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Visual Habituation and Dishabituation in Preterm Infants: A Review and Meta-analysis

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Abstract

We review comparative studies of infant habituation and dishabituation performance focusing on preterm infants. Habituation refers to cognitive encoding, and dishabituation refers to discrimination and memory. If habituation and dishabituation constitute basic information-processing skills, and preterm infants suffer cognitive disadvantages, then preterms should show diminished habituation and dishabituation performance. Our review provides evidence that preterm infants' habituation and dishabituation are impoverished relative to term infants. On the whole, effect sizes indicated that the differences between preterms and terms are of a medium magnitude. We also find that preterms' performance is moderated by risk factors, stimulus materials, procedural variables, and age. These factors need to be taken into account in the construction of tests in which habituation-dishabituation tasks are employed. Overall, the habituation-dishabituation paradigm presents a promising approach in the diagnosis of cognitive status and development in preterm infants.

Keywords

habituation; dishabituation; preterm development; cognitive development; meta-analysis

1. Introduction

1.1 Epidemiology of Preterm Birth

The term infant is delivered about 38 to 42 weeks after the mother's last menstrual period. The World Health Organization (WHO) defines *preterm* birth as delivery before 37 completed weeks of gestation (and low birth weight if born under 2500 g). Rates of preterm birth vary around 10% and with country. Among the 4 million new births each year in the United States, approximately 12.3% of children are born too early – that is, approximately 1 in 8 babies (Martin et al., 2007). Among European countries, preterm birth rates vary widely, ranging from 5.3% in Lithuania to 11.4% in Austria. In Germany, the preterm birth

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rate amounts to 8.9% (EURO-PERISTAT Project, 2008; Macfarlane & Blondel, 2005). Overall, according to Beck et al. (2009), the highest rates of preterm birth are in North America and Africa (10.6% and 11.9%), and the lowest are in Europe (6.2%). Moreover, wherever trend data are available, rates of preterm birth are increasing. For example, the premature birth rate in the United States increased by more than 30% between 1981 and 2003 (Martin et al., 2007). Women pregnant through certain infertility treatments, poor women, and those under age 16 or over 35 have increased risk; even single babies conceived by *in vitro* fertilization are more likely to be preterm (Jackson, Gibson, Wu, & Croughan, 2004). Other factors that are associated with preterm birth include poor diet, maternal stress, lack of prenatal care and smoking, increased use of caesarean deliveries, and growth in multiple birth rates as well as ongoing technological advances in neonatal care that promote the viability of very small infants (Behrman & Butler, 2006; Davidoff et al., 2006; Goldenberg, Culhane, Iams, & Romero, 2008; Hamilton, Martin, & Sutton, 2004). Moutquin (2003) described the etiological heterogeneity of preterm birth leading to taxonomy of three main categories: medically indicated (iatrogenic) preterm birth, preterm premature rupture of membranes (PPROM), and spontaneous (idiopathic) preterm birth. The cause of spontaneous preterm birth tends to be unknown, and therefore it is difficult to predict and prevent (Behrman & Butler, 2006; Steer, 2005).

Preterm infants are commonly classified according to gestational age, the period of time between conception and birth (the number of weeks that the baby has been *in utero*) as well as birth weight. Postmenstrual age (PA) is gestational age plus chronological age, the time elapsed between birth and date of assessment. Age of preterms is usually described in terms of corrected age (Wilson & Cradock, 2004), denoting the age of the child from the expected date of delivery. Corrected age is determined by subtracting the number of weeks born before 40 weeks of gestation from the child’s chronological age. Gestational age is normally trichotomized as “mild preterm birth” (32–36 weeks gestational age); “very preterm birth” (28–31 weeks gestational age); and “extremely preterm birth” (< 28 weeks gestational age). Birth weight is trichotomized as “low birth weight (LBW)” 1500 – 2499 g; “very low birth weight” (VLBW) 1000 – 1499 g; “extremely low birth weight” (ELBW) ≤ 1000 g).

