Developmental trajectories of attention and executive functioning in infants born preterm:

The influence of perinatal risk factors and maternal interactive styles

Eva van de Weijer-Bergsma

NetChild
Network for Childhood Disability Research in The Netherlands

ISED
Institute for the Study of Education and Human Development

Langeveld Institute for the Study of Education and Development in Childhood and Adolescence

Cover design Kitty van der Veer
Layout Renate Siebes, Proefschrift.nu
Printed by GVO drukkers & vormgevers B.V. | Ponsen & Looijen, Ede
ISBN 978-90-393-5033-1

Developmental trajectories of attention and executive functioning in infants born preterm:

The influence of perinatal risk factors and maternal interactive styles

Ontwikkelingspaden van aandacht en executief functioneren bij te vroeg geboren baby's:
De invloed van perinatale risicofactoren en moederlijke interactiestijlen
(met een samenvatting in het Nederlands)

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de
Universiteit Utrecht op gezag van de rector magnificus,
prof.dr. J.C. Stoof, ingevolge het besluit van het college
voor promoties in het openbaar te verdedigen
op vrijdag 12 juni 2009 des middags te 12.45 uur

door

EVA VAN DE WEIJER-BERGSMA

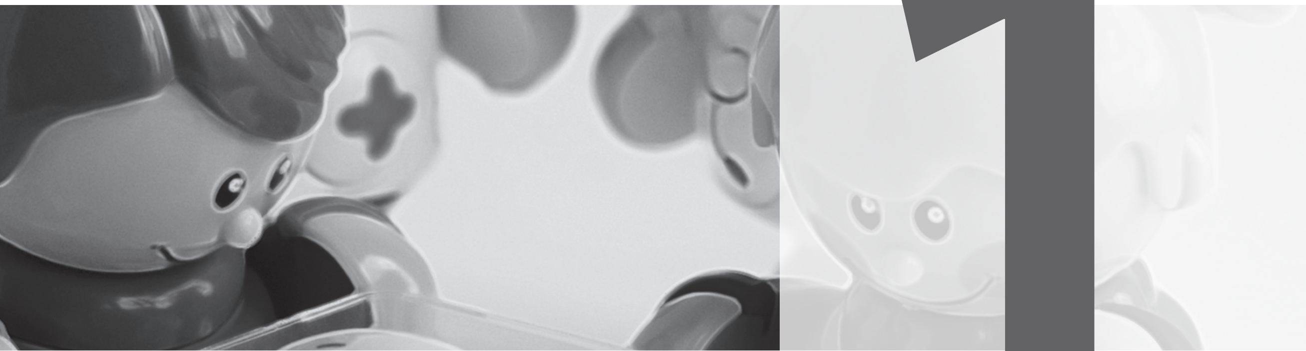
geboren op 20 november 1976 te Amsterdam

Promotor: Prof.dr. M.J. Jongmans

Co-promotor: Dr. L. Wijnroks

This thesis was published with financial support of Tolo Toys Ltd.

Contents



1

General introduction

Introduction

Due to medical advances in neonatal care, there is an increase in the survival rate of infants who are born prematurely (gestational age < 37 weeks). With this increasing survival rate there is growing concern about the development and functioning of these infants. A vast amount of research has shown that infants born preterm are at a heightened risk for major developmental disabilities (e.g., mental retardation, sensory disorders and cerebral palsy) as well as less severe dysfunctions (e.g., learning disabilities and attention deficit/hyperactivity disorder (ADHD)) (Anderson & Doyle, 2003; Aylward, 2002a, 2005; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Pritchard et al., 2008). Even school-aged children born preterm who have intellectual abilities within the normal range often have learning disabilities and require special educational services (Aylward, 2002a; Salt & Redshaw, 2006). Indeed, various studies have shown that children born preterm have more difficulties with attention and executive functioning (e.g., working memory and inhibition) at school age than children born at term (Bayless & Stevenson, 2007; Bohm, Smedler, & Forssberg, 2004; Mikkola et al., 2005; Taylor, Minich, Klein, & Hack, 2004). However, not all infants who are born preterm develop such problems. Although learning and attentional problems are difficult to detect during infancy or early childhood (Aylward, 2002a, 2002b), detection of infants at risk for these less severe dysfunctions is vital for early intervention and treatment (Johnson & Marlow, 2006; Johnson, Wolke, & Marlow, 2008).

In our opinion, there are two important reasons why early identification of learning and attentional problems in infants born preterm is hampered at the moment. First, early screening instruments that are currently most widely used in infancy are usually global cognitive measures, such as the Bayley Scales of Infant Development (3rd edition; Bayley, 2006). Although global cognitive measures gain predictive value after the first year of life, they are usually not very predictive during infancy, particularly for borderline or mild developmental deficits (Siegel, 1989). Moreover, such measures are not sensitive enough to identify problems in more specific areas of cognitive functioning, such as attention, working memory and inhibition (Johnson & Marlow, 2006). Secondly, the development of infants born preterm is determined by a complex interaction between biological and environmental factors. Information on which biological factors are most important, might help with the early identification of infants at risk, whereas information about important environmental influences is vital for intervention programs. However, there is currently not enough knowledge on this issue.

Another major criticism on previous studies on the development of infants born preterm, is the focus on group means, which can mask individual patterns of development (Aylward, 2002b). Recent advances in statistical methods, such as Latent Growth Modeling (LGM), provide us with a means to investigate and combine intra-individual developmental trajectories and inter-individual differences in these trajectories. Unfortunately, studies applying these new statistical methods in the area of development of preterm born infants are currently very scarce.

Since early differences in attention and executive functioning (EF) are thought to underlie preterm infants heightened risk for developmental delay and learning disabilities (Aylward, 2002a; Davis & Burns, 2001; Davis, Burns, Snyder, & Robinson, 2007), the aim of this thesis is to examine individual differences in developmental trajectories of attention and EF in a sample of infants born preterm, using LGM. Also, the predictive value of perinatal risk factors and variations in maternal interactive styles for individual differences in these trajectories is examined.

Background

Attention and executive functioning

Attention and EF are considered important prerequisites for learning and development. By attention we mean the attention an infant or child has for events, objects, tasks, and problems in the external world (Posner & Petersen, 1990; Posner & Raichle, 1994; Ruff & Rothbart, 1996). An influential neuropsychological model of attention development that covers the entire life span was proposed by Posner and colleagues (Posner & Petersen, 1990; Posner & Raichle, 1994). According to this account there are three interconnected attention networks in the brain, including (1) the orienting system or posterior attention network, (2) the alerting or arousal system, and (3) the executive control system or anterior attention network.

The orienting system, consisting of a spatial orienting network in the parietal cortex and an object recognition pathway in the temporal cortex, becomes fully functional during the first 6 months of life, and is related to the orientation or movement of attention toward specific locations in the environment. The alerting or arousal system, involves parts of the brainstem and later in development also the right frontal lobe, and is related to the capacity to maintain or sustain a state of alert arousal, enabling effortful processing of information. When infants develop into toddlers, the executive control system begins to mature, involving areas of the frontal cortex, in particular the prefrontal cortex. During this period, attention becomes more related to planned, self-generated activity with objects. Functions associated with higher level control of attention overlap with the more general domain of EF, which also includes working memory, planning, switching and inhibitory control. Although there is general consensus that attention and EF are strongly related, there is still much discussion on *how* they are related (Garon, Bryson, & Smith, 2008; Kane & Engle, 2002; Posner & Petersen, 1990; Posner & Raichle, 1994). Although Posner and colleagues have argued that a central attention system (also called 'the executive attention network') underlies the emerging EF abilities (Posner & Petersen, 1990; Posner & Raichle, 1994), the issue whether there are several dissociable EF abilities such as working memory, inhibition, set-shifting and attention or whether one underlying process such as attention or inhibition is involved in all EF abilities, is still open to debate. Recently, Garon et al. (2008) have proposed an integrated view that considers EF to be a unitary construct with partly dissociable components. According to this view, attention is the basic building block for the other EF components to develop from. Until now, it remains uncertain which view is most in agreement with reality.

Nevertheless, it is generally recognized that attention development is influenced by the emergence of such EF abilities. The age-related increase during the first two years of life in the ability to sustain attention, for example, is considered to (partly) reflect this emerging higher-level control over attention (Ruff & Rothbart, 1996). Important transitions in EF are assumed to take place around 9 months and 12 months of age, when infants show important changes in their performance on tasks requiring such higher-level control abilities, such as the A-not-B task (Diamond, 1985, 1991; Diamond & Goldman-Rakic, 1989). In the A-not-B task infants have to search for a hidden toy in one out of two locations. When infants have retrieved the toy successfully two times in a row at the first location (location A), the side of hiding is reversed to location B. This reversal trial requires an infant to remember where the toy was hidden (working memory), to inhibit the previously rewarded response (inhibitory control), and to allocate their attention effectively during the task.

Factors that are predictive for the development of infants born preterm

In developmental psychology it is widely recognized that infant and child development is influenced by the interaction between biological factors (such as perinatal factors, gender, and temperament) as well as environmental characteristics (such as culture, socioeconomic factors and parental behaviors) (Sameroff & MacKenzie, 2003). When an infant is born preterm, both biological factors and environmental factors are likely to be compromised. That is, the infant's organs (including the brain) are usually insufficiently developed, and they require medical support for survival outside the womb. The shorter the duration of pregnancy, the greater the risks for medical complications. This stressful and often uncertain period is also likely to affect parents emotionally and psychologically, which may influence the way they interact with their infant after discharge from hospital. Moreover, infants born preterm are often characterized as having a more difficult temperament (e.g., less active, less predictable, more easily overstimulated) than infants born at term (Feldman & Eidelman, 2007; Hughes, Shults, McGrath, & Medoff-Cooper, 2002), which indicates that they have more difficulties regulating their own arousal level and behaviors. These difficulties in self-regulation can make it more challenging to interact with these infants.

Perinatal risk factors in infants born preterm

Perinatal risk factors that are considered to be predictive of cognitive development in infants born preterm are gestational age (GA), birth weight (BW), and the presence and severity of several medical complications that are associated with preterm birth. That is, the immaturity of organs systems (especially the brain), which is related to being born at a lower GA, has its possible consequences for the development of these children. It has been found for example, that preterm birth is associated with decreased cerebral volumes during childhood. Frontotemporal and hippocampal regions seem to be most vulnerable, and boys are more likely to be affected than girls (Ment & Vohr, 2008). However, these differences might be explained by preterm infants heightened risk for insults to the brain, rather that the immaturity of the brain in itself. In addition, the circumstances under which infants born preterm have to survive during the neonatal period differs dramatically from the uterus in which stimulation from outside is dampened. As a result, the premature brain is confronted with stimulation, which perhaps it cannot respond to in an organized manner (McGrath, 2008). Although this exposure to increased intensity of stimulation may have harmful effects on brain development, it also has been suggested that the increased intensity of stimulation may advance white matter maturation processes in certain areas of the brain, some of which are related to visual processing (Gimenez et al., 2008). In sum, the consequences of being born when brain structures are still immature are still unresolved at the moment, Medical complications that have been linked to suboptimal cognitive development are brain injury and respiratory problems. The two most common types of brain injury in infants born preterm are intraventricular hemorrhage (IVH) and periventricular leukomalacia (PVL), which are both related to either the reduction in oxygen supply to bodily tissues (i.e., hypoxia) or more severe low oxygen level due to inadequate blood flow (i.e., ischemia) (Luciana, 2003). Infants who are born preterm are also at risk for infant respiratory distress syndrome (IRDS), often resulting in chronic lung problems (i.e., brunchopulmonary dysplasia; BPD), which in turn may result in chronic hypoxia

A-not-B looking version at T_1 and T_2

A-not-B reaching version at T_1 and T_2

A-not-B reaching version at T_3

Selection of toys used at T_1, T_2 and T_3

Figure 1 Materials used for the A-not-B task. T_1, 7 months CA; T_2, 10 months CA; T_3, 14 months CA.

of the brain. Brain regions that are vulnerable to hypoxia and ischemia include areas that are considered important for attention and EF development, such as the frontal cortex and the striatum, which has dense interconnections with the hippocampus, thalamus and prefrontal cortex (Luciana, 2003).

Maternal interactive styles and development of infants born preterm

The sensitivity of a mother to her infant's signals, her prompt and contingent responses to these signals and the amount of support a mother provides to her infant are thought to play an important role in infant and child development (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008; Shin, Park, Ryu, & Seomun, 2008; Warren & Brady, 2007). Since infants born preterm have more difficulties with self-regulation and are at risk for developmental delays, these interactive styles are assumed to be especially important for this population (Landry, Smith, Swank, Assel, & Vellet, 2001). Higher levels of maternal sensitive responsiveness are assumed to facilitate attention and EF development since it will place fewer demands on the immature attention abilities of an infant and will provide external support for the regulation of arousal (Haley & Stansbury, 2003; Landry, Garner, Swank, & Baldwin, 1996). High levels of maternal directiveness (i.e., the extent to which a mother tries to control her infants behavior by verbal or physical prompts) are often viewed as a negative influence on child development (Marfo, 1992). However, since infants born preterm have more difficulties regulating their own behavior, a more directive approach may give them the external structure they need to obtain certain goals (Landry, Miller-Loncar, & Smith, 2002).

Questions addressed in the present thesis

The focus of this thesis is on individual differences in early developmental trajectories of attention and EF in infants born preterm, which are considered to be predictive of later global cognitive functioning. These individual differences are assumed to be predicted by perinatal risk factors as well as maternal interactive styles. The predictive value of maternal interactive styles however, may differ with infants' ability to regulate their own behavior.

These hypotheses were examined by addressing four questions: (1) what is the predictive value of perinatal risk factors for individual differences in early development of attention and executive functioning in infants born preterm?, (2) are differences in early attention and EF development related to subsequent global cognitive functioning?, (3) what is the relationship between maternal interactive styles and attention and EF development?, and (4) does this relationship differ with variations in infant self-regulation?

Research design

Participants

Previous studies have focused mainly on the comparison between groups of children born preterm or at term. However, the finding that children born preterm, as a group, lag behind, when compared to children born at term, does not explain the variability within the group of children born preterm, or why some of these children even outperform children born at term. Like more recent studies (Carmody et al., 2006; Espy, Senn, Charak, Tyler, & Wiebe, 2007; Korkman et al., 2008), the present thesis focuses on the variability within the preterm population. In this project, 76 infants born preterm and their mothers were assessed at 7, 10 and 14 months corrected age (CA). These ages were chosen before and after transitions at 9 and 12 months of age in the development of attention and EF.

During the period of inclusion, between April 2004 and August 2005, a total number of 325 singleton infants born preterm (GA ≤ 36 weeks, BW < 2500 grams) were admitted to the Neonatal Intensive Care Unit (NICU; *n* = 266) or the Medium Care Unit (MCU; *n* = 53), or both (*n* = 6) of the Wilhelmina Children's Hospital in Utrecht, The Netherlands. After exclusion, 237 singletons were eligible for inclusion in the study, of which 119 children and their parents were randomly selected and invited by letter to participate (for details on exclusion criteria, see *Chapter 3*). Parents of 76 infants consented for their infant to take part in the study (63.9% of the invited parents). Comparison of participants and non-participants on perinatal risk factors (e.g., BW, GA, medical complications) showed that our sample was representative for a NICU population of infants born preterm. Attrition was low: only 2 infants did not complete the study beyond the first measurement occasion.

Methodological considerations

Infant measures

Attention and EF. The main outcome measures of this thesis are attention and EF abilities. Duration of sustained attention was observed at 7, 10 and 14 months CA during two free play tasks (first with one toy, followed by six toys simultaneously) (Ruff & Lawson, 1990) (for a detailed description of the task, see *Chapter 4*). Although this is commonly accepted to be an attention measure, emerging EF abilities are also considered to play an increasingly important role in performance. EF abilities (i.e., working memory and inhibition) were measured more directly at the same ages with the A-not-B task (Bell & Adams, 1999; Diamond, 1985; Diamond & Goldman-Rakic, 1989). The ability to sustain and control attention (i.e., executive attention) however, also is a prerequisite for performance on this task. To control for any potential effect of delays in motor development, at 7 and 10 months CA, a reaching as well as a looking version of the A-not-B task was used. Since all infants were expected to master the minimal motor abilities required for reaching at 14 months CA, at this age only a reaching version was administered (for a detailed description of the tasks, see *Chapter 3*).

Measurement occasions were planned around those ages during which important transitions in higher-level control abilities are expected to occur (i.e., at 9 and 12 months of age). Pictures of the materials used during these two tasks are presented in Figure 1 (A-not-B task) and Figure 2 (sustained attention during free play).

Global cognitive functioning. Global cognitive functioning was used a secondary outcome measure at 14 months CA, when global cognitive measures begin to gain predictive value for later global cognitive functioning. The Mental Scale of the Bayley

Scales of Infant Development-II (van der Meulen, Ruiter, Lutje Spelberg, & Smrkovsky, 2002) was used, since it is the most frequently used screening instrument in clinical neonatal follow-up programs and studies assessing early global cognitive functioning in this population.

Perinatal risk factors. Frequently, the influence of perinatal risk factors is investigated by assigning children born preterm to groups based on one of those factors (e.g., extremely LBW (ELBW) versus very LBW (VLBW) groups, or IVH versus no-IVH groups), or use of summary risk scores. However, dividing infants into, for instance, BW or GA groups is often based on arbitrary boundaries, in which much information is lost compared to when continuous data is used. In addition, since infants with lower BW or lower GA are more prone to medical complications (Aylward, 2002a, 2002b, 2005), BW or GA groups are likely to differ on the severity of medical complications as well. Finally, summary risk scores conceal information about the influence of more specific medical complications. Therefore, in this thesis the influence of perinatal risk factors (i.e., GA,

Figure 2 Materials used for the attention during free play task. T_1, 7 months CA; T_2, 10 months CA; T_3, 14 months CA.

BW, IVH, PVL, IRDS / BPD, gender) is investigated by using continuous data when possible (e.g., BW, GA) and incorporating each factor separately to investigate which factors contribute the most and how their influence changes over time.

Infant self-regulation. At 7 months CA, mothers filled out a subset of items from the revised Infant Behavior Questionnaire (IBQ-R) (Garstein & Rothbart, 2003) measuring the factor Orienting/Regulation.

Maternal measures

Maternal interactive styles. Maternal interactive styles were observed during mother-infant interactions at 7, 10 and 14 months CA, to investigate the predictive value of stability and change in levels of maternal sensitive responsiveness and directiveness (ELO scales, Wijnroks, 1998), two measures which have been studied widely in relationship with the cognitive development of infants and children (for a detailed description of the mother-infant interaction situation and the ELO-scales, see *Chapter 5*). Measurement occasions were based on transitions in infant development, rather

Task set-up at T_1 and T_2

Toys used at T_1 and T_2

Task set-up at T_3

Toys used at T_3

Figure 3 Materials used for the mother-infant interaction situation. T_1, 7 months CA; T_2, 10 months CA; T_3, 14 months CA.

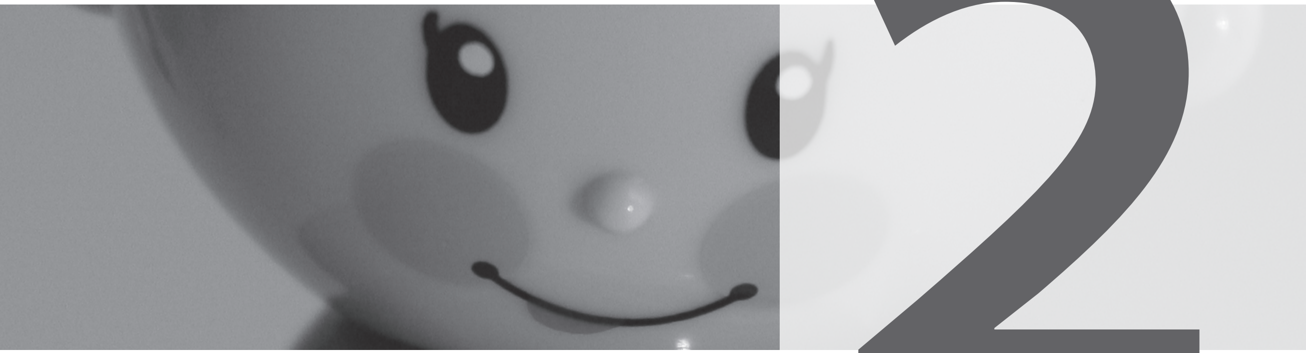
than on expected changes in maternal interactive styles. Pictures of the materials used and set-up of the mother-infant interaction situation are presented in Figure 3.

Statistical analysis

Intra-individual differences in attention and EF abilities are not necessarily very stable from one point in time to the next during the first year of life, when infants show such marked development in these areas. High correlations suggest that an infant or child who scores higher (or lower) on a certain task, will also score higher (or lower) on that task at a later point in time, indicating stability in their relative rank within the group, but these correlations do not tell us much about intra-individual change. Latent Growth Modeling (LGM) on the other hand, provides us with a means to investigate and combine intra-individual developmental trajectories and inter-individual differences in these trajectories. In this thesis, LGM will be used to investigate individual differences in developmental trajectories of attention and EF.

Outline of this thesis

In the following chapters, one review study and three empirical studies addressing the key issues of this thesis will be presented. *Chapter 2* concerns a review study of the literature on attention development in infants and preschool children born preterm. In this review, research examining the differences between preterm and full-term children is described, as well as studies investigating the influence of biological and environmental factors on individual differences within the preterm population. Also, the predictive value of early individual differences in attention for later cognitive and behavioral functioning is examined. In *Chapter 3*, we will examine the effect of several perinatal predictors on initial level and rate of developmental change in A-not-B performance during the first fourteen months of life in infants born preterm, and its relationship to subsequent global cognitive functioning. In *Chapter 4*, we will study which perinatal risk factors are predictive of individual differences in initial level and the rate of developmental change in sustained attention during free play. In addition, the relationship between developmental trajectories of sustained attention and subsequent global cognitive functioning will be assessed. *Chapter 5* focuses on the relationship between maternal interactive styles and individual differences in developmental trajectories of attention during free play and A-not-B performance, using multivariate LGM. Also, it is examined whether these relationships differ with variations in temperamental self-regulation. Finally, the presentation of these studies will be followed by a general discussion of the findings in *Chapter 6*.



2

Attention development in infants and preschool children born preterm: A review

E. van de Weijer-Bergsma,
L. Wijnroks, M.J. Jongmans

Infant Behavior and Development,
31(3), 333-351, 2008.

Abstract

A potential mechanism that can explain preterm childrens' heightened risk for the development of later cognitive and behavioral problems is attention. Attention is the ability of an infant or child to orient to, to shift between and to maintain focus on events, objects, tasks, and problems in the external world, processes which are all dependent on the functioning of attentional networks in the brain. The aim of this paper is to provide a review of the literature on attention development in children born preterm during the first four years of life. First, research examining the differences between preterm and full-term children indicates that early attention development in infants born preterm is less optimal and that these differences increase when infants grow into toddlers. Second, studies investigating individual differences within preterm populations reveal the influence of both biological factors and environmental factors. Third, individual differences in early orienting and sustained attention have been shown to be predictive of later attentional, cognitive and behavioral functioning in children born preterm. The importance of long-term follow-up studies, with a focus on individual developmental trajectories in orienting, sustained and executive attention, is emphasized.

Introduction

Due to medical advances, there is an increased survival rate in children who are born preterm (gestational age < 37 weeks) and/or have a low birth weight (LBW < 2500 grams) (Stoelhorst et al., 2005). However, especially those infants born preterm who have a very low birth weight (VLBW < 1500 grams) or extremely low birth weight (ELBW < 1000 grams) are at risk for developmental problems (Anderson & Doyle, 2003; Aylward, 2002a, 2005; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Salt & Redshaw, 2006). Although major disabilities (e.g., mental retardation, sensory disorders and cerebral palsy) are often detected during infancy and their incidence has remained constant, low severity dysfunctions (e.g., learning disabilities and ADHD) become more apparent when children grow older (i.e., at school age) (Aylward, 2005; Luciana, 2003), and their incidence has increased (for a review see Aylward, 2002a). Moreover, even children born preterm without apparent disabilities and who have intellectual abilities within the normal range, receive special educational services at a very high rate (Aylward, 2002a; Walther, den Ouden, & Verloove-Vanhorick, 2000).

Until now, many efforts have been made to investigate factors associated with developmental dysfunction in children born preterm. Many studies have concentrated on neonatal risk factors such as birth weight (BW), gestational age (GA), and medical complications. However, there are limitations to the conclusions that can be drawn from these studies. First, although associations with BW, GA and the severity of medical complications have been found (Aylward, 2002a; Cohen, Parmelee, Sigman, & Beckwith, 1982; Cooke, 2006; Hack et al., 2000; Short et al., 2003; Vohr et al., 2000; Wood et al., 2000), correlations are relatively low and therefore explain only little variance. Moreover, these biomedical factors are interrelated, making interpretations about their relative contribution difficult. Secondly, many studies have concentrated on global outcome measures, using scores on developmental assessments, such as the Bayley Scales of Infant Development (Bayley, 1969) or intelligence scores. A major problem with interpreting the results from such global measures is that they are often poor predictors for later functioning (Hack et al., 2005; Siegel, 1989; Slater, 1995), because these measures usually appeal to various underlying functions and abilities. As a result, there is a gap in our understanding of the underlying deficits or processes that cause developmental problems in children born preterm. A third limitation is related to the use of comparisons between preterm and full-term groups. The finding that children born preterm, as a group, lag behind, when compared to children born at term, does not explain the variability within the group of children born preterm, or why some of these children even outperform children born at term. Moreover, it is difficult to interpret differences between children born preterm and children born at term, since we do not know whether the observed deficits are permanent or temporary delays followed by catch-up. Although some studies suggest that deficits in infants born preterm are structural during early childhood, or even become worse when children grow older (Aylward, 2002a; Koller, Lawson, Rose, Wallace, & McCarton, 1997), others have reported catch-up in some preterm subgroups (Taylor, Minich, Klein, & Hack, 2004; Tideman, 2000).

A potential mechanism that can explain a heightened risk for developmental problems and within-group variability among children born preterm is attention. By attention we mean the attention an infant or child has for events, objects, tasks, and problems in the external world, which is dependent on the functioning of attentional networks in the brain (Posner & Petersen, 1990; Posner & Raichle, 1994). Because infants and young children are confronted with a complex environment filled with vast amounts of stimulation, they need to be selective in what they attend to and responsive when important events occur, in order to function well. Also, they have to learn to show persistence to complete tasks despite obstacles and distractions, but at the same time be able to disengage attention from activities that are ineffective (Ruff & Rothbart, 1996). The development of attention has been studied from different viewpoints. Whereas some studies emphasize the cognitive products of visual attention, other focus on the process of attention in itself (Colombo, 2004). First and originally, attention measures have been used as a tool to study the development of other cognitive abilities, such as recognition memory and habituation (i.e., products of attention). Second, due to advances in cognitive neuroscience, attention development per se and associated brain development has sparked interest (i.e., process of attention). Also, research with clinical populations has triggered interest for the predictive value of early attention for future dysfunction in attention and other areas. For example, the finding that school-aged children, who were born preterm, are at risk for attention difficulties possibly leading to a diagnosis of ADHD (Aylward, 2002a; Bayless & Stevenson, 2007; Bhutta et al., 2002; Mick, Biederman, Prince, Fischer, & Faraone, 2002; Salt & Redshaw, 2006) has led researchers to propose that early problems in the regulation of attention may underlie the individual variability between infants born preterm and their vulnerability as a group for developmental delay and learning problems (Aylward, 2002a; Davis & Burns, 2001).

Therefore, the aim of the present paper is to provide a review of studies investigating the development of attention per se (i.e., the process of attention) in infants and preschool children who were born preterm. First, early attention development in typically developing children will be described from a cognitive neuroscience perspective. Second, literature on attention development in children born preterm will be evaluated. We aim to (1) identify differences in attention development during infancy and the preschool years between children born preterm and children born at term, (2) distinguish important environmental and biological predictors of attention development in children born preterm, and (3) examine the predictive value of early attention development for later functioning in children born preterm.

A cognitive neuroscience perspective on early development of attention

An influential neuropsychological model of attention development that covers the entire life span was proposed by Posner and colleagues (Posner & Petersen, 1990; Posner & Raichle, 1994). According to this account there are three interconnected attention networks in the brain, including (1) the orienting system or posterior attention network, (2) the alerting or arousal system, and (3) the executive control system or anterior attention network.

The orienting system, consisting of a spatial orienting network in the parietal cortex and an object recognition pathway in the temporal cortex, becomes fully functional during the first 6 months of life, is related to the orientation or movement of attention toward specific locations in the environment and involves a number of behavioral processes, including disengagement, shifting, inhibition of return and anticipatory eye movements (Johnson, 2005; Johnson & Tucker, 1996). Orienting can occur overtly (observed by saccades in eye-movements) and covertly (without eye-movements). Whereas overt shifts of attention can be observed directly, covert shifts of attention are inferred from the faster detection of targets after a cue. Although this distinction suggests two discrete processes, in daily life covert and overt shifts of attention often occur together (Butcher, 2000; Klein, 2004). A large amount of our knowledge on overt orienting in infancy comes from long-established paradigms such as habituation, novelty preference, and violation of expectation (VExP) paradigms. Although these paradigms are often referred to as visual attention paradigms, they are originally designed to investigate the development of other aspects of cognition, such as speed of information processing or recognition memory. However, in trying to capture the underlying processes that can explain individual differences in these cognitive abilities, researchers have concentrated on different aspects of visual attention during these tasks, besides the main outcome measures such as habituation rate and novelty preference. These attention measures include look duration (longest look and mean looking time), and changes of attentional focus (shifts of gaze between paired targets). Longer look durations and slower shift rates are considered to be indicative of less efficient disengagement and shifting of attention (Colombo, 2002, 2004; Rose, Feldman, & Jankowski, 2001). More recently, marker tasks for several brain regions involved in the development of orienting of attention have been developed, such as disengagement tasks, the visual expectation paradigm (VExP), and inhibition of return (IOR) (Johnson, 2005; Johnson, Posner, & Rothbart, 1991; Posner & Raichle, 1994). Disengagement tasks are used to measure an infant's ability to disengage gaze and attention by adding a peripheral stimulus to a central fixation stimulus. To be able to orient to the peripheral stimulus an infant has to disengage its attention from the central stimulus (Johnson et al., 1991). The visual expectation paradigm (VExP) is used to measure the ability to direct attention based on expectations, in contrary to the reactive attention based on the presentation of stimuli itself. By presenting stimuli in regular alternation patterns on the left- or on the right-hand side of the infant, the ability to form expectations and make anticipatory eye movements is measured (Johnson et al., 1991; Posner & Raichle, 1994). Although anticipatory attention is controlled by internal processes, in this simple form it is considered part of the orienting system (Posner & Raichle, 1994; Ruff & Rothbart, 1996). The IOR paradigm is used to investigate the tendency not to shift back attention to a recently attended location, by presenting a target stimulus more than 300 msec after a cue. As a result, target detection is slower at the cued location than at the uncued location. This phenomenon is assumed to encourage orienting toward novelty. IOR can be used to investigate the tendency not to shift back attention after overt orienting (by replacing a central stimulus for a peripheral cue for 3 sec), and it can also be used to investigate IOR after covert orienting (by adding a cue to the central stimulus for 100 msec) (Butcher, 2000; Johnson, 2005).

The alerting or arousal system, involves parts of the brainstem and later in development also the right frontal lobe, and is related to the capacity to maintain a state of alert arousal, enabling effortful processing of information. Knowledge about the development of this network during infancy and early childhood mainly comes from the behavioral observation of sustained attention (sometimes also called focused attention or focused exploration) during free play, video-watching and more or less structured tasks. The behavioral observation of sustained attention is based on the assumption that it is accompanied by (1) a narrowing or restriction of selectivity to fewer elements, and (2) an increase in the degree of effort or energy that is directed at the target task (Ruff & Rothbart, 1996). Sustained attention during free play, for instance, is defined as episodes of manipulation of a toy while looking at the toy with a serious facial expression (Ruff & Lawson, 1990). The observation of off-task behavior (measured by pauses and exposure times) during habituation or novelty preference paradigms can also be viewed as an indirect measure of sustained attention (Rose, Feldman, McCarton, & Wolfson, 1988).

Several neuropsychological models of attention development agree that the development of attention is accompanied by a (gradual) shift from subcortical processing to increasing cortical control over attention (Colombo, 2001, 2002; Johnson, 2005; Posner & Petersen, 1990; Posner & Raichle, 1994). When infants develop into toddlers, the executive control system begins to mature, involving areas of the frontal cortex, in particular the prefrontal cortex. During this period, attention becomes more related to planned, self-generated activity with objects. Functions associated with higher level control of attention overlap with the more general domain of executive function (EF), which also includes working memory, planning, switching and inhibitory control. In fact, some researchers suggest isomorphic relationships between executive attention and other executive functions, such as working memory, switching and fluid intelligence (Engle, 2002; Kane & Engle, 2002). Because there are no tasks available that purely measure executive attention in infants and preschool children, executive attention is most frequently assessed using marker tasks of the dorsolateral prefrontal cortex (DLPC), a brain area that is involved in several executive functions, such as working memory, inhibition and executive attention. Marker tasks of DLPC functioning in infancy and early childhood are, for example, delayed-response-type tasks, such as the classical A-not-B (AB) task (Diamond & Goldman-Rakic, 1989), in which infants have to retrieve a hidden object from one of two (or more) locations following a delay, after which the location of hiding is changed. Other similar tasks are Delayed Alternation and Spatial Reversal in which a reward is hidden out of the child's sight and the side of hiding is changed, either alternating between the left and right location, or changing sides after a criterion of consecutive correct retrievals, respectively (Espy et al., 2002).

The development of these three attention networks is described by Ruff & Rothbart (1996). From their extensive review of the literature it has, for example, become evident that infants are selective in their attention from the first day of life, looking longer at some pictures or designs than others. During the first year of life, when the orienting network becomes functional, attention is governed by the novelty of objects and events encountered by the infant, but repeated experience reduces novelty and leads the infant to notice new details and information. Although very young infants are very selective in their attention, they may have much difficulty disengaging from highly salient stimuli. This phenomenon is also called 'sticky fixation' or 'obligatory attention'. Initially, from birth to 8 or 10 weeks of age, looking duration increases, possibly due to the emergence of alertness. From 3 to 5 or 6 months looking duration decreases, reflecting improved ability to disengage attention (Colombo, 2001, 2002). Although most shifts in attention seem to be reactive during this period, infants become able to make anticipatory eye movements based on expectations around this age. Around 7 months of age there are other contexts, such as when infants show manipulative play with several toys or objects simultaneously, in which the length of looking increases with age, reflecting increased sustained or focused attention, which enables infants to explore objects in the environment. This is the result of the increasing influence of the emerging executive control system over the arousal system. A dramatic transition of attention behaviors is observed around 18 to 24 months, when the frontal cortex is undergoing further development. During this period children show a further increase in looking during play, and looking at complex visual displays, such as television. Besides their growing ability to manage attention in the face of potential distracting features when they are playing with several toys at once, infants become more able to plan and self-generate the direction of their attention, by facilitating or inhibiting lower level processes. During the preschool years, when children are confronted with more occasions where they have to attend to events that are intrinsically uninteresting, a higher level control of attention becomes even more apparent. The ability to plan ahead and engage in complex activity further develops and supports the sustaining of attention when more external demands are placed on the child.

Attention development in infants and preschool children born preterm

In the following sections the development of attention in infants and preschool children born preterm will be described. First, studies comparing performance of children born preterm and children born at term will be discussed. Second, risk and protective factors that may be predictive of early attention development within the preterm population will be investigated. Finally, we will examine the predictive value of early attention development for later functioning in children born preterm. In this paper the focus is on research using behavioral measures of visual attention during the first four years of life. Studies are included when they fit Posner's model of attention networks and when one of the tasks or paradigms described in section 1 (Early development of attention) has been used. Studies using habituation, novelty preference or VExP paradigms are only discussed when one or more of the underlying visual attention processes, that were mentioned earlier, are investigated. Since our primary focus is on visual attention of the infant or preschool child in itself, and not on attention skills during interaction with parents, studies investigating joint attention or exploratory play as a direct function of maternal scaffolding will not be subject to review. Information about sample characteristics and measurements used in the studies described in this review are presented in Tables 1a and 1b.

The articles in this review were selected using the keywords "preterm", "premature", "birth weight", "attention", "sustained", "focused", "executive", "orienting", "cognitive", and "development", during an online computer search in PubMed, SCOPUS and Google between June 2006 and June 2007. After a first selection, an extended search was done based on the reference list of the selected articles.

Comparison of early attention development between children born preterm and children born at term

The orienting system

Studies using marker tasks of visual orienting indicate that infants born preterm exhibit less efficient attention behaviors than infants born at term during the first 6 months of life (Butcher, 2000; Butcher, Kalverboer, Geuze, & Stremmelaar, 2002; Hunnius, 2004; Stroganova, Posikera, & Pisarevskii, 2005; Stroganova, Posikera, Pisarevskii, & Tsetlin, 2006a, 2006b). For example, even though both low- and high-risk infants born preterm initially showed faster gaze shifts than infants born at term in a study by Butcher et al. (2002), and all groups displayed similar developmental trajectories between 6 and 26 weeks of age in simple gaze shifting as well as in disengagement from an attended stimulus, two observations led the authors to conclude that both groups of infants born preterm disengaged less efficient than the full-term group. First, infants born preterm continued to display a less mature form of errors with increasing age, by persistent staring at the fixation stimulus, in contrast to infants born at term, who increasingly made errors away from the target at older ages. Second, infants born preterm showed less errors than infants born at term. Although this latter finding may seem to indicate superior performance, Butcher et al. (2002) argue that the type of errors the full-term group made indicate more mature inhibition of not only attention to the fixation stimulus but also the inhibition of a response to a highly salient peripheral target in order to look to another, apparently more attractive location. Less mature errors by infants born preterm were also found in a study by Hunnius (2004). Again infants born preterm shifted gaze faster than their full-term born peers initially, but this effect diminished after 16 weeks of age. In addition, infants born preterm showed less mature shifting behavior, and were more inclined to continue staring at the fixation stimulus, despite similar developmental trajectories in gaze shifting frequency when compared to infants born at term. Hunnius (2004) was able to demonstrate that it were abstract stimuli in contrast to facial stimuli that posed a particular challenge for preterm born

Table 1a Sample characteristics of preterm (sub)groups

Authors	n	Neonatal medical status	GA M	GA SD	GA Range	BW M	BW SD	BW Range	Exclusion criteria
Bonin et al. (1998)	34		32.15	2.36	27-36	1712.35	392.71	1000-2466	CNS disorders, congenital malformation syndromes, BPD, IVH > I, 5-min Apgar < 5, assisted ventilation > 28 days,
Butcher (2000)	11	PVE < 14 days	30.3	1		1234	207		IVH > I, ROP, NBRS score≥ 5
	10	PVE ≥ 14 days	28.7	1.2		1126	259		
Butcher et al. (2002)	11	PVE < 14 days	30.3	1		1234	207		IVH > I, ROP, NBRS score≥ 5
	10	PVE ≥ 14 days	28.7	1.2		1126	259		
Caravale et al. (2005)	30				30-35				Congenital abnormalities, major neurological signs
Espy et al. (2002)	29		32.4	2.2	28-36.5	1774	484	739-2475	GA < 28 wks, IVH > II, PVL, seizures, chronic lung disease, BPD
Hunnius (2004)	10		29.6	1.8	27.3-32.4	1267	468	640-2035	ROP > I
Kopp & Vaughn (1982)	76		33	2.98	26-37	1979.5	485	800-2500	Multiple birth, SGA, motor or sensory handicaps, Bayley MDI < 60 at 2 yrs
Landry et al. (1985)	14	RDS & IVH	30.29	1.82	27-33	1229.29	181.3	950-1500	Sensory handicap, CP diagnosis, non-IVH-related hydrocephalus
	9	RDS, no IVH	30.33	2.50	27-34	1296.33	259.68	920-1640	
Lawson & Ruff (2004)	55		29.9	2.2	26-37	1091	209	685-1470	Sensory or neurological problems, significant impairment
Matthews et al. (1996)	10		35.5	0.79	34-36	2480	310	1815-2750	
McGrath et al. (2005)	32	Healthy	31.6	1.7	28-34	1539	201	900-1820	
	53	Medical	29.4	2.3	25-33	1278	311	780-1800	
	32	Neurological	28.4	2.12	24-33	1158	267	720-1670	
	28	SGA	31.9	2.8	26-36	1142	344	640-1750	
Pridham et al. (2000)	16	BPD			≤ 32	1039.7	329.12		IVH > II
	20	RDS			≤ 32	1219.92	91.84		
Ross et al. (1992)	30	IVH grade I-II	30.2	1.4		1431.1	226		IVH >II, congenital malformations, neurosensory deficits
	30	No IVH	30.5	1.5		1494.7	256		
Rose et al. (1988)	50		31.4	1.7	29-36	1183.9	210.9	760-1460	
Rose et al. (1991)	63		31.3	1.7	26-36	1163.1	226.8	420-1460	
Rose et al (2001, 2002ab)	59		29.6	2.9	25-36	1107.9	282.6	551-1747	Congenital, neurological or physical abnormalities
Ruff et al. (1990)	63		30.9	2.1		1207	339		
Sigman et al. (1977)	28		33.2	3.1		1926.7	434.5		
Sigman and Cohen et al. (1980, 1983, 1986)	122		33.0		25-37	1911		800-2495	Congenital anomalies or syndromes, blindness
Stroganova et al. (2005, 2006ab)	19		30.11	1.82	< 32	1400	222.86		SGA, IVH, PVL, ROP, neonatal convulsions, Korner's medical risk index > 3
Sun (2003)	37		28	1.86		1008	246		Severe visual, auditory or neurological impairment, congenital abnormalities
Tu et al. (2007)	103		29.3	2.7		1282.7	481.4		
Vicari et al. (2004)	19		32	1.5	29-34	1597	436.4	910-2330	Congenital abnormalities, abnormal cerebral ultrasound, CP, blindness, deafness, IQ ≤ 90
Wilcox et al. (1996)	18		34.06	0.8	32-35	2150	240	1800-2570	Multiple birth, SGA, neurological insult, genetic & chromosomal abnormalities, infection, disease
Woodward et al. (2005)	92		27.9	2.4	≤ 32	1088	315.2		Congenital abnormalities
Wijnroks et al. (1998, 2003)	66		32	3	25-36	1668	631	690-3210	Multiple birth, IVH > II, hydrocephalus

GA, gestational age in weeks; BW, birth weight in grams; CNS, central nervous system; PVE/L, periventricular echogenecity/leukomalacia; BPD, bronchopulmanory dysplasia; RDS, respiratory distress syndrome; IVH, intraventricular hemorrhage; ROP, retinopathy of prematurity; CP, cerebral palsy; SGA, small for gestational age.

