duration of pregnancy in weeks?*
2. Wat was het geboortegewicht van uw kind (in gram)?	*What was the baby's weight (in grammes) at birth?*
3. Heeft uw kind weleens oorontsteking gehad?	*Has the child had recurring ear infections?*
4. Waren er problemen tijdens de zwangerschap of de bevalling?	*Were there any difficulties during pregnancy or labour?*
5. Hoe is de gezondheid van uw kind tot heden?	*Has your child experienced any health issues?*
6. Komen taal/spraakstoornissen (bijvoorbeeld dyslexie) voor in de familie?	*Do language and speech disorders run in the family?*
7. Komt hyperactiviteit voor in de familie?	*Does hyperactivity run in the family?*

8. Komt chronische verkoudheid voor in de familie?	*Does a sensitivity to colds run in the family?*
9. Komt slechthorendheid voor in de familie?	*Do hearing problems run in the family?*
10. Komen neurologische problemen voor in de familie?	*Do neurological problems run in the family?*
11. Komen psychische problemen (depressive, angststoornis, etc.) voor in de familie?	*Do psychological problems run in the family?*
12. Indien ja bij vraag 6-11, kunt u dit toelichten? Welke is vastgesteld middels een officiële diagnose?	*If yes for question 6-11, please elaborate. Which of the problems are officially diagnosed?*
13. Als een van bovengenoemde bij uw kind voorkomen, gebruikt uw kind hiervoor medicijnen?	*If one of the afore-mentioned problems (question 6-11) applies to your child as well, does s/he take prescription drugs?*

Grove motorische ontwikkeling	***Gross motor development***
14. Op welke leeftijd (in maanden) ging uw kind voor het eerst zitten?	*At what age (in months) was your child able to sit?*
15. Op welke leeftijd (in maanden) ging uw kind voor het eerst kruipen?	*At what age (in months) was your child able to crawl?*
16. Op welke leeftijd (in maanden) ging uw kind voor het eerst lopen?	*At what age (in months) was your child able to walk?*
17. Hoe verliep het kruipproces? Nog niet gekropen / op handen en knieën / op de buik / zittend / op handen en voeten / anders, namelijk …	*In what way did your child crawl? Has not crawled yet / on hands and knees / pushing forward on stomach / pushing forward in sitting position / on hands and feet / other …*

Orale motorische ontwikkeling	***Oral motor development***		
18. Mijn kind drinkt uit (meerdere mogelijk):	Fles	Tuitbeker	Gewone beker
My child is able to drink from (more than one answer possible):	*Bottle*	*Sippy cup*	*Regular*
19. Mijn kind verslikt zich met drinken:	Niet	Weinig	Vaak
My child chokes while drinking:	*No*	*Seldom*	*Often*
20. Kan uw kind al kauwen?		Ja	Nee
Is your child able to chew?		*Yes*	*No*

21. Kan uw kind zuigen aan een rietje?	Ja	Nee
Is your child able to drink with a straw?	*Yes*	*No*
22. Kan uw kind likken aan een ijsje?	Ja	Nee
Is your child able to lick ice cream?	*Yes*	*No*
23. Kan uw kind een kaarsje uitblazen?	Ja	Nee
Is your child able to blow out a candle?	*Yes*	*No*

Algemene motorische ontwikkeling	***General motor development***			
24. Hoe verloopt de motorische ontwikkeling volgens u?	Langzaam	Normal	Snel	Weet niet
How would you judge your child's progress in motor development?	*Slow*	*Normal*	*Fast*	*Do not know*

Spraak- en taalontwikkeling	***Speech and language development***	
25. Hoe oud (in maanden) was uw kind toen hij/zij het eerste woordje sprak?		
At what age (in months) did your child utter his/her first word?		
26. Gebruikt uw kind al twee-woord zinnen?	Ja	Nee
Is your child able to use two-word sentences?	*Yes*	*No*
27. Gebruikt uw kind al drie-woord zinnen?	Ja	Nee
Is your child able to use three-word sentences?	*Yes*	*no*

Spelgedrag (aandacht)	***Play behaviour (attention)***	
28. Kan uw kind opgaan in het spel dat het op dat moment aan het spelen is?	Ja	Nee
Does your child become engaged in the game s/he is playing?	*Yes*	*No*
29. Verwisselt uw kind het ene speeltje snel voor het andere?	Ja	Nee
Does your child change toys quickly?	*Yes*	*No*
30. Is uw kind snel afgeleid tijdens het spelen?	Ja	Nee
Is your child easily distracted while playing?	*Yes*	*No*
31. Houdt uw kind ervan voorgelezen te worden?	Ja	Nee
Does your child like to be read to?	*Yes*	*No*
32. Pakt uw kind zelf vaak boekjes om in te "lezen" (bladeren)?	Ja	Nee
Does your child flick through books by him/herself often?	*Yes*	*No*