1.2 Medical Issues

Preterm low birth-weight babies have average hospital stays of 45 to 50 days, and between one-third and one-half experience one or more rehospitalizations during the first 3 years of life (Behrman & Butler, 2006). Serious health problems and developmental delays are more pronounced among very preterm and very low birth weight babies, who account for between 14% and 15% of all preterm, low-birth-weight births in the United States. In Europe, very preterm births account for about 1% of all births. The Institute of Medicine (Behrman & Butler, 2006) estimated the annual societal economic burden associated with preterm birth in the United States to be $26.2 billion in 2005 (or $51,600 per infant born preterm). In Germany, the cost difference between a term and a preterm delivery amounts to about €10,550 (Kirschner, Halle, & Pogonke, 2009).

Very preterm, very low birth-weight infants are at increased risk for brain complications, such as intraventricular hemorrhage (IVH) and periventricular leukomalacia, both of which are associated with significant developmental delay (Allin, 2006). Intraventricular hemorrhage is defined by bleeding in areas surrounding the lateral cerebral ventricles (Luciana, 2003). IVH is classified into one of four grades with Grade 1 being the mildest degree of severity. IVH can injure the hippocampus, a site of recognition memory (e.g., Aylward, 2005; Kirwan, Wixted, & Squire, 2008). Beauchamp et al. (2008) found that very preterm infants with relatively small hippocampal volumes displayed working memory deficits at age 2 years. Reduced myelination has also been found in preterm, as compared to term, infants’ white matter (Mewes et al., 2006; Woodward, Mogridge, Wells, Inder, 2004;

Volpe, 2003). Even preterms without early brain injury are characterized by a potential disruption in the development of brain structures such as the corpus callosum (Aylward, 2005). Birth before 28 to 30 weeks gestation can result in lung tissue which is very fragile, increasing the risk that this tissue will be injured. Injured lung tissue tends to trap air, collapse, or fill with mucus. Respiratory distress syndrome (RDS) is associated with infants born younger than 32 weeks of gestational age, with 80% of infants born younger than 27 weeks' gestation developing RDS (Behrman & Butler, 2006; Verma, 1995). Sometimes bronchopulmonary dysplasia (BPD) or chronic lung disease (CLD) follow RDS in preterm infants (Vanhatalo, Ekblad, Kero, & Erkkola, 1994). Respiratory distress syndrome is indexed by the length of time on oxygen.

Bhutta and Anand (2001) linked cumulative brain injuries to observed cognitive deficits. Neuropsychological studies provide evidence that long-term cognitive and behavioral outcomes of preterm birth range from severe impairments, such as language disorders, to less severe problems, such as mild cognitive delays or visuomotor difficulties (e.g., Case-Smith, Butcher, & Reed, 1998; Feldman, 2009; Moster, Lie, & Markestad, 2008). Wood et al. (2000) found about 50% of their cohort of 30-month-old preterm infants from the United Kingdom and Ireland had a disability in mental or psychomotor development, neuromotor function, or sensory and communication function domains with approximately 25% reaching criteria for severe disability. In turn, these disabilities were predictive of child outcome at 6 years when the rate of moderate or severe disability observed was 46% (Marlow, Wolke, Bracewell, & Samara, 2005). Anderson and Doyle (2003) reported that 55% of survivors born very preterm and extremely low birth weight in Australia exhibited clinically significant neurobehavioral impairment in middle childhood. Lefebvre, Glorieux, and St-Laurent-Gagnon (1996) reported a 30% overall incidence of abnormality in their cohort of Canadian preterm infants (born between 23 and 29 weeks gestation). Therefore, across countries findings have shown similar rates of atypical development, which have tended to occur in approximately 50% of extremely preterm infants.

Neurodevelopmental outcome effects appear to be much stronger in preterms who experience multiple risk factors including IVH, RDS, and a birth weight of less than 1500 g (e.g., Foulder-Hughes & Cooke, 2003; Wolke, Ratschinski, Ohrt, & Riegel, 1994). Dividing all samples that are included in our review into preterms with IVH or RDS problems, preterms with other disturbances (excluding IVH or RDS problems), and preterms without additional risk factors, is confounded with both differences in birth weight and, to a lesser extent, gestational age. All preterm samples with no additional problems are characterized by low birth weight and by gestational ages between about 30 and 36 weeks (see Table 2). Most preterm samples with IVH or RDS have very low birth weight and a gestational age between about 30 and 33 weeks (see Table 4). The group of preterms with complications other than IVH or RDS (see Table 4) is, for the most part, comparable to the group of preterms with no additional complications in both birth weight and gestational age. Separation of these two groups is, thus, probably artificial. It is possible that preterms who are classified in the present review as non-risk *de facto* suffer similar complications as preterms with additional complications (except IVH or RDS problems), but that depictions of these complications were omitted in the research reports.