Table 1b Sample characteristics continued: Number of participants in full-term control groups, age at time of testing attention, attention measures, and year of birth

Authors	Full-term controls *n*	Age at time of testing	Attention measures	Cohort
Bonin et al. (1998)	36	2-4-6 m	looking duration during habituation / novelty preference	
Butcher (2000)	16	6-26 wks, 2-4 wk interval	Inhibition of return (IOR)	1995-1999
Butcher et al. (2002)	16	6-26 wks, 2-4 wk interval	Disengagement task	1995-1999
Caravale et al. (2005)	30	3 to 4 yrs*	Leiter International Performance Scale Revised (sustained attention)	1998
Espy et al. (2002)	29	2 to 3 yrs*	Delayed Alternation / Spatial Reversal	
Hunnius (2004)	20	6-26 wks, 4 wk interval	Disengagement task	
Kopp & Vaughn (1982)	0	8 m	Sustained attention during exploratory manipulation	
Landry et al. (1985)	10	7 m	Attention getting / attention holding during habituation / novelty preference	1980-1981
Lawson & Ruff (2004)	0	7 m, 2-3 yrs	Focused attention during free play	1989-1990
Matthews et al. (1996)	10	28-60 wks, 4 wk interval	A-not-B task, reaching and non-reaching version	
McGrath et al. (2005)	39	4 yrs*	Sustained attention during problem solving task	1985-1989
Pridham et al. (2000)	43	8 m	Focused exploration during free play	1987-1992
Ross et al. (1992)	30	10 m	A-not-B task	
Rose et al. (1988)	43	7 m	Exposure time & pauses during visual recognition	1979-1981
Rose et al. (1991)	46	12 m	Exposure time, looking duration & pauses during visual recognition	1979-1981
Rose et al (2001, 2002ab)	144	5-7-12 m	Looking duration, shift rate & pauses during visual recognition / continuous familiarization, frequency of anticipatory attention during visual expectation (VexP)	1994-1997
Ruff et al. (1990)	91	1-2-3 yrs	Focused attention during free play	
Sigman et al. (1977)	28	Expected due date	Looking duration	
Sigman and Cohen et al. (1980, 1983, 1986)	16	Expected due date	Looking duration	1972-1974
Stroganova et al. (2005, 2006ab)	22	5 m	Frequency and maintainance of anticipatory attention during visual expectation (VExP)	
Sun (2003)	74	8 m	A-not-B task, sustained attention during free play	1998-1999
Tu et al. (2007)	55	8 m	Focused attention during toy exploration	2001-2004
Vicari et al. (2004)	19	3 to 4 yrs*	Leiter International Performance Scale Revised (sustained attention)	1998
Wilcox et al. (1996)	21	2.5- 4.5-6.5 m	Looking duration during violation of expectation (VEP)	
Woodward et al. (2005)	103	2 yrs	Multisearch Multilocation task	1998-2000
Wijnroks et al. (1998, 2003)	0	18-24 m	Off-task behavior during problem solving	1986-1988

* Preterm group tested at chronological age, not corrected for prematurity.

infants. The tendency in preterm born infants to be captured by stimuli was also observed in a study investigating IOR following covert orienting (Butcher, 2000). Again Butcher (2000) showed that both groups followed the same developmental trajectories in IOR following covert orienting, and that infants born preterm demonstrated fewer errors than infants born at term, infants born preterm had more difficulty suppressing looks to the cue, that had already been covertly attended to.

The results from VExP paradigms, another marker task, indicate that infants born preterm show similar abilities to make an anticipatory eye-movement on the basis of a regular pattern of events, compared to infants born at term (Rose, Feldman, Jankowski, & Caro, 2002a), but have more problems maintaining their anticipatory attention than infants born at term (Stroganova et al., 2005; Stroganova et al., 2006a, 2006b). For example, Rose et al. (2002a) found similar frequencies in anticipatory eye movements in 5-, 7-, and 12-month-old infants born preterm and infants born at term. A more recent study by Stroganova et al. (2005) confirmed these findings in 5-month-old infants born preterm, but also found that infants born preterm had more trouble maintaining anticipatory attention (i.e., maintaining gaze fixation after anticipatory eye movement) than infants born at term. These problems with maintaining anticipatory attention were associated with a relative deficit in the functional synchronization of activity in the lower temporal areas of the cortex (Stroganova et al., 2006a), and a lack of active up-regulation of parasympathetic heart rate (Stroganova et al., 2006b) in infants born preterm.

The finding that infants born preterm display less efficient disengagement and shifting of attention is supported by studies investigating habituation and novelty preference, in which longer looking durations and slower shift rates are considered to reflect less mature attention skills (Bonin, Pomerleau, & Malcuit, 1998; Landry, Leslie, Fletcher, & Francis, 1985; Rose et al., 2001; Rose et al., 2002a; Rose et al., 1988; Ross, Tesman, Auld, & Nas, 1992). Although some researchers failed to find differences in looking durations in infants born preterm and infants born at term between 2 and 6 months of age during the encoding phase of a VExP paradigm (Wilcox, Nadel, & Rosser, 1996), or during habituation and novelty preference (Bonin et al., 1998), studies with medically at risk samples (i.e., suffering perinatal medical complications) found infants born preterm to look longer than infants born at term at the expected due date (Sigman, Kopp, Littman, & Parmelee, 1977), and at 5, 7 and 12 months of age (Rose et al., 2001). Keeping the developmental trend of looking duration in mind, with it's initial increase during the first 8 to 10 weeks of life, i.e., before looking durations decreases as a result of more efficient disengagement (Colombo, 2001, 2002), longer looking durations are not likely to mean the same thing at different ages. In fact, longer looking at the expected due date may be the result of initial higher alertness in infants born preterm, whereas the same finding at 5, 7 and 12 months is likely to be indicative of more difficulty disengaging attention in infants born preterm. Besides longer looking durations, infants born preterm display slower shift rates in comparison to infants born term after 6 months of age, in contrast to their earlier faster shift rates. Landry et al. (1985), for example, found that 7-month-old, high-risk infants born preterm had more trouble turning from a blinking light to the habituation stimulus (referred to as 'attention getting'), compared to low-risk infants born preterm and infants born at term, suggesting less efficient disengagement and shifting of attention. Poorer shifting skills in infants born preterm were also demonstrated in a longitudinal study by Rose and colleagues (Rose et al., 1988; Rose, Feldman, Wallace, & McCarton, 1991), who showed that these infants showed less changes in attentional focus than infants born at term, at 7 months (Rose et al., 1988), but not at 12 months (Rose et al., 1991). Similar differences in attention behaviors were found in another longitudinal study by Rose and colleagues, who showed that infants born preterm not only looked longer, but also shifted slower between targets than infants born at term at 5, 7 and 12 months of age in a paired comparison task (Rose et al., 2001), and at 12 months in a new continuous familiarization technique (Rose, Feldman, & Jankowski, 2002b). Probably, longer looking duration and slower shifting are more likely to be related to severity of medical condition than prematurity per se.

In sum, results from marker tasks of visual orienting as well as habituation and novelty preference paradigms suggest that, after an initial period of higher alertness, infants born preterm show less efficient orienting of attention than infants born at term during the first year of life, characterized by a tendency to be captured by stimuli, less efficient disengagement and shifting of attention and problems with maintaining anticipatory attention.

The alerting or arousal system

The literature on sustained attention during free play in infants born preterm shows some contradictory results. Whereas some researchers found infants born preterm to show less sustained attention and more off-task behavior than infants born at term (Rose et al., 2001; Rose et al., 1988; Sun, 2003; Tu et al., 2007), others found no differences (Pridham, Becker, & Brown, 2000; Rose et al., 1991), or even found longer periods of sustained attention in infants born preterm than infants born at term during free-play (Ruff, Lawson, Parrinello, & Weissberg, 1990). Sun (2003), for example, showed that 8-month-old infants born preterm show shorter periods of sustained attention and more off-task behavior during free play with several toys, than infants born at term. A trend of lower quality of sustained attention in 8-month-old infants born preterm, compared to infants born at term, was also found by Tu et al. (2007). Pridham et al. (2000), on the other hand, found no differences in sustained attention between 8-month-old infants born preterm and infants born at term during free play. Moreover, a longitudinal study by Ruff et al. (1990), conducted at 1, 2 and 3.5 years of age, revealed longer periods of sustained attention in infants born preterm than infants born at term at 2 years, but only when developmental scores were above 80. These differences in results are difficult to explain. Although Ruff et al. (1990) speculate that longer periods of sustained attention in children born preterm may be caused by a tendency to be less active and more compliant, making it easier for these children to focus and maintain attention, this hypothesis can not explain why other studies report less sustained attention in children born preterm.

Studies investigating off-task behavior during novelty preference paradigms also show inconsistent results. For instance, although Rose et al. (1988) showed that infants born preterm spent more time off target than infants born at term at 7 months (Rose et al., 1988), these differences disappeared at 12 months (Rose et al., 1991). In another longitudinal study, Rose and colleagues found opposite results, when infants born preterm showed more off-task behavior at 12 months of age, but not at 5 or 7 months of age, in a paired comparison task (Rose et al., 2001).

When infants become toddlers, and the arousal system becomes more and more under the control of the executive control system, researchers report more matching results, indicating shorter periods of sustained attention in children born preterm than in children born at term (Caravale, Tozzi, Albino, & Vicari, 2005; McGrath et al., 2005; Vicari, Caravale, Carlesimo, Casadei, & Allemand, 2004). For example, McGrath et al. (2005) demonstrated that high-risk children born preterm were less attentive than children born at term during a problem solving task at 4 years of age (not corrected for prematurity). This finding is consistent with that of Vicari et al. (2004) and Caravale et al. (2005), who found that even low-risk children born preterm showed shorter periods of sustained attention, during a structured barrage task, than children born at term, at 3 to 4 years (not corrected for prematurity).

In sum, studies investigating sustained attention during infancy show some contradicting results, suggesting that problems with sustaining attention are not always evident in infants born preterm during infancy. However, the few studies investigating sustained attention during the preschool years are more congruent, suggesting that problems with sustained attention become more visible in children born preterm with increasing age, regardless of their risk status.

The executive control system

Researchers investigating executive attention skills in infants born preterm also report some contradictory findings (Matthews, Ellis, & Nelson, 1996; Ross et al., 1992; Sun, 2003). Matthews et al. (1996) found, for example, that 6- to 14-month-old, low-risk infants born preterm outperformed infants born at term at a reaching as well as a non-reaching version of the AB task, suggesting an advantage of extrauterine experience of children born preterm in comparison to children born at term. However, the results of a study by Ross et al. (1992) indicated poorer AB performance in 10-month-old infants born preterm compared to infants born at term. Similar findings were reported in a more recent study, which demonstrated that 8-month-old infants born preterm perform poorer on both inhibitory aspects and working memory aspects of the AB task, than infants born at term (Sun, 2003). In this study, infants born preterm had more trouble finding hidden objects, and were more inclined to reach toward the incorrect location after the side of hiding was changed. Also, infants born preterm were distracted more often by the cup that covered the toy, making them fail to retrieve the goal object (Sun, 2003). These differences in results can be explained by the fact that infants in the study by Matthews et al. (1996) were part of a healthy low-risk sample, in contrast to the studies by Ross et al. (1992) and Sun (2003), in which infants born preterm formed a more heterogeneous group differing in degrees of medical risk.

The few studies that have investigated executive attention during the preschool years are more congruent and show some surprising patterns of performance in children born preterm (Espy et al., 2002; Woodward, Edgin, Thompson, & Inder, 2005). Using two delayed-response-type tasks, similar in format to the AB task, Espy et al. (2002)

compared 2- to 3-year-old, low-risk children born preterm with full-term peers. Although children born preterm performed comparably on the Spatial Reversal task to children born at term, children born preterm chose a previously un-rewarded location more often than children born at term in de Delayed Alternation task, instead of the more common and expected perseverative error of reaching toward a previously rewarded location. Espy et al. (2002) argue that this specific response bias of persistently choosing a maladaptive and unrewarding strategy might be viewed as an early indication of the frequently observed executive dysfunction at school-age in children born preterm. This unique pattern of errors was also found in a study by Woodward et al. (2005). During an age appropriate AB task at 2 years of age, children born preterm showed overall poorer performance than children born at term. Also, children born preterm were nearly twice as likely to make non-perseverative errors than children born at term, whereas children born at term tended to make the anticipated perseverative error.

In sum, taking into account the mixed results from infant studies and the more congruent results from preschool studies using delayed response tasks, it seems that problems with executive attention become more apparent with increasing age, even in low-risk infants born preterm. Surprisingly, however, preschoolers born preterm do not seem to have problems with inhibition of a previously rewarded response, but rather with inhibiting attention to irrelevant task-features or distracters (such as the cup that covered the toy or other hiding wells). This pattern of errors suggests difficulties with higher level control of sustained attention, and already can become visible in infancy.

Risk and protective factors in early attention development

In developmental psychology it is widely recognized that infant development is influenced by – the interaction between – biological factors (such as perinatal factors, postural control, gender and temperament), and environmental factors (such as socioeconomic factors and parental interactive behaviors) (Sameroff & MacKenzie, 2003). In the following section we will examine the biological and environmental factors that may influence early attention development within the preterm population. Although many of these factors are interrelated – perinatal factors in particular – (e.g., infants who are born at a shorter gestational age, have lower birth weights), the influence of each factor is discussed separately.

Biological factors

Gestational age. There has been some debate on the issue whether premature birth in itself has a negative influence on development (Sesma & Georgieff, 2003). In fact, some results from studies comparing infants born preterm with infants born at term suggest an advantage of preterm birth in attentional abilities, especially when age was corrected for prematurity. For example, studies investigating disengagement showed that infants born preterm initially shifted faster than full-term infants, although this difference disappeared at older ages (Butcher, 2000; Butcher et al., 2002; Hunnius, 2004). An advantage of additional experience in infants born preterm was also suggested by Matthews et al. (1996) who found better AB performance in infants born preterm than in infants born at term. Studies investigating the predictive value of GA within the preterm population show mixed results. Although Rose et al. (2002a) failed to find a relationship between GA and off-task behavior during infancy, studies during preschool age did link shorter GA to poorer attention skills in infants born preterm. That is, preschoolers, who were born at a shorter GA tended to perform poorer on the AB task at 2 years (Woodward et al., 2005), and to show less sustained attention during problem solving at 4 years than preschoolers born after longer GA, but still before their expected birth date (McGrath et al., 2005), suggesting that birth at a less mature state can have detrimental effects on attention development. In an effort to disentangle the effects of maturation of the central nervous system from the time of conception versus the effects of exposure to extrauterine environmental stimulation, Sun (2003) not only compared infants born preterm with infants born at term of the same corrected age (8 months), but also with infants born at term of the same chronological age (10-11 months). Her findings that infants born preterm performed more poorly than infants born at term of both ages on all measures of sustained and executive attention, suggest that the effects of immaturity are greater than the effects of additional extrauterine experience. Comparison within the preterm group, however, revealed no significant difference between infants born before or after 28 weeks of gestation, suggesting that GA has little influence on attention development over the effects of prematurity per se, at least not at this early age.

In conclusion, it seems that, although premature birth may give infants an early advantage in some domains due to greater experience in the extrauterine environment, this advantage is probably short-term and the negative effects of immaturity are greater than the positive effects of extrauterine exposure. The association between shorter GA and poorer attention skills in preschoolers in particular, may suggest that children born preterm grow into their attention deficits. However, whether these negative effects of shorter GA on attention skills are due to immaturity or to other related differences (such as differences in level of stress or pain) is not clear. For example, a more premature birth is likely to be accompanied by more neonatal pain-related stress, because children born at a shorter GA often need more medical interventions and skin breaking procedures.

Birth weight. Although Rose et al. (1988) found that lower BW in 7-month-old infants born preterm was related to poorer attention abilities, the predictive value of BW was not confirmed by the majority of studies reviewed here (Bonin et al., 1998; McGrath et al., 2005; Pridham et al., 2002; Rose et al., 2002a; Sun, 2003; Woodward et al., 2005). BW did not correlate significantly with visual orienting at 5, 7 or 12 months (Bonin et al., 1998; Rose et al., 2002a), sustained attention during free play at 8 months (Pridham et al., 2000), AB performance at 2 years of age (Woodward et al., 2005), or sustained attention during problem solving at 4 years (McGrath et al., 2005). Comparisons between different BW groups of infants born preterm also failed to reveal any differences. Neither looking duration between 2 and 6 months of age differ between VLBW and LBW infants born preterm (Bonin et al., 1998), nor did sustained attention during free play or AB performance differ between ELBW and VLBW infants born preterm at 8 months (Sun, 2003). Nevertheless, Sun (2003) did report that the difference in AB performance between ELBW infants born preterm and infants born at term was greater (and significant) than the difference between VLBW infants born preterm and infants born at term. Moreover, although the difference between ELBW and VLBW infants was not significant, the results were in the expected direction. The failure to reach statistical significance is probably due to small sample sizes. These results suggest that lower BW has a negative gradual effect on executive attention. On the other hand, it is possible that these BW-groups differed in other aspects as well (e.g., medical complications).

An issue that is related to BW is intrauterine growth retardation. Although many infants born preterm have appropriate weight for gestational age, a potential risk factor in infants born preterm is intrauterine growth retardation, usually resulting in being small for gestational age and having a subnormal head circumference (Gibson, Carney, & Wales, 2006; Peterson, Taylor, Minich, Klein, & Hack, 2006; Rugolo, 2005). While smaller head circumference was predictive of less mature attention skills during visual recognition at 7 months (Rose et al., 1988), no relationship was found between being small for gestational age and attention skills during a VExP paradigm between 5 and 10 months (Rose et al., 2002a), or between intrauterine growth retardation and AB performance at 2 years (Woodward et al., 2005).

In conclusion, despite some associations with BW and head circumference, the evidence for the predictive value of BW and related indices of growth for early attention development has not been very strong.

Medical risk. Several studies have investigated the association between presence and/or severity of medical complications, during the perinatal period, and attention skills in infants born preterm. The predictive value of medical complications is usually investigated by using summary scores of neonatal risk, or by determining the relationship with more specific risk factors or medical complications, such as bronchopulmonary dysplasia (BPD) and intraventricular hemorrhage (IVH), either by calculating correlations or by assigning infants born preterm to subgroups based on the presence or severity of medical complications.

The predictive value of summary risk scores for early attention development has not been very strong. Although Rose et al. (2001) found that more medical complications were associated with less optimal attention at 5 months, this relationship lost statistical significance at 7 and 12 months. Summary risk scores also showed no relationship to inattentiveness during the first year of life (Rose et al., 2002a), AB performance at 2 years (Woodward et al., 2005), or sustained attention during problem solving at 4 years (McGrath et al., 2005). However, Sun (2003) reported that, although infants born preterm with high medical risk scores did not differ significantly from infants born preterm with low medical risk scores on sustained attention and AB performance measures at 8 months, the difference in AB performance between high medical risk infants born preterm and infants born at term was greater (and significant) than low-risk infants born preterm and infants born at term. Taking into account that the difference in AB performance between low risk and high risk infants was in the expected direction, and that these groups had small sample sizes, these results suggest that medical risk has a gradual effect on the development of executive attention. However, since infants with lower BW are more prone to medical complications (Aylward, 2002a, 2002b, 2005), it is possible that these groups based on medical risk consisted of roughly the same children as the BW-groups, mentioned earlier.

The results regarding the predictive value of more specific medical complications are mixed as well. The detrimental effects of perinatal brain injury on attention development has been confirmed by Landry et al. (1985), who showed that infants born preterm with IVH displayed longer looks during habituation than infants born preterm without IVH. Ross et al. (1992), however, failed to find any differences in AB performance between infants born preterm with or without IVH at 10 months. Other researchers also did not find significant associations between IVH and inattentiveness in the first year of life (Rose et al., 2002a), or between severity of IVH (grade III or IV) and AB performance at 2 years (Woodward et al., 2005). Butcher and colleagues (Butcher, 2000; Butcher et al., 2002) also failed to find a relationship between a transient form of periventricular leukomalacia (PVL), another perinatal brain injury often seen in infants born preterm, and disengagement or inhibition of return during the first 26 weeks of life. However, Woodward et al. (2005) found that AB performance at 2 years was related to white matter injury at term, which is usually the result of a perinatal insult (e.g., anoxia), in various brain areas (such as the DLPC). Poorer AB performance was also related to increasing volumes of cerebrospinal fluid.

The harmful effects of lung disease were confirmed by the finding that infants who required more oxygen or ventilation assistance had longer look durations, lower shift rate and longer pauses at 5 and 7 months, although not at 12 months (Rose et al., 2001; Rose et al., 2002b). However, neither the presence of respiratory distress syndrome (RDS) was significantly associated with inattentiveness during the first year of life (Rose et al., 2002a), nor was the presence of BPD for AB performance at 2 years (Woodward et al., 2005).

Other neonatal risk factors, which are related to medical complications, have been found to be associated with attention performance in infants born preterm. Longer hospital stay, and lower 1-minute and 5-minute Apgar scores were found to be related to longer looks and lower shift rates in 5- to 7-month-old infants born preterm (Rose et al., 2001; Rose et al., 2002b; Rose et al., 1988). Furthermore, neonatal pain-related stress, indexed by the number of skin-breaking procedures from birth to term, was associated with poorer sustained attention in 8-month-old infants born preterm. However, although early life stress is associated with future elevated cortisol levels, no relationship between cortisol level at 8 months and sustained attention was found in the same study (Tu et al., 2007). Also, children who's mothers had fever and children who suffered from sepsis at the time of delivery performed worse on the AB task at 2 years of age (Woodward et al., 2005). The relationship between maternal fever and outcome was mediated by the level of white matter injury in the brain, as measured by MRI at term, but the relationship between infant sepsis and outcome persisted after white matter injury was controlled for (Woodward et al., 2005).

In conclusion, despite some mixed results, the presence and severity of medical complications seem to have a negative influence on attention development. However, as we stated earlier, since GA, BW and severity of medical complications are interrelated, it is difficult to come to any conclusions about the relative contribution of any of these to attention development. In fact, the reported results from Sun (2003) suggest that the influence of GA, BW and medical risk is not strong enough within the preterm population to add to the effect of prematurity in itself. An attempt to disentangle these neonatal risk factors has been made by McGrath et al. (2005), who investigated sustained attention during problem solving at 4 years in four subgroups of infants born preterm and a full-term control group. Infants born preterm were assigned to a healthy (HPT), medical (MPT), neurological (NPT) and small for gestational age (SGA) group, based on the absence or presence and severity of specific medical complications. They found that infants born at term showed more sustained attention than infants born preterm in the medical and neurological groups, but not the healthy or SGA groups, suggesting that medical complications, but not GA or BW, are important predictors for sustained attention at 4 years.

Postural control. Adequate postural control in sitting and head control is necessary for reaching behaviors, and thus influences the ability to explore objects. Since many infants born preterm show problems in the regulation of muscle tone, early postural control is a potential predictor of attention development in infants born preterm (Wijnroks & van Veldhoven, 2003). In fact, individual differences in postural control have been shown to be related to subsequent attention behavior in infants born preterm. Infants born preterm with clear signs of hyperextension and elbow extension at 6 months showed more off-task behavior (i.e., inattention) during two problem solving tasks than infants born preterm with adequate postural control at 24 months, but not at 18 months (Wijnroks & van Veldhoven, 2003).

Gender. Since mortality and morbidity in infants born preterm is higher in boys than in girls, and male gender is associated with a heightened risk for developmental delay in infants born preterm (Elsmen, Hansen Pupp, & Hellstrom-Westas, 2004; Salt & Redshaw, 2006; Stevenson et al., 2000), gender is a potential predictor for early attention development as well. The results concerning the predictive value of gender are somewhat mixed. Although gender was not related to sustained attention during free play at 8 months (Kopp & Vaughn, 1982; Pridham et al., 2000; Tu et al., 2007), or AB performance at 2 years (Woodward et al., 2005), boys showed poorer sustained attention than girls during problem solving at 4 years (McGrath et al., 2005).

Temperament. Attention abilities are thought to be related to temperamental aspects as well. Temperament has been defined as constitutionally based individual differences in emotional, motor, and attentional reactivity and self-regulation. It has been proposed that attentional efficiency plays an important role in successful self-regulation (Rueda, Posner, & Rothbart, 2004a; Ruff & Rothbart, 1996). Infants born preterm are often described by clinicians and parents as more 'difficult' and 'less responsive', suggesting that infants born preterm have problems with self-regulation. Hence, early parental report of infant temperament, and self-regulation in particular, may be a valuable predictor of attention development in infants born preterm. Nevertheless, the only study in this review that examined the predictive value of temperament shows that responsiveness to care, which is considered to reflect self-regulatory abilities, was not related to sustained attention at 8 months (Pridham et al., 2000).

Environmental factors

Since environmental factors, such as maternal IQ, educational level and socioeconomic status (SES) of the parent(s), quality of the home environment (measured with the HOME) (Bacharach & Baumeister, 1998), maternal knowledge of child development and maternal coping (Veddovi, Gibson, Kenny, Bowen, & Starte, 2004) have been shown to influence cognitive, language and behavioral development in infants born preterm, their predictive value for early attention development is of great interest to many researchers. It is however, not always clear what these factors represent. Most of the time they reflect a mixture of genetic factors, level of intellectual stimulation, and the mother's mental health. SES appeared to be positively related to sustained attention during problem solving at 4 years (McGrath et al., 2005), however, no relationship was found between maternal level of education or quality of the home environment and sustained attention during free play at 8 months (Pridham et al., 2000). Also no significant relationship was found between SES, maternal level of education or family income, on the one hand, and AB performance at 2 years, on the other (Woodward et al., 2005). Sun (2003) found that maternal psychological wellbeing, but not maternal level of education or family income, was related to AB performance in 8-month-old infants born preterm and born at term.

An environmental factor that can be observed more directly is the social interaction a parent has with an infant. Research has shown that observed maternal scaffolding during interaction immediately increases the complexity of infant exploratory play and that this effect was even more apparent in medically high-risk infants born preterm than in low-risk infants born preterm and infants born at term (Landry, Chapieski, & Schmidt, 1986; Landry, Garner, Swank, & Baldwin, 1996). Moreover, maternal interactive behaviors during play have been demonstrated to influence later global cognitive abilities, language skills and behavioral outcomes in both infants born preterm and infants born at term (Assel et al., 2002; Murray & Hornbaker, 1997; Schmidt & Lawson, 2002; Wijnroks, 1998), and these beneficial effects of high quality interactions are even greater for infants born preterm (Landry et al., 1986; Landry, Smith, Swank, Assel, & Vellet, 2001; Poehlmann & Fiese, 2001; Smith et al., 1996). The few studies investigating the influence of maternal interactive behaviors on early attention in infants born preterm show some different results (Pridham et al., 2000; Tu et al., 2007; Wijnroks, 1998). The effects of maternal behaviors were demonstrated in a study by Pridham et al. (2000), who found that 8-month-old infants born preterm of mothers, who more often used attention redirecting behaviors (i.e., directing of attention to another object than the one already attended to by the infant), showed less sustained attention when playing alone. The buffering effect of maternal behavior on sustained attention in 8-month-old infants born preterm was also demonstrated by Tu et al. (2007), who found that a higher quality of maternal interactive behaviors was related to better sustained attention, in mothers who experience low parenting stress but not in mothers who experience high parenting stress. Wijnroks (1998) found, however, that quality of maternal interactive behaviors, such as attention redirecting behaviors, in the first year of life was not predictive of sustained attention in the second year of life in infants born preterm. Surprisingly, no studies were found investigating the influence of maternal behaviors on the development of orienting of attention or executive attention.

Early attention development as predictor of later attentional, global cognitive and behavioral functioning

In the beginning of this paper we discussed the importance of attention processes for subsequent development. When attention does play this important role in development we would expect early attention to be a powerful predictor of future functioning. The few studies that have investigated the predictive value of early attention development indicate that individual differences in early orienting of attention and sustained attention are indeed important predictors of later attentional, as well as cognitive and behavioral functioning (Cohen & Parmelee, 1983; Kopp & Vaughn, 1982; Lawson & Ruff, 2004; Ruff et al., 1990; Sigman & Beckwith, 1980; Sigman, Cohen, Beckwith, & Parmelee, 1986).

Orienting of attention in infants born preterm has been shown to be modestly stable over the first year of life (Rose et al., 2001; Rose et al., 2002a). For example, Rose et al. (2001) showed that individual differences in looking duration and shift rate were modestly stable between 5 and 7 months, and between 7 and 12 months of age (Rose et al., 2001). The same was found for individual differences in the frequency of anticipatory eye movements from 5 to 7 months, and from 7 to 12 months of age (Rose et al., 2002a). The predictive value of early orienting of attention for later global cognitive functioning was demonstrated in a study by Sigman and Cohen and colleagues (1980; 1983; 1986), who demonstrated that infants born preterm who displayed longer looks at 40 weeks gestational age (i.e., the expected due date) received lower developmental scores at 18 and 25 months of age (Sigman & Beckwith, 1980), and lower intelligence scores at 5 years (Cohen & Parmelee, 1983), and at 8 years (Sigman et al., 1986). So, surprisingly, even though the developmental trend of looking duration (Colombo, 2001, 2002) might suggest that longer looking during this period in life is a sign of initial higher alertness, these results suggest that longer looking at the expected due date can be considered a risk factor for subsequent developmental delay.

With regard to the stability of sustained attention, Ruff et al. (1990) found that sustained attention in 1-year-old infants born preterm was predictive of sustained attention at 3,5 years, but not 2 years. Lawson and Ruff (2004) found that sustained attention during free play in 7-month-old infants born preterm was predictive of sustained attention at 2 years, but not 3 years. Additionally, they found sustained attention at 7-months to be predictive of behavioral problems (i.e., hyperactivity and impulsivity) at 4 to 5 years, and global cognitive abilities at 2, 3 and 4 to 5 years. The predictive value of early sustained attention for later global cognitive abilities was also demonstrated by Kopp & Vaughn (1982), who found that boys, but not girls, born preterm who showed more sustained attention during exploratory manipulation at 8 months had higher developmental scores at 2 years.

In sum, individual differences in early orienting of attention show modest stability during the first year of life and are predictive of later global cognitive development and intelligence scores in children born preterm. In addition, individual differences in sustained attention show stability during infancy and the preschool years and are predictive of later global cognitive and behavioral functioning in children born preterm. Unfortunately, there are no studies, to our knowledge, investigating the stability or predictive value of early executive attention in infants and children born preterm.

Discussion

The aim of this review was to (1) identify differences in attention development during infancy and the preschool years between children born preterm and children born at term, (2) distinguish important environmental and biological predictors of attention development in children born preterm, and (3) examine the predictive value of early attention development for later functioning in children born preterm.

First, the results described in this review indicate that infants born preterm show less mature visual orienting of attention, less sustained attention and have more trouble with executive attention when compared to infants born at term. Although less efficient attention may not always be evident during infancy, and infants born preterm may even show some initial superior attentional functioning, problems with attention seem to become more apparent as infants born preterm grow into toddlers. Studies investigating executive attention also suggest that infants born preterm have particular problems with the inhibition of potential distracters during executive attention tasks, instead of the expected inhibition of a prepotent response. This unique pattern of errors suggest that the attention problems of infants and children born preterm are not so much the same as attention problems in other populations, but may well be qualitatively different. Second, the literature also shows that early attention development in children born preterm is influenced by biological factors as well as environmental factors. Although additional extrauterine experience may give infants born preterm an initial advantage, the (im)maturational aspects of preterm birth (and perhaps related factors such as neonatal stress) seem to override these effects in time. While some evidence is more convincing than others, biological factors that have been shown to increase the risk of early attention problems in infants born preterm are gestational age, lower BW, more severe medical complications, male gender, and inadequate postural control. Environmental factors that have been found to be associated with attention problems in infants born preterm are lower SES, lower maternal psychological wellbeing and maternal attention redirecting behaviors. Third, while there is little information about the stability and predictive value of early executive attention for later functioning, early orienting of attention and sustained attention show stability during the first year and the first three years of life, respectively. Moreover, early orienting of attention is related to global cognitive development during preschool-age and intelligence during school-age. In addition, sustained attention during infancy is related to cognitive abilities and behavioral problems in children born preterm, during the preschool years.

These findings give rise to several explanations and raise new questions. First, although children born preterm show problems in attention behaviors that are associated with Posner's three attention networks, the conclusion that all networks are compromised in children born preterm must be handled with care. As Posner has emphasized, the three networks are interactive, leaving open the possibility, for example, that less optimal performance on sustained attention tasks may be caused by an increased influence by the executive control system over the arousal system. Because most studies concentrate on behaviors associated with only one of the attention networks, there is little to no knowledge about the interaction between attention networks, and how dysfunction in one network may result in less optimal development and functioning of the other networks.

Also, there are several explanations for the observed trend of a decline in attentional skills in children who were born preterm. Three explanations – which are not mutually exclusive – focus on developmental processes in children. First, it is suggested that subtle deficits in early infancy cause infants born preterm to have less successful experiences and less opportunity to learn (Aylward, 2005). As a consequence, small initial differences may expand over time. A second possibility is that, as the brain matures and children become more capable of complex cognitive processes, subtle deficits in infants born preterm become more apparent (Sesma & Georgieff, 2003), sometimes referred to as 'growing into deficit' in the neuropsychological literature. A third reason has to do with increasing demands from the environment when infants become toddlers, requiring more complex skills and challenging preterm born children's vulnerable abilities (Sesma & Georgieff, 2003). It should be noted, however, that the conclusions in this review are based on comparisons between studies which differ greatly not only in the attention measures they use, but also in sample characteristics (including age of the children). For this reason, two alternative explanations for a decline in attentional skills must be considered. One explanation has to do with differences in birth cohorts. Preterm populations studied, say, 20 years ago (e.g., cohorts studied by Landry et al., 1985 and Rose et al., 1988, 1991) are likely to differ in type and extent of medical complications suffered by the children compared to more recently studied preterm populations, because they were born at a time when treatments and technologies in neonatal intensive care units were less advanced (Aylward, 2002a, 2002b). On the other hand, new medical treatments that have resulted in the increased survival of infants born preterm, may have changed the composition of the preterm population to a more high-risk one, and these treatments may also have detrimental effects on development on their own. Steroid treatment, for example, has been linked to lower attention scores in 8-year-old children, who were born preterm and suffered from BPD (Short et al., 2003). A second alternative explanation for a decline in attentional skills lies in the use of correction for prematurity. In the assessment of premature infants it has become standard practice to correct the child's age for prematurity, at least for the first two years of life (Aylward, 2002a, 2002b; Wilson & Cradock, 2004). Accordingly, the studies in this review that were conducted during the first two years of life did correct for prematurity, whereas the majority of studies conducted at later ages did not (see Table 1b, Sample characteristics continued). The possibility that the trend of worsening outcome with age is confounded by an age-related change in correction for prematurity should therefore not be discarded. Moreover, closer inspection of differences within the preterm population may uncover other developmental courses, besides a trend of worsening outcome. In a review on cognitive development and brain plasticity in children born preterm, Luciana (2003) refers to three other possible developmental paths observed in animal studies. In the first developmental course, damage is so severe that development is hindered without recovery. In the second, development follows the expected path regardless of evidence of injury. In the third, development may be slowed initially but there seems to recover with increasing age.

In addition, the risk and protective factors that were discussed complicate the subject even more. While associations between early attention development and several biological and environmental factors have been found, relationships were not always strong and results from different studies were mixed. A possible explanation for these incongruent results is that the impact of different factors varies with different forms of attention or becomes visible at different ages. It has been shown, for example, that environmental effects on development become more apparent around 24 to 36 months of age (Aylward, 2002b). The interaction between biological risk factors and environmental factors makes the issue even more complicated, especially since many children are exposed to both biologic and environmental risk. Environmental influences can temper or aggravate the developmental problems that occur as a result from biologic factors. Although extreme biological events may override moderating environmental influences (Aylward, 2002a, 2002b), infants born preterm with high medical risk may be more susceptible to positive or negative environmental influences than infants born preterm with low medical risk (Landry et al., 1986, 1996). The influence of environmental factors may also be dependent on infant characteristics, such as temperament. A study with 4-month-old infants born at term showed, for example, that highly responsive infants show better attentional performance if parented by mothers who were less actively involved during toy play interactions (Miceli, Whitman, Borkowski, Braungart-Rieker, & Mitchell, 1998). Thus, what seems to be of crucial importance – especially for infants at risk – is the fit between parental interactive styles and infant characteristics.

Although the relationship between temperamental self-regulation and attention development has been discussed briefly, the single study that investigated this relationship found no significant association. The topic, however, is of considerable relevance, since brain-imaging studies have shown that self-regulation is associated with activation of (partly) the same brain structures as executive attention (Rothbart & Posner, 2005; Rueda et al., 2004a; Rueda, Posner, & Rothbart, 2005a). Although some researchers emphasize that attentional functioning influences self regulatory abilities (e.g., attention to a visual stimulus can have a powerful soothing effect) (Rueda et al., 2004a, 2005a), and others stress that problems in attentional control are caused by deficits in self-regulation (Davis & Burns, 2001), it is difficult to say which ability emerges first. Keeping the findings for a similar brain basis in mind, it is probably more likely that self-regulatory and attention abilities develop at roughly the same time, each influencing the development of the other.

It should also be noted that there are potential predictive factors that have not been discussed here. Risk factors that – to our knowledge – have not yet been investigated in relation to early attention development, but have been shown to be predictive of attention performance in school-aged children born preterm are problems in peripheral sensory systems (i.e., stereopsis) (Torrioli et al., 2000), and early minor motor difficulties (Jeyaseelan, O'Callaghan, Neulinger, Shum, & Burns, 2005). There is also increasing interest in the consequences of perinatal brain injury in specific brain areas, such as the hippocampus and the caudate nucleus, which have important interconnections to the prefrontal cortex (Abernethy, Cooke, & Foulder-Hughes, 2004; Luciana, 2003).

In conclusion, review of the literature confirms that infants and preschool children who are born preterm show less efficient attention behaviors than infants and preschool children born at term. Furthermore, early individual differences between children born preterm are influenced by biological as well as environmental factors, and are predictive of later attentional, cognitive and behavioral functioning. However, from this review it also becomes clear that some important questions remain insufficiently answered: (1) how stable are individual differences in orienting, sustained and executive attention from infancy until adolescence? (2) do problems in one attention network influence the functioning and development of other attention networks?, (3) are patterns of change in children born preterm indeed characterized by a decline over time, structural delay, catch-up, or by a combination of these?, (4) how does the influence of biologic and environmental factors vary over time and how do these interact?, and (5) how do early individual developmental trajectories in attention predict later attentional, cognitive and behavioral functioning? To answer these questions, future follow-up studies should ideally cover the age range from infancy to adolescence, with regular measurements of different attention processes, taking into account several biological and environmental predictors. Repeated measures of environmental factors at different ages are necessary to investigate whether there are periods when infants or children are particularly sensitive for environmental influences. If possible, infants born preterm should be compared to infants born at term of the same corrected age as well as the same chronological age after the second year of life, to rule out effects of age-adjusted scores. However, when elimination of a full-term control group results in larger sample size(s) in preterm (sub)group(s), this may be a serious consideration. Large sample sizes allow one to look more closely at individual differences in developmental trajectories between infants born preterm. Also, we need to be more precise about which neurological processes can lead to later attentional difficulties and how these processes might be mediated by the influence of experience and moderated by specific child characteristics, such as self-regulation. In this review, the neuropsychological model of attention development by Posner and colleagues (Posner & Petersen, 1990; Posner & Raichle, 1994) has proven to be a useful framework to group the vast amount of studies from different backgrounds, investigating visual attention in infants and preschool children born preterm. In fact, more recently, an adult test for the efficiency of the orienting, alerting and executive attention networks, the Attention Network Test (ANT) (Fan, McCandliss, Sommer, Raz, & Posner, 2002) has been adapted to study the development of these networks during childhood (Rueda et al., 2004b), and has been used to study attention in children as young as 4 years of age (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005b). Therefore, Posner's model of attentional networks provides a useful framework to structure future attention research in a more developmental perspective, especially since its provides a well-established battery of measures for the functioning of the attention networks from childhood into adulthood.

Understanding of the specific attention problems that infants and children born preterm face, and the biological and environmental factors that influence them is crucial for effective intervention. Knowledge on the biological risk factors that make infants born preterm vulnerable to problems in attention can be helpful in the early selection of groups of infants for follow-up programs and intervention. A better understanding of how maternal interactive behaviours interact with infant characteristics is necessary to customize intervention to individual parent-infant dyads. Also, when there is more insight in which aspects of attention are most prone to delay or dysfunction, specific attention trainings can be developed to influence the efficiency of attentional functioning. There has been an encouraging report of an executive attention training in 4-year-old and 6-year-old children, in which the training increased not only attentional functioning (demonstrated by higher attention scores and more adult-like brain activation), but also increased overall IQ (Rueda et al., 2005b).

3

Individual differences in developmental trajectories of A-not-B performance in infants born preterm

E. van de Weijer-Bergsma, L. Wijnroks, J. Boom,
L.S. de Vries, I.C. van Haastert, M.J. Jongmans

Submitted for publication in
Developmental Neuropsychology

Abstract

Since early attention and executive functioning are potentially important predictors of developmental delay and learning difficulties in infants born preterm, this study assessed the effect of several perinatal predictors on the development of A-not-B performance between 7 and 14 months corrected age in 76 infants born preterm, and its relationship to subsequent global cognitive functioning. Latent Growth Modeling showed that gestational age, respiratory problems and intraventricular hemorrhage were predictive factors of the rate of developmental change in A-not-B performance. Moreover, initial level and rate of developmental change in A-not-B performance were predictive of global cognitive functioning.

Introduction

With increased survival rates in infants who are born preterm (gestational age < 37 weeks) and/or with a low birth weight (LBW < 2500 grams), concerns about their increased risk for major developmental disabilities (e.g., mental retardation, sensory disorders and cerebral palsy) as well as low severity dysfunctions (e.g., learning disabilities and attention deficit/hyperactivity disorder (ADHD)) have grown (Anderson & Doyle, 2003; Aylward, 2002a, 2005; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Salt & Redshaw, 2006). Major disabilities are often detected early in life. Low severity dysfunctions, however, are difficult to detect during infancy or early childhood, although they become more apparent when children grow older (i.e., at school age) (Aylward, 2005; Luciana, 2003).

Although there is a vast amount of studies investigating early cognitive development of children born preterm, there are some methodological issues that limit the conclusions that we can draw from previous studies. Firstly, most studies investigating the early cognitive development of children born preterm have concentrated on global outcome measures, using scores on developmental assessments, such as the Bayley Scales of Infant Development (Bayley, 1969). Because these global measures usually appeal to various underlying functions and abilities, they are often poor predictors for later functioning (Hack et al., 2005; Johnson, Wolke, & Marlow, 2008; Siegel, 1989; Slater, 1995). As a result, there is a gap in our understanding of the underlying deficits or processes that cause developmental problems in children born preterm. Thus, there is a need to focus on more specific cognitive processes, such as attention, inhibition and working memory (Aylward, 2002a).

Secondly, the focus of most of these studies lies on the comparisons between preterm and full-term groups. However, the finding that children born preterm, as a group, lag behind, when compared to children born at term, does not explain the variability within the group of children born preterm, or why some of these children even outperform children born at term. More recently, researchers are becoming increasingly aware that it is important to focus on the variability *within* the preterm population (Carmody et al., 2006; Espy, Senn, Charak, Tyler, & Wiebe, 2007; Korkman et al., 2008), which is, for an important part, influenced by differences in perinatal risk.

Thirdly, however, conclusions are often limited as a result of operationalisations of perinatal medical risk. Perinatal risk factors that are considered to be predictive of cognitive development in infants born preterm are gestational age (GA), birth weight (BW), and the presence and severity of several medical complications that are associated with preterm birth. That is, the immaturity of organs systems (especially the brain), which is related to being born at a lower GA, has its possible consequences for the development of these children. Although BW is related to GA, preterm infants who are small for their GA are likely to have suffered prenatal physiological stress due to maternal malnutrition or placental insufficiency (Luciana, 2003). Medical complications that have been linked to suboptimal cognitive development are brain injury and respiratory problems. The two most common causes of brain injury in infants born preterm are intraventricular hemorrhage (IVH) and periventricular leukomalacia (PVL), which are both related to either the reduction in oxygen supply to bodily tissues (i.e., hypoxia) or more severe low oxygen level due to inadequate blood flow (i.e., ischemia). Important brain regions that are vulnerable to hypoxia and ischemia are maturation dependent and include the frontal cortex and the striatum, which has dense interconnections with the hippocampus, thalamus and prefrontal cortex. Infants who are born preterm are also at risk for infant respiratory distress syndrome (IRDS), often resulting in chronic lung problems (i.e., brunchopulmonary dysplasia; BPD), which in turn may result in chronic hypoxia of the brain (Luciana, 2003). The influence of those perinatal risk factors is often investigated by assigning children born preterm to groups based on one of those factors (e.g., extremely LBW (ELBW) versus very LBW (VLBW) groups, or IVH versus no-IVH groups), or use summary risk scores. However, dividing infants into, for instance, BW or GA groups is often based on arbitrary boundaries, in which much information is lost compared to when continuous data is used. In addition, since infants with lower BW or lower GA are more prone to medical complications (Aylward, 2002a, 2002b, 2005), BW or GA groups are likely to differ on the severity of medical complications as well. Finally, summary risk scores conceal information about the influence of more specific medical complications.

So, to do justice to the complexity of the origins of preterm children's heightened risk for developmental delay and learning disabilities, there is a need for longitudinal studies on the early development of underlying, more specific cognitive processes, with a focus on explaining the individual variability within the preterm population by using continuous data on several perinatal risk factors.

More recently, the finding that school-aged children, who were born preterm, are at risk for attention problems and executive dysfunction possibly leading to a diagnosis of ADHD (Aylward, 2002a; Bayless & Stevenson, 2007; Bhutta et al., 2002; Mick, Biederman, Prince, Fischer, & Faraone, 2002; Salt & Redshaw, 2006; Shum, Neulinger, O'Callaghan, & Mohay, 2008; Smith, Keeney, Zhang, Perez-Polo, & Rassin, 2008), has led researchers to suggest that problems in the early development of attention and executive functioning may underlie the individual variability between infants born preterm and their vulnerability as a group for developmental delay and learning problems (Aylward, 2002a; Davis & Burns, 2001). The term executive functioning (EF) relates to planned, self-generated and goal-directed behaviors which require higher-order control over more automatic responses. The development of EF is related to the functioning of the prefrontal cortex, more specifically the dorsolateral prefrontal cortex (DLPFC), which starts to mature when infants develop into toddlers

(Goldman-Rakic, 1987). Although there is general consensus that attention and executive functioning are strongly related, there is still much discussion on how they are related (Garon, Bryson, & Smith, 2008; Kane & Engle, 2002; Posner & Petersen, 1990; Posner & Raichle, 1994). The issue whether there are several dissociable EF abilities such as working memory, inhibition, set-shifting and attention or whether one underlying process such as attention or inhibition is involved in all EF abilities, is open to debate. Although there is evidence for dissociable EF components, based on factor analyses research in adults, a single factor model of EF was found in preschool children (Wiebe, Espy, & Charak, 2008). It is possible that the component view of EF is based on conceptual assumptions and not a real existent division, at least not during early development. The idea that attention underlies all EF abilities has been suggested by Posner and colleagues who have argued that a central attention system (also called 'the executive attention network') underlies the emerging EF abilities, by regulating other brain networks (Posner & Petersen, 1990; Posner & Raichle, 1994). Recently, Garon et al. (2008) have proposed an integrated view that considers EF to be a unitary construct with partly dissociable components. According to this view, attention is the basic building block for the other EF components to develop from. Until now, it remains uncertain which view is most in agreement with reality.

Nevertheless, from a neuropsychological point of view, there is a marker task of DLPFC functioning available during infancy, which requires both attention as well as executive control processes: the classical Piagetian A-not-B task (Diamond & Goldman-Rakic, 1989). In the A-not-B task infants have to retrieve a hidden object from one of two (or more) locations following a delay. Only after the object is retrieved successfully two times in a row at the first location (location A), the side of hiding is changed (to location B). Performance on this 'reversal trial' is dependent on the infant's ability to keep the location of the toy in mind (working memory), to inhibit reaching to the previously rewarded location (inhibitory control), and to control attention during the task. By increasing the delay between hiding and seeking task-difficulty is increased. Other similar tasks used during infancy and preschool-age are Delayed Alternation and Spatial Reversal in which a reward is hidden out of the child's sight and the side of hiding is changed, either alternating between the left and right location, or changing sides after a criterion of consecutive correct retrievals, respectively (Espy et al., 2002).

A-not-B development in infants born at term

Studies investigating the development of A-not-B performance in infants born at term show that these skills start to emerge around 7 to 8 months, and indicate transition periods around 9 and 12 months of age (Bell & Fox, 1992; Diamond, 1985; Diamond & Goldman-Rakic, 1989). Although only a minority of infants is able to uncover a hidden object at 7 months of age, from 7.5 months of age onwards infants become able to find a hidden object even on reversal trials and the delay infants can tolerate increases with increasing age. Diamond (1985) reported a gradual and continuous developmental pattern during the first year of life, in which the average delay between hiding and seeking necessary to evoke the A-not-B error (i.e. the failure to retrieve an object on the reversal trial) increases from 2 seconds at 7.5 to 8 months, to 5 seconds at 9 months, to delays of 10 seconds or more at 12 months. Nevertheless, individual differences between infants were large. Also, until 9 months of age many infants have some difficulty retrieving an object after the side of hiding has been reversed, which is assumed to reflect that the DLPFC is still too immature to support the abilities required by the task. Between 9 and 12 months of age, the DLPFC seems to reach the maturity level necessary to support certain critical cognitive functions, although it will not be fully developed until many years later (Diamond, 1991). Similarly, Bell & Fox (1992) reported wide individual variability and a clear change across age, with infants able to handle a reversal trial with an average delay of 1 second at 8 months, 4 seconds at 10 months and 7.5 seconds at 12 months of age. Although Ahmed & Ruffman (1998) have suggested that infants are able to find a hidden object at longer delays when they merely have to look at the correct side of hiding, instead of manually reaching for it, this conclusion is based on the comparison of performance on the regular A-not-B task with performance on a violation-of-expectancy paradigm, in which the duration of looking toward 'possible' and 'impossible' events is investigated(Ahmed & Ruffman, 1998). It has been argued that violation-of-expectancy paradigms only investigate familiarity with certain events, and are not appropriate for testing real knowledge about hidden objects (Bell & Adams, 1999). Bell & Adams (1999), therefore, have investigated the comparability between a looking and a reaching version of the A-not-B task, in which every aspect of the procedure was kept constant, except for the response output, which would involve the Frontal Eye Fields (looking) and the motor cortex (reaching). Indeed, they found comparable performance in 8-month-old infants, on a looking and reaching version of the A-not-B task, indicating that these two versions of the task involve similar but not identical brain circuitry.

A-not-B development in infants born preterm

A recent review on early attention development in infants and preschoolers born preterm has indicated that differences in performance between children born preterm and born at term on the A-not-B tasks and other marker tasks of the DLPFC become more apparent when infants grow into toddlers (van de Weijer-Bergsma, Wijnroks, & Jongmans, 2008). That is, whereas high risk infants born preterm (e.g., who suffered more medical complications) performed poorer than infants born at term (Ross, Tesman, Auld, & Nas, 1992; Sun, 2003; Sun, Mohay, & O'Callaghan, 2008), relatively healthy low risk infants born preterm were found to outperform infants born at term on both a looking and a reaching version of the A-not-B task , which indicates a possible advantage of additional experience outside the womb for healthy infants born preterm (Matthews, Ellis, & Nelson, 1996). During toddler hood however, poorer performance on A-not-B type tasks was found not only in high risk (Woodward, Edgin, Thompson, & Inder, 2005) but also in low risk preterm born populations (Espy et al., 2002). These results also indicate that the predictive value of perinatal risk factors for individual variations *within* the preterm population may vary over time. Since the results with regard to this issue are rather inconsistent between studies, it remains unclear which factors contribute the most to the poorer performance of children born preterm. Sun (2003), for example, did not find a significant effect of GA, BW, or medical risk on A-not-B performance in 8-month-old infants born preterm when infants were assigned to GA (born before or after 28 weeks of gestation), BW groups (VLBW versus ELBW) or high versus low medical risk groups. It should be noted that the results from the groups based on BW and medical risk were in the expected direction. The failure to reach statistical significance is probably due to small sample sizes. At 10 months of age, Ross et al. (1992) found that A-not-B performance did not differ between infants born preterm with low severity IVH (grade I or II) or without IVH. At 2 years of age, poorer performance on the A-not-B task was associated with lower GA, infant sepsis and maternal fever at the time of delivery, increasing volumes of cerebrospinal fluid, and white matter injury at term in the DLPFC and other brain areas. A-not-B performance at 2 years was not found to be related to BW, severity of IVH (grade III or IV), the presence of BPD, or a medical summary risk score (Woodward et al., 2005).

So, several perinatal risk factors seem to be related to the individual differences in A-not-B performance within the preterm population and their impact seems to vary across ages. However, it remains unclear which factors contribute the most and how exactly their influence changes over time. This is partly due to the methodological issues mentioned earlier, such as assignment of infants to BW, GA or medical risk groups with somewhat arbitrary boundaries and considerable overlap and differences in the operationalisation of medical risk.

Limitations and gaps in previous research

In sum, previous studies suggest that poorer performance on the A-not-B task becomes clearer when infants born preterm grow into toddlers, even in children who are considered to be relatively healthy and low-risk. Although several perinatal risk factors have been found to be predictive of individual differences in A-not-B performance within the preterm population, the results are rather inconsistent. Because the majority of the studies described in the previous section did not use a longitudinal design, conclusions about the development and individual variability of A-not-B performance in this population are based on findings from different cohorts and are possibly confounded by other factors. The finding that differences seem to become more apparent when children grow older, hence, may be an artifact of variations in perinatal risk between cohorts. The inconsistent findings with regard to the predictive value of GA, BW and medical risk may also be caused by differences in sample characteristics between cohorts, as well as differences in sample size, and operationalisations of medical risk. Furthermore, none of these studies on infants born preterm investigated how A-not-B performance is related to global cognitive functioning.

Aims of the present study

Because early attention and EF are potential important predictors of later problems in cognitive development and learning of infants born preterm, the aims of the present study were to investigate (1) individual differences in the development of A-not-B performance in infants born preterm by using a longitudinal, within-subjects, design between 7 and 14 months corrected age (CA, age calculated from the expected date of delivery), (2) the predictive value of several perinatal risk factors for the early development of A-not-B performance, and (3) the strength of the relationship between the development in A-not-B performance and subsequent global cognitive development.

Measurement started at 7 months CA to investigate potential effects of additional extra-uterine experience by infants born preterm. Since important transitions are expected at 9 and 12 months of age, the second and third measurements were planned around those ages (at 10 and 14 months CA) in an effort to capture maximal individual variation.

To control for any potential effect of delays in motor development, at 7 and 10 months CA, a reaching as well as a looking version of the A-not-B task was used. Since all infants were expected to master the minimal motor abilities required for reaching at 14 months CA, at this age only a reaching version was administered.

We expect infants born preterm to tolerate increasing delays between hiding and seeking with increasing age. The rate at which the skills necessary to perform on the A-not-B task emerge and develop may vary between individual infants. Although infants who were born at a lower gestational age may have an initial advantage, the rate of developmental change in A-not-B performance is expected to be negatively influenced by a lower GA, a lower BW, and more (severe) respiratory problems, IVH or PVL. The relationship between A-not-B development and global cognitive functioning is expected to be positively related but not very strong, since global cognitive measures tap into a variety of processes.

Method

Participants

During the period of inclusion, between April 2004 and August 2005, a total number of 325 singleton infants born preterm (GA ≤ 36 weeks, BW < 2500 grams) were admitted to the Neonatal Intensive Care Unit (NICU; n = 266) or the Medium Care Unit (MCU; n = 53), or both (n = 6) of the Wilhelmina Children's Hospital in Utrecht, The Netherlands. Ethical permission for the study was granted by the hospital's ethics committee.

Thirty infants died during the neonatal period. Exclusion criteria were congenital or chromosomal disorders (n = 21), (possible) congenital infections such as HIV (n = 2), significant sensory disorders (n = 3), uncertainty about GA (n = 3), and incomplete data (n = 5). Maternal factors that led to exclusion were drug- or alcohol abuse (n = 5), maternal age < 18 years (n = 1), non-biological mother (e.g., egg donation or adoption) (n = 1), parental consanguinity (n = 1), no knowledge or use of the Dutch language (n = 11), maternal death (n = 1), move abroad (n = 3), or alien status (n = 1).

After exclusion, 237 singletons were eligible for inclusion in the study, of which 119 children and their parents were randomly selected and invited by letter to participate. Parents were contacted by phone at least 1 week later to give them the opportunity to ask questions and to ask whether they were interested in participation. Also, even when parents could not be reached by phone, they were able to sign up for the study by returning an informed consent form. Parents of 76 infants consented for their infant to take part in the study (63.9% of the invited parents).

There were no significant differences between participants (n = 76) and non-participants (n = 161) from the NICU and MCU in gender, severity or presence of medical complications such as IRDS, asphyxia or small for gestational age. However, participants were born at a lower mean GA (p < .01), with a lower BW (p < .05), and suffered from more severe IVH (p < .05) than non-participants. Since the great majority of participants in our study were admitted to the NICU (n = 72), a comparison between participants and non-participants from the NICU was also made. Comparison with NICU infants showed no differences in perinatal characteristics. Based on these comparisons we consider our sample to be representative for a NICU population of infants born preterm. None of the infants was diagnosed with cerebral palsy (CP) at 14 months corrected age.

Attrition during the study was very low; only two infants did not complete the study and only participated at the first measurement. Another infant missed the second measurement due to scheduled surgery. Seventy-three infants completed all three measurement sessions but data from five infants had to be excluded, due to incorrect administration of the tasks by one experimenter, leaving 68 infants with complete data for the analysis. Sample characteristics are presented in Table 1.

Measurements

Neonatal medical risk

Information about GA, BW and perinatal medical complications was extracted from hospital files. The presence and severity of brain injury was assessed using cranial

Table 1 Sample characteristics (n = 68)

Variable		Mean (SD)	Range		
Gestational age (weeks)		30.62 (2.26)	26–35		
Birth weight (grams)		1450 (432)	830–2370		
Bayley MDI score (14 months CA)		103.5 (15.6)	66–136		
IRDS grade / BPD	Grade I	Grade II	Grade III	Grade IV	BPD
n	11	8	9	1	7
IVH grade	Grade I	Grade II	Grade III	Grade IV	
n	5	3	6	1	
PVL grade	Grade I	Grade II	Grade III	Grade IV	
n	11	1	0	0	
Asphyxia (*n*)	5				
SGA	SGA	Extreme SGA			
n	2	2			
Gender (*n*)	46 boys (67.7%)				

SD, standard deviation; MDI, Mental Developmental Index; CA, corrected age; IRDS, infant respiratory distress syndrome; BPD, bronchopulmonary dysplasia; IVH, intraventricular hemorrhage; PVL, periventricular leukomalacia; SGA, small for gestational age (3rd percentile > BW < 10th percentile), Extreme SGA (BW < 3rd percentile).

ultrasound. Intraventricular hemorrhage (IVH) was scored ranging from 0 (no IVH) to 4 (IVH grade IV) (Papile, Burstein, Burstein, & Koffler, 1978). Periventricular leukomalacia (PVL) was scored ranging from 0 (no PVL) to 4 (PVL grade IV) (de Vries, Eken, & Dubowitz, 1992). Infant respiratory distress syndrome (IRDS; grades I-IV) (Giedion, Haefliger, & Dangel, 1973) and / or bronchopulmonary dysplasia (BPD) resulted in a respiratory score, ranging from 0 (no respiratory problems) to 5 (BPD). Since male gender is considered a biological risk factor for developmental problems, gender was also used as a predictor (score 0 = male, score 1 = female). Although asphyxia and being small for gestational age (SGA) were also considered potentially important perinatal predictors, variation in these predictors was too small to include them in the analysis.

A-not-B performance

Based on procedures by Diamond and colleagues (Diamond, 1985; Diamond & Goldman-Rakic, 1989; Diamond, Prevor, Callender, & Druin, 1997) and Bell & Adams (1999), age-appropriate reaching and looking versions of the A-not-B task were administered at 7 and 10 months CA, whereas at 14 months CA only a reaching version was administered (see Table 2 for A-not-B procedures).

In the ***reaching version of the A-not-B task***, infants were seated on their mothers' lap at a table, measuring 90 cm (L) x 60 cm (W) x 75 cm (H), painted in a light blue color, covered by a tabletop of the same color. When the tabletop was removed, two wells embedded in the table appeared, 11 cm in diameter, 5 cm deep, and 30 cm apart from center to center. For the first three items, when no wells were used, the table was covered by the tabletop of the same color. Yellow fabric cloths used to cover the toy measured 20 cm square. Infants were seated at the table, so they were positioned in the midline of the wells and able to look and reach into the wells. The experimenter was seated at the opposite side of the table facing the infant and the parent. A large assembly of toys, varying in shape, color and texture and sized to fit in the wells was accessible to the experimenter. To ensure that the reaching and looking versions of the task are similar in every aspect, the infant's gaze to the hiding site was broken and brought to the midline by calling the infant's name. Testing always started with a toy partially hidden under a cloth (item 1, see Table 2), to make sure that an infant was able to retrieve a hidden object. All items were administered maximally three times. When an infant was able to find a hidden object under one of two identical cloths (item 3), A-not-B testing began. After two successful retrievals at side A, the toy was hidden in the opposite side B (i.e., reversal trial). When infants successfully retrieved the toy from the B well in two out of three A-A-B trials (i.e., did not make the A-not-B error) the delay between hiding and seeking was increased. Complexity of the task was increased by increasing the delay between hiding and seeking from 0 to 1 to 3 to 5 to 8 seconds. Scores ranged from 0 to 8 (see Table 2). During hiding and the delay, mothers were asked to hold their infants' hands to keep them from reaching too soon. The question "Where is the toy?" from the experimenter served as a signal for mothers to allow their infant to reach and search the toy.

In the ***looking version of the A-not-B task***, infants were seated on their mother's lap, 110 cm from the same testing table, covered by the light blue tabletop. Two identical blue

Table 2 Procedures A-not-B task

Item		Score	Corrected age (months)		
			7*	10*	14†
1	Object partially covered by one cup / cloth	1	S	S	X
2	Object completely covered by one cup / cloth	2	X	X	X
3	Object hidden under one of two identical cups / cloths	3	X	X	X
4	A-not-B with 0 second delay	4	X	X	X
5	A-not-B with 1 second delay	5	X	X	X
6	A-not-B with 3 second delay	6	X	X	X
7	A-not-B with 5 second delay	7	X	X	S
8	A-not-B with 8 second delay	8	X	X	X
9	A-not-B with invisible displacement, 3 second delay	9			X
10	A-not-B with invisible displacement, 5 second delay	10			X
11	A-not-B with invisible displacement, 8 second delay	11			X

* Both a looking and a reaching version of the task was administered; † Only a reaching version of the task was administered. X, item part of testing procedure at that age.

and orange cups (Ø 11 cm) were used to hide the toys. Two circles on the tabletop marked the position left and right locations of hiding, where the experimenter manipulated a mechanical toy and hid it under one of the two cups. After the toy was hidden, the infant's gaze to the hiding site was broken and brought to the midline by calling the infant's name. The administration of the looking version was identical to the reaching version, except that eye movements were scored as performance behavior, instead of reaching and uncovering a well. The direction of the first eye movement after being brought to midline was scored as either correct or incorrect. Gaze direction during delays was kept at midline by keeping eye contact and counting out loud during the period of the delay.

A-not-B with invisible displacement. At 14 months CA the reaching version of the A-not-B task was adjusted, and more complex items were added to the task, in which displacement of the hidden toy was invisible. These invisible displacement items were based on the A-not-B task with invisible displacement by Diamond et al. (1997). Infants were seated at a table on their mothers' lap. Instead of two hiding wells, two orange and blue cups (Ø 11 cm, height 12 cm) were used to hide the toys. To make the toys easy accessible, no lids were used. The infants were seated low enough so they were not able to see the toy once it was placed inside the cup. Since infants of this age are expected to have more trouble sitting still on their mother's lap and A-not-B performance at this age is assumed to be more stable, a different, more flexible testing procedure was used, than at 7 and 10 months CA. Administration always started with a 'regular' A-not-B trial with 5 seconds delay (item 7). When an infant's reach on the reversal trial was correct, the delay was incremented to 8 seconds, whereas a wrong reach on the reversal trial resulted in a shortening of the delay to 3 seconds. When the infant reached correctly at this delay, the 5 second delay was administered again. Administration of the test ended when an infant failed an item twice. If an infant successfully recovered an object at a delay of 8 seconds, the invisible displacement items were introduced. In these items infants did not see the toy itself change position, but saw the cup with the hidden toy move to the left or the right changing position with the second cup. Although a reaching response is necessary for performance, these items also have a large visual component. After two successive correct reaches, the side of hiding was changed. Again, complexity of the items was increased by increasing the delay between hiding and seeking from 3 to 5 to 8 seconds. Scores ranged from 0 to 11 (items 1 to 8 were identical to the items of the A-not-B reaching task, see Table 2).

Global cognitive functioning

Global cognitive functioning was measured at 14 months CA using the Mental Scale of the Bayley Scales of Infant Development (BSID-II NL) (van der Meulen, Ruiter, Lutje Spelberg, & Smrkovsky, 2002), resulting in a Mental Developmental Index (MDI) score (expected mean = 100, SD = 15). Administration of the BSID-II-NL was based on the corrected age of the infants, and always started at the items for 14-month-old children.

Procedure

Mothers and infants were visited at home at 7 months CA (± 1 week) and 10 months CA (± 1 week), and were invited for assessment at our laboratory at 14 months CA (± 1 week). Parents did not receive payment for their participation, but did receive refunding for traveling expenses. Infants were rewarded with a surprise gift after every appointment, consisting of an age-appropriate toy. Measurement sessions were planned at a time of the day when parents expected their infant to be alert. When infants were asleep at arrival, testing was postponed until they awoke. Also, testing was paused when necessary (e.g., in case of fussiness, mealtime, diaper change), but breaks were held in between tasks when possible. Assessments were part of a larger battery of tests and observations, which were recorded on video. The sequence of tasks was kept constant for all participants. During home visits, at 7 and 10 months CA, assessment started with the looking and reaching versions of the A-not-B task, respectively. Then infants played alone for 4 minutes during a sustained attention task. Finally, infants played for 5 minutes with their mothers. For every measurement session 2½ hours were reserved. In practice, no appointment exceeded 1½ hours, of which infant testing took approximately 20 to 40 minutes. The 14-months assessment at our laboratory started with the A-not-B task with invisible displacement. Next, the Mental Scale of the BSID-II was administered, followed by the sustained attention task. Finally, mother and infant played together for 5 minutes. Again, appointments did not exceed 1½ hours, and pauses were held when necessary. After the third session, parents received a report of their infant's performance on the Mental Scale of the BSID-II and a copy of all video materials. Infants with a developmental score below 85 were invited for an aftercare follow-up at 2 years of age by a special educator/ developmental specialist (ICvH) at the children's hospital.

Tasks were administered by the first author and four experimenters, who were trained by the first author. Correct administration of the tasks was controlled by the first author.

Statistical analysis

Latent Growth Modeling (LGM) was used to model the individual developmental trajectories for performance on the A-not-B task, the influence of perinatal medical risk factors (GA, BW, IVH, PVL, IRDS or BPD, and gender) on these trajectories, and their subsequent relationship to global cognitive functioning. LGM makes it possible to investigate individual variability in developmental trajectories, as well as testing the influence of predictors in order to explain this variability. In LGM, each individual's growth over time (i.e., developmental trajectory) is represented by a regression line, which can be described by a unique intercept (initial level) and slope (rate of change). As a result, a given sample is described by group means and variances for intercept and slope, which are assumed to be distributed normally. Predictor variables can be incorporated to explain the inter-individual variance in initial level and rate of change. Because variances, by definition, cannot be smaller than zero (i.e., a negative value) and thus two-sided testing gives an underestimated significance level (Stoel, Garre, Dolan, & van den Wittenboer, 2006), one-sided *p* values were considered to investigate the significance of variance around the intercept and slope means. One-sided *p* values were also considered when associations between variables were in the expected direction. To prevent wrongful removal of non-significant paths from the model due to low statistical power or a sample smaller than 100 (Kline, 2005), paths were maintained in the model at a 0.10 significance level.

Growth models were analyzed using Amos (version 7.0; Arbuckle, 2006). Overall model fit was evaluated by Chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI). By convention, models have a good fit if χ^2 is low, RMSEA is less than 0.05, and CFI and TLI are close to 1 (Arbuckle, 2006). The chi-square difference statistic ($\Delta\chi^2$), which tests the null hypothesis of identical fit, was used to test the statistical significance of the decrement or improvement in overall fit as paths are eliminated (trimming) or added (building), respectively. When trimming the model, the removal of a path should not lead to a significantly worse model. In line with this, acceptance of the null-hypothesis (a small $\Delta\chi^2 < 3.84$) indicates a significant improvement of the model, because one degree of freedom is gained. In contrast, when building a model, the loss of one degree of freedom should lead to a large enough decrease in χ^2 ($\Delta\chi^2 > 3.84$) to reject the null-hypothesis, i.e., that the models are identical (Kline, 2005).

Results

Normality of distributions, descriptives and correlations

Normality of the distributions of the variables was examined by calculating the standardized skewness and kurtosis index (statistic divided by standard error). None of the values were found to be higher than 3, indicating that the distributions did not significantly differ from normality.

Descriptive values and correlations are presented in Table 3. Inspection of the percentages of infants who passed the first A-not-B item shows that the vast majority of infants were not able to handle a reversal trial at 7 months CA. A McNemar test showed

Table 3 Descriptives and correlations for the A-not-B task (*n* = 68)

				7 months CA		10 months CA	
		Mean (SD)	% of infants passing A-not-B reversal	Looking *p*	Reaching *p*	Looking *p*	Reaching *p*
7 months CA	Looking	1.76 (0.98)	1.5%				
	Reaching	1.56 (1.06)	2.9%	.042			
10 months CA	Looking	2.81 (1.36)	22.1%	.000	.034		
	Reaching	3.94 (2.01)	45.6%	.008	.226*	.202*	
14 months CA	Reaching	6.51 (2.17)	85.3%	.044	.042	.296**	.065

SD, standard deviation; CA, corrected age. 1-tailed significance *$p < .05$, **$p < .01$.

that the number of children who can handle a reversal trial (i.e., item 4) increased significantly from 7 to 10 months CA ($p < .000$), as well as from 10 to 14 months CA ($p < .000$). At 14 months CA the vast majority of infants was able to handle reversal trials during the A-not-B task. This indicates that the ability to execute control emerges around 10 months CA in infants born preterm.

Growth models of A-not-B performance

First, growth of performance on the looking and reaching A-not-B task was modeled by a linear trend. The first measurement occasion at 7 months CA was chosen as time point zero. To account for differences in interval between measurements, regression weights for the slope were fixed at 1 and 2.3 for the measurements at 10 and 14 months CA, respectively. This model did not fit the data well. In the next step, the observed variable mean of the looking version at 10 months CA was relaxed, allowing the looking and reaching versions to differ at this age, because a paired samples t test showed that performance at 10 months CA was significantly higher on the reaching version than on the looking version of the A-not-B task ($t\ (67) = -4.26$, $p < .001$). This model provided a significant improvement ($\Delta\chi^2 = 27.47$, df = 1, $p < .000$) and fitted the data well. Then, removal of the non-significant covariation between the intercept and slope factor did not result in a significant decrement ($\Delta\chi^2 = 0.11$, df = 1, $p = .75$) and fitted the data well[1,2] (model fit indices are presented in Table 4). This last model, with a mean intercept factor of 1.68 ($p < .001$) and a mean slope factor of 2.12 ($p < .001$),

[1] To investigate whether growth was indeed best described by a linear growth curve, the linear model was compared to a non-linear model. In this non-linear model the first two loadings were fixed to 0 and 1, but the third loading was freely estimated. The results for this model revealed an estimated parameter value of 2.12 and did not provide a significant improvement ($\Delta\chi^2 = 0.518$, df = 1, $p = 0.47$).

[2] Because of a slight non-normal distribution of the observed variables, the asymptotic results were controlled with a 1500-sample bootstrap (Arbuckle, 2006), which confirmed the linear model.

Table 4 Model fit indices (n = 68)

Model	χ^2	df	p	TLI	CFI	RMSEA
Basic linear model	6.69	10	.754	2.171	1.000	.000
Model with perinatal predictors	21.21	21	.446	.994	.996	.012
Model with predictors and Bayley MDI	29.00	27	.361	.952	.964	.033

χ^2, Chi-square; df, degrees of freedom; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation; MDI, Mental Developmental Index.

was used for further analysis. A visual presentation of the mean intercept and slope is presented in Figure 1. The individual variation around the slope factor mean (0.288) was found to be significant ($p < .05$), indicating that infants differed in their rate of change over time. The individual variation around the intercept factor mean (0.069) was not significant ($p = .20$), which indicates that we cannot rule out the possibility that infants do not differ in their initial level (see Discussion).

Secondly, to assess the predictive value of perinatal risk factors for individual variation in the initial level and rate of change in A-not-B performance, all predictors (BW, GA, gender, IVH, PVL and IRDS / BPD) were added to the model at the same time. Then, the model was trimmed one step at a time, excluding the paths with non-significant parameters. Predictors without any remaining paths to the slope were removed from the model. Next, the model was built by adding co-variances between predictors step by step, based on the modification indices, but only when theoretically sound. Finally, to asses the relationship between A-not-B development and subsequent global cognitive functioning, Bayley MDI was added to the model.

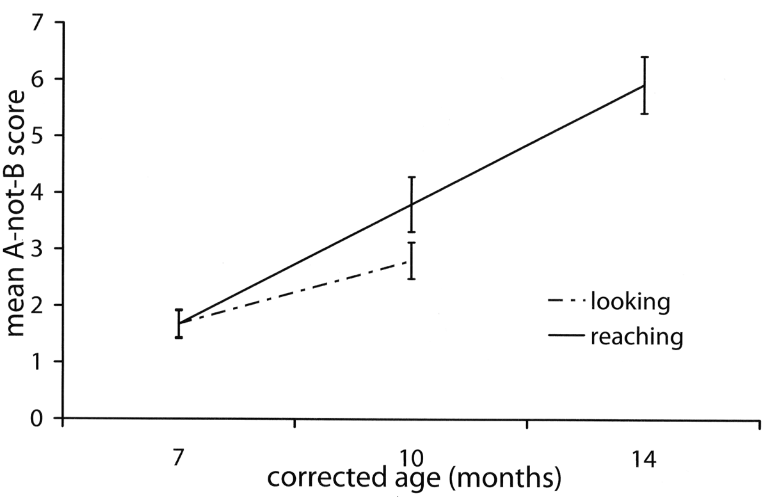


Figure 1 Mean increase of A-not-B task performance (for best fitting linear model). Error bars represent the 95% confidence intervals around the estimated means.

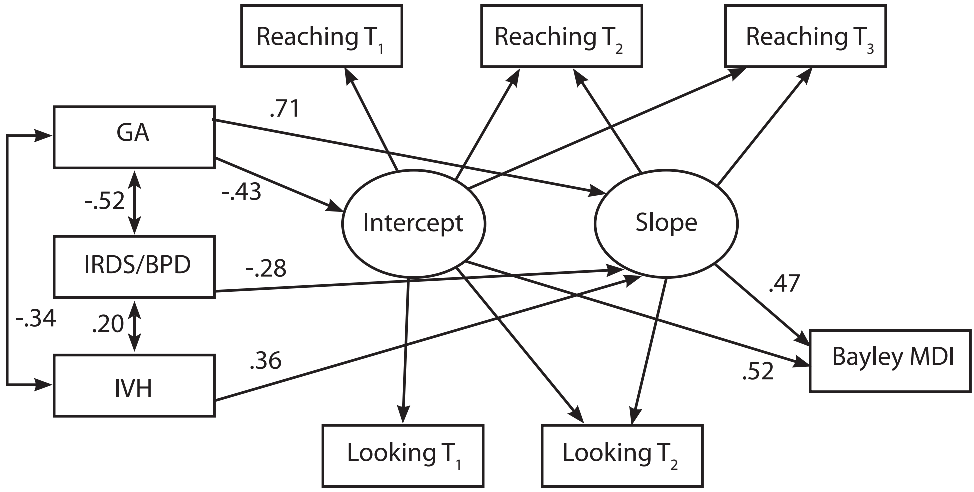


Figure 2 Latent growth model of A-not-B performance with standardized regression weights for predictors (GA, gestational age; IRDS / BPD, infant respiratory distress syndrome / bronchopulmonary dysplasia; IVH, intraventricular hemorrhage) and Bayley Mental Developmental Index (MDI) as outcome variable. Reaching, reaching version of the A-not-B task; Looking, looking version of the A-not-B task; T_1, 7 months corrected age (CA); T_2, 10 months CA; T_3, 14 months CA.

The results show that BW, gender, and PVL were no significant predictors of variations in either the intercept or the slope factor. GA significantly predicted variation in the intercept as well as in the slope. Infants born at a lower GA showed a higher initial level ($p < .05$) but a slower rate of developmental change ($p < .01$). Also, more severe respiratory problems were predictive of a slower rate of developmental change ($p < .10$).[3] Contrary to our expectations, more severe IVH was found to be significantly predictive of a faster rate of developmental change ($p < .05$). In addition, a lower GA was significantly related to more severe IVH ($p < .01$) and more severe respiratory problems ($p < .001$). In addition, more severe respiratory problems were related to more severe IVH ($p < .10$).[4] Finally, global cognitive outcome at 14 months CA was significantly predicted by the initial level ($p < .05$) as well as the rate of developmental change in A-not-B performance ($p < .01$). Infants who scored lower initially and showed slower developmental change had lower subsequent global cognitive outcome scores. According to the fit indices, this model fitted the data well (see Table 4). The final model with standardized regression weights for predictors and Bayley MDI score is presented in Figure 2.

[3] The removal of IRDS as a predictor did not provide a significant improvement ($\Delta\chi^2 = 1.58$, df = 1, $p = 0.21$).

[4] Although $\Delta\chi^2$ failed to reach statistical significance ($p = .10$), all other fit indices indicate model improvement. Therefore, the covariance between IVH and IRDS was maintained in the model.

Discussion

Developmental trajectories of A-not-B performance

The results show that the mean developmental change in A-not-B performance in infants born preterm can be best described by a linear increase. Infants were not found to differ significantly in their initial ability to find a hidden object. There are two possible reasons for this. First, the statistical power was probably low due to the sample size in combination with the statistical analysis that was used, and indicates that differences in the population are small. As a rule of thumb, a sample size of at least 100 subjects is considered a 'medium' sample size and a better minimum for any type of Structural Equation Modeling analysis (Kline, 2005). Secondly, there seems to be a floor effect at 7 months CA. It should be emphasized, however, that the intercept mean and variance represent estimations of (variation in) the initial level based on information from all measurement occasions. They are not equal to the observed mean and variance at 7 months CA. In fact, the observed variation at the first measurement occasion was larger than the estimated intercept variance. In addition, the finding that the variations in initial level, although small, could be predicted from differences in GA indicates that these variations were meaningful. As such, it was valuable to use this age as a starting point. Infants did show wide individual variability in the rate of developmental change in A-not-B performance. The rate of developmental change was not significantly related to the infant's initial level of functioning.

The finding that initial differences are small, but the rate of development differs greatly among infants is in line with the hypothesis that differences in performance on the A-not-B task do indeed become more apparent when children grow older. When we compare performance of our sample to the results of Diamond (1985) and Bell & Fox (1992), this conclusion seems to be confirmed. The majority of infants in our sample was not able to handle a reversal trial at 7 months CA, which is comparable to the results reported by Diamond (1985) and Bell & Fox (1992) at this age. The differences between samples become more evident at older ages. The delay that is necessary to evoke the A-not-B error in our sample increased, on average, from 2 seconds at 10 months CA to 6,5 seconds at 14 months CA. The delays reported by Bell & Fox (1992) and Diamond (1985) are considerably longer at 10 months (4 and 7,5 seconds, respectively) and at 12 months (7,5 and 10 seconds, respectively) in infants born at term. This seems to suggest that correction for prematurity alone is not enough and that other underlying mechanisms play a role in the differences between infants born preterm and born at term.

Predictive value of perinatal risk factors

The differences in the initial level of performance as well as individual differences in the rate of developmental change in A-not-B performance could be attributed to differences in several perinatal risk factors. Infants who were born at a lower GA showed a higher initial level of performance on the A-not-B task, but a slower developmental rate, which supports the idea that the influence of risk factors may change over time. In addition, infants who suffered more severe respiratory problems showed a slower rate of developmental change. Contrary to our expectations, more severe intracranial hemorrhage was related to faster developmental change. Together, these perinatal risk factors explained 19% and 70% respectively, of the individual variation in the initial level and rate of developmental change in the A-not-B task performance. BW, PVL and gender were not significant predictors of the rate of development.

The initial advantage of a lower GA might be explained by differences in chronological age. When infants are tested at ages corrected for prematurity, those who were born at a lower GA are by definition older in chronological age and thus have more extra-uterine experience (Matthews et al., 1996). It seems that this additional experience gives preterm infants at least an initial advantage. However, this advantage is only temporary, and the (im)maturational aspects of being born to soon seem to override this effect in time. In fact, GA explained the largest proportion (51%) of the individual variation in the rate of development on the A-not-B task performance.

There are two possible explanations – which are not mutually exclusive – for the counterintuitive finding that infants with more severe IVH showed faster developmental change. First, the timing of the hemorrhage may play an important role in the effects on A-not-B development. Studies on brain plasticity in newborn rats have shown, for example, that timing of the lesion is crucial for recovery of brain functioning, which can vary dramatically from one week to the next (Kolb & Gibb, 2007). When we consider that prenatal development of the prefrontal cortex occurs mainly in the last trimester of gestation (and continues postnatal into adolescence) (White & Nelson, 2004), it is possible that hemorrhages at a later stage of gestation – even when less severe – will have more severe consequences for those specific abilities tapped by the A-not-B task. In fact, the frequently reported finding that infants born at a higher GA suffer from less severe IVH was confirmed in our sample. Secondly, the effects of cerebral damage may differ between infants, not only as a result of the timing of the injury, but also as a result of co-occurrence with other risk factors or medical complications. In a review on brain plasticity in infants born preterm, Luciana (2003) describes that maternal infection during pregnancy, for example, may lead to a complex cascade of events, leaving infants more vulnerable to cerebral lesions. So, it is possible that an unknown selection bias has taken place in our study and that only those infants who were resilient after IVH entered our study, whereas other infants died after the same complication or whose more adverse consequences made parents decline participation. Male gender is such a potential risk factor. Inspection of the relationship between IVH and gender, for example, revealed that in our sample infants with more severe IVH were predominantly girls, whereas infants who suffered less severe IVH were mainly boys ($p < .05$). Given the finding that boys are more susceptible to the negative effects of perinatal medical complications (Elsmen, Hansen Pupp, & Hellstrom-Westas, 2004; Stevenson et al., 2000), it is possible that boys with more severe IVH were not included in the study because of higher mortality and morbidity which possibly led to either exclusion from the study or to a decline of participation by parents. Moreover, since boys are more likely to suffer from white matter abnormalities than girls (Ment & Vohr, 2008), they might show less successful recovery from lower grades of IVH. In that case, gender might act as a confounder for the relationship between IVH and rate of development. It is also possible that associated white matter damage was underestimated, using cranial ultrasound rather than magnetic resonance imaging (MRI). Recent studies show that

MRI is more reliable than cranial ultrasound in detecting subtle white matter lesions (Miller et al., 2005; Woodward, Anderson, Austin, Howard, & Inder, 2006).

Relationship to subsequent global cognitive functioning

Subsequent global cognitive functioning at 14 months CA was significantly predicted by individual differences in the initial level and rate of change in A-not-B performance. Together they explained 33% of the individual variation in global cognitive outcome. The finding that Bayley MDI score at 14 months CA was predicted by the initial level and rate of developmental change in A-not-B performance but not related to A-not-B performance at 14 months CA (r = .084) suggests a specific direction of causality and is in line with the theoretical assumption that the development of more specific processes underlies differences in global cognitive functioning. This indicates that early attention and EF measures may provide valuable information to identify which infants born preterm are at risk for problems in later functioning.

Limitations of the present study

Several limitations of the present study are worth mentioning. First of all, although the sample size of this study was of a substantial size for a longitudinal study with infants born preterm, the sample was relatively small. Due to the related small statistical power, variation in the estimated initial level of A-not-B performance failed to reach statistical significance. It is possible that this also caused the failure to find a significant covariation between the initial level of performance and the rate of developmental change. In addition, it is possible that certain perinatal predictors were discarded as unrelated as a consequence of the same issue, although their contribution is probably small.

Secondly, the aim to study a heterogeneous sample of infants born preterm has had an influence on the composition of the sample, which is worth discussing. On the one hand, applying wide inclusion criteria with regard to GA and BW has led to a sample which is representative for a NICU population. As a result, however, some of the medical complications that we considered to be potentially important for A-not-B development (i.e., asphyxia and SGA) showed too little variation to be included in the analysis. Nonetheless, the incidence of these complications in our sample was comparable to the incidence in the eligible NICU population, indicating that these complications are not diagnosed very frequently in a heterogeneous preterm population. On the other hand, some exclusion criteria (such as the diagnosis of cerebral palsy) have eliminated certain infants born preterm with particular characteristics from the study. This may have led to a selection bias, such as the one described earlier, in which, for example, boys with more severe hemorrhages were excluded from the study due to higher mortality or morbidity than girls.

Third, although the items of the A-not-B task were carefully chosen to represent increasing difficulty, it is not likely that every item represents an equivalent step in difficulty. The items of the task seem to fall somewhat into three categories, where the first three items measure the ability to find a hidden object (first on a primary location, later on a reversal trial), items 4 to 8 focus on an increase in delay between hiding and seeking, whereas items 9 to 11 focus on an increase in delay with invisible displacement. Therefore, the results are perhaps influenced by the fact that most infants failed performance beyond the first three items at 7 months CA. When the first measurement would have started one month later for example, it is likely that more infants would have been able to handle a reversal trial. In that case, perhaps the initial level of performance could have been related to the rate of developmental change. Nevertheless, as we mentioned before, the finding that these differences could be predicted from differences in GA indicates that the variation that was found in the sample was meaningful.

Recommendations for future research and practical implications

Although this is the first study, to our knowledge, to use Latent Growth Modeling to investigate the development of A-not-B performance in infants born preterm, it is only a beginning. Further follow-up is necessary to investigate whether (1) differences between infants increase, remain stable or become smaller into toddlerhood, (2) developmental patterns that are characterized by delay are transient, reach a permanent level, or become larger with age. Also, to gain better understanding of how attention and EF abilities and their development are interrelated, it will be vital to examine the relationship between A-not-B performance and other types of attention and EF tasks.

In clinical follow-up of infants born preterm, the Bayley scales are often used (usually at 2 years CA) to detect developmental delays. However, although clinical observations during the administration of the Bayley scales can provide useful information on early problems in attentional and executive functioning, such global outcome measures are not very sensitive to problems in more specific cognitive areas (Johnson & Marlow, 2006; Johnson et al., 2008). Consequently, there is a need for early screening instruments that tap into more specific processes (Davis, Burns, Snyder, & Robinson, 2007; Johnson et al., 2008). The results from this study could provide researchers with information necessary to begin to develop such a screening instrument. An interesting finding is that, at 10 months CA, infants had more trouble with the looking version than with the reaching version of the A-not-B task. This is in contrast to the findings from Matthews et al. (1996) who found performance on both versions of the task to be comparable. In fact, this finding is even more surprising when we consider the hypothesis of some researchers that a reaching response is physiologically and psychologically more complex than a looking response (Hofstadter & Reznick, 1996). There are two explanations for these findings. First of all, where visual exploration is an important activity during the first six months of life, at 10 months, most infants even those born preterm (van Haastert, de Vries, Helders, & Jongmans, 2006) have started to crawl and the physical exploration of the environment and objects has become more important. It is possible that the reaching version of the task is more compelling and rewarding at this age than the looking version, making it easier for infants to attend to the reaching version of the task. In addition, in the looking version, infants were not rewarded by playing with the toy and the physical distance from the toy makes it a bigger challenge to attend to this version of the task. The finding that the looking version of the task at 10 months CA was strongly related to performance on the task at 14 months CA seems to confirm that the looking version of the A-not-B task places greater demands on the immature abilities of these infants. The results from this study suggest that looking behavior can be an important, more distinguishing outcome measure of EF and attention behaviors during a period in which locomotor abilities and exploration develop.