1.3 Preterm Cognitive Prognosis

Premature birth is a major cause of developmental delay. In recent years, concern has shifted from the survival of preterm (and low birth weight) infants toward their long-term prognosis and quality of life. Despite improved survival rates, disability rates associated with preterm status have remained stable, leading to more survivors with disabilities and impairments as an absolute number (Anderson, Doyle, & the Victorian Infant Collaborative Study Group, 2003; Goldberg & DiVitto, 1983; Hintz, Kendrick, Vohr, Poole & Higgins, 2005; Lefebvre et al., 1996; Vohr, Wright, Poole, & McDonald for the NICHD Neonatal Research Network Follow-Up Study, 2005; Zwicker & Harris, 2008).

Poor long-term outcomes have been documented in preterm infants in various domains of development, including motor, sensory, cognitive, and behavioral (for reviews see Anderson & Doyle, 2008; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Salt & Redshaw, 2006; Zwicker & Harris, 2008). Vohr et al. (2000) found that ~50% of a cohort of extremely preterm and extremely low birth weight infants in the United States had abnormal neurodevelopmental and sensory assessments. Similar incidence in cohorts of preterm and low birth weight infants have been found in various countries (Anderson & Doyle, 2003; Khan et al., 2006; Lefebvre et al., 1996; Marlow et al., 2005; Wood et al., 2000).

In their meta-analysis, Bhutta et al. (2002; see also Bhutta, 2004) pointed out that preterm birth is associated with lower cognitive test scores at school age, a conclusion supported by Anderson and Doyle’s (2008) review. Impairments in preterms’ (recognition) memory performance have been documented, not only in the first year of life (e.g., Rose, Feldman, & Jankowski, 2001), but in later childhood as well (e.g., Beauchamp et al., 2008; Isaacs et al., 2000; Luciana, Lindeke, Georgieff, Mills, & Nelson, 1999; Rose & Feldman, 1995). Furthermore, gestational age and birth weight appear to be directly proportional to cognitive performance: the younger the gestational age and lower the birth weight, the lower the cognitive score. Scores on the Mental Development Index (MDI) of the Bayley Scales of Infant Development have been shown to be significantly lower in preterm, as compared to term, children from 18 months to 30 months (Foster-Cohen, Edgin, Champion, & Woodward, 2007; Hintz et al., 2005; Khan et al., 2006; Rose, Feldman, Jankowski & van Rossem, 2005; Vohr et al., 2000; Wood et al., 2000). Similar results have been reported for the Griffiths Mental Development Scales (Lefebvre et al., 1996). Cognitive deficits, as documented by IQ scores, have been shown to persist into the early school years (6 to 7 years; Anderson, Doyle & the Victorian Infant Collaborative Study Group, 2003; Marlow et al., 2005; Wiener, Rider, Oppel, Fischer, & Harper, 1965), middle childhood (12 years; Constable et al., 2008), and adolescence and young adulthood (15 and 19.5 years; Allin et al., 2007, 2008).

Cognitive development is impaired not only in high-risk, but also in low-risk preterms, that is in preterms without neurological deficits such as cerebral palsy or mental retardation or hearing loss (e.g. Atkinson & Braddick, 2007; Caravale, Tozzi, Albino, & Vicari, 2005; de Haan, Bauer, Georgieff, & Nelson, 2000; Luoma, Herrgård, & Martikainen, 1998). In Caravale et al. (2005), low-risk preterms, at 3 to 4 years of age, obtained relatively lower scores in an intelligence test, a visual perception test, a location memory test, and a sustained attention test.