The slow maturation of the frontal cortex and its related networks suggests that EF is not only vulnerable to early brain damage, but also heavily dependent on the environment for its development (Garon et al., 2008). Building on this idea, environmental remediation of executive control of attention in the form of training has been developed and proven to be effective in 4- to 6-year-old children (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005b). However, since early parenting has been shown to be an important predictor of subsequent attentional ability in children born at term (Belsky, Fearon, & Bell, 2007) and infants born preterm have been found to be even more susceptible to the positive effects of sensitive responsive parenting than infants born at term (Landry, Garner, Swank, & Baldwin, 1996; Landry, Smith, & Swank, 2006), preventive interventions directed at enhancing parental sensitive responsiveness to their preterm infant is a potentially effective strategy to remediate EF development at even an earlier age. In fact, an intervention program has been developed, targeted at assisting parents in adjusting their interaction style to match the neurobehavioral needs of their (preterm) infant (Infant Behavioral Assessment and Intervention Program: IBAIP), in which strategies are offered to support the infant's neurodevelopmental progression and self-regulatory competence. A pilot study investigating the effects of this intervention program has shown to be promising; preterm infants in the intervention group showed more exploratory behavior, more successful self-regulation and less stress behavior than preterm infants in the control group (Koldewijn et al., 2005; Koldewijn et al., 2009).

Acknowledgements

First, we thank all the families who gave their time and effort to participate in this study. We also thank Adele Diamond for her hospitality and training on the administration of the A-not-B task. The assistance of Hanna Mulder, Inge Griffioen, Lise Vergeer, and Hilke Rijnen in the collection of data and of Mirjam Moerbeek on statistical advice is gratefully acknowledged. Finally, we would like to thank Tolo Toys Ltd. for their generous donation of presents for the participating infants.

4

Individual differences in developmental trajectories of sustained attention during free play in infants born preterm

E. van de Weijer-Bergsma, L. Wijnroks, J. Boom, I.C. van Haastert, M.J. Jongmans

Submitted for publication in *Infant Behavior and Development*

Abstract

It is generally recognized that infants born preterm are at a heightened risk for developmental delay and learning disabilities. Since early visual attention is potentially an important predictor of global cognitive functioning and learning in infants born preterm, this study assessed the influence of several perinatal predictors on individual differences in developmental trajectories of sustained visual attention between 7 and 14 months corrected age in 76 infants born preterm. Also, the predictive value of these trajectories for subsequent global cognitive functioning was investigated. Sustained attention was observed during two free play sessions with either 1 toy or 6 toys at 7, 10 and 14 months corrected age. Latent Growth Modeling showed that the presence of mild periventricular leukomalacia was a predictive factor of the rate of developmental change in sustained attention. Moreover, the rate of developmental change in sustained attention was predictive of global cognitive functioning.

Introduction

Infants born preterm are at a heightened risk for developmental delay and learning disabilities (Anderson & Doyle, 2003; Aylward, 2002a, 2005; Bhutta, Cleves, Casey, Cradock, & Anand, 2002). Early visual attention is considered an important predictor for global cognitive functioning and learning in infants born preterm (Aylward, 2002a; Davis & Burns, 2001; van de Weijer-Bergsma, Wijnroks, & Jongmans, 2008). Until now, there are relatively few longitudinal studies that have assessed the influence of perinatal risk factors on attention development during the first two years of life in infants born preterm. Earlier studies have focused on the prediction of infant's status at a certain point in time, but failed to examine the factors which can predict intra-individual changes over time and inter-individual differences in these changes. In the present study, the predictive value of several perinatal risk factors for the developmental trajectories of sustained attention between 7 and 14 months corrected age (CA, calculated from the due date) in infants born preterm was assessed using Latent Growth Modeling.

Development of sustained attention in infants born at term

Information about visual attention is usually gathered during infancy by observing looking behaviors. From an extensive review of the literature by Ruff and Rothbart (1996) it has become evident that infants are selective in their attention from the first day of life, looking longer at some pictures or designs than others. During the first year of life, attention is governed by the novelty of objects and events encountered by the infant. Repeated experience however, reduces novelty and leads the infant to notice new details and information. Although young infants are very selective in their attention, they may have difficulty disengaging from highly salient stimuli (Ruff & Rothbart, 1996). This phenomenon is also called 'sticky fixation' or 'obligatory attention'. Initially, from birth to 8 or 10 weeks of age, looking duration increases, possibly due to the emergence of alertness. As a result of experience, looking duration decreases from 3 to 5 or 6 months, reflecting more efficient learning or information processing and an improved ability to disengage attention (Colombo, 2001, 2002). In order to function well, infants need to develop the ability to exert control over what they are attending to and over the degree of narrowing and intensity of attention (Posner & Raichle, 1994). A narrow focus of attention, accompanied by an increase in the intensity of attention is usually referred to as 'sustained attention', which allows infants or children to explore objects or events in the environment. From around 7 months of age, the length of looking behavior increases with age under some circumstances (such as free play), reflecting increased sustained attention. Knowledge about the development of sustained attention (sometimes also called 'focused attention' or 'focused exploration') during infancy and early childhood mainly comes from the observation of looking behaviors during free play, video-watching and more or less structured tasks. The duration of sustained attention during free play has been shown to increase during the first 3 years of life in several cross-sectional (Sarid & Breznitz, 1997) and longitudinal studies (Kannass & Oakes, 2008; Ruff & Lawson, 1990; Ruff, Lawson, Parrinello, & Weissberg, 1990) and even further during more complex tasks from 3,5 years up to about 10 years of age (Betts, McKay, Maruff, & Anderson, 2006; Kannass & Colombo, 2007). According to attention researchers (Ruff & Rothbart, 1996; Posner & Raichle, 1994) the development of sustained attention is dependent on the development of interconnected attention networks or systems in the brain. The 'orienting network' is related to the movement of attention towards objects and events in the environment and is located in the parietal and temporal cortex. The 'arousal network' depends on subcortical structures such as the brainstem, which helps to control the level of arousal and alertness. These two networks – which are considered part of one 'orienting / investigative' system by Ruff & Lawson (1990) – become fully functional during the first year of life and are thought to underlie attention processing during that period. Under the control of this system, attention is governed by novelty and sustained attention occurs when novelty is sufficient or important enough to trigger further exploration. However, towards the end of the first year of life, when the frontal cortex starts to mature, a new attention network starts to emerge that enables higher-level control of attention. With the emergence of this higher-level control network, sustained attention is considered to become less influenced by novelty and more under the control of planned, self-generated activity with objects (Colombo, 2001; Posner & Raichle, 1994; Ruff & Rothbart, 1996). Important transitions in these higher-level control abilities are assumed to take place around 9 months and 12 months of age, when infants show important changes in their performance on tasks requiring such higher-level control abilities, such as the A-not-B task (Diamond, 1985, 1991; Diamond & Goldman-Rakic, 1989). In the A-not-B task infants have to retrieve a hidden object from one of two (or more) locations following a delay. Only after the object is retrieved successfully two times in a row at the first location (location A), the side of hiding is changed (to location B). Performance on this 'reversal trial' is dependent on the infant's ability to keep the location of the toy in mind (working memory), to inhibit reaching to the previously rewarded location (inhibitory control), and to control attention during the task. Between 7 and 9 months of age, infants become able to find hidden objects but still often fail when the side of hiding is changed. From around 9 months of age, infants are able to handle reversal trials with increasing delays between hiding and seeking. By 12 months of age, performance on the task will be more skillful and infants can handle delays of 10 seconds or more (Diamond, 1985, 1991).

Development of sustained attention during free play in infants born preterm

The results from several studies regarding the differences in sustained attention during free play between infants born preterm and born at term are rather mixed (Pridham, Becker, & Brown, 2000; Ruff & Lawson, 1990; Ruff et al., 1990; Sun, 2003; Tu et al., 2007; van de Weijer-Bergsma et al., 2008). Sun (2003) for example, showed that 8-month-old infants born preterm show shorter periods of sustained attention and more off-task behavior during free play with several toys, than infants born at term. A trend of lower quality of sustained attention during free play in 8-month-old infants born preterm compared to infants born at term was also found by Tu et al. (2007). Pridham et al. (2000), on the other hand, found no differences in sustained attention between 8-month-old infants born preterm and infants born at term during free play. Moreover, a longitudinal study by Ruff et al. (1990), conducted at 1, 2 and 3.5 years of age, revealed longer periods of sustained attention during free play at 2 years of age in infants born preterm compared to infants born at term, but only when developmental scores were above 80. Although Ruff et al. (1990) speculate that longer periods of sustained attention in children born preterm may be caused by a tendency to be less active and more compliant, making it easier for these children to focus and maintain attention, this hypothesis can not explain why other studies report less sustained attention in children born preterm.

These differences in results are more likely to be explained by differences in the procedures, definitions, and dependent measures that were used in the studies described above. First of all, whereas in some studies sustained attention was observed during free play with several toys simultaneously (Pridham et al., 2000; Ruff et al., 1990), others observed sustained attention with a single toy (Tu et al., 2007; Sun, 2003). This raises the question whether procedures that differ in the number of toys that are presented provide similar measures of sustained attention, especially since Ruff and co-workers have reported differences in the organization and distribution of attention behaviors in a 1-toy and a 6-toy condition over time. That is, 10 month-old (Ruff & Capazzoli, 2003) and 1-year-old infants born at term (Ruff & Lawson, 1990) displayed more organized attention behaviors during the 1-toy condition compared to the 6-toy condition, although this difference was not apparent in 26-month-old children (Ruff & Capazzoli, 2003). Also, infants were predominantly attentive during the first minute of a two-minute free play session in the 1-toy condition, whereas attention was more evenly distributed across the two-minute period in the 6-toy condition. In the present study, both a 1-toy and a 6-toys condition will be included in order to examine the effects of task-condition. Secondly, while some researchers defined sustained attention as intent looking at an object while manipulating it, accompanied by reduced extraneous motor movement and vocalizations (Ruff et al., 1990; Sun, 2003), others also included mere looking and holding (Pridham et al., 2000). Physiological studies on the involvement of the autonomic nervous system in attention processes seem to support a more narrow definition of sustained attention as these studies have shown that sustained attention is accompanied by a deceleration in heart rate and certain other somatic changes, such as inhibition of movement, which facilitate attention (Lansink & Richards, 1997; Richards & Cronise, 2000). In the present study, the behavioral definition of Ruff and co-workers (Ruff et al., 1990) will therefore be used. Finally, measures of sustained attention varied between studies from total duration of sustained attention (Ruff et al., 1990), to average duration (i.e., total duration divided by number of episodes; Sun, 2003), to a global 5-point rating scale for the quality of sustained attention (Tu et al., 2007). In the present study, the total duration of sustained attention will be used as a measure of sustained attention, following Ruff and coworkers (Ruff et al., 1990).

Individual differences in sustained attention have been shown to be low to modestly stable in infants born preterm, but in general the results are inconsistent and difficult to explain. Ruff et al. (1990) for example, found sustained attention at 1-year to be predictive of sustained attention at 3.5 years, but not at 2 years of age. However, in these analyses different attention behaviors were combined (e.g., focused attention, off-task / inattention), making it difficult to disentangle the contribution of the different behaviors. Also, time laps between measurements were relatively large. In another study by Lawson & Ruff (2004), with comparable time laps, sustained attention at 7 months of age was found to be predictive of sustained attention at 2 years but not at 3 years, only for high-risk children (i.e., children at or above the median of a composite risk score). In this study, sustained attention at 7 months was also found to be predictive of global cognitive abilities at 2, 3 and 4 to 5 years (Lawson & Ruff, 2004). The predictive value of sustained attention at 8 months for global cognitive outcome at 2 years was also demonstrated by Kopp and Vaughn (1982) in boys but not in girls born preterm (Kopp & Vaughn, 1982).

In sum, these results suggest that, during a period in which attention is showing such marked development, intra-individual differences in sustained attention are not very stable from one point in time to the next. High correlations suggest that an infant or child who scores higher (or lower) on a certain task, will also score higher (or lower) on that task at a later point in time, indicating stability in their relative rank within the group, but these correlations do not tell us much about intra-individual change. Recent statistical advances, on the other hand, provides us with a means to investigate and combine intra-individual developmental trajectories in sustained attention and inter-individual differences in these trajectories, by using Latent Growth Modeling (LGM). In the present study, individual differences in developmental trajectories in sustained attention will be investigated, using repeated measures with smaller time laps than previously described.

Since individual differences in cognitive development within the preterm population are known to be related to differences in perinatal risk factors, such as gestational age (GA), birth weight (BW) and the presence and severity of medical complications (Aylward, 2005; Luciana, 2003), several of the studies described above investigated their predictive value for sustained attention development. However, the results are mixed. Sun (2003) for example, did not find a significant effect of GA, BW, or medical risk on sustained attention at 8 months when infants born preterm were assigned to GA groups (born before or after 28 weeks of gestation), BW groups (very low BW versus extremely low BW) or high versus low medical risk groups. Pridham et al. (2000) also failed to find an association between GA or gender and sustained attention at 8 months. A recent study however, did find neonatal pain-related stress, indexed by the number of skin-breaking procedures from birth to term, to be associated with poorer sustained attention in 8-month-old infants born preterm (Tu et al., 2007). The number of skin-breaking procedures, however, also could be considered an indicator of the severity of illness. Lawson and Ruff (2004) did not find a composite risk score (including GA, gender and maternal education) to be associated with sustained attention at 7 months, although it moderated the association between sustained attention at 7 months and 2 years. A study conducted at a chronological age of 4 years showed that a global rating of the quality of sustained attention during a problem-solving task was related to GA and male gender, but not to BW or a summary risk score (McGrath et al., 2005). On the other hand, when 4-year-old children born preterm were assigned to one of four subgroups (a healthy (HPT), medical (MPT), neurological (NPT), and small for gestational age (SGA) group, based on the absence or presence and severity of specific medical complications) and compared to a full-term control group, only the children born preterm in the MPT and NPT groups showed less sustained attention than the children born at term (McGrath et al., 2005). This suggests that medical complications, but not GA or BW per se, are important predictors for sustained attention at 4 years.

In sum, although individual differences in sustained attention seem not to be influenced greatly by GA, BW, gender and medical risk during infancy, some of these perinatal risk factors do seem to gain predictive power when infants grow older. However, it remains unclear which factors contribute the most and how exactly their influence changes over time. This is partly due to the methodological issues. For instance, dividing infants into BW or GA groups is often based on somewhat arbitrary boundaries, in which much information is lost compared to when continuous data is used. In addition, since infants with lower BW and/ or lower GA are more prone to medical complications (Aylward, 2002a, 2002b, 2005), BW or GA groups are likely to differ on the severity of medical complications as well. In addition, it might be that GA or BW in itself have little explanatory power and that factors which are more directly related to the underlying mechanisms of attention development, are more important. Moreover, summary risk scores conceal information about the influence of more specific medical complications. Medical complications that have been linked to suboptimal cognitive development are brain injury and respiratory problems. The two most common causes of brain injury in infants born preterm are intraventricular hemorrhage (IVH) and periventricular leukomalacia (PVL). Both conditions are related to either the reduction in oxygen supply to bodily tissues (i.e., hypoxia) or more severe low oxygen level due to inadequate blood flow (i.e ischemia). Infants who are born preterm are also at risk for infant respiratory distress syndrome (IRDS), often resulting in chronic lung problems (i.e., brunchopulmonary dysplasia; BPD), which in turn may result in chronic hypoxia of the brain (Luciana, 2003). Latent Growth Modeling allows us to include all these potentially important perinatal risk factors in the analysis simultaneously, yet as separate variables.

Aims of the present study

Because early sustained attention is a potential important predictor of later global cognitive functioning and learning in infants born preterm, the aims of the present study were to investigate: (1) individual differences in developmental trajectories of sustained attention in infants born preterm by using a longitudinal, within-subjects design between 7 and 14 months CA; (2) the predictive value of several perinatal risk factors for the early development of sustained attention; and (3) the strength of the relationship between the development in sustained attention and subsequent global cognitive functioning, by using Latent Growth Modeling (LGM).

Given the heterogeneity of the preterm population, we expected the rate of developmental change in sustained attention to vary between individual infants. Although perinatal factors might not be very good predictors of the infant's status at a given point in time, they might be predictive of developmental change across time points. Therefore, we expected that the rate of developmental change in sustained attention would be negatively influenced by a lower GA, a lower BW, and more (severe) respiratory problems, IVH or PVL. Finally, we expected that the relationship between sustained attention development and global cognitive functioning to be positively related but not very strong, since global cognitive measures tap into a variety of processes.

Methods

Participants

During the period of inclusion, between April 2004 and August 2005, a total number of 325 singleton infants born preterm (GA ≤ 36 weeks, BW < 2500 grams) were admitted to the Neonatal Intensive Care Unit (NICU; $n = 266$), the Medium Care Unit (MCU; $n = 53$) or both units ($n = 6$) of the Wilhelmina Children's Hospital in Utrecht, The Netherlands. Ethical permission for the study was granted by the hospital's ethics committee.

Thirty infants died during the postnatal period. Other exclusion criteria were congenital or chromosomal disorders ($n = 21$), (possible) congenital infections such as HIV ($n = 2$), significant sensory disorders ($n = 3$), uncertainty about GA ($n = 3$), and incomplete data ($n = 5$). Maternal factors that lead to exclusion were drug- or alcohol abuse ($n = 5$), maternal age < 18 years ($n = 1$), non-biological mother (e.g., egg donation or adoption) ($n = 1$), parental consanguinity ($n = 1$), no knowledge or use of the Dutch language ($n = 11$), maternal death ($n = 1$), move abroad ($n = 3$), or alien status ($n = 1$).

After exclusion, 237 singletons were eligible for inclusion in the study, of which 119 children and their parents were randomly selected and invited by letter to participate. Parents were contacted by phone at least one week later to give the opportunity to ask questions and to ask whether they were interested in participation. Also, parents were able to sign up for the study by returning an informed consent form. Parents of 76 infants consented for their infant to take part in the study (63.9% of the invited parents).

There were no significant differences between participants ($n = 76$) and non-participants ($n = 161$) from the NICU and MCU in gender, severity or presence of medical complications such as IRDS, asphyxia or small for gestational age. However, participants were born at a lower mean GA ($p < .01$) with a lower BW ($p < .05$), and suffered from more severe IVH ($p < .05$) than non-participants. Since the great majority of participants in our study was initially admitted to the NICU ($n = 72$), a comparison between participants and non-participants from the NICU was also made revealing no differences in perinatal characteristics. Based on these comparisons we consider our sample to be representative for a NICU population of infants born preterm. None of the infants was diagnosed with cerebral palsy at 14 months CA.

Measurements

Neonatal medical risk

Information about GA, BW and perinatal medical complications was extracted from hospital files. The presence and severity of brain injury was assessed using cranial ultrasound scans and judged by a neonatal neurologist. IVH was scored ranging from 0 (no IVH) to 4 (IVH grade IV) (Papile, Burstein, Burstein, & Koffler, 1978). Periventricular leukomalacia (PVL) was scored ranging from 0 (no PVL) to 4 (PVL grade IV) (de Vries, Eken, & Dubowitz, 1992). Infant respiratory distress syndrome (IRDS; grades I–IV) and / or bronchopulmonary dysplasia (BPD) resulted in a respiratory score, ranging from 0 (no respiratory problems) to 5 (BPD). Since male gender is considered a biological risk factor for developmental problems, gender was also used as a predictor (score 1 = male, score 2 = female).

Sustained attention

Sustained attention was observed and videotaped at 7, 10 and 14 months CA during a free-play session. Measurement occasions were planned around those ages during which important transitions in higher-level control abilities are expected to occur (i.e., at 9 and 12 months of age). Infants played alone while sitting in a car seat at a small table (60 x 30 cm [width x depth]) with raised edges to prevent the toy(s) from falling from the table. Administration was ended when infants became fussy or cried. Sustained attention was defined as the duration of intent looking at the object while manipulating, accompanied by a decrease in motor movement (Ruff & Lawson, 1990). Only episodes of looking while manipulating with a duration of more than 2 seconds were considered sustained attention. The dependent measure was the cumulative duration of sustained attention in seconds over the first 90 seconds of the free play period. Videotapes were independently scored from DVD (Digital Video Disc) by two blinded observers at half speed using PowerDVD mediaplayer. At every age, 10 videos were scored by both observers in order to assess inter-rater reliability. Single measures intraclass correlations (ICC) ranged from .71 to .99 (mean ICC .80) indicating substantial to outstanding observer agreement.

1-toy condition. Infants played for two minutes with a single toy. All the toys were age-appropriate hard plastic toys painted in primary colors: for the infants at 7 and 10 months CA an easy to grasp rattle with colored beads and for the infants at 14 months CA an activity play triangle with a revolving mirror and beads and a turning knob was used.

6-toy condition. Infants played for two minutes with six toys simultaneously. The toys represented basic shapes with elements and sounds that can be manipulated: a ball that could partly be squeezed resulting in a squeaking sound, a hexagon shaped frame with a bell-ball (ball containing a bell) that could be manipulated inside, a spinningtop shaped toy with two bell-balls revolving around the top, a triangle shaped toy with mirrors on two sides and a tube containing small colored beads on the other side that made a rattling sound when shaken, and a cuboid with primary shaped holes. Inside the cuboid a cylinder could be turned around using a dial, to pass pictures of equally shaped figures along the holes. Turning the dial resulted in a rattling sound. The sixth toy was a cube frame filled with a sphere that is painted with moons and stars. When an infant rolls the sphere, it makes a tingling sound.

Procedure

Mothers and infants were visited at home at 7 months CA (± 1 week) and 10 months CA (± 1 week), and were invited for assessment at our laboratory at 14 months CA (± 1 week). Parents did not receive payment for their participation, but did receive refunding for traveling expenses. Infants were rewarded with a gift after every appointment, consisting of an age-appropriate toy. Measurement sessions were planned at a time of the day when parents expected their infant to be alert. When infants were asleep at arrival, testing was postponed until they awoke. Also, testing was paused when necessary (e.g., in case of fussiness, mealtime, diaper change), but breaks were held in between tasks when possible. Assessments were part of a larger battery of tests and observations, which were recorded on video. The sequence of tasks was kept constant for all participants. During the home visits, the assessment started with the A-not-B task (the results regarding this task are presented in *Chapter 3*. Then infants played alone with 1 toy first, followed by playing with 6 toys simultaneously during the sustained attention task. Finally, infants played for 5 minutes with their mothers. For every measurement session 2½ hours were reserved. In practice, no appointment exceeded 1½ hours, of which infant testing took approximately 20 to 40 minutes. The 14-months assessment at our laboratory started with the A-not-B task. Next, the Mental Scale of the BSID-II (Dutch version) was administered. Then infants played alone during the sustained attention task, first with 1 toy, then with 6 toys simultaneously. Finally, mother and infant played together for 5 minutes. Again, appointments did not exceed 1½ hours and pauses were held when necessary. After the last session, parents received a report of their infant's performance on the Mental Scale of the BSID-II and a copy of all video materials. Infants with a mental developmental index score below one standard deviation were invited for an aftercare follow-up at 2 years CA by a special educator/ developmental specialist (ICvH) at the children's hospital.

Statistical analysis

First, Latent Growth Modeling (LGM) was used to determine the form that most adequately described the separate developmental trajectories for 1-toy and 6-toy sustained attention. Then, the influence of perinatal medical risk factors (GA, BW, IVH, PVL, IRDS / BPD and gender) on these trajectories was modeled and their relationship to subsequent global cognitive functioning. LGM makes it possible to investigate individual variability in developmental trajectories, as well as to test the influence of predictors in order to explain this variability. In LGM, each individual's growth over time is represented by a regression line, which can be described by a unique intercept (initial level) and slope (rate of change). As a result, a given sample is described by group means and variances for intercept and slope. Predictor variables can be incorporated to explain the inter-individual variance in initial level and rate of change. Because variances, by definition, cannot be smaller than zero (i.e., a negative value) and thus two-sided testing gives an underestimated significance level (Stoel, Garre, Dolan, & van den Wittenboer, 2006), one-sided *p* values were considered to investigate the significance of variance around the intercept and slope means. One-sided *p* values were also considered when associations between variables were in the expected direction. To prevent wrongful removal of non-significant paths from the model due to low statistical power or a sample smaller than 100 (Kline, 2005), paths were maintained in the model at a 0.10 significance level. When observed data have a non-normal distribution, the standard errors used for significance tests and confidence intervals are generally too small. In that case, bootstrapping is a method to estimate valid standard errors and confidence interval, in which repeated samples are drawn (with replacement) from the observed sample (Hox, 2002).

Growth models were analyzed using Mplus version 5 (Muthen & Muthen, 2006). Overall model fit was evaluated by Chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI). By convention, models have a good fit if χ^2 is low, RMSEA is less than 0.05, and CFI and TLI are close to 1 (Arbuckle, 2006). The chi-square difference statistic ($\Delta\chi^2$), which tests the null hypothesis of identical fit, was used to test the statistical significance of the decrement or improvement in overall fit as paths are eliminated (trimming) or added (building), respectively. When trimming the model, the removal of a path should not lead to a significantly worse model. In line with this, acceptance of the null-hypothesis (a small $\Delta\chi^2 < 3.84$) indicates a significant improvement of the model, because one degree of freedom is gained. In contrast, when building a model, the loss of one degree of freedom should lead to a large enough decrease in χ^2 ($\Delta\chi^2 > 3.84$) to reject the null-hypothesis, i.e., that the models are identical (Kline, 2005).

Missing values

Two infants did not complete the study beyond the first measurement due to attrition. Due to technical problems with video equipment, observations during the free play task were lost for the 1-toy condition in 3 infants at 7 months, 2 infants at 10 months, and 3 infants at 14 months. In the 6-toys condition 1 observation was lost at 7 months, 2 at 10 months, and 4 at 14 months. Free play in the 1-toy condition was aborted before the minimally required 90 seconds of free play due to fussiness or crying in 2 infants at 10 months, and in 18 infants at 14 months. In the 6-toy condition free play was aborted ahead of time in 1 infant at 7 months, 2 infants at 10 months, and in 16 infants at 14 months. The 18 and 16 infants for whom data was lost at 14 months due to fussiness or crying did not differ from infants for whom we had a complete data set on GA, BW, PVL, IVH, IRDS, gender or Bayley MDI scores. Neither did they differ in the outcome measures of sustained attention at the earlier assessments at 7 and 10 months CA. So there is no evidence that the infants with missing data on the free play session at 14 months were different on these characteristics from those who completed the free play session. One infant was not yet able to grasp and hold the toys at 7 months. Another infant missed the appointment at 10 months due to scheduled surgery.

Only data from infants with observations for 2 or 3 waves available were used ($n = 71$). Since LGM software can handle missing data, missing values were not imputated. For the 1-toy condition, longitudinal data over all three waves was available for 48 infants and data for two waves was available for 21 infants ($n = 69$). For the 6-toys condition, there was data available for 50 en 20 infants respectively ($n = 70$). Based on scatter plots in combination with Mahalanobis distances, 2 multivariate outliers on sustained attention measures were identified and excluded for the 1-toy condition, leaving 67 infants for the analysis. For the 6-toy condition, 6 multivariate outliers were excluded, leaving 63 infants for the analysis. These 6 outliers from the 6-toy condition did not differ from infants left in the analyses on all of the previously mentioned background variables, except that they suffered from more severe respiratory problems ($p < .05$). Sample characteristics are presented in Table 1.

Results

Normality of distributions, descriptives and correlations

Normality of the distributions of the variables was examined by calculating the standardized skewness and kurtosis index (statistic divided by standard error). Because the distributions of sustained attention at 7 months CA were shown to be skewed in the 1-toy as well as the 6-toy condition (skewness values 3.1 and 3.5, respectively), the asymptotic results were controlled with a 1000-sample bootstrap.

Table 1 Sample characteristics ($n = 71$)

Variable		Mean (SD)	Range		
Gestational age (weeks)		30.55 (2.18)	26–35		
Birth weight (grams)		1458 (422)	830–2370		
Bayley MDI score (14 months CA)		103.7 (15.73)	66–136		
IRDS grade / BPD	Grade I	Grade II	Grade III	Grade IV	BPD
n	13	8	11	1	6
IVH grade	Grade I	Grade II	Grade III	Grade IV	
n	6	4	5	1	
PVL grade	Grade I	Grade II	Grade III	Grade IV	
n	10	1	0	0	
Asphyxia (*n*)	4				
SGA	SGA	Extreme SGA			
n	2	2			
Gender (*n*)	47 boys (66.2%)				

SD, standard deviation; MDI, Mental Developmental Index; CA, corrected age; IRDS, infant respiratory distress syndrome; BPD, bronchopulmonary dysplasia; IVH, intraventricular hemorrhage; PVL, periventricular leukomalacia; SGA, small for gestational age (3^{rd} percentile > BW < 10^{th} percentile), Extreme SGA (BW < 3^{rd} percentile).

Table 2 Descriptives and correlations for 1-toy and 6-toy sustained attention

	Mean	SD	*n*	1-toy condition 7 months CA	10 months CA	14 months CA	6-toy condition 7 months CA	10 months CA	14 months CA
1-toy condition									
7 months CA	19.08	15.94	66		.046	-.072	.267*		
10 months CA	24.00	14.82	64			.196†		.152	
14 months CA	47.88	23.30	52						-.036
6-toy condition									
7 months CA	11.87	10.84	63					-.020	-.019
10 months CA	19.86	13.36	63						-.198†
14 months CA	32.51	15.92	49						

n = 45–66. SD, standard deviation; * $p < .05$ one-tailed; † $p < .10$ one-tailed.

Table 3 Model fit indices for 1-toy sustained attention

Model	χ^2	df	*p*	TLI	CFI	RMSEA
Non-linear model	0.60	2	.742	1.000	1.000	.000
Model with PVL	1.24	3	.743	1.759	1.000	.000
Model with PVL and Bayley MDI	2.48	6	.871	1.844	1.000	.000

n = 67. χ^2, Chi-square; df, degrees of freedom; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation; PVL, periventricular leukomalacia; MDI, Mental Developmental Index.

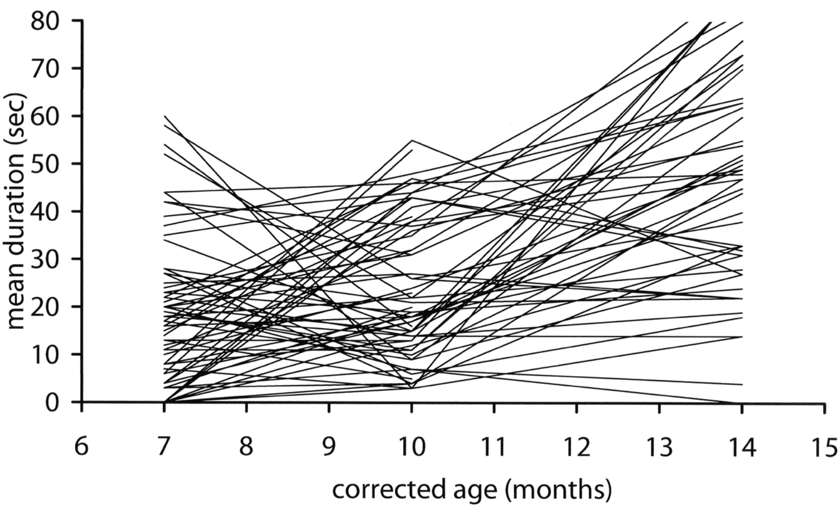


Figure 1 Individual developmental trajectories for cumulative duration of 1-toy sustained attention (*n* = 67).

Descriptive values and correlations for the sustained attention task are presented in Table 2. As can be seen from Table 2, mean duration of sustained attention increased with age in both the 1-toy and the 6-toy condition.

Growth models of sustained attention

First, increase in 1-toy sustained attention was modeled by a linear trend. The first measurement occasion at 7 months CA was chosen as time point zero. To account for differences in interval between measurements, regression weights for the slope were fixed at 1 and 2.3 for the measurements at 10 and 14 months CA respectively. This model did not fit the data well, according to the fit indices. Inspection of the individual developmental trajectories (see Figure 1) indicates that a non-linear trend may provide a better description of the data. Ideally, when four or more measurement occasions are available, a non-linear trend is investigated by adding a quadratic term to the model (Kline, 2005). Because there were only three measurement occasions available, a non-linear model was tested by relaxing the third regression weight for the slope allowing this parameter value to be freely estimated.[1] This non-linear model had good fit indices (see Table 3) and was used for further analysis. The estimated parameter value for the third regression weight was 5.74, which implies that the duration of sustained attention on the last measurement occasion accelerated by factor of 4.74 instead of an increase of 1.3 as in the rejected strictly linear model (with the third regression weight fixed to 2.3). The mean intercept was estimated to be 19.07 ($p < .001$) and the mean slope was estimated to be 5.04 ($p < .001$). A visual presentation of the average trajectory is presented in Figure 2. The individual variation around the slope mean (11.15) was not significant ($p = .12$) as was the individual variation around the intercept mean (3.47; $p = .45$). The robustness of these results was controlled with a 1000-sample bootstrap. Such bootstrapped results are less affected by violations of assumptions such as the non-normal distribution of the 1-toy sustained attention at 7 months CA, and by our small sample size. This analysis confirmed the results. In addition, the reported 95% confidence interval for the variance around the intercept mean is minus 50.58 to plus 57.51, which indicates that we do not know how large the real variation in initial level in the preterm population is. The 95% confidence interval for the variance around the slope mean is minus 7.53 to plus 29.82, which indicates that the conclusion that infants do not differ in their rate of developmental change is premature.

Second, increase in 6-toy sustained attention was modeled by a linear trend. Again, this model did not fit the data well according to the negative variances that were estimated.

---

[1] Ideally, a non-linear model is tested by adding a quadratic term to the model, which describes the mean and individual variance in acceleration or deceleration of the rate of change. However, to identify such a model, four measurement occasions are minimally required. Since our data only provided three measurement occasions, we resolved this issue by allowing the third slope regression weight to be freely estimated. A disadvantage of this solution however, is that it is not possible to disentangle the individual variation in rate of change and the individual variation in acceleration or deceleration in this rate of change. As a consequence, the sharp increase was somewhat forced in this model and the third measurement occasion contributed the most to the slope factor. From the individual developmental trajectories (see Figure 1) however, it can be seen that variation in the acceleration is likely to differ between infants. To capture this individual variation it is recommended to include at least four measurement occasions in future studies.

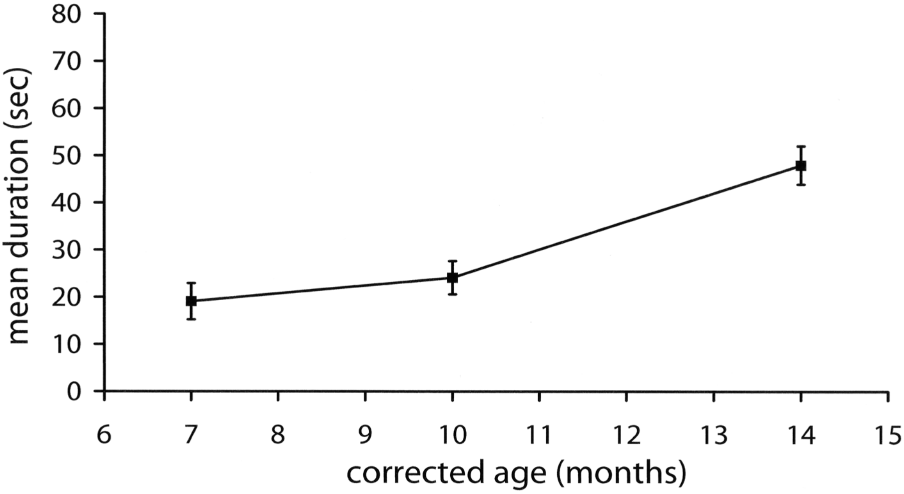


Figure 2 Mean increase in cumulative duration of 1-toy sustained attention (for best fitting non-linear model). Error bars represent the 95% confidence intervals around the estimated means.

Removal of the non-significant covariation between the intercept and slope factor did not resolve this issue. Even when the third regression weight for the slope was relaxed, the solution was inadmissible and negative variances were estimated, indicating that the data could not be described by LGM. As a consequence, the next steps of the analysis were conducted with the model for 1-toy sustained attention only.

Third, to assess the predictive value of perinatal risk factors for individual variation in the initial level and rate of change in 1-toy sustained attention, all predictors (BW, GA, gender, IVH, PVL and IRDS / BPD) were added to the slope factor at the same time. Then, the model was trimmed one step at a time, excluding the paths with non-significant parameters. Predictors without any remaining paths to the slope were removed from the model. Next, the model was built by adding co-variances between predictors step by step, based on the modification indices but only when theoretically sound. Finally, to assess the relationship between sustained attention development and subsequent global cognitive functioning, Bayley MDI scores were added to the model. The results show that BW, GA, gender, IVH and IRDS/ BPD were no significant predictors of variations in the slope factor. PVL however, did predict variation in the slope. Remarkably, infants who suffered from PVL showed a faster rate of developmental change in comparison to infants without PVL (standardized estimate = .34, $p < .01$). This model fitted the data well (see Table 3 for fit indices). In Figure 3 the mean duration of sustained attention at all three ages for infants with and

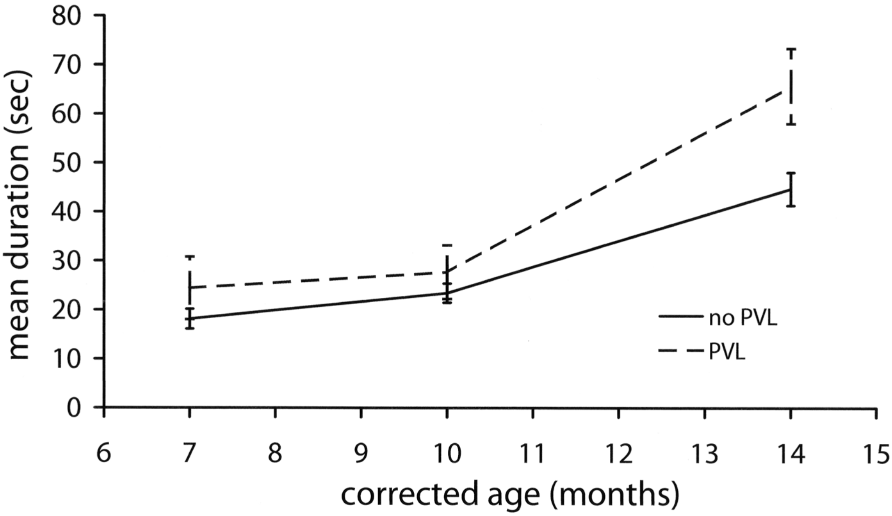


Figure 3 Mean increase in cumulative duration of 1-toy sustained attention for infants born preterm with PVL (n = 8–10) and without PVL (n = 44–56).

without PVL is presented. It can be seen that the faster rate of developmental change in infants with PVL is not due to catch-up of an earlier delay. This finding indicates that individual variation in the slope factor was meaningful, although it failed to reach statistical significance in the basic model. Finally, when including the Bayley MDI score at 14 months of age, the results showed that the rate of developmental change in sustained attention tended to be negatively related to global cognitive outcome at 14 months CA (standardized estimate = -.39, p = .08). This model fitted the data well according to the fit indices (see Table 3).

Discussion

This is, to the best of our knowledge, the first longitudinal study to investigate the developmental trajectories of sustained attention during free play within a sample of infants born preterm between 7 and 14 months CA. Important features of this study are the use of an observational measure of duration of sustained attention (in contrast to a global qualitative rating), small time intervals between measurements (planned around periods during which important transitions in higher-level control are expected) and the comparison between two task-conditions (1-toy versus 6-toy condition).

First, a significant increase in the mean duration of sustained attention in the 1-toy condition was found. This is consistent with earlier findings from Lawson & Ruff (2004), who found sustained attention to increase from 7 months to 1 year of age in infants born preterm. This age-related increase indicates that infants are able to show more sustained attention when they grow older. The non-linear results showed that the developmental increase predominantly occurred between 10 and 14 months CA. This suggests that the increase in the ability to sustain attention is not gradual, but that it shows a period of accelerated development, which points to a possible transition during this period. An important underlying mechanism for this accelerated increase may be the transition in higher-level control abilities around 12 months of age as reported by Diamond (1985, 1991). With a developmental increase in higher-level control processes, infants probably become more able to inhibit their attention to irrelevant objects and events (Ruff & Rothbart, 1996). We can not rule out however, that the observed acceleration at 14 months CA might also be influenced partly by the particular toy that was used and the setting of the assessment which both differed from the first two measurement occasions at 7 and 10 months CA in which these were kept constant. Ideally, in developmental research every aspect of a task is kept constant across waves including the toys that are used. Unfortunately, toys that are appropriate at one age are often not appropriate at older ages and vice versa. Like previous longitudinal studies (Kannass & Oakes, 2008; Lawson & Ruff, 2004; Ruff & Lawson, 1990; Ruff et al., 1990) we used a different toy at different ages. So it is possible that part of the increase observed between 10 and 14 months is influenced by this change in the toy that was presented. Similarly, the change in assessment setting from the infant's home (first two appointments) to the laboratory (third appointment) is a possible influence. That is, the finding that observations were aborted relatively often at 14 months compared to 7 and 10 months is probably due to several factors related to this age, such as increased mobility of the infants, increased weariness of strangers (stranger anxiety) in combination with a testing situation in a strange environment which could also have influenced performance in infants who did complete the assessment. However, in that case a dampening effect on the amount of sustained attention would have been expected. Related to this issue is the fact that the results are based on incomplete data. In particular, data was missing of a relatively large group of infants (about 19%) who did not complete the third assessment. Although missing data was not related to a number of variables that we considered potentially related (e.g., Bayley MDI score), the accelerated increase could be an artifact of a larger number of possibly "poorer performing" infants at the first two measurements and a smaller number of possibly "better performing" infants at the third measurement. However, the finding that infants for whom data was lost at the third measurement did not differ in sustained attention at 7 and 10 months CA does not support this possibility. This coincides with the conclusions from a recent extensive review on attrition due to fussiness in infant attention research in which no support was found for the assumption that exclusion of fussy infants influences experimental outcome (Slaughter & Suddendorf, 2007). Despite the significant increase at group level, individual differences in the rate of developmental change in sustained attention with 1 toy were not significant. However, the finding that individual differences were significantly predicted by the presence of mild PVL and in turn were predictive of global cognitive functioning seems to indicate that this variation was meaningful despite being not significant. It must be stated that the relationships were not in the expected direction. This issue will be discussed later.

Secondly, a significant increase in the mean duration of 6-toy sustained attention between 7 and 14 months CA was found, which is consistent with findings from previous longitudinal (Ruff & Lawson, 1990) and cross-sectional (Ruff & Capozzoli, 2003) studies with infants and preschoolers born at term. However, we were not able to fit a model which adequately described individual growth in this sample. Although inter-individual stability was low on 6-toy sustained attention, the model for 1-toy sustained attention demonstrates that this does not necessarily pose a problem for LGM. The failure to fit a model was probably due to the fact that associations tended to be negative over time (see Table 2). Low stability and negative correlations over time in the duration of looking during a multiple object free play task were reported previously by Kannass and coworkers (Kannass & Oakes, 2008; Kannass, Oakes, & Shaddy, 2006) and are not uncommon in infant attention studies (Colombo, Mitchell, O'Brien, & Horowitz, 1987).

An explanation for the counterintuitive results from the 1-toy condition as well as the inability to model growth in the 6-toy condition may come from the earlier mentioned studies with full-term infants, which have investigated the distribution of attention during free play in a 1-toy and 6-toy condition (Ruff & Lawson, 1990; Ruff & Capazzoli, 2003). The finding, for example, that the distribution of attention differed between these conditions in such a way that 10-month-old and 1-year-old infants showed more attention during the first minute in the 1-toy condition compared to the second minute of free play, whereas attention was more evenly distributed over the total period in the 6-toys condition (Ruff & Lawson, 1990; Ruff & Capazzoli, 2003) indicates that increasing familiarity with a single object causes infants to habituate during the course of the session in the 1-toy condition, whereas infants can shift attention to another object in the 6-toy condition when attention to one toy has been habituated. This suggests that during the first year of life, sustained attention in the 1-toy condition, as measured by the duration of looking time, also reflects individual differences in speed of information processing or learning. We assume that the increase in looking and exploration at group level indeed reflects that infants are able to sustain their attention for longer periods of time, but we speculate that at an individual level longer looking duration may not necessarily reflect the ability to maintain focused for a longer period of time. At an individual level, a number of different processes may underlie looking duration which may operate in opposite directions. In addition, they will probably not operate all together at the same time at the same age. This will depend on several factors such as the maturation of the brain or specific brain dysfunctions, attractiveness of the objects and the child's individual experiences. One such process might be the increasing ability to stay alert for a longer period of time due to the development of the arousal network in the brainstem (Posner & Raichle, 1994). Another process might be the development of higher-level control functions, such as the ability to control attention voluntary (executive attention). With increasing age, infants will be able to demonstrate more complex and sophisticated movements of the hands due to maturation of the motor system, which allows the infants to explore and manipulate the objects for a longer time. Consequently, when objects are manipulated in more complex ways, more information of these objects will become available and must be processed, which takes more time and therefore longer looking time. On the other hand, there is another process working in the opposite direction and most likely leading to a decrease in looking duration over time: the increasing speed of information processing (due to the development of white matter in the brain). Shorter looking time in habituation paradigms is assumed to reflect faster habituation or faster speed of information processing. Moreover, faster habituation has been found to be related to higher scores on IQ-tests and vice versa (Bornstein & Sigman, 1986). Shorter looking time will be most likely shown in tasks which are no longer challenging enough, such as the 1-toy condition. However, some infants will need more time to process information than others. That is, longer looking behavior could reflect less efficient information processing in some infants, whereas in others it may reflect the emergence of high-level control functions.

In sum, when all these processes are operating during free play, one cannot hold that longer looking time demonstrates more advanced development than shorter looking time. There might be an optimal duration of looking time during object manipulation. When we assume that the age-related increase in looking duration reflects an increase in the information that is being processed, it is not unlikely that this increase is stronger in infants who need more time to process this information. This line of reasoning can explain our rather unexpected findings when we consider that a stronger increase in duration of looking over time was related to lower global cognitive outcome scores at 14 months. In addition, infants with mild PVL showed a stronger increase in the duration of looking with increasing age in the 1-toy condition than infants without PVL. This would then indicate that infants with mild PVL are less efficient in the processing of the increasing amount of information. The negative effects of PVL on attention performance was also found in a study by Katz et al. (1996) who found that 6- to 8-year-old children born preterm with both mild (e.g., IVH grade I or II and / or transient periventricular flaring) or severe neonatal cerebral lesions (e.g., IVH grade III or IV and / or PVL) made more errors on a Continuous Performance Test (Katz et al., 1996). Also similar to our results, Kannass & Oakes (2008) found looking duration in a single object condition at 9 months to be negatively related to vocabulary at 31 months in infants born at term, whereas looking duration in a multiple object condition was positively related. These authors also suggest that a single object free play session is akin to a habituation task and is therefore more likely to reflect the efficiency in information processing in which a shorter looking duration reflects more mature attentional responding, at least in younger infants. The multiple object free play session, in which several toys compete for attention, is assumed to provide a more valid measure of the ability to sustain attention, since several other toys are available when attention to one toy has been habituated (Ruff & Lawson, 1990; Kannass & Oakes, 2008). However, there are reasons to assume that habituation and speed of information processing also influence sustained attention with 6 toys. That is, the earlier cited cross-sectional (Ruff & Capazzoli, 2003) and longitudinal (Ruff & Lawson, 1990) studies by Ruff & co-workers also show that the distribution of attention changes with age in the 6-toy condition, with 10-month-old and 1-year-old infants being predominantly attentive at the beginning of the period (reflecting processes of habituation) while 26-month-old and 2-year-old children show little change over time and 42-month-old or 3,5-year-old children show an increase in sustained attention over time within a session. Attention in younger children seems to be mainly controlled by the physical properties of an object (for example novelty) according to Ruff and Capazolli (2003), while attention at an older age is more likely to be governed by the complexity of the activity with objects or endogenous control (i.e., higher-level control). Although this is apparently even more true when only a single object is available, habituation to novelty also seems to influence sustained attention in multiple object conditions. Consequently, these age-related changes in the influence of habituation may have played a role in our inability to model growth in the 6-toy condition. However, there are additional factors that probably have played a role in our inability to model 6-toy sustained attention. Observations of the 6-toy free play task revealed that the condition under which the task was obtained could not prevent the occurrence of relatively random but disturbing events which possibly influenced infant performance such as coincidental contact with other toys than the one that was played that caused distraction for some infants. In addition, the competitive aspect of the task changed substantially when infants dropped some of the toys and only few toys were left on the table. This indicates that the way the task was designed was not standardized sufficiently to create an equal situation for each infant. Especially when higher-level control processes are just beginning to emerge and infants are still very susceptible to distraction, these events are probably of great influence on their attention performance. The behaviors that were observed during the 6-toy condition seem to imply that the task did not provide us with a reliable measure of sustained attention at this young age, at least not in infants born preterm.

In conclusion, the partly counterintuitive findings regarding the 1-toy condition as well as the inability to model the 6-toy condition suggest that looking and exploratory behaviors during free play tasks reflect the functioning of earlier developing attention systems (i.e., orienting and arousal system) as well as later developing attention system (i.e., higher level control system). In other words, the observed age-related increase in the duration of looking and exploration in the present study may reflect the ability of infants to become more able to sustain attention (possibly due to an increase in the ability to inhibit their attention to surrounding objects or events), but the inter-individual differences in the duration of looking also may reflect differences in habituation and the efficiency of information processing. The relative contribution of these processes is likely to change with task conditions and with age, but are also likely to differ between individual infants. According to Ruff & Rothbart (1996, p 117) "the time from 9 to 18 months represents a transition period during which attention comes under the control of both systems [e.g., the orienting/investigative system and the higher-level control system] rather than one". It is possible that habituation influences are more apparent or prolonged apparent in infants born preterm, due to slower development of either habituation or higher-level control abilities, or both. Indeed, the results of our study on A-not-B development in the same sample of infants born preterm (see *Chapter 3*) compared to the results from studies with infants born at term (Bell & Fox, 1992; Diamond, 1985) suggest that higher-level control abilities show a slower pace of development in infants born preterm.

Recommendations for future research

Until recently, infant looking behaviors during free play tasks have been considered to reliably reflect sustained attention. More recently, there has been growing awareness that the nature of attention processes underlying behavior during free play tasks changes with age. However, the extent to which these different attention processes are reflected by the free play task is not only dependent on developmental changes in these systems but also on task conditions. Although our findings in a sample of infants born preterm confirm that a complex interplay between habituation and higher-level control abilities influence attention during free play, more research is necessary to gain more knowledge about the processes underlying performance during free play tasks, in full-term infants as well. Experimental manipulations of task conditions may provide insight on this issue, but only when all other circumstances are designed in such a way that the task is truly standardized. For example, toys could be attached to the table top to prevent infants from dropping toys from the table and to ensure that task conditions remain the same for each infant. In addition, to control for the possible effect of attractiveness or age-appropriateness of toys, it will be necessary to present infants with different toys successively in the 1-toy condition, following more recent procedures (Kannass & Oakes, 2008; Lawson & Ruff, 2004). In that way, toys that are appropriate for ages along the whole study spectrum can be presented at each age. Although most studies compare the 1-toy condition to the 6-toy condition, the effect of task load (i.e., the amount of toys) has - to our knowledge - never been investigated in more detail. Manipulation of the number of toys that are presented simultaneously may provide additional insight on this issue. Longitudinal studies with dense time intervals are needed to investigate which underlying attention processes are influencing looking and exploratory behaviors during free play tasks at certain ages, and when important transitions occur. For example, it would be useful to incorporate other tasks that are known to rely on orienting (e.g., habituation or novelty paradigms) and higher-level control abilities (e.g., A-not-B task) to investigate their relative influence on looking and exploratory behaviors during free play. The influence of habituation processes may also be identified by looking at the distribution of attention behaviors over time within a given task, as was done by Ruff and coworkers (Ruff & Lawson, 1990; Ruff & Capazzoli, 2003). Information about how and when these transitions occur in infants born full-term is necessary before we can draw conclusions about whether these transitions are delayed in infants born preterm.

Many of the results from this study coincide with previous findings. It would be very tempting to draw straightforward conclusions from these results. However, the use of LGM has allowed us to look at the data in a way that was not available earlier. This study illustrates that even when intra-individual stability is low, individual developmental trajectories may be described by a latent growth curve. On the other hand, when a mean increase in an outcome measure is found but individual developmental trajectories can not be described by a growth curve, this may indicate that we are not measuring the same construct at every age with a certain task. In that way, LGM provides us with a broader and more complete picture of how developmental change occurs, and gives new meaning to the results that were found.

Acknowledgements

First, we thank all the children and parents who participated in this study for their time and effort. The assistance of Hanna Mulder, Inge Griffioen, Lise Vergeer and Hilke Rijnen in the collection of data is gratefully acknowledged. Finally, we would like to thank Tolo Toys Ltd. for their generous donation of toys for the sustained attention task and the presents for the participating infants.

5

Maternal interactive styles and individual differences in developmental trajectories of attention and executive functioning in infants born preterm

E. van de Weijer-Bergsma, L. Wijnroks,
I.C. van Haastert, J. Boom, M.J. Jongmans

Submitted for publication in
Child Development

Abstract

This study assessed how maternal interactive styles predict individual differences in the development of attention and executive functioning in 76 infants born preterm, and whether this varies with infant temperament, i.e., self-regulation. Maternal sensitive responsiveness and directiveness were observed during a mother-infant interaction situation at 7, 10 and 14 months corrected age. At the same ages, sustained attention was observed during free play, and executive functioning was measured using the A-not-B task. Multivariate Latent Growth Modeling showed that consistently higher levels of directiveness predicted a stronger increase in A-not-B performance, which did not vary with infant self-regulation. Maternal interactive styles did not predict the development of attention. These results suggest that preterm infants' executive functioning development may benefit from a more structured approach.

Introduction

Infants who are born preterm (gestational age < 37 weeks) are at a heightened risk for developmental delay and learning disabilities (Aylward, 2002a; Hack et al., 2005; Pritchard et al., 2008; Taylor, Minich, Klein, & Hack, 2004). More recently, the finding that school-aged children, who were born preterm, are at risk for attention problems and executive dysfunction possibly leading to a diagnosis of ADHD (Aylward, 2002a; Bayless & Stevenson, 2007; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Mick, Biederman, Prince, Fischer, & Faraone, 2002; Salt & Redshaw, 2006; Shum, Neulinger, O'Callaghan, & Mohay, 2008; Smith, Keeney, Zhang, Perez-Polo, & Rassin, 2008), has led researchers to suggest that problems in the early development of attention and executive functioning (EF) may underlie the individual variability between infants born preterm and their vulnerability as a group for developmental delay and learning problems (Aylward, 2002a; Davis & Burns, 2001). In two recent studies, we reported that individual differences in the rate of developmental change, between 7 and 14 months corrected age (CA), in sustained attention during free play and EF abilities in infants born preterm are predictive of subsequent global cognitive functioning (see *Chapter 3* and *Chapter 4*). In addition, several perinatal risk factors were found to be predictive of these individual differences in developmental change. It is assumed, however, that the effect of perinatal risk on cognitive development can be aggravated or tempered by environmental influences, in particular by the way a mother interacts with her preterm infant. However, the consequences of a preterm birth may also jeopardize the way mothers interact with her infant. Information on how infant and parent characteristics interact is essential for the development of effective intervention strategies (Clark, Woodward, Horwood, & Moor, 2008). Therefore, this study investigates how (changes in) maternal interactive styles are related to individual differences in early sustained attention and EF development in infants born preterm, and whether these relationships vary with differences in infant self-regulation.

Maternal sensitive responsiveness and directiveness

The quality of parenting is considered to play an important role in infant and child development. Two parental interactive behaviors that are frequently investigated are maternal sensitivity or responsiveness and maternal directiveness or control (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008; Johnson, 2005; Landry, Miller-Loncar, &

Smith, 2002; Masur, Flynn, & Eichorst, 2005; Wijnroks, 1997).

Sensitivity and responsiveness are used somewhat interchangeably, and will therefore be termed *sensitive responsiveness* in this article. It refers to the ability of a parent to focus on the infant's signals, to interpret them correctly and to respond promptly and contingently (Ainsworth, Blehart, Waters, & Wall, 1978; Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008). A sensitive responsive interactive style is considered to facilitate global cognitive development since it supports the immature abilities of an infant and it will make learning experiences more successful. A sensitive responsive interactive style also places fewer demands on infants' limited attentional capacities (i.e., by following the activity and attention direction of the infant) (Landry & Chapieski, 1989), and provides infants with external support in regulating their arousal level (Albers, Riksen-Walraven, Sweep, & de Weerth, 2008; Crockenberg & Leerkes, 2004; Haley & Stansbury, 2003). Since the development of attentional control and self-regulation are thought to be strongly linked (Berger, Kofman, Livneh, & Henik, 2007; Rueda, Posner, & Rothbart, 2004a), such external support provided by parents may also facilitate attention and EF development.

Directiveness refers to the degree to which a parent selects the topics of conversation or play, uses imperatives or commands and using verbal and physical prompts to control the child's behavior. This is also sometimes referred to as parental 'control' (Forcada-Geux, Pierrehumbert, Borghini, Moessinger, & Muller-Nix, 2006). A directive interactive style is characterized by repeated efforts to control or regulate the attention or behavior of an infant or child (Masur & Turner, 2001). Most theorists and researchers agree that a directive interaction style, especially when it is intrusive, may have a negative influence on the social and cognitive development of an infant, as it hampers the infant's striving for autonomy and feelings of self-efficacy (Clark et al., 2008; Marfo, 1992; Muller-Nix et al., 2004). Consequently, this would lead to less exploration by the infant and lower levels of self-esteem.

Studies on the stability of interactive styles have shown that individual differences between mothers in sensitive responsiveness are fairly stable (Dallaire & Weinraub, 2005; Masur & Turner, 2001), but less stable in directiveness (Masur & Turner, 2001). Although directiveness and sensitive responsiveness are often found to be negatively related, these two styles do not represent opposite ends of the same construct (Murray & Hornbaker, 1997). That is, a mother who is highly sensitive and responsive may use some directive strategies as well, and a mother who is very unresponsive may not use any directive strategies at all. However, very high scores on sensitive responsiveness are not likely to coincide with very high scores on directiveness.

Maternal interactive styles and preterm birth

The event of a premature birth can influence the way a mother interacts with her infant in various manners. First of all, preterm birth is considered a very stressful experience for parents and found to be related to increased levels of maternal stress, anxiety and depression (Davis, Edwards, Mohay, & Wollin, 2003; Feldman & Eidelman, 2007; Muller-Nix et al., 2004; Poehlmann & Fiese, 2001; Spear, Leef, Epps, & Locke, 2002) which in turn may affect the way these mothers interact with their infant (Korja et al., 2008; Wijnroks, 1999; Zelkowitz, Papageorgiou, Bardin, & Wang, 2009). Secondly, infants born preterm are often characterized as being more temperamentally difficult than infants born at term. That is, infants born preterm have been reported to be less predictable, more irritable, more easily over-stimulated, and more withdrawing from new situations and to have less regular feeding and sleeping patterns than infants born at term (Feldman & Eidelman, 2007; Haley, Grunau, Oberlander, & Weinberg, 2008; Hsu & Jeng, 2008; Hughes, Shults, McGrath, & Medoff-Cooper, 2002). These behaviors indicate that infants born preterm have more difficulties with regulating their own state of arousal and behavior (i.e., self-regulation) than infants born at term. As a result, it is possibly more challenging to interact with these infants. So, interactions with infants born preterm are potentially complicated by the neurobiological risk of the infant as well as their mothers' emotional distress.

Studies investigating differences in maternal interactive styles between mothers of infants born preterm and mothers of infants born at term show some mixed results. Whereas some studies support the hypothesis that interactions with preterm infants are more challenging and lead mothers to respond less sensitive and more directive (Clark et al., 2008; Feldman & Eidelman, 2007; Muller-Nix et al., 2004), other studies have shown that mothers of preterm infants are even more responsive to their infants (Reissland & Stephenson, 1999; Salerni, Suttora, & D'Odorico, 2007; Schmucker et al., 2005). Feld & Eidelman (2007), for example, found that mothers of infants born preterm displayed less talking, touching and looking during feeding in the neonatal period, and less synchronization of their behavior to their infant's alertness at 3 months. Similarly, Muller-Nix et al. (2004) found mothers of 6-month-old infants born preterm to be less sensitive and more controlling, but only when their infant was considered relatively at high-risk (i.e., suffered more severe medical complications). Clark et al. (2008) also found parents of 2-year-old children born preterm to be less sensitive and more intrusive during a problem solving task than parents of children born at term, but only when children were born extremely preterm (gestational age < 28 weeks). Schmuker, Brish et al. (2005) found mothers of infants born preterm to be less facially responsive but *more* verbally responsive at 3 months. Higher levels of verbal responsiveness in mothers of infants born preterm than in mothers of infants born at term were also found by Reissland & Stephenson (1998). Similarly, Salerni et al. (2007) found mothers of 6-month-old infants born preterm to be more verbally responsive than mothers of infants born at term, even though infants born preterm were less verbally responsive than infants born at term. So, it seems that mothers of preterm infants are generally somewhat less sensitive and more directive, but also more verbally responsive than mothers of infants born at term. This indicates that mothers of preterm infants stimulate their infants mainly in a verbal way, which might sometimes be interpreted as intrusive.

The results from a recent study by Coppola, Cassiba and Costantini (2007) however, suggest that a comparison between mothers of infants born preterm and infants born at term does not do justice to the complexity of the issue. These authors found that the relationship between maternal sensitivity and infant birth status was moderated by mothers' own secure or insecure attachment representation. That is, secure mothers who had an infant born preterm were more sensitive than secure mothers with an infant born at term, whereas insecure mothers showed the opposite pattern (Coppola, Cassiba, & Costantini, 2007). These findings suggest that a complex interplay between infant and maternal characteristics determines how a mother reacts to her premature infant.

Maternal interactive styles and global cognitive development in infants born preterm

The predictive value of maternal sensitive responsiveness and directiveness for cognitive and behavioral development has been investigated in several studies with infants and children born preterm (Landry, Garner, Denson, Swank, & Baldwin, 1993; Landry, Smith, Miller-Loncar, & Swank, 1997; Landry, Smith, Swank, Assel, & Vellet, 2001; Landry, Smith, Swank, & Miller-Loncar, 2000; Moore, Saylor, & Boyce, 1998; Murray & Hornbaker, 1997; Smith, Landry, & Swank, 2006; Smith et al., 1996). Murray & Hornbaker (1997), for example, found sensitive responsiveness at 12 months to be positively related to global cognitive outcome and receptive language skills at 24 months in both high-risk infants (i.e., infants admitted to a NICU, including infants born preterm) and low-risk infants born at term. Similarly, higher levels of responsiveness at 2 years were associated with a higher 5-year global cognitive outcome in infants born preterm, in a study by Moore et al. (1998). The facilitative effect of responsiveness was also found by Landry and coworkers (Landry et al., 1997, 2001; Smith et al., 2006), in a longitudinal study with a large cohort of infants born at term, as well as medically low-risk and medically high-risk infants born preterm. In addition, the results from this large scale study showed that children displayed faster global cognitive development when mothers were *consistently* highly responsive during infancy as well as the preschool years, compared to when mothers were highly responsive only during infancy (Landry et al., 2001). This influence of consistent responsiveness during infancy and the preschool years on global cognitive functioning was still visible at 10 years of age (Smith et al., 2006). In the same cohort, Landry and coworkers also investigated the predictive value of attention maintaining style. This style is considered a more specific form of sensitive responsiveness and refers to the extent to which mothers maintain their infant's interest in objects or toys by following the child's focus of attention, commenting on the child's activity, and elaborating on the child's theme of conversation or play (Landry, Garner, Swank, & Baldwin, 1996; Smith et al., 1996). Higher levels of attention maintaining have been found to be predictive of higher global cognitive and language skills during the first year of life (Smith et al., 1996), and a faster rate of developmental change in cognitive development from infancy into preschool age (Landry et al., 1997, 2001).

The results regarding the predictive value of directiveness for global cognitive development are somewhat mixed, and indicate that directiveness may facilitate global cognitive development during infancy, but that it may hinder development when it persists beyond the first two years. In the study by Landry et al. (2000), for example, directiveness was found to positively support cognitive skills during the first two years of life, but to have a negative influence on cognitive development beyond the first two years. However, Landry and coworkers also found that higher levels of restrictiveness during infancy predicted a slower rate of developmental change in cognitive development from infancy into preschool age (Landry et al., 1997, 2001). The hypothesis that directiveness is negatively related to cognitive development beyond infancy was confirmed by Moore et al. (2005), who showed that directiveness at 2 years was related to lower global cognitive functioning at 5 years. Similarly, Murray & Hornbaker (1997) found directiveness at 12 months to be negatively related to receptive language skills, but not to expressive language skills or global cognitive functioning at 24 months.

The influence of maternal interactive styles on global cognitive functioning might also depend on child characteristics related to a preterm birth, such as severity of medical complications. Landry and coworkers, for example, have shown that infants born preterm who suffered more severe neonatal medical complications may benefit less from a sensitive responsive style than infants born preterm with less severe complications (Landry et al., 1993; Smith et al., 2006), but are also more strongly influenced by the negative effects of restrictiveness (Landry et al., 1997).

In sum, there is strong evidence that higher levels of (consistent) sensitive responsiveness facilitate global cognitive development in infants and children born preterm and born at term. The somewhat mixed results regarding directiveness suggest that higher levels of directiveness may provide infants born preterm the external structure and support they need to obtain certain goals earlier in infancy, but that it may be important for mothers to gradually withdraw this type of support when infants become more active agents and reach a higher level of autonomy (Landry, Miller-Loncar, & Smith, 2002). In other words, a directive approach will become intrusive when it is not adapted to an infant's needs. One might speculate, that infants born preterm will benefit from a more controlling and structured approach by the mother since they have more difficulties in regulating their behavior during infancy.

Maternal interactive styles and attention and EF development in infants born preterm

Since infants born preterm have more difficulties with self-regulation, and the development of attentional control and self-regulation are thought to be strongly linked (Berger et al., 2007; Rueda et al., 2004a), the level of maternal sensitive responsiveness and directiveness may be of special importance to the development of attention and EF in these infants. Landry and coworkers (Landry et al., 1993, 1996) reported an interesting finding that supports the idea that mothers are able to regulate their infant's immediate behavior. They found that higher levels of attention maintaining during a joint-play session facilitated the exploration of toys during that session in infants born preterm. In addition, the effects of this interactive style on exploratory play were stronger for infants born preterm when mothers used more structured strategies (i.e., specific directions about how to play with a toy) compared to when mothers merely verbally labeled or pointed toward objects (Landry et al., 1993). This finding not only confirms that a sensitive responsive approach, by trying to maintain the infant's attention, may help to regulate the behavior of infants born preterm, but as discussed above with respect to global cognitive functioning, also indicates that they may indeed benefit from a more directive approach at this age.

To the best of our knowledge, only a few studies have focused on the predictive value of sensitive responsiveness and directiveness for early attention (Tu et al., 2007; Wijnroks, 1998) and EF development (Assel, Landry, Swank, Smith, & Steelman, 2003; Landry, Miller-Loncar, Smith, & Swank, 2002b) in infants and preschool children born preterm. However, none of these studies found a direct relationship between maternal sensitive responsiveness or directiveness and the development of attention. In a study by Wijnroks (1998), neither maternal sensitive responsiveness nor directiveness observed at 6 and 12 months was found to be related to inattention during problem solving tasks at 18 and 24 months in infants born preterm (Wijnroks, 1998). In this study, inattention was measured by counting the number of times the infant was looking away from the task. Low levels of inattention were assumed to reflect the ability to sustain attention (Wijnroks, 1998). Tu et al. (2007) only found an indirect effect of positive maternal behaviors (including sensitivity) on quality of focused sustained attention during free play. More specifically, maternal behavior was found to buffer the negative influence of neonatal pain related stress (indexed by the number of skin-breaking procedures from birth to term) on focused attention but only when mothers experienced relatively low levels of parenting stress (Tu et al., 2007). This buffering effect of positive maternal behaviors was not found in infants whose mothers experienced higher levels of stress. These results cannot be explained by a lower quality of maternal behaviors, since mothers in these two groups were not found to differ on this measure. An alternative explanation might be that mothers who experience more stress are less consistent in their parenting behaviors, which would coincide with the findings by Landry et al. (2001).

In contrast to studies with respect to attention development, the few available studies showed that maternal interactive styles seem to predict EF development in children born preterm at least at the age of two years and beyond. The cohort that was followed by Landry and coworkers (Assel et al., 2003; Landry et al., 2002b), demonstrated that, irrespective of the child's birth status (preterm vs born at term), children who received higher levels of verbal scaffolding (i.e., contingent instruction by parents which requires sensitive responsive and attention maintaining behaviors) at 3 years showed better performance on two tasks measuring EF skills (i.e., a spatial reversal task and independent goal-directed play) at 6 years, mediated by their language and problem solving skills at 4 year. On the other hand, maternal directiveness at age 2 acted as a direct negative influence on visual-spatial and executive function skills at 3 years measured by independent goal-directed play, which in turn predicted math abilities at 8 years (Assel et al., 2003).

Limitations of previous studies

Although various studies investigated the predictive value of maternal interactive styles for cognitive development in infants born preterm, most studies focused on global cognitive development. Studies on maternal interactive styles and attention development in infants born preterm are relatively scarce. In addition, the only study on maternal interactive styles and EF development in children born preterm was conducted beyond 2 years of age. So it remains unclear how maternal interactive styles are related to attention and EF development in the first two years of life. In addition, none of these studies investigated how *stability* or *change* in maternal interactive styles may predict attention and EF development. Modeling growth in maternal interactive styles as well as infant outcome measures allows us to investigate whether stability or changes in maternal interactive styles are associated with infant development.

Aims of the present study

Because maternal interactive behaviors may play an important role in early attention and EF development in infants born preterm, the aims of the present study were to investigate: (1) how (changes in) maternal interactive styles are related to developmental trajectories in attention and EF in infants born preterm between 7 and 14 months corrected age (CA), and (2) how these relationships vary with differences in infant self-regulation, by using multivariate multi-group Latent Growth Modeling in a longitudinal, within-subjects design during the first fourteen months of life. Measurement occasions were chosen around ages during which important transitions in infant development are expected to occur, rather than based on expected changes in maternal interactive styles.

We expect that a directive interactive style will show a less stable pattern during the study period compared to a sensitive responsiveness interactive style. Since a sensitive responsiveness interactive style helps infants to regulate their immature attentional control abilities, we expect preterm infants' rate of attention and EF development to be positively related to a consistently sensitive responsiveness interactive style. In addition, because maternal directiveness offers infants with external support, directiveness is also expected to be positively related to attention and EF development, although this effect may diminish with infants' increasing age. Finally, the positive effects of higher levels of sensitive responsiveness and directiveness are expected to be stronger for infants who have more difficulties with self-regulation.

Methods

Participants

During the period of inclusion, between April 2004 and August 2005, a total number of 325 singleton infants born preterm (gestational age ≤ 36 weeks, birth weight < 2500 grams) were admitted to the Neonatal Intensive Care Unit (NICU; *n* = 266) or the Medium Care Unit (MCU; *n* = 53), or both units (*n* = 6) of the Wilhelmina Children's Hospital in Utrecht, The Netherlands. Ethical permission for the study was granted by the hospital's ethics committee.

Thirty infants died during the postnatal period. Other exclusion criteria were congenital or chromosomal disorders (*n* = 21), (possible) congenital infections such as HIV (*n* = 2), significant sensory disorders (*n* = 3), uncertainty about gestational age (GA) (*n* = 3), and incomplete data (*n* = 5). Maternal factors that lead to exclusion were drug- or alcohol abuse (*n* = 5), maternal age < 18 years (*n* = 1), non-biological mother (e.g., egg donation or adoption) (*n* = 1), parental consanguinity (*n* = 1), no knowledge or use of the Dutch language (*n* = 11), maternal death (*n* = 1), move abroad (*n* = 3), or alien status (*n* = 1).

After exclusion, 237 singletons were eligible for inclusion in the study, of which 119 children and their parents were randomly selected and invited by letter to participate. Parents were contacted by phone at least 1 week later. Also, parents were able to sign up for the study by returning an informed consent form. Parents of 76 infants consented for their infant to take part in the study (63.9% of the invited parents).

There were no significant differences between participants (n = 76) and non-participants (n = 161) from the NICU and MCU in gender, severity or presence of medical complications such as respiratory problems,[1] asphyxia or small for gestational age. However, participants were born at lower mean gestational age (GA) ($p < .01$), with a lower birth weight (BW) ($p < .05$), and suffered from more severe intraventricular hemorrhage (IVH) ($p < .05$) than non-participants. Since the great majority of participants in our study were admitted to the NICU (n = 72), a comparison between participants and non-participants from the NICU was also made. Comparison with NICU infants showed no differences in perinatal characteristics. Based on these comparisons we consider our sample to be representative for a NICU population of infants born preterm. None of the infants was diagnosed with cerebral palsy at 14 months CA.

Measurements

Maternal measures

Maternal interactive styles. Mother-infant interactions were videotaped at 7, 10 and 14 months CA during a 5-minute free play session. At 7 and 10 months CA, mothers played with their infant while sitting on the ground at a small table (60 x 60 [width x depth]) with raised edges to prevent the toys from falling. Infants were seated in a car seat at the opposite side of the table, facing their mother to enable eye-contact. Mothers were provided with 6 age-appropriate toys, including a rolling pop-up teddy, a squeaking duck, a wooden rattle with beads, a soft ball, a soft water-repellent book, and a stacking clown (consisting of two shapes with tingling balls inside, a rattling ball with a clown's face, and a hat with a prism inside). Mothers were asked to play with their infant as they would normally do, and they were told that they were free to decide which of the toys they used and how long they played with them. It was also emphasized that they were free to abort the session when their infant became fussy or started to cry. At 14 months CA, mothers and their infants played while sitting on a carpet, with two different toys consecutively. First, they played for 2,5 minutes with a jigsaw puzzle and then for 2,5 minutes with a pop-up toy, in which four different farm animals pop up when the associated lever is manipulated.

Maternal interactive styles were rated on a nine-point 'sensitivity' scale (Ainsworth et al., 1978) and 5 five-point rating scales which measured maternal 'quality of handling', 'timing', 'nondirectiveness', 'noninterference', and 'responsiveness' (ELO scales; Wijnroks, 1997; 1998). These five ELO scales were used, following the clusters

[1] Respiratory problems were scored based on the presence and severity of infant respiratory distress syndrome (IRDS; grades I-IV) (Giedion, Haefliger, & Dangel, 1973) and / or bronchopulmonary dysplasia (BPD), which resulted in a lung score, ranging from 0 (no lung problems) to 5 (BPD). IVH was scored ranging from 0 (no IVH) to 4 (IVH grade IV) (Papile, Burstein, Burstein, & Koffler, 1978). Periventricular leukomalacia (PVL) was scored ranging from 0 (no PVL) to 4 (PVL grade IV) (de Vries, Eken, & Dubowitz, 1992).

that were made by Wijnroks (Wijnroks, 1997, 1998, 1999) grouped 'sensitivity', 'responsiveness' and 'timing' into a cluster called 'sensitive responsiveness', whereas 'quality of handling', 'nondirectiveness, and 'noniterference' were grouped into a cluster called 'nonintrusiveness'. 'Sensitivity' is related to the extent to which a mother is attuned to the signals of her infant and responds in an appropriate way (score 1 = highly insensitive, score 9 = highly sensitive). 'Responsiveness' is related to the extent to which a mother responds to signals of her infant, such as vocalizing, smiling, and eye-contact (score 1 = non-responsive, score 5 = highly responsive).'Timing' is related to the introduction of new objects and instructions based on the interest and attention direction of the infant (score 1 = bad timing, score 5 = excellent timing). 'Quality of handling' is related to the way a mother stimulates and handles her infant physically (score 1 = rough, score 5 = gentle). 'Nondirectiveness' is related to the extent to which a mother determines the topic of play, physically or verbally (score 1 = highly directive, score 5 = not directive at all). 'Noninterference' is related to the extent to which a mother interrupts the activities and attention of her infant, either by distracting the infant or by hindering exploration (score 1 = highly interfering, score 5 = not interfering at all).

To investigate whether a factor analyses would reveal maternal interactive styles that are concurrent with the interactive styles mentioned in the introduction and the clusters made by Wijnroks (1997; 1999), a principal component analysis (PCA) with varimax rotation was performed. The PCA revealed two factors explaining 80.6% of the total variance at 7 months CA, 72.9% at 10 months CA, and 82.3% at 14 months CA. The first factor explained between 45.9% and 53.9% of the total variance across the three different ages and related to 'timing', 'noninterference', 'sensitivity' and 'responsiveness'. So, in contrast to the clusters formed by Wijnroks (1999), 'noninterference' loaded more strongly on the first factor. However, similar to our PCA results, Wijnroks (1999) found that noninterference was significantly related to sensitive responsiveness (r = .73, $p < .001$). Therefore, these four scales were summed and divided by the number of scales, and called '*sensitive responsiveness*' with scores ranging from 1 (very low sensitive responsiveness) to 6 (very high sensitive responsiveness). This measure reflects a mother's sensitivity to her infant's signals and the contingency of her responses. The second factor explained between 26.9% and 31.8% of the total variance across the three different ages and related to 'quality of handling' and 'nondirectiveness'. Both scales were re-scored so that a higher score related to higher directiveness and lower quality of handling, then summed and dived by the number of scales (i.e., two) and called '*directiveness*' with scores ranging from 1 (not directive at all) to 5 (very directive). This measure reflects the extent to which a mother controls the subject of play (verbally and physically). Sensitive responsiveness and directiveness were significantly negatively correlated at each age (r = -.54, r = - .45, and r = -.72 respectively at 7, 10 and 14 months CA). At every age, 10 videos were scored by a second observer in order to assess inter-rater reliability. Single measures intraclass correlations (ICC) at 7, 10 and 14 months CA, respectively, were .95, .96, and .99 for sensitive responsiveness, and .66, .84, and .90 for directiveness.

Infant measures

Self-regulation at 7 months CA. When infants were 7 months CA, mothers completed a subset of 70 items of the revised Infant Behavior Questionnaire (IBQ-R) (Garstein & Rothbart, 2003) translated to Dutch by van der Pal and coworkers (van der Pal et al., 2008). The items measured 5 behavioral scales which load onto the factor Orienting/ Regulation: low intensity pleasure, cuddliness/affiliation, duration of orienting, soothability, and smiling and laughter. The behavior items were rated on a 7-point Likert-type scale (1 = not present, 7 = always present) with an extra "does not apply" answer possibility, which received no numerical score when calculating mean scores for the scales.

Executive functioning: A-not-B task. Based on procedures by Diamond and colleagues (Diamond, 1985; Diamond & Goldman-Rakic, 1989; Diamond, Prevor, Callender, & Druin, 1997) and Bell & Adams (1999), age-appropriate looking and reaching versions of the A-not-B task were administered at 7 and 10 months CA. At 14 months CA, only a reaching version was administered (for a detailed description of materials and procedures see: van de Weijer-Bergsma, Wijnroks, Boom, de Vries, et al., submitted).

In the *reaching and looking versions of the A-not-B task*, infants had to search a toy that was hidden on one of two locations. The administration of the looking and reaching versions was identical, except for the response output. In the reaching version of the task, correct or incorrect reaching and uncovering one of the two locations was scored as performance behavior. In the looking version, the direction of the first eye movements after being brought to midline was scored as either correct or incorrect (Bell & Adams, 1999).

Testing always started with a toy partially hidden under a cloth (item 1), followed by a toy hidden completely under a cloth (item 2) to make sure that an infant was able to retrieve a hidden object. All items were administered maximally three times. When an infant was able to find a hidden object under one of two identical cloths or cups (item 3), A-not-B testing began. After two successful retrievals at side A, the toy was hidden in the opposite side B (i.e., reversal trial). When infants successfully retrieved the toy from side B in two out of three A-A-B trials (i.e., did not make the A-not-B error) the delay between hiding and seeking was increased. Complexity of the task was increased by increasing the delay between hiding and seeking from 0 to 1 to 3 to 5 to 8 seconds. Scores ranged from 0 to 8.

A-not-B with invisible displacement. At 14 months CA the reaching version of the A-not-B task was adjusted and more complex items were added to the task, in which displacement of the hidden toy was invisible. These invisible displacement items were based on the A-not-B with invisible displacement task by Diamond et al. (1997). Administration always started with a 'regular' A-not-B trial with 5 seconds delay. When an infant's reach on the reversal trial was correct, the delay was incremented to 8 seconds, whereas a wrong reach on the reversal trial resulted in a shortening of the delay to 3 seconds. When the infant reached correctly at this delay, the 5 second delay was administered again. Administration of the test ended when an infant failed an item twice. If an infant successfully recovered an object at a delay of 8 seconds, the invisible displacement items were introduced. In these items infants did not see the toy itself change position, but saw the cup that holds the toy move to left or right. In other words, the cup that holds the toy changed position with the second, empty cup. So, although a reaching response is necessary for performance, these items also have a large visual component. After two successive correct reaches, the side of hiding was changed. Again, complexity of the items was increased by increasing the delay between hiding and seeking from 3 to 5 to 8 seconds. Scores ranged from 0 to 11 (items 1 to 8 were identical to the items of the A-not-B reaching task administered at 7 and 10 months CA).

Sustained attention during free play. Sustained attention during free play was observed and videotaped at 7, 10 and 14 months CA during a 2-minute free-play session. Infants played alone with a single toy while sitting in a car seat at a small table (60 x 30 [width x depth]) with raised edges to prevent the toy from falling from the table. The toys that were used for playing were age-appropriate hard plastic, colorful toys. At 7 and 10 months CA an easy to grasp rattle with colored beads that could be manipulated was used, and at 14 months CA an activity play triangle with a revolving mirror, beads and a turning knob. Administration was ended when infants became fussy or started to cry. Sustained attention was defined as the duration of intent looking at the object while manipulating, accompanied by a decrease in motor activity (Ruff & Lawson, 1990). Only episodes of looking while manipulating with a duration of more than 2 seconds were considered sustained attention. The dependent measure was the cumulative duration of attention in seconds over the first 90 seconds of the free play period. Videotapes were independently scored by two blinded observers at half speed using PowerDVD mediaplayer. At every age, 10 videos were scored by both observers in order to determine inter-rater reliability. Single measures intraclass correlations (ICC) ranged from .71 to .99 indicating substantial to outstanding observer agreement.

Procedure

Mothers and infants were visited at home at 7 months CA (± 1 week) and 10 months CA (± 1 week), and were invited for an assessment at our laboratory at 14 months CA (± 1 week). Parents did not receive payment for their participation, but did receive refunding for traveling expenses. Infants received a present after every appointment, consisting of an age-appropriate toy. Measurement sessions were planned at a time of the day when parents expected their infant to be alert. When infants were asleep at arrival, testing was postponed until they awoke. Also, testing was paused when necessary (e.g., comforting, feeding, diaper change), but breaks were held in between tasks when possible. The sequence of tasks was kept constant for all participants. During home visits, at 7 and 10 months CA, assessment started with the looking and reaching versions of the A-not-B task, respectively. Then infants played alone for 4 minutes during the sustained attention during free play task. Finally, infants played for 5 minutes with their mother. No appointment exceeded 1½ hours, of which infant testing took approximately 20 to 40 minutes. The 14-months assessment at our laboratory started with the A-not-B task with invisible displacement. Next, the Mental Scale of the Bayley Scales of Infant Development II (van der Meulen, Ruiter, Lutje Spelberg, & Smrkovsky, 2002) was administered, followed by the sustained attention during free play task. Finally, mother and infant played together for 5 minutes. Again, appointments did not exceed 1½ hours, and pauses were held when necessary. After the third session, parents received a report of their infant's performance on the Mental Scale of the BSID-II and a copy of all video materials. Infants with a developmental score below 85 were invited for an aftercare follow-up at 2 years CA by a special educator/ developmental specialist (ICvH) at the children's hospital.

Tasks were administered by the first author and four experimenters, who were trained by the first author.

Statistical analysis

Latent Growth Modeling (LGM) makes it possible to investigate individual variability in developmental trajectories, as well as testing the influence of predictors in order to explain this variability. In a standard linear LGM, each individual's growth over time (i.e., developmental trajectory) is represented by a regression line, which can be described by a unique intercept (initial level) and slope (rate of change). The sample is described by group means and variances for intercept and slope (Kline, 2005). Analyses were conducted in three steps.

First, univariate Latent Growth Modeling (LGM) was used to determine the models that best described the developmental trajectories for the two maternal interactive styles (sensitive responsiveness and directiveness) as well as the two infant outcomes measures (sustained attention during free play and A-not-B performance). In all univariate models, the first measurement occasion at 7 months CA was chosen as time point zero. To account for differences in time interval between measurements, regression weights for the slope were fixed at 1 and 2.3 for the measurements at 10 and 14 months CA, respectively. Because variances, by definition, cannot be smaller than zero (i.e., a negative value) and thus two-sided testing gives an underestimated significance level (Stoel, Garre, Dolan, & van den Wittenboer, 2006), one-sided p values were considered to investigate the significance of variance around the intercept and slope means.

Secondly, multivariate (or parallel) LGM was used to investigate the predictive value of maternal sensitive responsiveness and directiveness for the development of infant attention and executive functioning, resulting in 4 multivariate models. Since infant characteristics may influence the way a mother interacts, we used covariances to investigate contemporary relations (correlations between intercepts of maternal interactive styles and infant outcome measures), over-time relationships (correlations between intercepts and slopes) and associated change (correlations between slopes). One-sided p values were considered when covariances between variables were in the expected direction.

Thirdly, multi-group LGM was used to assess whether the predictive value of maternal interactive styles for infant development varies with infant self-regulatory ability. Infants were assigned to one of two groups (Low versus High self-regulation) based on whether they scored below or above the median IBQ-R score at 7 months CA (median = 5,10). For all multivariate models, nested model comparisons were made between a constrained model (e.g., all aspects of the model are equal between groups) and a model in which covariances between maternal interactive styles and infant outcome models were estimated freely.

Growth models were analyzed using Amos version 7.0 (Arbuckle, 2006) and Mplus version 5.0 (Muthen & Muthen, 2006) when bootstrapping with missings was deemed useful. Overall model fit was evaluated by Chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI). By convention, models have a good fit if χ^2 is low, RMSEA is less than .05, and CFI and TLI are above .95. Model fit is acceptable, when RMSEA is less than .08 and CFI and TLI are above .90 (Hu & Bentler, 1999). In the multi-group comparisons the nested models (equal versus not equal) were evaluated using Chi-square differences ($\Delta\chi^2$). For every covariance that is estimated freely between the two groups, one degree of freedom is lost, and this should lead to a large enough decrease in χ^2 ($\Delta\chi^2 > 3.84$, $p < .05$) to reject the null-hypothesis, that the models are identical (Kline, 2005).