1.4 Age Matching

Research in preterm structure or function must consider age matching. Infants can be matched for either maturational age or experiential age (Matthews, Ellis, & Nelson, 1996). Maturational age comparisons use infants who were conceived at the same time and so are of the same postmenstrual age; experiential age comparisons use infants who are all tested the same amount of time after birth and thus have the same chronological or postnatal age. Age correction is controversial (Brandt & Sticker, 1991; DiPietro & Allen, 1991; Ross & Lawson, 1997) because of concerns about mistakenly overcorrecting or mis-estimating when conception actually occurred. Matching preterm and term infants on the basis of postmenstrual age controls for biological maturity; therefore, all infants are developmentally equivalent. This type of matching is based on the argument that development of preterm infants proceeds at the same rate as their term peers with a lag equal to the degree of prematurity. Preterm infants’ age is routinely adjusted in this way when estimating expected age of achievement of developmental milestones. Preterm infants are expected to arrive at milestones at an equivalent postmenstrual (but not postnatal) age to term infants. An advantage of this basis of matching is that biological maturity is controlled. Postmenstrual age matching has been used to examine differences between preterm and term infant brain development (Boardman et al., 2007; Woodward et al., 2004), neuromotor status (Gorga, Stern, Ross & Nagler, 1988), information processing (Rose, Feldman & Jankowski, 2002), language acquisition (Foster-Cohen et al., 2007; Sansavini et al., 2006), school behaviors (for example, aggression and shyness; Nadeau, Tessier, Boivin, Lefebvre & Robaey, 2003), and temperament (Oberklaid, Sewell, Sanson & Prior, 1991; Sajaniemi, Salokorpi & Wendt, 1998). However, this type of matching has often masked developmental problems in preterm infants (Brachfeld, Goldberg, & Sloman, 1980).

To ensure equivalent biological maturity, preterm and term infants necessarily differ on postnatal experience. Matching preterm and term infants on the basis of postnatal age equates groups for postnatal experience. This type of matching has tended to be used in older children. For example, Marlow et al., (2005) investigated cognitive and motor impairments in 6-year-olds, and Carmody et al. (2006) investigated the impact of medical and environmental risk in infancy on 15- to 16-year-olds; both used this standard of matching. Although postnatal age matching allows comparisons of infants with equivalent postnatal experience, it fails to account for additional experience (for example, through antenatal classes) or preparations parents of term infants have taken due to longer pregnancies. Another limitation of postnatal age matching is that preterm infants are developmentally younger than their term peers at any given assessment; in consequence, results may represent effects of immaturity rather than prematurity (Brachfeld et al., 1980). Whether postnatal experiences have extra effects appears to depend on the domain being studied (Goldberg & DiVitto, 1983). Comparisons in which preterm infants have more postnatal experience than term infants provide preterm infants with some apparent advantages.

Brachfeld et al. (1980) suggested using both postnatal and postconceptional age mates as comparisons or controls. Piper, Byrne, Darrah, and Watt (1989), who followed this recommendation, compared motor development of a group of moderately preterm infants to very preterm infants in one group at 8 and 12 months postnatal age and another group at 8 and 12 months postterm age, rather than have a term control group. The use of both postnatal and postterm age allowed Piper et al. (1989) to demonstrate the differential impact of biological maturity on gross and fine motor development. Gross motor function was determined to develop based on biological age; therefore, neurologically intact infants developed at normal rates based on postterm age regardless of gestational age. However, fine motor development was not programmed solely by biological maturity.

Most research in prematurity favors some form of age correction to help determine whether the aspect of development in question is under maturational control or is susceptible to extrauterine experience. For example, Siegel (1983) conducted a longitudinal study in which preterm and term infants were repeatedly assessed over the first 5 years of life. Examining correlations between measures of infants' corrected and uncorrected ages and later cognitive status, she found that age correction was appropriate in the early months but not later, suggesting that environmental influences grew in importance. Siegel's results are consistent with later recommendations for either full or half correction for prematurity during the first 2 years of life, but no correction thereafter (Blasco, 1989; Brandt & Sticker, 1991).