Table 1 Sample characteristics (*n* = 74)

Variable		Mean (SD)	Range		
Child characteristics					
Gestational age (weeks)		30.49 (2.23)	26–35		
Birth weight (grams)		1441 (425)	830–2370		
Bayley MDI score (14 months CA)		103.1 (15.7)	66–136		
IRDS grade / BPD	Grade I	Grade II	Grade III	Grade IV	BPD
n	13	8	11	1	8
IVH grade	Grade I	Grade II	Grade III	Grade IV	
n	6	4	6	1	
PVL grade	Grade I	Grade II	Grade III	Grade IV	
n	11	1	0	0	
Asphyxia (*n*)	5				
SGA	SGA	Extreme SGA			
n	2	2			
Gender (*n*)	48 boys (64.9%)				
Maternal characteristics					
Educational level		Median	Range		
		3 (HAVO/VWO)	2–5		
Cultural background		Dutch	Other		
		83.8%	16.2%		

SD, standard deviation; MDI, Mental Developmental Index; CA, corrected age; IRDS, infant respiratory distress syndrome; BPD, bronchopulmonary dysplasia; IVH, intraventricular hemorrhage; PVL, periventricular leukomalacia; SGA, small for gestational age (3rd percentile > BW < 10th percentile), Extreme SGA (BW < 3rd percentile), Educational level ranged from elementary school (score 1) to academic education (score 5).

Missing values

Although three measurements are required to conduct Latent Growth Modeling, LGM software can handle missing data, without statistical imputation. However, at least two measurements are needed for a participant to contribute to the slope and therefore to be included in the analyses. In line with this, only data from infants with data for two or three waves available were used. From the original sample (*n* = 76), two infants did not complete the study beyond the first measurement due to attrition (i.e., only had data for one wave), and were therefore completely excluded from the analyses. The remaining 74 infants contributed to the analyses, although they may have had data for only two waves for one or more of the variables. Specifically, for maternal interactive styles, longitudinal data over two waves was available for 4 mothers and data for all three waves was available for 70 mothers (*n* = 74). For the A-not-B task, data over two and three waves was available for 6 and 68 infants respectively (*n* = 74). For sustained attention during free play, data over two and three waves was available for 19 and 48 infants respectively (*n* = 67).[2] Some data was missing completely at random (i.e., due to technical problems with video equipment or incorrect administration of the task). Data for sustained attention during free play at 14 months CA was missing for several infants because observation were aborted before the minimally required 90 seconds of free play due to fussiness or crying. These infants however, were not found to differ in GA, BW, PVL, IVH, IRDS, gender, or Bayley MDI scores nor in their performance on the sustained attention during free play task at 7 and 10 months CA, from infants for whom we had complete data on this measure. This is in line with the conclusions from a recent extensive review on attrition due to fussiness in infant attention research in which no support was found for the assumption that exclusion of fussy infants influences experimental outcome (Slaughter & Suddendorf, 2007). Sample characteristics of the remaining 74 infants are presented in Table 1.

Results

Normality of distributions, descriptives and correlations

Normality of the distributions of the variables was examined by calculating the Normality of the distributions of the variables was examined by calculating the standardized skewness and kurtosis index (statistic divided by standard error). Because the distribution of sustained attention during free play at 7 months CA was shown to be skewed (skewness value = 3.1) the asymptotic results were controlled with a 1000-sample bootstrap (Arbuckle, 2006). None of the other measures showed values higher than 3, indicating that the distributions did not significantly differ from normality.

Descriptive values and correlations for maternal interactive styles and infant outcome measures are presented in Table 2.

[2] Two multivariate outliers for attention during free play were excluded based on scatter plots in combination with Mahalanobis distances.

Table 2 Descriptives and correlations for maternal interactive styles and infant outcome measures

	Mean (SD)	7 months CA	10 months CA
Maternal interactive styles			
Sensitive responsiveness			
7 months CA	3.68 (1.02)		
10 months CA	3.92 (0.91)	.48**	
14 months CA	4.05 (0.94)	.53**	.46**
Directiveness			
7 months CA	2.74 (0.75)		
10 months CA	2.60 (0.63)	.47**	
14 months CA	2.67 (0.67)	.20*	.35**

Infant outcomes			7 months CA		10 months CA	
A-not-B task			Looking	Reaching	Looking	Reaching
7 months CA	Looking	1.74 (0.99)				
	Reaching	1.53 (1.05)	.013			
10 months CA	Looking	2.81 (1.36)	.000	.034		
	Reaching	3.94 (2.01)	.008	.226*	.202*	
14 months CA	Reaching	6.61 (2.16)	.048	.014	.296*	.065
Attention during free play						
7 months CA		19.08 (15.94)				
10 months CA		24.00 (14.82)	.046			
14 months CA		47.88 (23.30)	-.072		.196†	

n = 51 – 74. SD, standard deviation; CA, corrected age. 1-tailed significance ** $p < .01$, * $p < .05$, † $p < .10$.

Univariate models

Maternal interactive styles. First, when testing the model for sensitive responsiveness, a negative variance around the slope appeared. Since a negative variance is not possible, the slope variance was set to a small value. When the slope variance was set to a value of 0.006, the model provided a good fit to the data. This linear model revealed a mean intercept factor of 3.72 (two-sided $p < .001$) and a mean slope factor of .15 (two-sided $p < .01$). Variation around the intercept factor mean (0.43) was significant (one-sided $p < .001$), indicating that mothers differed in their initial level of sensitive responsiveness. The variance around the slope that was mentioned above, indicated that mothers did not show systematic or significant differences in their rate of change. The covariance between intercept and slope factors was not significant, and fixing it to zero resulted in better model fit. Model fit indices for univariate models are presented in Table 3.

Secondly, directiveness was best described by a linear model with a mean intercept of 2.66 (two-sided $p < .001$). The slope factor mean had to be fixed to zero in order to fit the model, indicating that there was no significant mean change in directiveness

Table 3 Model fit indices for best fitting univariate models

Model	*n*	χ^2	df	*p*	TLI	CFI	RMSEA
Maternal interactive styles							
Sensitive responsiveness	74	2.66	3	.447	1.016	1.000	.000
Directiveness	74	2.48	2	.289	.931	.977	.057
Infant outcomes							
A-not-B task	74	7.15	10	.711	2.000	1.000	.000
Attention during free play	67	0.59	1	.443	1.000	1.000	.000

χ^2, Chi-square; df, degrees of freedom; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation.

at group level from 7 to 14 months CA. The variance around the intercept factor (.30, one-sided $p < .01$), indicates that mothers differed in their initial level of directiveness. The variance around the slope factor (.06) failed to reach significance (one-sided $p = .07$), but fixating this value to zero led to a decrement in global model fit (TLI < .90, CFI < .95, RMSEA > .08), indicating that mothers showed a small difference in their rate of change. Intercept and slope factor tended to be negatively related ($r = -.67$, two-sided $p = .08$), indicating that mothers who were more directive initially, showed less change over time. Model fit indices are presented in Table 3.

Infant outcomes. The latent growth model for A-not-B performance has been presented previously in Chapter 3. It was originally presented with data from 68 infants (i.e., those with complete data over the three waves). This model was re-run for this paper with data from 74 infants (i.e., those with data for two or three waves) and revealed practically identical results.[3] Importantly, the main conclusions are also identical to the original model, and will be summarized here. First, at group level, infants showed a substantial linear increase in their performance on the A-not-B task. At an individual level, infants differed in their initial level of performance as well as their rate of developmental change (for more details on how the model was constructed, see *Chapter 3*).

The results of the latent growth model for sustained attention during free play were presented in *Chapter 4*, and will therefore only be summarized here. At group level, infants showed a non-linear increase in duration of sustained attention during free play, indicating that infants are able to sustain their attention for longer periods as they grow older. At an individual level, infants differed in their rate of developmental change, but not their initial level of attention. Although infants showed an age-related increase in attention duration at group level, we argued that longer attention duration at an individual level did not necessarily reflect higher quality of attention, but less efficient information processing. That is, infants who showed a stronger increase in attention needed more time to process the increase in incoming information due to more complex exploration (for more details, see *Chapter 4*).

[3] A mean intercept factor of 1.65 ($p < .001$) and a mean slope factor of 2.17 ($p < .001$) were found (for comparison, the intercept and slope means for $n = 68$ were 1.68 and 2.12 respectively).

Table 4 Model fit indices for best fitting multivariate models

Model	*n*	χ^2	df	*p*	TLI	CFI	RMSEA
Sensitive responsiveness							
A-not-B task	74	31.44	28	.298	.905	.926	.040
Attention during free play	67	6.55	13	.924	1.317	1.000	.000
Directiveness							
A-not-B task	74	22.09	25	.631	1.183	1.000	.000
Attention during free play	67	0.59	1	.443	1.414	1.000	.000

χ^2, Chi-square; df, degrees of freedom; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation.

Multivariate models

Sensitive responsiveness and infant outcome. Initial sensitive responsiveness was not related to either initial level or rate of developmental change in A-not-B performance. Since mothers did not differ significantly in their rate of change in sensitive responsiveness, covariations between the slope and infant outcome were not estimated in the multivariate models. Initial sensitive responsiveness was also not related to rate of developmental change in sustained attention during free play (See Table 4 for fit indices). Since infants did not differ significantly in their initial level of sustained attention during free play, covariances between maternal interactive styles and initial level were not estimated.

Directiveness and infant outcome. Initial level of directiveness was not related to initial level of A-not-B performance. Initial level of A-not-B performance was also not related to rate of change in directiveness. Fixating these covariances to zero did not result in a significant decrement in model fit ($\Delta\chi^2 = 0.71$, $\Delta df = 2$, two-sided $p = .70$). Initial level of directiveness however, was significantly positively related to the rate of developmental change in A-not-B performance ($r = .44$, one-sided $p < .05$), indicating that the data confirm the hypothesis that maternal directiveness influences the rate of developmental change in A-not-B performance. In addition, the rate of change in directiveness showed a significant negative relationship to the rate of developmental change in A-not-B performance ($r = -.81$, two-sided $p < .05$), which indicates that stability in the level of maternal directiveness was related to faster developmental change in A-not-B performance. Neither initial level nor rate of change in directiveness were found to be related to the rate of change in sustained attention during free play, and these paths were fixed to zero (see Table 4 for fit indices).

One could speculate that very high levels of directiveness might easily lead to re-directing the infant's attention away from a topic on which it is focused and to interference of ongoing cognitive and attentional processes on part of the infant. Consequently, moderate levels of directiveness, i.e., directing the infant's attention to interesting objects and events without being too intrusive, might be more optimal than high levels of directiveness. Inspection of the distribution of directiveness ratings revealed that the vast majority of mothers in our sample received low to moderate scores. Only a minority of mothers received a score of 4 or higher (n = 7, n = 4, and n = 3 for observations at 7, 10 and 14 months CA, respectively). To test whether our findings were caused by this small proportion of mothers, we reran the analysis without the mothers who received a directiveness-rating of 4 or higher at one of the three waves (n = 12). The covariance between initial directiveness and A-not-B development became stronger (r = .64, p < .01), whereas the covariance between change in directiveness and A-not-B development remained similar (r = - 72, p < .05), indicating that the relationship between directiveness and A-not-B development was not caused by only a small sub sample of highest scoring mothers, but rather an effect of *moderate* levels of directiveness. The fact that the relationship between initial directiveness and A-not-B development became stronger, may even suggest that when directiveness levels become too high, this maternal interactive style will already start to have a negative effect during infancy. However, since only such a small proportion of mothers received a rating of 4 or higher, we can only speculate about this effect.

Infant self-regulation as a moderator

Multi-group analyses showed that the relationship between maternal sensitive responsiveness and infant development of sustained attention during free play and A-not-B performance did not differ for infants in the Low and High regulation groups (see Table 5 for nested model comparisons). The relationship between maternal directiveness and infants' development of attention and A-not-B performance also did not differ between the Low and High regulation groups.

Table 5 Nested model comparisons for self-regulation groups (Low versus High)

	Model fit indices						Model comparison		
Model	χ^2	df	p	TLI	CFI	RMSEA	$\Delta\chi^2$	Δdf	p
Sensitive responsiveness									
A-not-B task									
Equal	70.13	70	.473	.997	.997	.005			
Not equal	69.18	68	.437	.968	.970	.016	0.95	2	.662
Attention during free play									
Equal	27.59	39	.914	1.602	1.000	.000			
Not equal	26.48	38	.920	1.624	1.000	.000	1.11	1	.293
Directiveness									
A-not-B task									
Equal	51.60	69	.942	3.978	1.000	.000			
Not equal	51.13	67	.925	3.798	1.000	.000	0.48	2	.789
Attention during free play									
Equal	25.26	36	.910	1.701	1.000	.000			
Not equal	24.48	34	.885	1.654	1.000	.000	0.78	2	.676

χ^2, Chi-square; df, degrees of freedom; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation; Δ, difference. Model comparison p value > .05 indicates that model 'not equal' does not provide a significant improvement.

Discussion

Using multivariate multi-group Latent Growth Modeling, this longitudinal study investigated how (changes in) maternal interactive styles are related to developmental trajectories in attention and EF in infants born preterm between 7 and 14 months CA, and how these relationships vary with differences in infant self-regulation.

First, mothers showed a small linear increase in sensitive responsiveness at group level. At an individual level, mothers differed significantly in their initial level, but not their rate of change in sensitive responsiveness. This indicates that individual differences in sensitive responsiveness were fairly stable during the study period which is consistent with findings from previous studies (Dallaire & Weinraub, 2005; Landry et al., 2001; Masur & Turner, 2001), in which sensitive responsiveness was shown to be stable during infancy. Second, mothers showed no change in directiveness at a group level. At an individual level, mothers differed in their initial level as well as their rate of change over time, indicating that individual differences in directiveness were less stable over time. This finding is in agreement with the findings from Masur & Turner (2001). In addition, mothers who were more directive initially showed higher stability than mothers who were less directive initially.

Relationship between maternal interactive styles and infant development

Sensitive responsiveness showed no contemporary relationships, no over-time relationships and no associated change with either A-not-B performance or sustained attention during free play. Directiveness also had no contemporary relationship, no over-time relationship and no associated change with sustained attention during free play. However, directiveness did show an over-time relationship with A-not-B development, as well as associated change with A-not-B development. That is, mothers who were more directive initially and who showed slower rates of change in directiveness (i.e., persisted in this behavior over time) had infants who showed faster rates of developmental change in A-not-B performance between 7 and 14 months CA. When we consider that mothers who scored high on directiveness initially, showed the smallest change with age (given the negative correlation between intercept and slope), and mothers who showed the smallest change in directiveness had infants who showed faster rate of A-not-B development (given the negative correlation between slopes), this suggests that mothers who were more consistent in their higher levels of directiveness had infants who showed a faster rate of A-not-B development. Although it is possible that consistent directiveness facilitates faster A-not-B development, it is not impossible that the developmental progression of an infant on the A-not-B task in it self triggers consistency in the level of directiveness in their mothers. However, this last conclusion would be in contrast to the common finding that lower levels of functioning in mentally or physically disabled children evoke higher levels of directiveness (Marfo, 1992; Roskam, 2005; Wade et al., 2008). Although, in our sample, we found no relationship between infant characteristics (e.g., self-regulation at 7 months CA, global cognitive outcome scores at 14 months CA) and maternal directiveness, the finding that initial level of A-not-B performance was unrelated to the rate of change in directiveness indicates that the data especially support the model that an infant's level of functioning is influenced by maternal behaviors. Therefore, it seems more reasonable to assume that stability in higher levels of directiveness facilitated A-not-B development. These results suggest that the structure that is provided by mothers with a consistently directive approach is beneficial in the development of EF between 7 and 14 months CA in infants born preterm. During this study period, we found no evidence that a gradual decline in directiveness was important, at least not during this period. Based on the results from the studies on maternal directiveness and EF in children born preterm by Landry and coworkers (Assel et al., 2003; Landry et al., 2002b), it is possible that negative effects of prolonged higher levels of directiveness may become visible from 2 years of age onwards.

The hypotheses that were not confirmed in this study raise several questions: For example, why was there no relationship found between maternal interactive styles and the development of sustained attention during free play, and why was directiveness but not sensitive responsiveness predictive of A-not-B development? There are several explanations for these findings. With regard to the failure to find any relationship between either maternal interactive style and sustained attention during free play, it is possible that such a relationship may not become visible until after 14 months of age. It has been shown, for example, that environmental effects on development become more apparent between 2 to 3 years of age (Aylward, 2002b). Although Tu et al. (2007) did find a positive effect of quality of maternal interactive behaviors on sustained attention during free play at 8 months CA, this was only an indirect effect. Similar to our results, Wijnroks (1998) did not find a relationship between maternal interactive styles and inattention during problem solving in infants born preterm during the first two years of life. Our results are also in agreement with the findings from a study investigating this issue in infants born at term (Bono & Stifter, 2003), where higher levels of maternal attention maintaining were found to be positively related to focused attention during problem solving at 18 months, but not at 10 months. Other studies that did find a relationship between maternal sensitive responsiveness and attention development in children born at term were also conducted after 18 months of age (Belsky, Fearon, & Bell, 2007; Gaertner, Spinrad, & Eisenberg, 2008). However, if it is too early to find any effects of maternal behaviors at this age, then why did we find level of directiveness to be predictive of A-not-B development? This inconsistency might be explained by the processes underlying sustained attention during free play at different ages. As described earlier, we hypothesized that the individual differences in sustained attention during free play in this sample reflected differences in habituation and speed of information processing. During the first half year of life, the attention system in the brain underlying these orienting processes matures rapidly (Ruff & Rothbart, 1996), and may have reached close to mature levels at the time that the current study began. With increasing age, however, emerging higher-level control processes (which are more directly measured with the A-not-B task) are also starting to influence sustained attention during free play. The fact that a relationship between maternal behaviors and sustained attention during free play is commonly not found until before 18 months of age, may than be explained by the assumption that during this period, the influence of these higher-level control abilities is becoming more apparent in sustained attention during free play. In fact, in the studies on maternal directiveness and EF development by Landry and coworkers (Assel et al., 2003; Landry et al., 2002b) goal-directed free play was used as a measure of EF. However, that higher-level processes are developing at a later age than orienting processes does not necessarily mean that they are more strongly influenced by environmental factors. An alternative explanation for the difference in results for A-not-B performance and sustained attention during free play, is related to differences in the level of structure between tasks. That is, the A-not-B assessment provides a highly structured task-setting (i.e., with clear goals and an experimenter who provides the structure), while sustained attention during free play is unstructured. It is possible that infants of mothers who are more directive (i.e., provide more structure) have more experience with structured settings such as the A-not-B task, but that these effects are not (yet) generalized to relatively unstructured, and more ecologically valid settings such as free play situations. The physical closeness of their mother during the A-not-B task (i.e., infants sat on their mothers' lap) may even have made it easier for infants to generalize their experiences to that specific task situation. Finally, this leaves us with the question why we were not able to find any effects of sensitive responsiveness on A-not-B development. In contrast to our findings, Ayoun (1998) found that 11-month-old infants born at term who were able to handle a reversal trial on the A-not-B task had more responsive mothers than infants born at term who were not able to handle a reversal trial. This study however, did not use increasing delays between hiding and seeking, making it difficult to compare results (Ayoun, 1998). An explanation may be that our measures of maternal sensitive responsiveness were not fine-grained enough. The scales that we used were global ratings of maternal interactive styles. A frequency measure of attention maintaining as used by Landry et al. (1993, 1996) may provide a more sensitive measure of the differences between mothers since it is specifically aimed at sensitive responsiveness to the direction of an infant's attention. However, based on the findings by Landry et al. (1993) that infants born preterm benefited more from an attention maintaining style when strategies were structured and specific (e.g., mother says: "Yes, that piece of the puzzle fits in there") compared to when strategies were unspecific (e.g., mother says: "Yes, that is a puzzle"), it is also possible that we should take into account whether sensitive responsive behaviors are structured or not. Mothers who were rated as highly sensitive responsive in our study may have still differed in their level of activity as well as the specificity of their comments. A rating scale, that takes into account both directiveness and sensitive responsiveness at the same time, may show a more meaningful relationships with the development of infants born preterm. In their studies on lexical development in infants born at term, Masur and Flynn (2005, 2007) have suggested that it is important to make a distinction between supportive directiveness and intrusive directiveness. Supportive directiveness refers to the extent to which a parent uses directives and commands that support the focus of attention of the infant or child, whereas intrusive directiveness refers to directives and commands that redirect an infant's focus of attention (Flynn & Masur, 2007; Masur, Flynn, & Eichorst, 2005). Moreover, the ideal balance between a sensitive responsive and a directive or structured approach is probably dependent on how much support an infant needs and will differ between infants, perhaps depending on self-regulation abilities.

Infant self-regulation as a moderator of the predictive value of directiveness

Comparison between infants who scored low or high on self-regulation at 7 months CA, revealed no differences between the two groups with respect to the predictive value of maternal sensitive responsiveness or directiveness for attention and EF development. This finding does not confirm the hypothesis that the predictive value of maternal interactive styles varies with infant self-regulation. Nevertheless, although we were not able to confirm the hypothesis, it is too early to conclude that infant self-regulation does not serve as a moderator between maternal interactive styles and infant attention and EF development, for several reasons. First, infants were assigned to groups based on the median score in the sample, which could have made the differences between groups too small to evaluate this effect. With a larger sample perhaps it would have been possible to make a more meaningful distinction between infants who score low or high by comparing groups that score at least one standard deviation below or above the mean. Secondly, the fact that self-regulation was reported by mothers may have confounded the results. The way a mother views her own infant is likely to be influenced by her own personality, her psychological well-being as well as her knowledge on infant development. Objective observations of infant self-regulation in experimental situations may provide more reliable information on the differences between infants. In fact, a recent study found that, although different types of ratings on infants positive reactivity were in agreement, maternal reports of infant temperament on infant negative reactivity were not in agreement with observations by experimenters (Stifter, Willoughby, Towe-Goodman, & Investigators, 2008).

In our previous publications on the same cohort, we found that a lower gestational age was predictive of a higher initial level of performance on the A-not-B task, but also of a slower rate of developmental change in A-not-B performance. The presence and severity of respiratory problems tended to be related to a slower rate of developmental change in A-not-B performance. Surprisingly, we found more severe intraventricular hemorrhage (IVH) to be predictive of a faster rate of developmental change in A-not-B performance, although we argued that this effect was probably confounded by gender differences in the severity of IVH in our sample (see *Chapter 3*). The rate of developmental change in sustained attention during free play was predicted by the presence of mild periventricular leukomalacia (i.e., brain injury that is often seen in infants born preterm; PVL). We interpreted this finding as an indication that infants born preterm with mild PVL were less efficient in their information processing than infants born preterm without PVL (see *Chapter 4*). Although it would be very interesting to investigate how the effects of these perinatal risk factors are influenced by maternal interactive styles, our sample is too small to examine such interaction effects.

Implications for intervention

The findings from this study may have important practical implications for early intervention programs aimed at facilitating preterm infants' development. Many of such early intervention programs focus on increasing maternal sensitive responsiveness as a means of facilitating development (Browne & Talmi, 2005; Newnham, Milgrom, & Skouteris, 2008; Zelkowitz et al., 2008). The finding that EF development in infants born preterm may benefit from a moderate directive approach, suggests that it might be even more effective to coach parents in how to combine a sensitive responsive approach with an appropriate level of structure, and how to change this balance with the increasing autonomy of their infant. In fact, in a recent intervention study, Landry and coworkers (Landry, Smith, & Swank, 2006; Landry, Smith, Swank, & Guttentag, 2008) made a distinction between several aspects of responsiveness, including verbal scaffolding, which also has a clear element of providing structure to an infant or child.

Acknowledgements

First, we thank all the children and parents who participated in this study for their time and effort. The assistance of Renate Siebes in the observation of mother-infant interactions, and the assistance of Hanna Mulder, Inge Griffioen, Lise Vergeer and Hilke Rijnen in the collection of data is gratefully acknowledged. We also thank Adele Diamond for her hospitality and training on the administration of the A-not-B task. Finally, we would like to thank Tolo Toys Ltd. for their generous donation of toys for the sustained attention task and mother-infant interaction, as well as the presents for the participating infants.

6

General discussion

Introduction

A vast amount of research has shown that infants born preterm (gestational age < 37 weeks) are at a heightened risk for major developmental disabilities (e.g., mental retardation, sensory disorders and cerebral palsy) as well as less severe dysfunctions (e.g., learning disabilities and attention deficit/hyperactivity disorder (ADHD)) (Anderson & Doyle, 2003; Aylward, 2002a, 2005; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Pritchard et al., 2008). Even school-aged children born preterm who have intellectual abilities within the normal range often have learning disabilities and require special educational services (Aylward, 2002a; Salt & Redshaw, 2006). A growing body of research underscores the relevance of attention and executive functions (e.g., working memory and inhibition) for early childhood development and school achievement (Diamond, Barnett, Thomas, & Munro, 2007), such as learning mathematics and reading. The finding that children born preterm have more difficulties with attention and executive functioning (EF) at school age than children born at term (Bayless & Stevenson, 2007; Bohm, Smedler, & Forssberg, 2004; Mikkola et al., 2005; Taylor, Minich, Klein, & Hack, 2004), has led researchers to suggest that difficulties in attention and executive functioning (EF) underlie preterm infants' heightened risk for developmental delay and learning disabilities (Aylward, 2002a; Davis & Burns, 2001). The preterm population is a heterogeneous one, however, and not all infants born preterm develop such problems. The objective of this thesis was to examine the predictive value of perinatal risk factors and maternal interactive styles for individual differences in developmental trajectories of attention and EF within a preterm sample of infants examined at 7, 10 and 14 months corrected age (CA). Also, the relationship between these trajectories and subsequent global cognitive functioning were investigated. In the previous chapters of this thesis, one review and three empirical studies were presented. In this final chapter, a summary and general discussion of the main findings, followed by a general conclusion of the studies is provided. Additionally, strengths and limitations of the studies, recommendations for future research and practical implications are discussed.

Background

According to attention researchers (Posner & Raichle, 1994; Ruff & Rothbart, 1996) the development of attention is dependent on the development of three interconnected attention networks or systems in the brain. The orienting system, consisting of a spatial orienting network in the parietal cortex and an object recognition pathway in the temporal cortex which becomes fully functional during the first 6 months of life, is related to the orientation or movement of attention toward specific locations in the environment. The alerting or arousal system, involving parts of the brainstem and later in development also the right frontal lobe, is related to the capacity to maintain a state of alert arousal, enabling effortful processing of information. Although Posner & Raichle (1994) describe these two networks separately, they are considered part of one 'orienting / investigative' system by Ruff & Rothbart (1996). When infants develop into toddlers, the executive control system begins to mature, involving areas of the frontal cortex, in particular the prefrontal cortex. During this period, attention becomes more related to planned, self-generated activity with objects. Functions associated with higher level control of attention overlap with the more general domain of EF which also includes working memory, planning, switching and inhibitory control.

A review of the literature on attention development in children born preterm during the first four years of life was presented in *Chapter 2*. In this review, Posner's model of attention development was used as a framework to describe studies examining the differences between infants and preschool children born preterm and born at term in behavioral measures of visual orienting attention, sustained attention and executive attention (i.e., higher-level control over attention). With regard to orienting of attention, the findings suggest that infants born preterm show less efficient orienting than infants born at term during the first year of life, characterized by a tendency to be captured by stimuli, less efficient shifting and problems with maintaining anticipatory attention (Bonin, Pomerleau, & Malcuit, 1998; Butcher, 2000; Butcher, Kalverboer, Geuze, & Stremmelaar, 2002; Hunnius, 2004; Landry, Leslie, Fletcher, & Francis, 1985; Rose, Feldman, & Jankowski, 2001, 2002b; Rose, Feldman, Jankowski, & Caro, 2002a; Rose, Feldman, McCarton, & Wolfson, 1988; Ross, Tesman, Auld, & Nas, 1992; Sigman, Kopp, Littman, & Parmelee, 1977; Stroganova, Posikera, & Pisarevskii, 2005; Stroganova, Posikera, Pisarevskii, & Tsetlin, 2006a, 2006b). Studies investigating sustained attention during infancy showed mixed results, which indicates that problems with sustaining attention are not always evident in infants born preterm during infancy (Pridham, Becker, & Brown, 2000; Rose et al., 2001; Rose et al., 1988; Rose, Feldman, Wallace, & McCarton, 1991; Ruff, Lawson, Parrinello, & Weissberg, 1990; Sun, 2003; Tu et al., 2007). However, the few studies investigating sustained attention during the preschool years were more congruent, suggesting that problems with sustained attention become more visible in children born preterm with increasing age (Caravale, Tozzi, Albino, & Vicari, 2005; McGrath et al., 2005; Vicari, Caravale, Carlesimo, Casadei, & Allemand, 2004). Similarly, studies on executive attention showed mixed results during infancy (Matthews, Ellis, & Nelson, 1996; Ross et al., 1992; Sun, 2003) and more congruent results during preschool years (Espy et al., 2002; Woodward, Edgin, Thompson, & Inder, 2005). These results suggest that problems with higher-level control of attention become more apparent with increasing age. Moreover, these problems seem to become apparent even in infants who had suffered relatively low neonatal medical risk.

Studies investigating individual differences *within* the preterm population indicated that early attention development in these infants and children is influenced by biological factors as well as environmental factors (Bonin et al., 1998; Butcher, 2000; Butcher et al., 2002; Kopp & Vaughn, 1982; McGrath et al., 2005; Pridham et al., 2000; Rose et al., 2001, 2002a, 2002b; Rose et al., 1988; Ross et al., 1992; Sun, 2003; Tu et al., 2007; Wijnroks, 1998; Woodward et al., 2005). However, the predictive value of biological and environmental factors was not always strong and results from different studies were mixed. These mixed results, as well as the finding that difficulties with executive attention become more apparent even in infants who had suffered relatively low neonatal medical risk, may indicate that the predictive value of perinatal risk factors as well as environmental influences may change over time.

Although individual differences in orienting and sustained attention during infancy were found to be predictive of later global cognitive development and intelligence scores in children born preterm (Cohen & Parmelee, 1983; Kopp & Vaughn, 1982; Lawson & Ruff, 2004; Rose et al., 2001; Rose et al., 2002b; Ruff et al., 1990; Sigman & Beckwith, 1980; Sigman, Cohen, Beckwith, & Parmelee, 1986), there is currently no information on the stability and predictive value of executive attention during infancy for later cognitive functioning in infants born preterm.

From this review it has become clear that some important questions remain insufficiently answered. We tried to answer some of these questions in the three empirical studies that were presented in this thesis. In this thesis, we use the concept attention to refer mainly to the ability to maintain or sustain attention during free play tasks en the concept of EF to refer to higher-level control abilities, such as the ability to hold information in mind (working memory) and to inhibit inappropriate (motor) responses (inhibition). The following questions were formulated: (1) what is the predictive value of perinatal risk factors for individual differences in early development of attention and EF in infants born preterm?, (2) are differences in early attention and EF development related to subsequent global cognitive functioning?, (3) what is the relationship between maternal interactive styles and attention and EF development?, and (4) does this relationship differ with variations in infant self-regulation? These questions were examined in a group of 76 infants born preterm who were examined at 7, 10 and 14 months corrected age (CA). Measurement occasions were planned around ages during which important transitions in higher-level control abilities are expected to occur (i.e., around 9 and 12 months of age, see *Chapter 3*). Attention was assessed in two different free play situations, namely playing with one toy and playing with six toys. EF was assessed using the A-not-B task. In this task infants have to retrieve a hidden object from one of two (or more) locations following a delay. Only after the object is retrieved successfully two times in a row at the first location (location A), the side of hiding is changed (to location B). Performance on this 'reversal trial' is dependent on the infant's ability to keep the location of the toy in mind (working memory), to inhibit reaching to the previously rewarded location (inhibitory control), and to control attention during the task. By increasing the delay between hiding and seeking task-difficulty is increased. The mental scale of the Bayley Scales of Infant Development was used to measure global cognitive functioning at 14 months CA. Since group means may mask individual differences, and individual differences in attention and EF abilities may be relatively unstable during this period, Latent Growth Modeling (LGM) was used to investigate individual differences in developmental trajectories of attention and EF.

Study outcomes

Developmental trajectories of executive functioning in infants born preterm

In *Chapter 3*, the predictive value of several perinatal risk factors for individual differences in developmental trajectories of EF in infants born preterm between 7 and 14 months of age was investigated. Perinatal risk factors that were considered to be potentially important predictors were gestational age (GA), birth weight (BW), the presence and severity of respiratory problems, and the presence and severity of two types of brain injury (i.e., intraventricular hemorrhage, IVH, and periventricular leukomalacia, PVL). Also, the relationship between these trajectories and subsequent global cognitive development was examined.

The results from Latent Growth Modeling (LGM) showed that initial differences in A-not-B performance were small, but that the rate of development differed greatly among infants. These findings suggest that individual differences in performance on the A-not-B task become more apparent when children grow older. Whereas most infants at 7 months CA were not able to find a hidden object after the side of hiding was reversed, the initial level mostly reflected individual differences in object permanence.

The differences in the initial level of performance as well as individual differences in the rate of developmental change in A-not-B performance could be attributed to differences in several perinatal risk factors. In agreement with the results from Matthews et al. (1996), infants who were born at a lower gestational age (GA) showed a higher initial level of performance on the A-not-B task, indicating that infants born preterm have an initial advantage of additional extrauterine experience in object permanence. In fact, the finding from a recent study, which showed that the increase in intensity of stimulation that is associated with preterm birth facilitates white matter maturation in some areas of the brain, including areas that are related to visual processing (Gimenez et al., 2008), suggests that such an additional advantage in object permanence may be related to (temporarily) advanced visual processing. However, these findings come from a sample of infants born preterm who were admitted to a Neonatal Intensive Care Unit that used an individualized treatment program that involves reducing stimulation, among others. A study on such individualized programs has shown that such a reduction of stimulation is associated with higher neurobehavioral scores in infants born preterm (Als et al., 2004). These results suggest that while a low intensity of stimulation may enhance visual development, too much stimulation is harmful. However, lower GA was also related to a slower developmental rate, which indicates that this additional advantage disappears and the (im)maturational aspects of being born too soon override this effect in time. In addition, infants who had suffered (more severe) respiratory problems tended to show a slower rate of developmental change in A-not-B performance. Surprisingly, we found more severe intraventricular hemorrhage (IVH) to be predictive of a faster rate of developmental change. On the other hand, we had sufficient reason to assume that this effect was probably confounded by gender differences in the severity of IVH in our sample.

Comparison of our results with the results from studies with infants born at term (Bell & Fox, 1992; Diamond, 1985) also suggests that the differences between infants born preterm and infants born at term become more apparent with increasing age (*Chapter 2*). A trend of decline in EF abilities in infants born preterm compared to infants born at term may be the result of three developmental processes, which are not mutually exclusive. First, subtle deficits in early infancy may cause infants born preterm to have less successful experiences and less opportunity to learn, causing small differences to expand over time (Aylward, 2005). Second, as the brain matures and children become more capable of complex cognitive processes, subtle deficits in infants born preterm may become more apparent (Sesma & Georgieff, 2003). This process is sometimes referred to as 'growing into deficit' in the neuropsychological literature. Third, when infants become toddlers, increasing demands from the environment require more complex skills and may challenge preterm born children's vulnerable abilities (Sesma & Georgieff, 2003). In addition, in line with the theoretical assumption that the development of more specific processes underlies differences in global cognitive functioning, we found that individual differences in the initial levels and rate of developmental change in A-not-B performance predicted subsequent global cognitive functioning.

Developmental trajectories of sustained attention during free play in infants born preterm

In *Chapter 4*, the predictive value of several perinatal risk factors for individual differences in developmental trajectories of sustained attention during free play in infants born preterm was investigated. Again, the relationship between these trajectories and subsequent global cognitive development was examined.

Many of the results on the development of sustained attention during free play from this study coincide with the results from previous studies. At group level for example, infants born preterm showed a significant increase in the mean duration of sustained attention during free play with one toy. LGM revealed that the increase in attention while playing with one toy showed accelerated development between 10 and 14 months CA, which could be indicative of a transition in higher-level control abilities during this period, with infants becoming more able to inhibit their attention to irrelevant objects and events. However, our interpretation of the results is that longer durations of attention do not necessarily reflect a higher quality of attention for each infant. In fact, longer duration of attention could reflect also less efficient habituation or information processing at this age in some infants. We argued that with the age-related increase in sustained attention, there is more information about the toys to be processed. As a result, the increase in attention during free play will be even stronger for infants who need more time to process this information. The assumption that habituation plays a role in attention during free play has also been suggested by Ruff and coworkers (Ruff & Capazzoli, 2003; Ruff & Lawson, 1990). In fact, Ruff & Rothbart (1996) stated that although higher-level control abilities start to play a role between 9 and 18 months of age, attention is also still governed by the orienting/investigate system.

We also found a mean increase in the duration of sustained attention during free play with six toys. Individual differences in performance on this task were highly unstable however, and could not be described by a latent growth model. Low stability and even negative correlations over time in the duration of looking during a multiple object free play task were reported previously by Kannass and coworkers (Kannass & Oakes, 2008; Kannass, Oakes, & Shaddy, 2006) and are not uncommon in infant attention studies (Colombo, Mitchell, O'Brien, & Horowitz, 1987). Observations of the task indicated that performance was influenced by random events, and perhaps was not a reliable measure in our sample. Another explanation however, for this instability in infant development of attention may come from recent advances in the processes of change underlying brain and cognitive development. During the first two years of life, brain development is extremely dynamic, and is associated with a rapid elaboration of dendritic branches and new synapses reflected in an increase in gray matter (Knickmeyer et al., 2008). Under the influence of experiences and the competition and interactions between different brain regions, synaptic connections will be eliminated while others will be strengthened. This line of reasoning is consistent with Mark Johnson's Interactive Specialization view, which states that different brain regions will change their pattern of connectivity during development. The response properties of a specific region are partly determined by its patterns of connectivity to other regions and their pattern of activity. Changes in response properties of cortical regions occur as they interact and compete with each other. This means that some cortical regions may begin with poorly defined functions and are consequently partially activated in a wide range of different tasks and contexts. During development, activity-dependent interactions between regions improve the functions of regions, such that their activity becomes restricted to a narrower set of circumstances (Johnson, 2001). So according to this view, brain functions are rather diffuse initially, but the process of interregional interactions results in pathways that are more specialized whereas integration enhances communication between these more specialized pathways. These dynamic and rapidly occurring processes might explain why stability in infants' performance on the sustained attention during free play task is so low.

With regard to the predictive value of perinatal risk factors, we found that infants born preterm who had suffered mild PVL showed a faster rate of developmental change in sustained attention while playing with one toy. We speculated that relatively longer durations of attention in the one-toy condition on part of the infants with mild PVL may be viewed as less efficient processing of the increasing amount of information. This explanation was consistent with the result that a faster rate of developmental change in sustained attention in the one-toy condition was related to lower subsequent global cognitive outcome.

Maternal interactive styles and attention and EF development in infants born preterm

Since infant development is considered to be influenced by the quality of parenting, the final study presented in *Chapter 5* of this thesis investigated how (changes in) maternal sensitive responsiveness and directiveness are related to individual differences in early attention and EF development in infants born preterm, and whether these relationships vary with differences in infant self-regulation.

A sensitive responsive interactive style is assumed to facilitate global cognitive development, and also attention and EF development, since a mother who is sensitive to her infant's signals and who responds adequately and contingently will place fewer demands on her infant's limited attentional capacities (Landry, Garner, Swank, & Baldwin, 1996), and helps to regulate the arousal level of her infant (Albers, Riksen-Walraven, Sweep, & de Weerth, 2008; Haley & Stansbury, 2003). This type of interactive style is assumed to be of special importance to infants born preterm, since they have more difficulties regulation their behavior (i.e., self-regulation). Because of these difficulties in self-regulation, infants born preterm may also benefit from a somewhat more structured approach during infancy (i.e., maternal directiveness). As infants become more able to regulate their behavior, it will probably be important for mothers to gradually withdraw this type of support (Landry, Miller-Loncar, & Smith, 2002). Since the development of attentional control and self-regulation are thought to be strongly linked (Berger, Kofman, Livneh, & Henik, 2007; Rueda, Posner, & Rothbart, 2005a), such external support provided by mothers may also facilitate attention and EF development.

Multivariate LGM revealed that mothers who were (consistently) more directive had infants who showed faster EF development, which indicates that infants born preterm, as hypothesized, benefited from a somewhat structured approach during the study period. These results are in agreement with the findings from Landry and coworkers (Landry, Smith, Swank, & Miller-Loncar, 2000) who found maternal directiveness to be positively related to global cognitive development in infants born preterm during the first two years of life. However, we found no relationship between maternal directiveness and sustained attention development. In addition, contrary to our expectations maternal sensitive responsiveness was not related to sustained attention or EF development. We found no evidence that these relationships varied between infants who differed in their self-regulation abilities.

The fact that we did not find any relationships between maternal interactive styles and sustained attention during free play was in agreement with a study of Wijnroks (1998) who found no significant relationship between maternal interactive behaviors, which was observed at the infant's age of 6, 9 and 12 months, and the infant's level of inattention during a problem solving task at 18 and 24 months of age. Inattention was measured by counting the number of times the infant was looking away from the task. Low levels of inattention was assumed to reflect the ability to sustain attention. In addition, our results were consistent with results of a study in infants born at term (Bono & Stifter, 2003) and suggests that social influences may not become apparent before 18 months of age. A possible reason for this might be that attention abilities are more strongly influenced by genetic variations. There are some indications that attention (as well as EF) might be under strong genetic control (Goldberg & Weinberger, 2004; Greene, Braet, Johnson, & Bellgrove, 2008; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005b). On the other hand, even when abilities such as attention an EF are under strong genetic control, this does not necessarily mean that they cannot be influenced by environmental factors. In a homogeneous environment, genetic factors tend to have a larger effect than environmental variations. In a heterogeneous environment, when circumstances are more extreme (neglect, abuse) genetic factors may be less important. So, it is possible that variations in maternal interactive styles in our study were not large enough to influence attention development. However, it should be noted that the gene-environment interaction may differ between the negative and positive ends of a trait continuum (Diamond, 2009). For example, it has been shown that poorer reading skills tend to be more heritable in a favorable environment, whereas better reading skills are more heritable when parent's educational level is low. How gene-environment interaction differs between the positive and negative ends of the continuum for attention development is currently not clear (Diamond, 2009). The finding that training programs specifically aimed at enhancing attention and EF abilities have sorted positive effects in children (Diamond et al., 2007; Dowsett & Livesey, 2000; Klingberg et al., 2005; Rueda et al., 2005b; Shalev, Tsal, & Mevorach, 2007), also suggests that perhaps environmental stimulation needs to be more specific to show a strong influence on attention and EF development.

A possible explanation for the inconsistency that EF was predicted by maternal interactive styles, and attention was not, is that infants who have more directive mothers are more used to the structure that is provided by an experimental setting such as the A-not-B task. Such influences may not have generalized (yet) to the unstructured (more naturalistic) setting of a free play session.

The failure to find any effects of maternal sensitive responsiveness may have been caused by the fact that global rating scales were used. We argued that a more fine-grained observational measure of sensitive responsiveness specifically aimed at the attention direction of an infant (e.g., a frequency measure of maternal attention maintaining behaviors as used by Landry et al., 1997), may be more effective in finding such a relationship. In addition, we argued that it is necessary to focus on the extent to which mothers combine a sensitive responsive and directive approach.

Challenges and limitations

Investigating the predictive value of perinatal risk factors

Since the aim of this thesis was to investigate the large individual variability within the preterm population, we incorporated a highly heterogeneous sample of infants born preterm. Although our sample size was larger than most of the studies reviewed in *Chapter 2*, it was fairly small for such a heterogeneous sample. As a result, some of the perinatal risk factors that we considered potentially important for the development of infants born preterm (i.e., asphyxia, small for GA) did not show enough variability within our sample to be included in the analyses. Our sample size also placed us in a dilemma about whether or not to maintain paths that failed to reach statistical significance ($p < .10$). In *Chapter 3*, we found that the presence and severity of respiratory problems tended to predict a slower rate of developmental change in A-not-B performance. It has been suggested by Kline (2005) that paths that fail to reach statistical significance should not be removed too quickly when statistical power is low or sample size is smaller than 100. However, since we are aware that spurious relations are more often found in small samples, we would like to emphasize that these findings should be replicated before strong conclusions can be drawn. In addition, it is possible that a selection bias confounded some of the results. For example, we found that gender and the severity of IVH were significantly interrelated in our sample, with boys having less severe grades of IVH than girls. The counterintuitive effect of IVH on A-not-B development was possibly an artefact of this association with gender. Finally, to investigate whether certain events (e.g., extremely preterm birth, maternal infection) leaves some infants to be more vulnerable to cerebral lesions than others, a more specific sub-sample of infants born preterm would be more effective.

Processes underlying performance

Although we did not explicitly investigate the relationship between attention and EF in this study, there is general consensus that they are strongly related (Garon, Bryson, & Smith, 2008; Kane & Engle, 2002; Posner & Petersen, 1990; Posner & Raichle, 1994), although there is still a debate on *how* they are related. Throughout the course of working on this thesis, we were repeatedly confronted with the complexity of this issue. In *Chapter 2*, we used Posner's model of attention development as a framework to review the literature. Following Posner's terminology we described the processes underlying performance on the A-not-B task as 'executive attention'. Although this concept shows considerable overlap with the term 'executive functioning', our awareness of the distinction between the two concepts has grown. Whereas executive attention refers to higher-level, attentional control, EF refers to several higher-level control abilities, such as working memory and inhibition, although some researchers also include attention. Since the A-not-B task taps into working memory, inhibition as well as attention, in the remaining chapters of the thesis we chose to use the term EF or higher-level control abilities for the processes underlying A-not-B performance.

The choice of tasks in this study was based on the assumption that sustained attention during free play is considered to come under the increasing influence of EF abilities, while the A-not-B task (i.e., EF measure) also requires an infant to sustain and control attention to the relevant features of the task. However, it remains unclear which of these processes is affected when infants show poorer performance. Some of the studies that were described in our review (*Chapter 2*) indicate that infants born preterm had particular problems with inhibiting their attention to irrelevant task features (Espy et al., 2002; Sun, 2003; Sun, Mohay, & O'Callaghan, 2008). We chose to focus on the outcome measure that is most frequently used in A-not-B research, which is the performance on reversal trials with varying delays, but it would be interesting to observe and examine at a microgenetic level how infants behave during the task. Behavior that might be interesting to observe for example, is how infants respond to switching of locations, or whether looking and reaching-movement are combined and coordinated during searching for the objects. Coordination of looking and reaching would be interesting in the light of our findings with regard to the reaching and the looking version of the A-not-B task. Although our results at 7 months CA confirmed the results of Bell & Adams (1999), who reported that performance on these tasks is comparable, we found that infants born preterm had more difficulties with the looking version of the task at 10 months CA, on average. It has not been investigated yet which processes underlie the differences between these two versions of the task. We speculated that the lack of immediate reward and the physical distance with regard to the hidden toys made it a bigger challenge for infants to attend to this version of the task. However, other differences in procedural aspects of the task may also be of influence on A-not-B performance. It has been shown for example, that performance on the A-not-B task is influenced by the extent to which the covers are distinguishable from the background surface, the sequence of trials, and the salience of the toy that is hidden (Thelen, Schoner, Scheier, & Smith, 2001). These findings have led Thelen and coworkers to challenge the assumption that the A-not-B task is a reliable measure of working memory and inhibition. However, Diamond (2001) has argued that although small alterations may influence performance on this task, it will only affect the delay that infants can handle. In fact, she argued that most alterations *should* affect performance because they change the demand on working memory and inhibitory abilities (Diamond, 2001). This issue should be resolved when most aspects of the task are kept constant between infants. However, one particular aspect of the procedure of the A-not-B task that may still be of relevance with regard to this issue is the salience of the objects that are hidden (Clearfield, Dineva, Smith, Diedrich, & Thelen, 2009). In the current study, to warrant infants' attention and interest in the task we offered a different toy when interest in the previous toy had dissipated (although not on a reversal trial). We cannot rule out that differences in salience of the toys may have influenced infants' performance. However, it should be noted that infants in our study differed greatly in the toys they found most attractive, which suggests that toy salience may even differ between infants when the object or toy used is kept constant between infants.

Finally, the processes underlying sustained attention during free play are often assumed to be more evident. Longer periods of sustained attention during free play are commonly considered to reflect a higher quality of attention and processing. However, based on the results from our study (*Chapter 4*) we argued that this conclusion may not always be justified, at least not in infants born preterm between 7 and 14 months CA. In fact, we found that at an individual level, longer periods of attention were related to poorer cognitive outcome and to the presence of mild PVL and consequently we interpreted that longer periods of attention reflected less efficient information processing of increasing amounts of information. An increase in the ability to inhibit attention to irrelevant objects and events (i.e., higher-level control abilities) will be an advantage in situations with an increasing amount of information. It can be speculated that only when higher-level control abilities start to play a larger role in sustained attention during free play, that longer periods of attention will reflect more advanced development. Therefore, in future studies on the data presented in this thesis, we plan to examine how the developmental trajectories of sustained attention during free play and the A-not-B task are related, using parallel Latent Growth Modeling. Given the assumption that infants who showed a stronger increase in duration of sustained attention during free play are less efficient in information processing, in our sample, we would expect a stronger increase in A-not-B development to be negatively related to the rate of change in sustained attention during free play. However, with increasing age, when higher-level control abilities start to gain more influence on sustained attention during free play, it is possible that a reversed relationship will start to emerge. Also, it is necessary to gain more knowledge on different processes underlying performance on both tasks and how their relative contribution changes with age.

Future research

Long-term follow-up

We were able to show that infants differ significantly in their rate of development of attention and EF between 7 and 14 months CA, but since we chose not to study one or more control groups, and no normative data is available for the tasks uses in this study, we do not know whether these developmental trajectories were typical or atypical. Given the large individual variability within the preterm population it is very likely that a proportion of infants in our sample will show a normal developmental path. Further follow-up into school age is necessary to investigate whether (1) differences between infants increase, remain stable or become smaller, (2) developmental patterns that are characterized by delay are transient, reach a permanent level, or become larger with age, and (3) how these individual differences in developmental trajectories relate to later problems in attentional, global cognitive or behavioral functioning. The results from a recent meta-analysis on attention and EF development in school-aged children born preterm indicate that differences between children born preterm and children born at term are still visible during school age (Mulder, Pitchford, Hagger, & Marlow, In press). However, this meta-analysis also showed that differences in selective attention (i.e., performance on visual search tasks) seem to become smaller from preschool to 11-years of age but only for moderately preterm children (average GA of study sample $\geq$ 26 weeks). Mulder et al. (In press) suggest that the differences between children born preterm and born at term also are a function of the timing and tempo of development in children born preterm. A widening gap may be found for example, when children born at term show rapid development in certain skills, which would suggest that problems are becoming worse in children born preterm. It is possible however, that children born preterm show the same acceleration at a later age, which indicates that development, although temporarily delayed, shows catch-up.

Indeed, some efforts have already been made to follow the children from the sample reported on in this thesis. Recently, this sample was seen at 3,5 years of age and a large battery of tasks tapping into EF abilities was administered. Data preparation and analyses are expected within the next year.

Latent Growth Modeling

Only few studies have used latent growth modeling (LGM) to investigate individual differences in developmental trajectories of global cognitive development in infants and children born preterm (Landry, Smith, Miller-Loncar, & Swank, 1997; Landry, Smith, Swank, Assel, & Vellet, 2001; Lawrence & Blair, 2003; Smith, Landry, & Swank, 2006) . To the best of our knowledge, this thesis presents the first study in which LGM is used to analyze individual differences in developmental trajectories of attention and EF in infants born preterm. In *Chapter 3* and *Chapter 4* of this thesis, we showed that even when intra-individual stability is low, individual developmental trajectories may be described by a latent growth curve. In addition, the finding that a latent growth curve was not able to describe individual developmental trajectories in sustained attention during free play with six toys, even though a mean increase was found at group level, illustrates that LGM provides us with a more complete picture of how developmental change occurs compared to more conventional statistical methods, such as correlations. We would like to argue that latent growth modeling (or similar statistical methods) should become standard practice in longitudinal studies in children born preterm, since it allows us to look at developmental data in ways that were not available earlier, and gives new meaning to the results that are found. Although LGM offers us ways to investigate individual differences, it should be mentioned that standard LGM is based on the implicit assumption that populations are homogeneous, with regard to the shape of developmental trajectories as well as the predictors of the variability within these trajectories. Latent Growth Mixture Modeling (LGMM) on the other hand, provides us with a way to handle longitudinal data from a person-centred perspective. It allows researchers to identify subpopulations which can be described by different growth trajectories, predicted by different sets of risk and protective factors (Connel & Frye, 2006; Duncan, Duncan, & Strycker, 2006). Such a person-centred approach may be especially relevant in preterm populations, since typical as well as atypical developmental trajectories may occur. A disadvantage of LGMM is that it requires large longitudinal samples, even larger than required in standard LGM.

In this study, we were able to test a non-linear trend by allowing the third regression weight to be freely estimated (*Chapter 4*). However, since a minimum of four measurements is required to add a quadratic term to a growth model, it is recommended to include four measurement occasions in future studies. This allows researchers to disentangle individual variation in the rate of change from variation in the acceleration or deceleration in this rate of change.

Practical implications

Early screening instrument

The finding that early differences in sustained attention and EF are predictive of subsequent global cognitive functioning suggests that screening instruments that tap into such specific processes could help to identify infants who are at risk for delays in these areas of functioning. Some of the findings from the studies presented in this thesis may provide useful information which is necessary to initiate the development of such an instrument. The finding that infants had more trouble with the looking version of the A-not-B task than the reaching version at 10 months CA, indicates that looking behaviors may be a more distinguishing outcome measure at that age. However, more research on this subject will be necessary to confirm these findings before efforts to introduce these measures, for example, as part of routine follow-up care of children born preterm should be undertaken.

Early parental intervention

Early intervention programs aimed at facilitating the development of infants born preterm often focus on increasing the quality of parenting behaviors. Most of these programs try to increase parent's sensitive responsiveness (Browne & Talmi, 2005; Kaaresen et al., 2008; Newnham, Milgrom, & Skouteris, 2008; Zelkowitz et al., 2008). However, the results from our study (*Chapter 5*) indicate that it may be even more effective to coach parents in how to combine a sensitive responsive interactive style with a more directive, structured approach. In fact, it has been argued that the more directive approach that is sometimes found in mothers of infants born preterm may in fact be an intuitive adaptation to the special needs of the preterm infant (Wijnroks, 1999). Mothers may attempt to compensate for a lack of initiative and activity of their infant by providing more structure. So, even though the interaction with an infant born preterm may be more challenging, researchers should be cautious not to interpret a higher directive interactive style as inferior by definition. However, since there are indications from previous studies that it is important to gradually withdraw a more directive approach when infants grow into toddlers (Assel, Landry, Swank, Smith, & Steelman, 2003; Landry, Miller-Loncar, Smith, & Swank, 2002), future studies should focus on how the balance between these two aspects of parenting influence sustained attention and EF development at different stages of this development.

General conclusions

The main outcomes of this thesis reveal that intra-individual differences over time in sustained attention and EF development in infants born preterm are not very stable between 7 and 14 months CA, which underlines the dynamics of the development of these processes during this period. Inter-individual differences in the rate of developmental change of sustained attention and EF however, are related to variations in perinatal risk, and predictive of subsequent global cognitive development. In addition, a structured approach by mothers (i.e., directiveness) seems to facilitate the development of EF abilities in infants born preterm between 7 and 14 months CA, irrespective of differences in infant self-regulation. No evidence was found for a facilitative effect of a sensitive responsive approach, although we have argued that it is the combination of the two maternal interactive styles that probably matters.

References

Abernethy, L. J., Cooke, R. W. I., & Foulder-Hughes, L. (2004). Caudate and hippocampal volumes, intelligence, and motor impairment in 7-year-old children who were born preterm. *Pediatric Research*, *55*(5), 1-10.

Ahmed, A., & Ruffman, T. (1998). Why do infants make A not B errors in a search task, yet show memory for the location of hidden objects in a nonsearch task? *Developmental Psychology*, *34*(3), 441-453.

Ainsworth, M., Blehart, M., Waters, E., & Wall, S. (1978). *Patterns of Attachment*. Hilsdale, NJ: Erlbaum.

Albers, E., Riksen-Walraven, J. M., Sweep, F. C. G. J., & de Weerth, C. (2008). Maternal behavior predicts infant cortisol recovery from a mild everyday stressor. *Journal of Child Psychology and Psychiatry*, *49*(1), 97-103.

Als, H., Duffy, F. H., McAnulty, G. B., Rivkin, M. J., Vajapeyam, S., Mulkern, R. V., Warfield, S. K., Huppi, P. S., Butler, S. C., Conneman, N., Fischer, C., & Eichenwald, E. C. (2004). Early experience alters brain function and structure. *Pediatrics*, *113*(4), 846-857.

Anderson, P., & Doyle, L. W. (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *Journal of the American Medical Association*, *289*(24), 3264-3272.

Arbuckle, J. L. (2006). *Amos 7.0 User's Guide*. Chicago, IL: Amos Development Corporation.

Assel, M. A., Landry, S. H., Swank, P. R., Smith, K. E., & Steelman, L. (2003). Precursors to mathematical skills: Examining the roles of visual spatial skills, executive processes, and parenting factors. *Applied Developmental Science*, *7*(1), 27-38.

Assel, M. A., Landry, S. H., Swank, P. R., Steelman, L., Miller-Loncar, C. L., & Smith, K. E. (2002). How do mothers' childrearing histories, stress and parenting affect children's behavioral outcomes? *Child: Care, Health & Development*, *28*(5), 359-368.

Aylward, G. P. (2002a). Cognitive and neuropsychological outcomes: More than IQ scores. *Mental Retardation and Developmental Disabilities*, *8*, 234-240.

Aylward, G. P. (2002b). Methodological issues in outcome studies of at-risk infants. Journal of Pediatric Psychology, 27(1), 37-45.

Aylward, G. P. (2005). Neurodevelopmental outcomes of infants born prematurely. *Developmental and Behavioral Pediatrics*, *26*(6), 427-440.

Ayoun, C. (1998). Maternal responsiveness and search for hidden objects and contingency learning by infants. *Early Development and Parenting*, *7*, 61-72.

Bacharach, V. R., & Baumeister, A. A. (1998). Direct and indirect effects of maternal intelligence, maternal age, income, and home environment on intelligence of preterm low-birth-weight children. *Journal of Applied Developmental Psychology*, *19*(3), 361-375.

Bayless, S., & Stevenson, J. (2007). Executive functions in school-aged children born very prematurely. *Early Human Development*, *83*(4), 247-254.

Bayley, N. (1969). *Bayley Scales of Infant Development*. San Antonio, TX: The Psychological Corporation.

Bayley, N. (2006). *Bayley Scales of Infant and Toddler Development* (3rd ed.). San Antonio, TX: Harcourt Assessment, Inc.

Bell, M. A., & Adams, S. E. (1999). Comparable performance on looking and reaching versions of the A-not-B task at 8 months of age. *Infant Behavior and Development*, *22*(2), 221-235.

Bell, M. A., & Fox, N. A. (1992). The relations between frontal brain electrical activity and cognitive development during infancy. *Child Development*, *63*, 1142-1163.

Belsky, J., Fearon, R. M. P., & Bell, B. (2007). Parenting, attention and externalizing problems: Testing mediation longitudinally, repeatedly and reciprocally. *Journal of Child Psychology and Psychiatry*, *48*(12), 1233-1242.

Berger, A., Kofman, O., Livneh, U., & Henik, A. (2007). Multidisciplinary perspectives on attention and the development of self-regulation. *Progress in Neurobiology*, *82*, 256-286.

Betts, J., McKay, J., Maruff, P., & Anderson, V. (2006). The development of sustained attention in children: The effect of age and task load. *Child Neuropsychology*, *12*(3), 205-221.

Bhutta, A. T., Cleves, M. A., Casey, P. H., Cradock, M. M., & Anand, K. J. S. (2002). Cognitive and behavioral outcomes of school-aged children who were born preterm. A Meta-analysis. *Journal of the American Medical Association*, *288*(6), 728-737.

Bohm, B., Smedler, A. C., & Forssberg, H. (2004). Impulse control, working memory and other executive functions in preterm children when starting school. *Acta Paediatrica*, *93*, 1363-1371.

Bonin, M., Pomerleau, A., & Malcuit, G. (1998). A longitudinal study of visual attention and psychomotor development in preterm and full-term infants during the first six months of life. *Infant Behavior and Development*, *21*(1), 103-118.

Bono, M. A., & Stifter, C. A. (2003). Maternal attention-directing strategies and infant focused attention during problem solving. *Infancy*, *4*(2), 235-250.

Bornstein, M. H., & Sigman, M. D. (1986). Continuity in mental development from infancy. *Child Development*, *57*(2), 251-274.

Bornstein, M. H., Tamis-LeMonda, C. S., Hahn, C., & Haynes, O. M. (2008). Maternal responsiveness to young children at three ages: Longitudinal analysis of a multidimensional, modular, and specific parenting construct. *Developmental Psychology*, *44*(3), 867-874.

Browne, J. V., & Talmi, A. (2005). Family-based intervention to enhance infant-parent relationships in the neonatal intensive care unit. *Journal of Pediatric Psychology*, *30*(8), 667-677.

Butcher, P. R. (2000). Longitudinal studies of visual attention in infants: *The early development of disengagement and inhibition of return*. *PhD Thesis*. Groningen, The Netherlands: Rijksuniversiteit Groningen.

Butcher, P. R., Kalverboer, A. F., Geuze, R. H., & Stremmelaar, E. F. (2002). A longitudinal study of the development of shifts of gaze to a peripheral stimulus in preterm infants with transient periventricular echogenicity. *Journal of Experimental Child Psychology*, *82*, 116-140.

Caravale, B., Tozzi, C., Albino, G., & Vicari, S. (2005). Cognitive development in low risk preterm infants at 3-4 years of life. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *90*, 474-479.

Carmody, D. P., Bendersky, M., Dunn, S. M., DeMarco, J. K., Hegyi, T., Hiatt, M., & Lewis, M. (2006). Early risk, attention, and brain activation in adolescents born preterm. *Child Development*, *77*(2), 384-394.

Clark, C. A. C., Woodward, L. J., Horwood, L. J., & Moor, S. (2008). Development of emotional and behavioral regulation in children born extremely preterm and very preterm: Biological and social influences. *Child Development*, *79*(5), 1444-1462.

Clearfield, M. W., Dineva, E., Smith, L. B., Diedrich, F. J., & Thelen, E. (2009). Cue salience and infant perseverative reaching: tests of the dynamic field theory. *Developmental Science*, *12*(1), 26-40.

Cohen, S. E., & Parmelee, A. H. (1983). Prediction of five-year Stanford-Binet scores in preterm infants. *Child Development*, *54*(5), 1242-1253.

Cohen, S. E., Parmelee, A. H., Sigman, M., & Beckwith, L. (1982). Neonatal risk factors in preterm children. *Applied Research in Mental Retardation*, *3*, 265-278.

Colombo, J. (2001). The development of visual attention in infancy. *Annual Review of Psychology*, *52*, 337-367.

Colombo, J. (2002). Infant attention grows up: The emergence of a developmental cognitive neuroscience perspective. *Current Directions in Psychological Science*, *11*(6), 196-200.

Colombo, J. (2004). Visual attention in infancy. Process and product in early cognitive development. In M. I. Posner (Ed.), *Cognitive Neuroscience of Attention* (pp. 329-341). New York: The Guilford Press.

Colombo, J., Mitchell, D. W., O'Brien, M., & Horowitz, F. D. (1987). The stability of visual habituation during the first year of life. *Child Development*, *58*, 474-487.

Connel, A. M., & Frye, A. A. (2006). Growth mixture modelling in developmental psychology: Overview and demonstration of heterogeneity in developmental trajectories of adolescent antisocial behaviour. *Infant and Child Development*, *15*, 609-621.

Cooke, R. W. I. (2006). Perinatal and postnatal factors in very preterm infants and subsequent cognitive and motor abilities. *Archives of Disease in Childhood - Fetal Neonatal Edition*, *90*, 60-63.

Coppola, G., Cassiba, R., & Costantini, A. (2007). What can make the difference? Premature birth and maternal sensitivity at 3 months of age: The role of attachment organization, traumatic reaction and baby's medical risk. *Infant Behavior and Development*, *30*, 679-684.

Crockenberg, S. C., & Leerkes, E. M. (2004). Infant and maternal behaviors regulate infant reactivity to novelty at 6 months. *Developmental Psychology*, *40*(6), 1123-1132.

Dallaire, D. H., & Weinraub, M. (2005). The stability of parenting behaviors over the first 6 years of life. *Early Childhood Research Quarterly*, *20*, 201-219.

Davis, D. W., & Burns, B. (2001). Problems of self-regulation: A new way to view deficits in children born prematurely. *Issues in Mental Health Nursing*, *22*(3), 305-323.

Davis, D. W., Burns, B., Snyder, E., & Robinson, J. (2007). Attention problems in very low birth weight preschoolers: Are new screening measures needed for this special population? *Journal of Child and Adolescent Psychiatric Nursing*, *20*(2), 74-85.

Davis, L., Edwards, H., Mohay, H., & Wollin, J. (2003). The impact of very premature birth on the psychological health of mothers. *Early Human Development*, *73*, 61-70.

de Vries, L. S., Eken, P., & Dubowitz, L. M. S. (1992). The spectrum of leukomalacia using cranial ultrasound. *Behavioral Brain Research*, *49*, 1-6.

Diamond, A. (1985). Development of the ability to use recall to guide action. *Child Development*, *56*(4), 868-883.

Diamond, A. (1991). Neuropsychological insights into the meaning of object concept development. In S. Carey & R. Gelman (Eds.), *The epigenesis of mind: Essays on biology and cognition* (pp. 67-110). Hillsdale, NJ: Erlbaum.

Diamond, A. (2001). Looking closely at infants' performance and experimental procedures in the A-not-B task. *Behavioral and Brain Sciences*, *24*(1), 38-41.

Diamond, A. (2009). The interplay of biology and the environment broadly defined. *Developmental Psychology*, *45*(1), 1-8.

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, *318*(5855), 1387-1388.

Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on Piaget's AB task: Evidence for dependence on dorsolateral prefrontal cortex. *Experimental Brain Research*, *74*, 24-40.

Diamond, A., Prevor, M., Callender, G., & Druin, D. P. (1997). Prefrontal cortex cognitive deficits in children treated early and continuously for PKU. *Monographs of the Society for Research in Child Development and Psychopathology*, *62*(4 (serial No. 252)).

Dowsett, S. M., & Livesey, D. J. (2000). The development of inhibitory control in preschool children: effects of "executive skills" training. *Developmental Psychobiology*, *36*(2), 161-174.

Duncan, T. E., Duncan, S. C., & Strycker, L. A. (2006). *An introduction to latent variable growth curve modeling. Concepts, issues, and applications* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Elsmen, E., Hansen Pupp, I., & Hellstrom-Westas, L. (2004). Preterm male infants need more initial respiratory and circulatory support than female infants. *Acta Paediatrica*, *93*, 529-533.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19-23.

Espy, K. A., Senn, T. E., Charak, D. A., Tyler, J., & Wiebe, S. A. (2007). Perinatal pH and neuropsychological outcome at age 3 years in children born preterm. *Developmental Neuropsychology*, *32*(2), 669-682.

Espy, K. A., Stalets, M. M., McDiarmid, M. M., Senn, T. E., Cwik, M. F., & Hamby, M. (2002). Executive functions in preschool children born preterm: Application of cognitive neuroscience paradigms. *Child Neuropsychology*, *8*(2), 83-92.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, *14*(3), 340-347.

Feldman, R., & Eidelman, A. I. (2007). Maternal postpartum behavior and the emergence of infant-mother and infant-father synchrony in preterm and full-term infants: The role of neonatal vagal tone. *Developmental Psychobiology*, *49*(3), 290-302.

Flynn, V., & Masur, E. F. (2007). Characteristics of maternal verbal style: Responsiveness and directiveness in two natural contexts. *Journal of Child Language*, *34*, 519-543.

Forcada-Geux, M., Pierrehumbert, B., Borghini, A., Moessinger, A., & Muller-Nix, C. (2006). Early dyadic patterns of mother-infant interactions and outcomes of prematurity at 18 months. *Pediatrics*, *118*(e107-e114).

Gaertner, B. M., Spinrad, T. L., & Eisenberg, N. (2008). Focused attention in toddlers: Measurement, stability, and relations to negative emotion and parenting. *Infant and Child Development*, *17*, 339-363.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*(1), 31-60.

Garstein, M. A., & Rothbart, M. K. (2003). Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development*, *26*(1), 64-86.

Gibson, A., Carney, S., & Wales, J. K. H. (2006). Growth and the premature baby. *Hormone Research*, *65*(suppl 3), 75-81.

Giedion, A., Haefliger, H., & Dangel, P. (1973). Acute pulmonary x-ray changes in hyaline membrane disease treated with artificial ventilation and positive end-expiratory pressure (PEP). *Pediatric Radiology*, *1*(3), 145–152.

Gimenez, M., Miranda, M. J., Born, A. P., Nagy, Z., Rostrup, E., & Jernigan, T. L. (2008). Accelerated cerebral white matter development in preterm infants: A voxel-based morphometry study with diffusion tensor MR imaging. *NeuroImage*, *41*, 728-734.

Goldberg, T. E., & Weinberger, D. R. (2004). Genes and the parsing of cognitive processes. *Trends in Cognitive Science*, *8*(7), 325-335.

Goldman-Rakic, P. S. (1987). Development of cortical circuitry and cognitive function. *Child Development*, *58*(3), 601-622.

Greene, C. M., Braet, W., Johnson, K. A., & Bellgrove, M. A. (2008). Imaging the genetics of executive function. *Biological Psychology*, *79*(1), 30-42.

Hack, M., Taylor, G. H., Drotar, D., Schluchter, M., Cartar, L., Andreias, L., Wilson-Costello, D., & Klein, N. (2005). Poor predictive validity of the Bayley Scales of infant development for cognitive function of extremely low birth weight children at school age. *Pediatrics*, *116*(2), 333-341.

Hack, M., Wilson-Costello, D., Friedman, H., Taylor, G. H., Schluchter, M., & Fanaroff, A. A. (2000). Neurodevelopment and predictors of outcomes of children with birth weights less than 1000 g. *Archives of Pediatrics and Adolescent Medicine*, *154*, 725-731.

Haley, D. W., Grunau, R. E., Oberlander, T. F., & Weinberg, J. (2008). Contingency learning and reactivity in preterm and full-term infants at 3 months. *Infancy*, *13*(6), 570-595.

Haley, D. W., & Stansbury, K. (2003). Infant stress and parent responsiveness: Regulation of physiology and behavior during still-face and reunion. *Child Development*, *74*(5), 1534-1546.

Hofstadter, M., & Reznick, J. S. (1996). Response modality affects human infant delayed-response performance. *Child Development*, *67*, 646-658.

Hox, J. J. (2002). *Multilevel analysis. Techniques and applications*. Mahwah, NJ: Lawrence Erlbaum Associates.

Hsu, H., & Jeng, S. (2008). Two-month-olds' attention and affective response to maternal still face: A comparison between term and preterm infants in Taiwan. *Infant Behavior and Development*, *31*, 194-206.

Hu, L. T., & Bentler, P. M. (1999). Cut-off criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1-55.

Hughes, M. B., Shults, J., McGrath, J., & Medoff-Cooper, B. (2002). Temperament characteristics of premature infants in the first year of life. *Developmental and Behavioral Pediatrics*, *23*(6), 430-435.

Hunnius, S. (2004). Through the eyes of an infant. *The early development of visual scanning and disengagement of attention*. *PhD thesis*. Groningen, The Netherlands: Rijksuniversiteit Groningen.

Jeyaseelan, D., O'Callaghan, M., Neulinger, K., Shum, D., & Burns, Y. (2005). The association between early minor motor difficulties in extreme low birth weight infants and school age attentional difficulties. *Early Human Development*, *82*, 249-255.

Johnson, M.H. (2001). Functional brain development in humans. *Nature Reviews Neuroscience*, *2*(7), 475-483.

Johnson, M. H. (2005). Vision, orienting, and attention. In *Developmental Cognitive Neuroscience* (2nd ed., pp. 53-77). Malden, MA: Blackwell Publishing.

Johnson, M. H., & Munakata, Y. (2005). Processes of change in brain and cognitive development. *Trends in Cognitive Science*, *9*(3), 152-158.

Johnson, M. H., Posner, M. I., & Rothbart, M. K. (1991). Components of visual orienting in early infancy: Contingency learning, anticipatory looking, and disengaging. *Journal of Cognitive Neuroscience*, *3*(4), 335-344.

Johnson, M. H., & Tucker, L. A. (1996). The development and temporal dynamics of spatial orienting in infants. *Journal of Experimental Child Psychology*, *63*, 171-188.

Johnson, S., & Marlow, N. (2006). Developmental screen or developmental testing? *Early Human Development*, *82*, 173-183.

Johnson, S., Wolke, D., & Marlow, N. (2008). Outcome monitoring in preterm populations. Measures and methods. *Journal of Psychology*, *216*(3), 135-146.

Kaaresen, P. I., Ronning, J. A., Tunby, J., Nordhov, S. M., Ulvund, S. E., & Dahl, L. B. (2008). A randomized controlled trial of an early intervention program in low birth weight children: outcome at 2 years. *Early Human Development*, *84*(3), 201-209.

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review*, *9*(4), 637-671.

Kannass, K. N., & Colombo, J. (2007). The effects of continuous and intermittent distraction on attention and cognitive performance in preschoolers. *Journal of Cognition and Development*, *8*, 63-77.

Kannass, K. N., & Oakes, L. M. (2008). The development of attention and its relations to cognitive skills in infancy and toddlerhood. Journal of Cognition and Development, 9(2), 222-246.

Kannass, K. N., Oakes, L. M., & Shaddy, D. J. (2006). A longitudinal investigation of the development of attention and distractibility. *Journal of Cognition and Development*, *7*, 381-409.

Katz, K. S., Dubowitz, L. M. S., Henderson, S., Jongmans, M. J., Kay, G. G., Nolte, C. A., & De Vries, L. S. (1996). Effect of cerebral lesions on Continuous Performance Test responses of school age children born prematurely. *Journal of Pediatric Psychology*, *21*(6), 841-855.

Klein, R. M. (2004). On the control of visual orienting. In M. I. Posner (Ed.), *Cognitive Neuroscience of Attention* (pp. 29-44). New York: The Guilford Press.

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2 ed.). New York, NY: The Guilford Press.

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlstrom, K., Gillberg, C. G., Forssberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD - a randomized, controlled trial. *Journal of the American Acadamy of Child and Adolescent Psychiatry*, *44*(2), 177-186.

Knickmeyer, R. C., Gouttard, S., Kang, C., Evans, D., Wilber, K., Smith, J. K., Hamer, R. M., Lin, W., Gerig, G., & Gilmore, J. H. (2008). A structural MRI study of human brain development from birth to 2 years. *Journal of Neuroscience*, *28*(47), 12176-12182.

Koldewijn, K., Wolf, M. J., van Wassenaer, A., Beelen, A., de Groot, I. J. M., & Hedlund, R. (2005). The Infant Behavioral Assessment and Intervention Program to support preterm infants after hospital discharge: A pilot study. *Developmental Medicine and Child Neurology*, *47*(2), 105-112.

Koldewijn, K., Wolf, M. J., van Wassenaer, A., Meijssen, D., van Sonderen, L., van Baar, A., Beelen, A., Nollet, F., & Kok, J. (2009). The Infant Behavioral Assessment and Intervention Program for very low birth weight infants at 6 months corrected age. *Journal of Pediatrics*, *154*(1), 33-38.

Koller, H., Lawson, K., Rose, S. A., Wallace, I., & McCarton, C. (1997). Patterns of cognitive development in very low birth weight children during the first six years of life. *Pediatrics*, *99*(3), 383-389.

Kopp, C. B., & Vaughn, B. E. (1982). Sustained attention during exploratory manipulation as a predictor of cognitive competence in preterm infants. *Child Development*, *53*, 174-182.

Korja, R., Savonlahti, E., Ahlqvist-Bjorkroth, S., Stolt, S., Haataja, L., Lapinleimu, H., & Piha, J. (2008). Maternal depression is associated with mother-infant interaction in preterm infants. *Acta Paediatrica*, *97*, 724-730.

Korkman, M., Mikkola, K., Ritari, N., Tommiska, V., Salokorpi, T., Haataja, L., Tammela, O., Paakkonen, L., Olsen, P., & Fellman, V. (2008). Neurocognitive test profiles of extremely low birth weight five-year-old children differ according to neuromotor status. *Developmental Neuropsychology*, *33*(5), 637-655.

Landry, S. H., & Chapieski, M. L. (1989). Joint attention and infant toy exploration: Effects of Down Syndrome and prematurity. *Child Development*, *60*, 103-118.

Landry, S. H., Chapieski, M. L., & Schmidt, M. (1986). Effects of maternal attention-directing strategies on preterms' response to toys. *Infant Behavior and Development*, *9*, 257-269.

Landry, S. H., Garner, P. W., Denson, S., Swank, P. R., & Baldwin, C. (1993). Low birth weight (LBW) infants' exploratory behavior at 12 and 24 months: Effects of intraventricular hemorrhage and mothers' attention directing behaviors. *Research in Developmental Disabilities*, *14*, 237-249.

Landry, S. H., Garner, P. W., Swank, P. R., & Baldwin, C. (1996). Effects of maternal scaffolding during joint toy play with preterm and full-term infants. *Merril-Palmer Quarterly*, *42*(2), 177-199.

Landry, S. H., Leslie, N. A., Fletcher, J. M., & Francis, D. J. (1985). Visual attention skills in premature infants with and without intraventricular hemorrhage. *Infant Behavior and Development*, *8*, 309-321.

Landry, S. H., Miller-Loncar, C. L., & Smith, K. E. (2002a). Individual differences in the development of social communication competency in very low birthweight children. In D. L. Molfese & V. J. Molfese (Eds.), *Developmental Variations in Learning: Applications to Social, Executive Function, Language, and Reading Skills* (pp. 81-112). London: Lawrence Erlbaum Associates, Publishers.

Landry, S. H., Miller-Loncar, C. L., Smith, K. E., & Swank, P. R. (2002b). The role of early parenting in children's development of executive processes. *Developmental Neuropsychology*, *21*(1), 15-41.

Landry, S. H., Smith, K. E., Miller-Loncar, C. L., & Swank, P. R. (1997). Predicting cognitive-language and social growth curves from early maternal behaviors in children at varying degrees of biological risk. *Developmental Psychology*, *33*(6), 1040-1053.

Landry, S. H., Smith, K. E., Swank, P. R., Assel, M. A., & Vellet, S. (2001). Does early responsive parenting have a special importance for children's development or is consistency across early childhood necessary? *Developmental Psychology*, *37*(3), 387-403.

Landry, S. H., Smith, K. E., & Swank, P. R. (2006). Responsive parenting: Establishing early foundations for social communication, and independent problem-solving skills. *Developmental Psychology*, *42*(4), 627-642.

Landry, S. H., Smith, K. E., Swank, P. R., & Guttentag, C. (2008). A responsive parenting intervention: The optimal timing across early childhood for impacting maternal behaviors and child outcomes. *Developmental Psychology*, *44*(5), 1335-1353.

Landry, S. H., Smith, K. E., Swank, P. R., & Miller-Loncar, C. L. (2000). Early maternal and child influences on children's later independent cognitive and social functioning. *Child Development*, *71*(2), 358-375.

Lansink, J. M., & Richards, J. E. (1997). Heart rate and behavioral measures of attention in six-, nine-, and twelve-month-old infants during object exploration. *Child Development*, *68*(4), 610-620.

Lawrence, F. R., & Blair, C. (2003). Factorial invariance in preventive intervention: Modeling the development of intelligence in low birth weight, preterm infants. *Prevention Science*, *4*(4), 249-261.

Lawson, K. R., & Ruff, H. A. (2004). Early focused attention predicts outcome for children born prematurely. *Developmental and Behavioral Pediatrics*, *25*(6), 399-406.

Luciana, M. (2003). Cognitive development in children born preterm: Implications for theories of brain plasticity following early injury. *Development and Psychopathology*, *15*, 1017-1047.

Marfo, K. (1992). Correlates of maternal directiveness with children who are developmentally delayed. *American Journal of Orthopsychiatry*, *62*(2), 219-233.

Masur, E. F., Flynn, V., & Eichorst, D. L. (2005). Maternal responsive and directive behaviors and utterances as predictors of children's lexical development. *Journal of Child Language*, *32*, 63-91.

Masur, E. F., & Turner, M. (2001). Stability and consistency in mothers' and infants' interactive styles. *Merill-Palmer Quarterly*, *47*(1), 100-120.

Matthews, A., Ellis, A. E., & Nelson, C. A. (1996). Development of preterm and full-term infant ability on AB, recall memory, transparent barrier detour, and means-end tasks. *Child Development*, *67*, 2658-2976.

McGrath, J. M. (2008). Supporting parents in understanding and enhancing preterm infant brain development. *Newborn and Infant Nursing Reviews*, *8*(4), 164-165.

McGrath, M. M., Sullivan, M., Devin, J., Fontes-Murphy, M., Barcelos, S., DePalma, J. L., & Faraone, S. (2005). Early precursors of low attention and hyperactivity in a preterm sample at age four. *Issues in Comprehensive Pediatric Nursing*, *28*, 1-15.

Ment, L. R., & Vohr, B. R. (2008). Preterm birth and the developing brain. *Lancet Neurology*, *7*(5), 378-379.

Miceli, P. J., Whitman, T. L., Borkowski, J. G., Braungart-Rieker, J., & Mitchell, D. W. (1998). Individual differences in infant information processing: The role of temperamental and maternal factors. *Infant Behavior and Development*, *21*(1), 119-136.

Mick, E., Biederman, J., Prince, J., Fischer, M. J., & Faraone, S. V. (2002). Impact of low birth weight on attention-deficit hyperactivity disorder. *Developmental and Behavioral Pediatrics*, *23*(1), 16-22.

Mikkola, K., Ritari, N., Tommiska, V., Salokorpi, T., Lehtonen, L., Tammela, O., Paakkonen, L., Olsen, P., Korkman, M., & Fellman, V. (2005). Neurodevelopmental outcome at 5 years of age of a national cohort of extremely low birth weight infants who were born in 1996-1997. *Pediatrics*, *116*(6), 1391-1400.

Miller, S. P., Ferriero, D. M., Leonard, C., Piecuch, R. E., Glidden, D. V., Partridge, C., Perez, M., Mukherjee, P., Vigneron, D. B., & Barkovich, A. J. (2005). Early brain injury in premature newborns detected with magnetic resonance imaging is associated with adverse early neurodevelopmental outcome. *Journal of Pediatrics*, *147*, 609-616.

Moore, J. B., Saylor, C. F., & Boyce, G. C. (1998). Parent-child interaction and developmental outcomes in medically fragile, high-risk children. *Children's Health Care*, *27*(2), 97-112.

Mulder, H., Pitchford, N. J., Hagger, M. S., & Marlow, N. (In press). Development of executive function and attention in preterm children: A systematic review. *Developmental Neuropsychology*.

Muller-Nix, C., Forcada-Geux, M., Pierrehumbert, B., Jaunin, L., Borghini, A., & Ansermet, F. (2004). Prematurity, maternal stress and mother-child interactions. *Early Human Development*, *79*, 145-158.

Murray, A. D., & Hornbaker, A. V. (1997). Maternal directive and facilitative interaction styles: Associations with language and cognitive development of low risk and high risk toddlers. *Development and Psychopathology*, *9*, 507-516.

Muthen, L. K., & Muthen, B. O. (2006). *Mplus*. Los Angeles: Muthen & Muthen.

Newnham, C. A., Milgrom, J., & Skouteris, H. (2008). Effectiveness of a modified mother-infant transaction program on outcomes for preterm infants from 3 to 24 months of age. *Infant Behavior and Development*, *32*(1), 17-26.

Papile, L. A., Burstein, J., Burstein, R., & Koffler, H. (1978). Incidence and evolution of subependymal and intraventricular hemorrhage: A study of infants with birthweights less than 1500 grams. *Journal of Pediatrics*, *92*, 529-534.

Peterson, J., Taylor, G. H., Minich, N. M., Klein, N., & Hack, M. (2006). Subnormal head circumference in very low birth weight children: Neonatal correlates and school-age consequences. *Early Human Development*, 82, 325-334.

Poehlmann, J., & Fiese, B. H. (2001). Parent-infant interaction as a mediator of the relation between neonatal risk status and 12-month cognitive development. *Infant Behavior and Development*, *24*, 171-188.

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25-42.

Posner, M. I., & Raichle, M. E. (1994). *Images of mind*. New York: Scientific American Library.

Pridham, K., Becker, P., & Brown, R. (2000). Effects of infant and caregiving conditions on an infant's focused exploration of toys. *Journal of Advanced Nursing*, *31*(6), 1439-1448.

Pritchard, V. E., Clark, C. A. C., Liberty, K., Champion, P. R., Wilson, K., & Woodward, L. J. (2008). Early school-based learning difficulties in children born preterm. *Early Human Development*, *doi:10.1013/j.earlyhumdev.2008.10.004*.

Reissland, N., & Stephenson, T. (1999). Turn-taking in early vocal interaction: A comparison of premature and term infants' vocal interaction with their mothers. *Child: Care, Health & Development*, *25*(6), 447-456.

Richards, J. E., & Cronise, K. (2000). Extended visual fixation in the early preschool years: Look duration, heart rate changes, and attentional inertia. *Child Development*, *71*(3), 602-620.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2001). Attention and recognition memory in the 1st year of life: A longitudinal study of preterm and full-term infants. *Developmental Psychology*, *37*(1), 135-151.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2002b). Processing speed in the 1st year of life: A longitudinal study of preterm and full-term infants. *Developmental Psychology*, *38*(6), 895-902.

Rose, S. A., Feldman, J. F., Jankowski, J. J., & Caro, D. M. (2002a). A longitudinal study of visual expectation and reaction time in the first year of life. *Child Development*, *73*(1), 47-61.

Rose, S. A., Feldman, J. F., McCarton, C. M., & Wolfson, J. (1988). Information processing in seven-month-old infants as a function of risk status. *Child Development*, *59*, 589-603.

Rose, S. A., Feldman, J. F., Wallace, I. F., & McCarton, C. (1991). Information processing at 1 year: Relation to birth status and developmental outcome during the first 5 years. *Developmental Psychology*, *27*(5), 723-737.

Roskam, I. (2005). A comparative study of mothers' beliefs and childrearing behavior: The effect of the child's disability and the mother's educational level. *European Journal of Psychology and Education*, *20*(2), 139-153.

Ross, G., Tesman, J., Auld, P. A. M., & Nas, R. (1992). Effects of subependymal and mild intraventricular lesions on visual attention and memory in premature infants. *Developmental Psychology*, *28*(6), 1067-1074.

Rothbart, M. K., & Posner, M. I. (2005). Genes and experience in the development of executive attention and effortful control. *New Directions for Child and Adolescent Development*, *109*, 101-108.

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Pappert Lercari, L., & Posner, M. I. (2004b). Development of attentional networks in childhood. *Neuropsychologia*, *42*, 1029-1040.

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2004a). Attentional control and self-regulation. In R. Baumeister & K. D. Vohs (Eds.), *Handbook of Self Regulation: Research, Theory, and Applications* (pp. 283-300). New York: Guilford Press.

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005a). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology*, *28*(2), 573-594.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005b). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences*, *102*, 14931-14936.

Ruff, H. A., & Capazzoli, M. C. (2003). Development of attention and distractibility in the first 4 years of life. *Developmental Psychology*, *39*(5), 877-890.

Ruff, H. A., & Lawson, K. R. (1990). Development of sustained, focused attention in young children during free play. *Developmental Psychology*, *26*(1), 85-93.