2. Infant Visual Habituation and Dishabituation

Given demographic trends in preterm incidence and viability, and confirmation of risk status for developmental outcomes of preterm birth, issues of early assessment have grown in importance. The most prominent contemporary experimental technique for testing perceptual and cognitive competencies in infancy is habituation-dishabituation (Bornstein, 1985, 1998; Colombo & Mitchell, 2009; Kavšek, 2000; Pahnke, 2007). In this paradigm, a *habituation* stimulus is presented to the infant for either one long period or several short periods (often equal to durations of infants' individual looks); afterwards, that is in the posthabituation or dishabituation period, a novel stimulus is shown. It is expected that the infant's attention to the habituation stimulus will decline during the habituation phase, but will afterward increase to the novel stimulus. According to the prevailing comparator model, these two patterns of responding are assumed to reflect information processing. During the habituation phase, the infant's attention to the habituation stimulus wanes as the infant constructs a mental representation of the stimulus and the stimulus becomes less novel or interesting. If the infant's attention is reactivated by the novel stimulus, that is if the infant recovers attention, the inference is made that the infant compared the novel stimulus with the mental representation (memory) of the habituation stimulus, and so remembered the one and discriminated the other. Instead of presenting the habituation and the novel stimuli singly and subsequently, the two stimuli can be shown side by side during the dishabituation period. If the infant prefers to look at the novel stimulus, that is if the infant displays a novelty preference, the inference is made that the infant recognizes the habituation stimulus and detects a difference between the stimuli. This performance also indicates the infant's *recognition memory* of the habituation stimulus.

The comparator model, and the ideas that habituation must involve the construction of a mental representation or memory trace of the habituation stimulus and dishabituation the successful discrimination between this memory trace and a novel stimulus, goes back to Sokolov's (1963, 1966) work on the orienting reaction. Several studies have elaborated this cognitive interpretation of habituation-dishabituation (e.g., Hunter & Ames, 1988; Jeffrey, 1976; Kaplan & Werner, 1986; Schöner & Thelen, 2006; Sirois & Mareschal, 2004). For example, Hunter and Ames (1988) postulated a ∩-function between attention and time. More specifically, they argued that an infant's attention toward a stimulus at first increases, as information about the stimulus is processed, and then decreases, as stimulus processing is progressively completed. If a second stimulus is introduced during the late periods of this habituation process (i.e., when attention toward the first stimulus has largely abated), the novel stimulus, because of its higher attractiveness value, will be preferred. In this case, dishabituation or a novelty preference is observed. If, however, the novel stimulus is shown in the early stages of the habituation process (i.e., when interest in the habituation stimulus has started to increase), the infant will prefer to look at the habituation stimulus because its attention-eliciting value is higher than is that of the newly introduced stimulus. In other words, the infant displays a familiarity preference.

Looking appears to have a natural course of development across infancy. Several studies have demonstrated an increase in duration of spontaneous looking at visual targets from birth to 2 or 3 months of age (see Colombo et al., 1999; Ruff & Rothbart, 1996). This phenomenon may originate from the emergence of alertness: over the first 2 to 3 months, the amount of time spent in a quiet awake state dramatically increases (e.g., Berg & Berg, 1987; Colombo, 2001). The increase of look duration during the first months of life is followed by a steep decrease of looking to about 6 to 9 months of age.

According to the comparator model, the age-related decrease in look duration reflects an increase in speed of stimulus encoding and/or of processing efficiency (e.g., Bornstein, 1998; Rose & Tamis-LeMonda, 1999). An alternative interpretation, disengagement theory (Colombo, 1995, 2002), suggests that, rather than reflecting infants' increasing capability of stimulus encoding, duration of looking at a stimulus display reflects infants' increasing ability to disengage from a stimulus. Recent research suggests that both stimulus encoding and disengagement contribute to the overall age-related decrement in duration of looking observed during the first year of life (Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001; Colombo, Shaddy, Richman, Maikranz, & Blaga, 2004; Domsch, Lohaus, & Thomas, 2008; for a discussion, see Kavšek, in preparation).

Ruff and Rothbart (1996; Rothbart & Bates, 2006) hypothesized that infant attention during the middle part of the first year of life is controlled by the posterior, reactive attentional brain system. This system guides object exploration: Attention is sustained if the object retains some novelty. With increasing familiarity, attention wanes, that is habituation occurs. Preterms habituate less efficiently than conceptionally matched term infants when they suffer CNS-related complications associated with prematurity, such as IVH (Ross, Tesman, Auld, & Nass, 1992), suggesting that visual functioning among preterm and term infants may differ (Bonin, Pomerleau, & Malcuit, 1998). Using a "continuous familiarization" task, which measures the speed of information processing by presenting infants with a series of paired stimuli where one changes from trial-to-trial and the other remains the same throughout, Rose et al. (2002) found that preterm and term infants did not differ on number of infants reaching criterion at each age, but that term infants were significantly faster at processing the stimuli than preterm infants at 5, 7, and 12 months. Term infants took about 20% fewer trials to reach criterion and spent 24–33% less time looking to the familiar stimulus than preterm infants. Although preterm infants were as quick to orient to change in the environment, they were slower at encoding what they saw. Preterm infants appear to be perceptually capable but cognitively disadvantaged. This finding in the visual modality has been replicated in auditory and tactile perception; preterm infants have been shown to respond to auditory and tactile stimuli in a similar manner to term controls but to be slower at processing information about these stimuli (see Goldberg & DiVitto, 1983). Thus, the information-processing disadvantage in preterm, relative to term, infants is generalized.

Measurement studies of the procedural and psychometric characteristics of habituation and of dishabituation in term infants show robust individual variation and adequate short-term reliability. These are two basic psychometric criteria. First, habituation and dishabituation are characterized by adequate individual variation. From a qualitative view, some infants show a linear or exponential decrease in habituation (to a learning criterion); other infants first increase then decrease looking; and still other infants show a fluctuating looking pattern (Bornstein & Benasich, 1986; Colombo et al., 2004). This qualitative perspective on habituation is supported by quantitative measures of duration and magnitude. For example, infants who habituate in a linear or exponential fashion require about one half the accumulated looking time to reach a constant habituation criterion as increase-decrease and fluctuating infants, who require approximately equivalent amounts of time (Bornstein & Benasich, 1986). Similarly, infants show substantial individual variation in dishabituation (Arterberry & Bornstein, 2002).

Second, the reliability of the habituation-dishabituation paradigm has been investigated qualitatively and quantitatively as well. Qualitatively, a nominal scale metric shows significant 10-day test-retest repeatability of habituation pattern (Bornstein & Benasich, 1986). More typical are reports of the reliability of quantitative habituation data. Tests administered closer in time yield higher reliability estimates: Day-to-day reliability (r) reaches .60 (e.g., Colombo, 1993). Kavšek (2004a) pointed out that mean short-term reliability of total amount of looking in habituation is .40. Mean short-term reliability of novelty preference is .27. Of course, estimates of the reliability of both habituation and dishabituation can be expected to vary with state and age of the child, stimulus used, and so forth.

The validity of the habituation-dishabituation paradigm as a measure of cognition is supported by evidence from studies of concurrent and predictive validity. Successful habituation minimally implies neurologic integrity and sensory competence in the infant. Beyond that, habituation represents an elementary kind of nonassociative learning (Kandel, 2007; Thompson & Spencer, 1966). The cognitive information-processing interpretation of habituation-dishabituation under the comparator model makes several straightforward predictions.

First, on an information-processing interpretation older and more mature babies ought to habituate more efficiently than younger and less mature babies (see Fantz, 1964). Bornstein, Pêcheux, and Lécuyer (1988) recorded total accumulated looking times over weekly habituation sessions in the same infants between 2 and 7 months of age. As they aged across the first year, infants required less and less cumulative exposure to reach a constant habituation criterion. The finding of significant decreases in duration of looking in infants across the initial parts of the first year has been repeated many times (Colombo & Mitchell, 2009; Colombo et al., 2004; Courage, Reynolds, & Richards, 2006; Friedman & Carpenter, 1971; Shaddy & Colombo, 2004; Slater & Morison, 1991).

The second prediction of an information-processing interpretation is related to the first: Normally developing babies habituate and dishabituate more efficiently than babies born at-risk for cognitive developmental delay. Children with Down syndrome or brain damage (e.g., micro- or anencephalia) either fail to habituate and dishabituate or habituate and dishabituate relatively inefficiently (Hepper & Shahidullah, 1992; Lester, 1975), as do infants who have been exposed *in utero* to cocaine or alcohol (S. W. Jacobson, J. L. Jacobson, Sokol, Martier, & Ager, 1993; S. W., Jacobson, J. L. Jacobson, Sokol, Martier, & Chiodo, 1996; Mayes, Granger, Frank, Schottenfeld, & Bornstein, 1993). As we see later, preterm infants (e.g., Rose et al., 2002) habituate and dishabituate less efficiently than term infants.

The third information-processing prediction is that infants ought to habituate to “simpler” stimuli more efficiently than to more “complex” stimuli. Evidence for this finding is replete in the literature on perceptual development (e.g., Caron & Caron, 1969; Hunter, Ames, & Koopman, 1983).