Ruff, H. A., Lawson, K. R., Parrinello, R., & Weissberg, R. (1990). Long-term stability of individual differences in sustained attention in the early years. *Child Development*, *61*, 60-75.

Ruff, H. A., & Rothbart, M. K. (1996). *Attention in Early Development: Themes and variations*. New York, NY: Oxford University Press, Inc.

Rugolo, L. M. (2005). Growth and developmental outcomes of the extremely preterm infant. *Jornal de Pediatria*, *81*(1 Suppl), S101-S110.

Salerni, N., Suttora, C., & D'Odorico, L. (2007). A comparison of characteristics of early communication exchanges in mother-preterm and mother-full-term infant dyads. *First Language*, *27*, 329-346.

Salt, A., & Redshaw, M. (2006). Neurodevelopmental follow-up after preterm birth: follow up after two years. *Early Human Development*, *82*, 185-197.

Sameroff, A. J., & MacKenzie, M. J. (2003). Research strategies for capturing transactional models of development: The limits of the possible. *Development and Psychopathology*, *15*(3), 613-640.

Sarid, M., & Breznitz, Z. (1997). Developmental aspects of sustained attention among 1- to 6-year-old children. *International Journal of Behavioral Development*, *21*(2), 303-312.

Schmidt, C. L., & Lawson, K. R. (2002). Caregiver attention-focusing and children's attention-sharing behaviours as predictors of later verbal IQ in very low birthweight children. *Journal of Child Language*, *29*, 3-22.

Schmucker, G., Brisch, K., Kohntop, B., Betzler, S., Osterle, M., Pohlandt, F., Pokorny, D., Laucht, M., Kachele, H., & Buchheim, A. (2005). The influence of prematurity, maternal anxiety, and infants' neurobiological risk on mother-infant interactions. *Infant Mental Health Journal*, *26*(5), 423-441.

Sesma, H. W., & Georgieff, M. K. (2003). The effect of adverse intrauterine and newborn environments on cognitive development: The experiences of premature delivery and diabetes during pregnancy. *Development and Psychopathology*, *15*, 991-1015.

Shalev, L., Tsal, Y., & Mevorach, C. (2007). Computerized progressive attentional training (CPAT) program: effective direct intervention for children with ADHD. *Child Neuropsychology*, *13*(4), 382-388.

Shin, H., Park, Y., Ryu, H., & Seomun, G. (2008). Maternal sensitivity: a concept analysis. *Journal of Advanced Nursing*, *64*(3), 304-314.

Short, E. J., Klein, N. K., Lewis, B. A., Fulton, S., Eisengart, S., Kercsmar, C., Baley, J., & Singer, L. T. (2003). Cognitive and academic consequences of bronchopulmonary dysplasia and very low birth weight: 8-year-old outcomes. *Pediatrics*, *112*(5), 359-366.

Shum, D., Neulinger, K., O'Callaghan, M., & Mohay, H. (2008). Attentional problems in children born very preterm or with extremely low birth weight at 7-9 years. *Archives of Clinical Neuropsychology*, *23*(1), 103-112.

Siegel, L. S. (1989). A reconceptualization of prediction from infant test scores. In M. H. Bornstein & N. A. Krasnegor (Eds.), *Stability and continuity in mental development* (pp. 89-103). Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers.

Sigman, M., & Beckwith, L. (1980). Infant visual attentiveness in relation to caregiver-infant interaction and developmental outcome. *Infant Behavior and Development*, *3*, 141-154.

Sigman, M., Cohen, S. E., Beckwith, L., & Parmelee, A. H. (1986). Infant attention in relation to intellectual abilities in childhood. *Developmental Psychology*, *22*(6), 788-792.

Sigman, M., Kopp, C. B., Littman, B., & Parmelee, A. H. (1977). Infant visual attentiveness in relation to birth condition. *Developmental Psychology*, *13*(5), 431-437.

Slater, A. (1995). Individual differences in infancy and later IQ. *Journal of Child Psychology and Psychiatry*, *36*(1), 69-112.

Slaughter, V., & Suddendorf, T. (2007). Participant loss die to “fussiness” in infant visual paradigms: A review of the last 20 years. *Infant Behavior & Development*, *30*, 505-514.

Smith, K. E., Keeney, S., Zhang, L., Perez-Polo, R., & Rassin, D. K. (2008). The association of early blood oxygenation with child development in preterm infants with acute respiratory disorders. *International Journal of Developmental Neuroscience*, *26*(1), 125-131.

Smith, K. E., Landry, S. H., & Swank, P. R. (2006). The role of early maternal responsiveness in supporting school-aged cognitive development for children who vary in birth status. *Pediatrics*, *117*, 1608-1617.

Smith, K. E., Landry, S. H., Swank, P. R., Baldwin, C. D., Denson, S. E., & Wildin, S. (1996). The relation of medical risk and maternal stimulation with preterm infants’ development of cognitive, language and daily living skills. *Journal of Child Psychology and Psychiatry*, *37*(7), 855-864.

Spear, M. l., Leef, K., Epps, S., & Locke, R. (2002). Family reactions during infants’ hospitalization in the neonatal intensive care unit. *American Journal of Perinatology*, *19*(4), 205-213.

Stevenson, D. K., Verter, J., Fanaroff, A. A., Oh, W., Ehrenkranz, R. A., Shankaran, S., Donovan, E. F., Wright, L. L., Lemons, J. A., Tyson, J. E., Korones, S. B., Bauer, C. R., Stoll, B. J., & Papile, L.-A. (2000). Sex differences in outcomes of very low birthweight infants: The newborn male disadvantage. *Archives of Disease in Childhood: Fetal and Neonatal Edition*, *83*(3), 182-185.

Stifter, C. A., Willoughby, M. T., Towe-Goodman, N., & Investigators, T. F. L. P. K. (2008). Agree or agree to disagree? Assessing the convergence between parents and observers on infant temperament. *Infant and Child Development*, *17*(4), 407-426.

Stoel, R. D., Garre, F. G., Dolan, C., & van den Wittenboer, G. (2006). On the likelihood ratiotest in structural equation modeling when parameters are subject to boundary constraints. *Psychological Methods*, *11*(4), 439-455.

Stoelhorst, G. M. S. J., Rijken, M., Martens, S. E., Brand, R., den Ouden, A. L., Wit, J. M., et al. (2005). Changes in neonatology: Comparison of two cohorts of very preterm infants (gestational age <32 weeks): The project on preterm and small for gestational age infants 1983 and the Leiden follow-up project on prematurity. *Pediatrics*, *115*(2), 396-405.

Stroganova, T. A., Posikera, I. N., & Pisarevskii, M. V. (2005). Endogenous attention in 5-month-old full-term and premature infants. *Human Physiology*, *31*(3), 262-268.

Stroganova, T. A., Posikera, I. N., Pisarevskii, M. V., & Tsetlin, M. M. (2006a). EEG rhythm in preterm and full-term infants at the age of five months in endogenous attention. *Human Physiology*, *32*(5), 517-527.

Stroganova, T. A., Posikera, I. N., Pisarevskii, M. V., & Tsetlin, M. M. (2006b). Regulation of sinus cardiac rhythm during different states of attention in full-term and preterm 5-month-old infants. *Human Physiology*, *32*(2), 161-168.

Sun, J. (2003). *Early indicators of executive function and attention in preterm and full-term infants*. *PhD thesis*. Brisbane, Australia: Queensland University of Technology.

Sun, J., Mohay, H., & O’Callaghan, M. (2008). A comparison of executive function in very preterm and term infants at 8 months corrected age. *Early Human Development*, *doi:10.1016/j.earlyhumdev.2008.10.005*.

Taylor, H. G., Minich, N. M., Klein, N., & Hack, M. (2004). Longitudinal outcomes of very low birth weight: Neuropsychological findings. *Journal of the International Neuropsychological Society*, *10*, 149-163.

Thelen, E., Schoner, G., Scheier, C., & Smith, L. B. (2001). The dynamics of embodiment: a field theory of infant perseverative reaching. *Behavioral and Brain Sciences*, *24*(1), 1-34; discussion 34-86.

Tideman, E. (2000). Longitudinal follow-up of children born preterm: Cognitive development at age 19. *Early Human Development*, *58*, 81-90.

Torrioli, M. G., Frisone, M. F., Bonvini, L., Luciano, R., Pasca, M. G., Lepori, R., et al. (2000). Perceptual-motor, visual and cognitive ability in very low birthweight preschool children without neonatal ultrasound abnormalities. *Brain and Development*, *22*, 163-168.

Tu, M. T., Grunau, R. E., Petrie-Thomas, J., Haley, D. W., Weinberg, J., & Whitfield, M. F. (2007). Maternal stress and behavior modulate relationships between neonatal stress, attention, and basal cortisol at 8 months in preterm infants. *Developmental Psychobiology*, *49*(2), 150-164.

van de Weijer-Bergsma, E., Wijnroks, L., & Jongmans, M. J. (2008). Attention development in infants and preschool children born preterm: A review. *Infant Behavior and Development*, *31*(3), 333-351.

van der Meulen, B. F., Ruiter, S. A. J., Lutje Spelberg, H. C., & Smrkovsky, M. (2002). *Bayley Scales of Infant Development II Nederlandse versie*. Lisse: Swets Testpublishers.

van der Pal, S., Maguire, C. M., Le Cessie, S., Veen, S., Wit, J. M., Walther, F. J., & Bruil, J. (2008). Parental stress and child behavior and temperament in the first year after the Newborn Individualized Developmental Care and Assessment Program. *Journal of Early Intervention*, *30*(2), 102-115.

van Haastert, I. C., de Vries, L. S., Helders, P. J. M., & Jongmans, M. J. (2006). Early gross motor development in preterm infants according to the Alberta Infant Motor Scale. *Journal of Pediatrics*, *149*(5), 617-622.

Veddovi, M., Gibson, F., Kenny, D. T., Bowen, J., & Starte, D. (2004). Preterm behavior, maternal adjustment, and competencies in the newborn period: What influence do they have at 12 months postnatal age? *Infant Mental Health Journal*, *25*(6), 580-599.

Vicari, S., Caravale, B., Carlesimo, G. A., Casadei, A. M., & Allemand, F. (2004). Spatial working memory deficits in children at ages 3-4 who were low birth weight, preterm infants. *Neuropsychology*, *18*(4), 673-678.

Vohr, B. R., Wright, L. L., Dusick, A. M., Mele, L., Verter, J., Steichen, J. J., Simon, N. P., Wilson, D. C., Broyles, S., Bauer, C. R., Delaney-Black, V., Yolton, K. A., Fleisher, B. E., Papile, L., & Kaplan, M. D. (2000). Neurodevelopmental and functional outcomes of extremely low birth weight infants in the National Institute of Child Health and Human Developmental Research Network, 1993-1994. *Pediatrics*, *105*(6), 1216-1226.

Wade, S. L., Taylor, H. G., Walz, N. C., Salisbury, S., Stancin, T., Bernard, L. A., Oberjohn, K., & Yeates, K. O. (2008). Parent–child interactions during the initial weeks following brain injury in young children. *Rehabilitation Psychology*, *53*(2), 180-190.

Walther, F. J., den Ouden, A. L., & Verloove-Vanhorick, S. P. (2000). Looking back in time: Outcome of a national cohort of very preterm infants born in The Netherlands in 1983. *Early Human Development*, *59*(3), 175-191.

Warren, S. F., & Brady, N. C. (2007). The role of maternal responsivity in the development of children with intellectual disabilities. *Mental Retardation and Developmental Disabilities Research Reviews*, *13*, 330-338.

White, T., & Nelson, C. A. (2004). Neurobiological development during childhood and adolescence. In R. Findling & S. C. Schulz (Eds.), *Schizofrenia in Adolescents and Children: Assessment, Neurobiology, and Treatment*. Baltimore, MD: John Hopkins University Press.

Wiebe, S. A., Espy, K. A., & Charak, D. A. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent Structure. *Developmental Psychobiology*, *44*(2), 575-587.

Wijnroks, L. (1997). Mother-infant interaction and contingency learning in pre-term infants. *Early Development and Parenting*, *6*(1), 27-36.

Wijnroks, L. (1998). Early maternal stimulation and the development of cognitive competence and attention of preterm infants. *Early Development and Parenting*, *7*, 19-30.

Wijnroks, L. (1999). Maternal recollected anxiety and mother-infant interactions in preterm infants. *Infant Mental Health Journal*, *20*(4), 393-409.

Wijnroks, L., & van Veldhoven, N. (2003). Individual differences in postural control and cognitive development in preterm infants. *Infant Behavior and Development*, *26*, 14-26.

Wilcox, T., Nadel, L., & Rosser, R. (1996). Location memory in healthy preterm and full-term infants. *Infant Behavior and Development*, *19*, 309-323.

Wilson, S. L., & Cradock, M. M. (2004). Review: Accounting for prematurity in developmental assessment and the use of age-adjusted scores. *Journal of Pediatric Psychology*, *29*(8), 641-649.

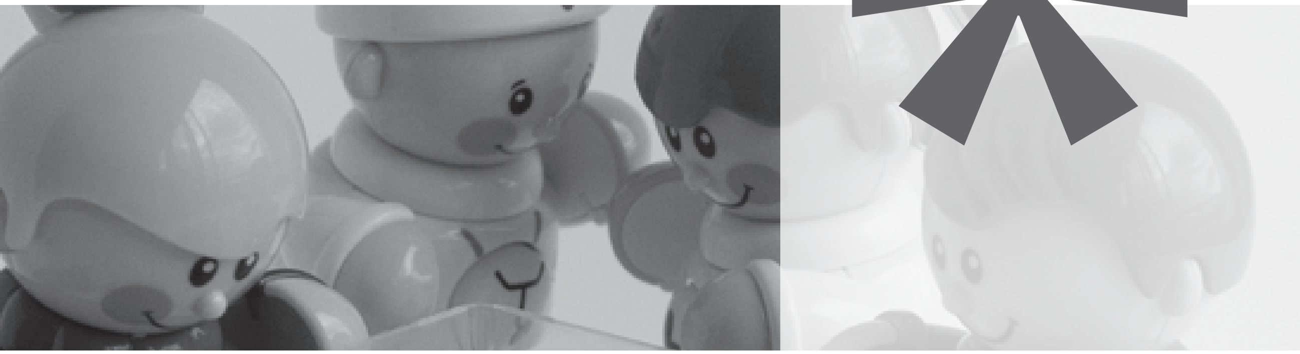
Wood, N. S., Marlow, N., Costeloe, K., Vhir, B., Gibson, A. T., & Wilkinson, A. R. (2000). Neurologic and developmental disability after extremely preterm birth. *The New England Journal of Medicine*, *343*(6), 378-384.

Woodward, L. J., Anderson, P. J., Austin, N. C., Howard, K., & Inder, T. E. (2006). Neonatal MRI to predict neurodevelopmental outcomes in preterm infants. *New England Journal of Medicine*, *355*(7), 685-694.

Woodward, L. J., Edgin, J. O., Thompson, D., & Inder, T. E. (2005). Object working memory deficits predicted by early brain injury and development in the preterm infant. *Brain*, *128*, 2578-2587.

Zelkowitz, P., Feeley, N., Shrier, I., Stremler, R., Westreich, R., Dunkley, D., Steele, R., Rosberger, Z., Lefebvre, F., & Papageorgiou, A. (2008). The Cues and Care trial: A randomized controlled trial of an intervention to reduce maternal anxiety and improve developmental outcomes in very low birthweight infants. *BMC Pediatrics*, *8*(38).

Zelkowitz, P., Papageorgiou, A., Bardin, C., & Wang, T. (2009). Persistent maternal anxiety affects the interaction between mothers and their very low birthweight children at 24 months. *Early Human Development*, *85*, 51-58.



Samenvatting
(Summary in Dutch)

Baby's die te vroeg geboren worden (bij een zwangerschapsduur korter dan 37 weken) hebben een verhoogd risico op zowel ernstige ontwikkelingproblemen (zoals mentale retardatie, sensorische beperkingen en cerebrale parese) als minder ernstige problemen (zoals leerstoornissen en aandachtsstoornissen zoals ADHD). Zelfs te vroeg geboren kinderen die op schoolleeftijd een intelligentieniveau binnen de grenzen van het normaalgebied hebben, ervaren vaker leerproblemen dan hun op tijd geboren leeftijdgenoten, en maken vaker gebruik van speciaal onderwijs. Uit onderzoek blijkt dat aandacht en andere specifieke cognitieve functies zoals werkgeheugen en inhibitie (ook wel executieve functies genoemd) van belang zijn voor de ontwikkeling van kinderen en hun prestaties op school, zoals het leren van lezen en rekenen. De bevinding dat te vroeg geboren kinderen op schoolleeftijd vaker problemen hebben met aandacht en executief functioneren, doet onderzoekers vermoeden dat problemen in deze functies mede ten grondslag liggen aan hun verhoogde risico op ontwikkelingsachterstanden en leerproblemen. Echter, de populatie te vroeg geboren kinderen is heel divers, en niet elke te vroeg geboren baby ontwikkelt zulke problemen. Om te vroeg geboren kinderen met dergelijke problemen al op jonge leeftijd hulp en interventie te kunnen bieden is het noodzakelijk om zo vroeg mogelijk de kinderen te identificeren die deze hulp nodig hebben. Kennis over de ontwikkeling van meer specifieke cognitieve functies zoals aandacht en executieve functies bij te vroeg geboren baby's kan helpen bij de ontwikkeling van screeningsinstrumenten. Kennis over welke omgevingsfactoren van invloed zijn op de ontwikkeling van deze functies is bovendien van belang voor de ontwikkeling van effectieve interventiemethoden.

In de studies beschreven in dit proefschrift werden individuele verschillen in ontwikkelingspaden van aandacht en executief functioneren onderzocht in een groep van te vroeg geboren baby's. Hierbij werd gekeken naar de voorspellende waarde van risicofactoren rond de geboorte (zwangerschapsduur, geboortegewicht, de aanwezigheid en ernst van medische complicaties) voor deze individuele verschillen in ontwikkelingspaden en de relatie tussen deze ontwikkelingspaden en algemeen cognitief functioneren. Tevens werd de relatie onderzocht tussen interactiestijlen van moeders tijdens het spelen met hun baby en de ontwikkeling van aandacht en executieve functies bij de baby zelf.

Aan de studies deden 76 te vroeg geboren baby's en hun moeders mee. De deelnemers werden geworven via het Wilhelmina Kinderziekenhuis in Utrecht (onderdeel van het Universitair Medisch Centrum Utrecht). De onderzoeksgegevens voor deze deelnemers werden verzameld op de momenten dat de baby's een gecorrigeerde leeftijd van 7, 10 en 14 maanden hadden (de gecorrigeerde leeftijden zijn berekend vanaf de uitgerekende datum van bevalling). De mate waarin baby's in staat waren hun aandacht vast te houden werd eerst geobserveerd terwijl zij speelden met één speeltje en daarna met zes speeltjes tegelijk. Executief functioneren (werkgeheugen en inhibitie) werd gemeten met behulp van kijk- en reikversies van de A-not-B taak. Bij deze taak wordt een speeltje verstopt op één van twee locaties en wordt de locatie van verstoppen verwisseld als een baby twee keer achter elkaar het speeltje op de vorige locatie heeft gevonden. Baby's moeten de plek van verstoppen onthouden (werkgeheugen) en hun reactie naar de vorige locatie onderdrukken (inhibitie). Tevens werd geobserveerd hoe moeders met hun baby speelden. Daarnaast vulden moeders een vragenlijst in over de mate waarin hun baby in staat is zijn / haar eigen gedrag te reguleren.

Hoofdstuk 2 geeft een overzicht van de literatuur over de ontwikkeling van aandacht in te vroeg geboren baby's en kinderen tijdens de eerste vier levensjaren, waarbij Posner's model van aandachtsontwikkeling gebruikt werd als theoretisch kader (Posner & Raichle, 1994). Posner maakt onderscheid tussen drie aandachtsnetwerken in de hersenen: een 'orienting' netwerk, een 'arousal' of ook wel 'alerting' netwerk genoemd en een 'executive control' netwerk, die onderling met elkaar verbonden zijn. De focus lag op het bespreken van studies waarbij gedragsmaten van visuele aandacht gebruikt werden om het richten van de aandacht ('orienting'), het vasthouden van de aandacht ('arousal' of 'alerting') en het controleren van de aandacht ('executive control') bij deze kinderen te meten. Het doel van het literatuuroverzicht was: (1) te identificeren welke verschillen er in aandachtsontwikkeling bestaan tussen te vroeg en op tijd geboren kinderen, (2) te bekijken welke biologische en omgevingsfactoren voorspellende waarde hebben voor individuele verschillen binnen de groep te vroeg geboren kinderen, en (3) te onderzoeken hoe deze individuele verschillen voorspellend zijn voor later functioneren van te vroeg geboren kinderen.

De resultaten lieten zien dat te vroeg geboren baby's meer problemen hebben met het richten, vasthouden en controleren van de aandacht dan op tijd geboren leeftijdsgenootjes. De verschillen tussen te vroeg en op tijd geboren baby's in het vasthouden van de aandacht en executieve functies lijken bovendien groter te worden naarmate zij de peuterfase bereiken. Individuele verschillen binnen de groep te vroeg geboren kinderen lijken samen te hangen met zowel biologische factoren (bijvoorbeeld zwangerschapsduur, geboortegewicht, medische complicaties, geslacht) als omgevingsfactoren (moederlijke interactiestijlen). Daarnaast werd gevonden dat de individuele verschillen in het richten en vasthouden van de aandacht voorspellend zijn voor later functioneren op het gebied van aandacht, gedrag en intelligentie. Zover bekend zijn er geen studies gepubliceerd die de voorspellende waarde van executieve functies voor later functioneren hebben onderzocht bij te vroeg geboren kinderen. De conclusies uit dit literatuuroverzicht worden echter gecompliceerd door meerdere methodologische aspecten, zoals verschillen tussen studies in meetinstrumenten, definities van medisch risico, en eigenschappen van de onderzoeksgroepen.

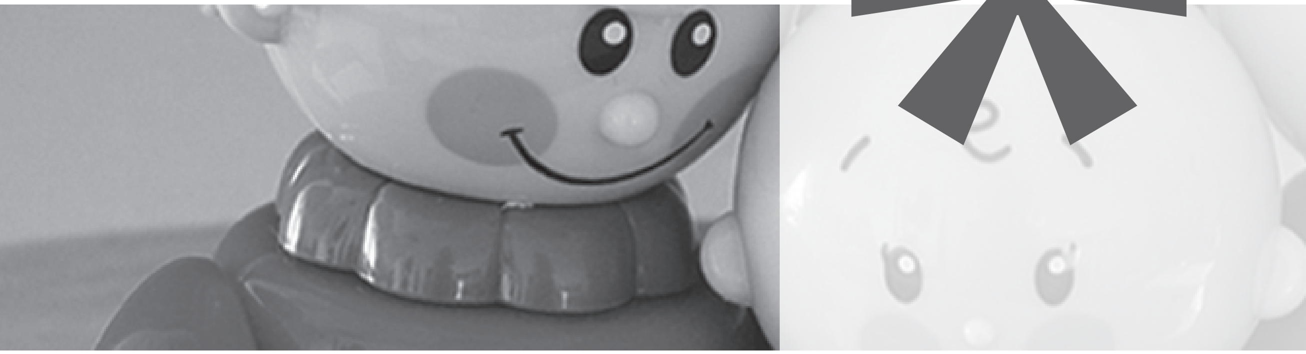
Uit het literatuuroverzicht werd duidelijk dat meerdere belangrijke vragen nog onvoldoende beantwoord zijn. Een aantal van deze vragen werden onderzocht in de *Hoofdstukken 3 tot en met 5* van dit proefschrift: (1) wat is de voorspellende waarde van risicofactoren rond de geboorte voor individuele verschillen in vroege ontwikkeling van aandacht en executieve functies bij te vroeg geboren baby's?, (2) zijn deze vroege individuele verschillen gerelateerd aan verschillen in later globaal cognitief functioneren?, (3) wat is de voorspellende waarde van moederlijke interactiestijlen voor de ontwikkeling van aandacht en executieve functies?, en (4) hangt dit af van de mate waarin een te vroeg geboren kind in staat is zijn / haar gedrag te reguleren (zelfregulatie)?

In *Hoofdstuk 3* werd de voorspellende waarde van risicofactoren rond de geboorte (zwangerschapsduur, geboortegewicht, geslacht en de aanwezigheid en ernst van medische complicaties) voor individuele verschillen in ontwikkelingspaden van executieve functies bij te vroeg geboren baby's onderzocht, met behulp van statistische analyses waarbij latente groeimodellen werden gebruikt. Hierbij werd executief functioneren gemeten met kijk- en reikversies van de A-not-B taak. Ook werd onderzocht hoe deze ontwikkelingspaden voorspellend waren voor globaal cognitief functioneren. De resultaten lieten zien dat meerdere risicofactoren rond de geboorte voorspellend waren voor de snelheid van ontwikkeling in executieve functies. Zowel het beginniveau (op de leeftijd van 7 maanden) als de snelheid van ontwikkeling in executieve functies (tussen de leeftijden van 7 en 14 maanden) waren voorspellend voor globaal cognitief functioneren (op de leeftijd van 14 maanden). Verschillen tussen te vroeg geboren baby's in het onderzoek werden groter naarmate de baby's ouder werden. Vergelijking met eerder onderzoek bij op tijd geboren kinderen lijkt bovendien te bevestigen dat problemen met executieve functies duidelijker zichtbaar worden naarmate baby's ouder worden.

In *Hoofdstuk 4* werd de voorspellende waarde van risicofactoren rond de geboorte voor individuele verschillen in ontwikkelingspaden van volgehouden aandacht bij te vroeg geboren baby's onderzocht, weer met behulp van latente groeimodellen. Volgehouden aandacht werd geobserveerd tijdens twee vrije spel situaties, eerst met één speeltje daarna met zes speeltjes tegelijk. Ook werd de voorspellende waarde van deze ontwikkelingspaden voor globaal cognitief functioneren onderzocht. De resultaten lieten zien dat een milde vorm van periventriculaire leukomalacie (een type hersenbeschadiging die regelmatig gezien wordt bij te vroeg geboren baby's in de neonatale periode) voorspellend was voor de snelheid van ontwikkeling in volgehouden aandacht tussen de leeftijden van 7 en 14 maanden. Tevens werd gevonden dat de snelheid van ontwikkeling in volgehouden aandacht (tussen de leeftijden van 7 en 14 maanden) voorspellend was voor globaal cognitief functioneren (op de leeftijd van 14 maanden). Wij beargumenteerden dat een langere duur van volgehouden aandacht niet per se een hogere kwaliteit van volgehouden aandacht weerspiegelt, maar mogelijk soms juist een tragere informatieverwerkingssnelheid. Voor baby's met een tragere informatieverwerkingssnelheid is een toename in volgehouden aandacht met het ouder worden dan ook mogelijk het gevolg van een toename in de stroom van inkomende informatie.

In *Hoofdstuk 5* werd de voorspellende waarde van moederlijke interactiestijlen voor de ontwikkeling van volgehouden aandacht en executieve functies bij te vroeg geboren baby's onderzocht, ditmaal door de latente groeimodellen van de ontwikkeling van aandacht en executieve functies te koppelen aan de latente groeimodellen van de moederlijke interactiestijlen. Een sensitieve responsieve interactiestijl (de mate waarin een ouder zich richt op de signalen van het kind, deze juist interpreteert en hierop adequaat reageert) heeft mogelijk een positieve invloed op de ontwikkeling van aandacht en executieve functies, omdat het minder eisen stelt aan de beperkte aandachtscapaciteit van een baby (door het volgen van de aandachtsrichting van de baby) en de baby steun biedt in het reguleren van zijn / haar gedrag. Een directieve of sturende interactiestijl, waarbij een moeder controle uitoefent over het gedrag van haar baby, wordt daarentegen vaak gezien als een negatieve invloed op de ontwikkeling van haar baby. Echter, omdat baby's nog moeite hebben met het reguleren van hun gedrag (zelfregulatie) kan een directieve interactiestijl ook structuur bieden en een positieve invloed hebben op de ontwikkeling van aandacht en executieve functies tijdens de babytijd. Naast het onderzoeken van de voorspellende waarde van deze twee interactiestijlen voor de ontwikkeling van volgehouden aandacht en executieve functies bij te vroeg geboren baby's, werd in dit hoofdstuk tevens gekeken of deze voorspellende waarde sterker was bij kinderen die meer moeite hadden hun gedrag te reguleren. De resultaten lieten zien dat een (consistent) hoger niveau van directiviteit samenhing met een sterkere toename in executieve functies tussen de leeftijd van 7 en 14 maanden, ongeacht de mate van zelfregulatie van de baby. Moederlijke interactiestijlen waren niet voorspellend voor de ontwikkeling van aandacht. Deze resultaten suggereren dat de ontwikkeling van executieve functies bij te vroeg geboren baby's baat heeft bij een moederlijke interactiestijl die meer structuur biedt.

In *Hoofdstuk 6* wordt een samenvatting en algemene discussie van de resultaten van het literatuuroverzicht en de drie studies gegeven. De belangrijkste uitkomsten van de studies beschreven in dit proefschrift zijn dat individuele verschillen tussen te vroeg geboren kinderen over tijd in aandacht en executieve functies niet erg stabiel zijn tussen de leeftijden van 7 en 14 maanden. Dit bevestigt de dynamiek in de ontwikkeling van deze functies tijdens deze periode. Individuele verschillen in de snelheid van ontwikkeling in aandacht en executieve functies hangen echter samen met verschillen in risicofactoren rond de geboorte en zijn voorspellend voor globaal cognitief functioneren op de leeftijd van 14 maanden. Tevens lijkt een meer gestructureerde aanpak door moeders (directiviteit) bij te dragen aan de ontwikkeling van executieve functies bij te vroeg geboren baby's, onafhankelijk van de mate van zelfregulatie van de baby, in de onderzochte periode. Er werd geen evidentie gevonden voor een positief effect van een sensitieve responsieve interactiestijl, hoewel wij beargumenteren dat de effectiviteit van het bieden van structuur in belangrijke mate afhankelijk is van of een moeder gevoelig is voor de signalen van haar kind (sensitieve responsiviteit). Na de belangrijkste uitkomsten worden de uitdagingen besproken die wij tegenkwamen bij het onderzoeken van de voorspellende waarde van risicofactoren rond de geboorte en de functies die ten grondslag liggen aan de prestatie op de gebruikte taken. Tevens worden er aanbevelingen voor onderzoek gedaan met een nadruk op langdurige follow-up en het gebruik van statistische methoden zoals latente groeimodellen. Tot slot wordt de praktische betekenis van de resultaten besproken betreffende de vroege opsporing van te vroeg geboren baby's met een verhoogd risico op problemen en mogelijkheden voor interventie op deze jonge leeftijd.



Dankwoord

In bijna ieder proefschrift kun je een dankwoord vinden dat begint met iets in de strekking van: "De succesvolle afronding van dit proefschrift is afhankelijk geweest van een heleboel anderen". Doordat het al zo vaak geschreven is lijken deze woorden hun betekenis te verliezen of minder oprecht. Maar nu ik de hectische periode van het afronden van het proefschrift zelf heb meegemaakt besef ik dat deze woorden wel degelijk gemeend zijn. En dus wil ook ik hier de mensen bedanken door wiens inzet, steun of inspirerende woorden dit proefschrift is geworden wat het is.

Allereerst wil ik mijn promotor Marian Jongmans en co-promotor Lex Wijnroks bedanken, die net zo enthousiast over het onderwerp van mijn promotieonderzoek waren als ikzelf.

Beste Lex, wat heb ik het getroffen met jou als dagelijks begeleider. Ik heb genoten van onze vele inhoudelijke discussies over het proefschrift. Je hebt mij daarbij altijd het gevoel gegeven dat ik een gelijkwaardige gesprekspartner was. Ook heb je mij geleerd altijd kritisch te blijven denken. Ook wil ik je bedanken voor jouw inlevingsvermogen als het tegenzat. Het is regelmatig voorgekomen dat ik in zak en as bij je aanklopte, maar altijd kwam ik weer geïnspireerd en met goede moed uit onze gesprekken.

Beste Marian, wat een hartelijk welkom heb ik door jou ervaren toen ik op mijn eerste werkdag een bloemetje en een kaart op mijn bureau vond. Je combineert je warme vrouwelijke eigenschappen op een prettige manier met de eigenschappen die nodig zijn om hoogleraar te zijn: warm en invoelend, maar zakelijk en doelmatig wanneer nodig! Ik bewonder je enorme hoeveelheid kennis over te vroeg geboren kinderen en de complexiteit van de factoren die hun ontwikkeling beïnvloeden. Het was fijn om op jouw 'prioriteitenlijstje' te staan de afgelopen maanden!

En dan Jan Boom, mijn LGM-vraagbaak. Beste Jan, bedankt dat je mij wegwijs hebt willen maken in de wereld van latente groeimodellen. Als die ellendige negatieve varianties weer eens de kop op staken, wist jij altijd weer een remedie. Als co-auteur op alle drie de empirische artikelen heb je een grote bijdrage geleverd aan de totstandkoming van dit proefschrift. Ontzettend bedankt daarvoor.

Daarnaast wil ik de medewerkers van de afdeling Neonatologie van het Wilhemina Kinderziekenhuis bedanken voor de goede zorg die zij gegeven hebben aan de kinderen die daar zo kwetsbaar hun leven begonnen. In het bijzonder wil ik Linda de Vries en Inge-Lot van Haastert bedanken, die ook een belangrijke bijdrage hebben geleverd aan de totstandkoming van aan aantal van de artikelen in dit proefschrift. Linda, hartelijk dank dat je ondanks jouw immens drukke schema tijd hebt gevonden om bij te dragen aan het eerste empirische artikel van dit proefschrift. Inge-Lot, ik bewonder je betrokkenheid en professionaliteit. Je hebt de artikelen elke keer zo snel, maar nauwgezet voorzien van commentaar, ongelooflijk! Ook wil ik je bedanken voor jouw onmisbare hulp bij mijn zoektocht in het 'dossier-doolhof'.

Tevens wil ik hier de ouders en kinderen die aan het onderzoek hebben meegewerkt ontzettend bedanken. Zonder jullie gastvrijheid, tijd en moeite was dit onderzoek niet mogelijk geweest. Het was bijzonder om jullie kinderen gedurende deze eerste jaren van hun ontwikkeling te mogen volgen.

De intensieve dataverzameling was niet mogelijk geweest zonder de inzet van onderzoeksassistenten, Hilke Rijnen, Lise Vergeer, Inge Griffioen en in het bijzonder Hanna Mulder. Dank jullie wel!

Adele Diamond, thank you for your generous hospitality during my visit to Waltham, MA, and for training me on the A-not-B task. Heidelise Als, I really appreciate your valuable suggestions to improve our research plan when I was just starting this project. Thank you!

Ook de leden van de promotiecommissie wil ik bedanken voor hun bereidheid om dit proefschrift te beoordelen en aanwezig te zijn bij de verdediging ervan: prof. dr. Marcel van Aken, prof. dr. Frank van Bel, prof. dr. Anke Bouma, prof. dr. Joop Hox, en prof. dr. Marianne Riksen-Walraven.

Ik wil graag alle collega's van Gehandicaptenzorg en Leerproblemen bedanken voor de prettige werksfeer, en een aantal in het bijzonder. Met name mijn geweldige paranimfen, Renate Siebes en Mariët van der Molen, wil ik bedanken voor de gezelligheid en betrokkenheid. Lieve Renate, wat heb ik het getroffen met jou als kamergenote. Ik zou willen dat ik zo attent was als jij. Op werkelijk talloze manieren ben je betrokken geweest bij dit proefschrift: zelfbenoemd 'secretaresse', pilot-deelnemer (samen met Marah), dvd-expert, observator, drukbegeleider en de 'aio support-desk' zijn daar slechts enkelen van. Lieve Mariët, we hebben ontzettend gelachen samen. In onze gesprekken was je een klankbord voor mij, en hadden we het over werk, relaties, het ouderschap en de combinatie van deze. Gelukkig kunnen we nu samen gaan lunchen in Amsterdam. Jullie zijn beiden echte vriendinnen geworden en hopelijk komen we elkaar nog 'te pas' in de toekomst! En natuurlijk ook nog Evelyn Kroesbergen, Rachèl Kemps en Jolanda Douma. Evelyn, ik vond het ontzettend leuk om samen met jou tot dezelfde 'maffia' te behoren! Rachèl, bedankt voor de gezellige tijd toen we nog kamergenoten waren, en ik vond het erg leuk om met Jelle aan jouw onderzoek mee te doen. Jolanda, bedankt voor het langsbrengen van koekjes en chocolade op de momenten dat ik in mijn middagdipje zat.

Ook de collega-AiO's van Pedagogiek en Onderwijskunde wil ik bedanken voor de gezelligheid. Een aantal van hen wil ik bij naam noemen. Muriel en Veroni, bedankt voor de prachtige foto's met jullie meiden. Tim, bedankt voor de kletspraatjes, de OLLI samenwerking en dat je de eerste versie van mijn overzichtsartikel kritisch wilde lezen. Sanne, bedankt voor de gezellige autorit naar en het verblijf in Würzburg!

Er zijn ook een aantal collega's die ik wil bedanken voor hun ondersteuning in praktische zaken. Ruth Cramer, beste Ruth, bedankt voor jouw geduld en flexibele instelling als ik weer eens langs kwam met ongebruikelijke oplossingen voor allerlei praktische problemen. Erica van Doorn, beste Erica, ik zal de gezellige praatjes die we tijdens jouw computerondersteuning hadden erg missen.

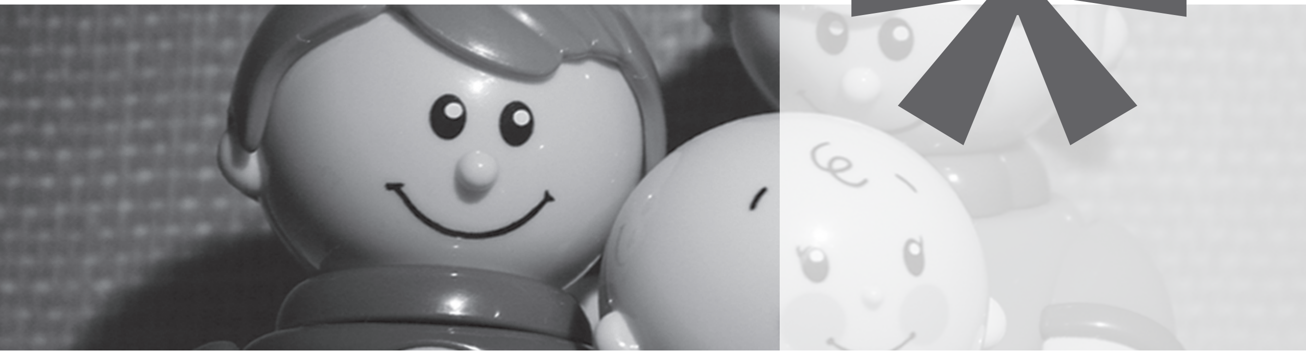
Tolo Toys Ltd. has made a generous donation of toys to this study, as well as a very generous donation to the printing costs of this PhD thesis. Stephen Reardon, Jim Brearly and Luc Schwartau, thank you so much for your interest in our study!

Tevens wil ik hier Kitty van der Veer bedanken, die de omslag en uitnodiging van dit proefschrift ontworpen heeft. Kitty, bedankt dat je zoveel geduld voor deze veeleisende klant op kon brengen ondanks al die computer- en internetfrustraties. Ik vind het eindresultaat helemaal geweldig!

Mijn familie wil ik uiteraard ook bedanken. Lieve Loes, of het *nature* of *nurture* is, of een gen-omgeving-interactie, dat weet ik niet, maar van jou heb ik geleerd mijn eigen pad te kiezen, en mij niet te veel te laten leiden door 'hoe het hoort'. Bedankt voor je oprechte interesse in wat ik doe, je 'strenge' moederadviezen, en je inzet als oppasoma toen Jelle nog zo klein was en ik net aan dit uitdagende project begon. Ik vind het heel fijn om te zien dat jullie daardoor zo'n bijzondere band hebben opgebouwd. Lieve Edmond, het is gewoon ontzettend fijn dat je er nog bent! Straks heb ik weer meer tijd om jou en Cobi op te komen zoeken in Varsseveld. Lieve Neeltje en Daan, gewoon bedankt omdat jullie mijn grote zus en kleine broertje zijn! En dan mijn ongekend zorgzame schoonouders, Bep en Jaap, waar ik het zo mee getroffen heb. Bep, ik zeg het vaak gekscherend, maar het is o zo waar, zonder jouw onvoorwaardelijke steun zou ik nooit dit proefschrift hebben kunnen afronden. Zonder enig spoor van twijfel stond je steeds weer op de stoep om in te springen wanneer er zieken waren of het huishouden een zootje was. En Jaap, ook jij zat hier toch steeds weer op die avonden na een hele lange dag werken. Lieve Clara, suikertante. Ook jij hebt aan de wieg gestaan van deze promotie, want zonder jouw betrokkenheid en steun had ik nooit kunnen beginnen aan mijn studie Psychologie, laat staan een promotietraject.

En dan mijn drie mannen! Barry, mijn lief! Bedankt voor de ruimte die je mij geeft om mijn eigen pad te volgen (lees: het geduld dat je hebt voor mijn eigenwijze en soms betweterige houding☺), en dat je mij waarschuwt wanneer je ziet dat ik voorbijga aan die dingen die ik het meest belangrijk vind. Je kent mij beter dan wie dan ook. Wat heerlijk om op één lijn te zitten over de meest belangrijke aspecten van ons leven. Ik wil heel graag samen met jou oud en rimpelig worden (wel graag in die volgorde). Lieve Jelle, mijn vrolijke, wijze en gevoelige mannetje. En een kleine filosoof / neuropsycholoog in dop. Je moest eens weten hoe dicht je bij de waarheid zat toen je op 4-jarige leeftijd vroeg: "Mama, hoe gaat dat eigenlijk in je hoofd: 'denken'? Gaat dat met allemaal kabeltjes?" En Abe, aapje, je bent de grootste kleine boef die ik ken. Je weet al zo goed wat je wel en niet wilt! Aan de toename in frequentie van de woorden 'nee' en 'zelluf doen' uit jouw mondje leid ik af dat het tijd wordt dat ik de balans tussen sensitieve responsiviteit en directiviteit weer wat aan moet passen.

En voor alle anderen die dit lezen, bedankt dat je de tijd hebt genomen om dit proefschrift open te slaan. Volgende week is er een mondelinge overhoring!



Curriculum vitae

Eva van de Weijer-Bergsma is geboren in Amsterdam op 20 november 1976. Na 3 jaar onderwijs te hebben gevolgd op het Barlaeusgymnasium, heeft zij in 1994 haar HAVO-diploma behaald op het Montessori Lyceum Amsterdam. Na een toelatingsexamen (colloqium doctum) werd zij in 1998 toegelaten tot de studie Psychologie aan de Universiteit van Amsterdam. In augustus 2003, vlak na haar huwelijk met Barry, studeerde zij cum laude af met een specialisatie Klinische Neuropsychologie bij de programmagroepen Ontwikkelingspsychologie en Psychonomie. In september 2003 werd haar eerste zoon Jelle geboren.

Na haar afstuderen begon zij aan haar promotieonderzoek bij de afdeling Algemene Pedagogiek en Orthopedagogiek van de Universiteit Utrecht, waaraan zij vanaf 2004 tot 2009 heeft gewerkt. In 2008 kreeg Eva de ISED-artikelprijs toegekend voor haar overzichtsartikel over de ontwikkeling van aandacht bij te vroeg geboren kinderen. Tijdens haar promotietraject werd haar tweede zoon Abe geboren.

Sinds april 2009 werkt Eva als onderzoeker / psycholoog bij UvA-Virenze te Amsterdam, een academisch behandelcentrum voor ouders en kinderen.