Fourth, if habituation involves processing information, infants habituated to one stimulus should later be able to distinguish a novel stimulus in comparison with their internal mental representation of the now familiar stimulus. Several studies show significant associations between infants’ habituation and dishabituation performance (e.g., Bornstein & Ruddy, 1984; Colombo, Mitchell, & Horowitz, 1988). Slater, Morison, and Rose (1983) habituated newborns to a stimulus, allowing them to use only one eye. On later testing, when the babies viewed the two stimuli through the other eye they recovered looking to a new stimulus, compared to the habituation stimulus. This interocular transfer indicates that information about the stimulus acquired via habituation must be processed centrally (cortically or subcortically) in the brain.

Evidence supporting each of the four foregoing predictions contributes to validating an information-processing interpretation of visual habituation-dishabituation in infants. The information-processing interpretation converges with concurrent individual differences in the normal population. Infants and young children who habituate efficiently prefer complex over simple patterns, show advanced sensorimotor development, explore their environment rapidly, play in relatively more sophisticated ways, solve problems quickly and attain concepts readily, and excel at operant learning, oddity identification, picture matching, and block configuration (for reviews, see Bornstein, 1985; Colombo, 1993).

3. Predictive Validity of Visual Habituation and Dishabituation in Preterm and Term Infants

The validity of infant habituation-dishabituation has also been evaluated by comparing infant performance early in life with performance years later as children. The presumption in this comparison is that, if individuals who perform well on infant tests also do well on standardized tests (such as of intelligence) as children, then the original tests must be assessments of cognition in infancy. Habituation possesses moderate lagged predictive validity. Infants who habituate efficiently in the first 6 months of life later, between 2 and at least 18 years of age, perform better on assessments of cognitive competence, including standardized psychometric tests of intelligence as well as measures of representational ability, such as language and symbolic play. Sigman, Cohen, and Beckwith (1997) found that newborns' length of fixation predicted adolescents' span of apprehension at 18 years, a speed-of-processing task in which adolescents had to say whether or not a target was present in a tachistoscopically presented array. Rose and Feldman (1995) examined relations between infant visual recognition memory and child performance at 11 years in a Specific Cognitive Abilities test (SCA: Cyphers, Fulker, Plomin, & DeFries, 1989; Thompson, Detterman, & Plomin, 1991). They found that nearly all their infancy measures related to the assessment of perceptual speed.

Several meta-analyses conclude that there is a moderate, but significant, correlation between infant visual habituation-dishabituation and standardized test outcomes later in childhood (e.g., Bornstein & Sigman, 1987; Colombo, 1993; Kavšek, 2004b; McCall & Carriger, 1993). Most recently, Kavšek (2004b) included 38 samples from 25 studies. The averaged weighted normalized predictive correlation coefficient (Hedges & Olkin, 1985) across studies of habituation in populations of normal babies is .40; for at-risk samples, it is .30; and for all samples combined, .36. These predictive correlations are not due to extreme scores or atypical populations or random effects, but hold for populations of both normal and at-risk infants across years, samples, ages, laboratories, stimuli, and modalities (including visual and auditory) as well as with different procedures and measures in infancy and childhood. Furthermore, Kavšek (2004b) identified an interaction between predictor and risk status of infant participants. More specifically, for non-clinical samples, the correlation between habituation and later intelligence was higher than was the correlation between dishabituation and later intelligence, *r*s = .40 and .32 respectively. For risk samples, however, dishabituation turned out to be a more robust predictor of later cognition and intelligence than habituation, *r*s = .50 and .30, respectively.

Although we do not know whether (or how many) studies failed to obtain predictive validity on these infant measures, we know of no correlations that report findings in the opposite direction. Moreover, the predictive validity of cognitive performance between infancy and childhood might depend, in part or in whole, on stability in the infant's social, didactic, or material environments - how significant people in children's lives interact with them, how they teach, or what kinds of physical surroundings they provide. Experimental observation shows, however, that, although mother contributes to infant cognitive growth, some stability obtains in the infant independent of maternal early and late didactic contributions (Bornstein, 1985; Bornstein et al., 2006). External experiences and family influences, both genetic and experiential, undoubtedly play a role in child mental development, but they do not exclusively mediate predictive validity (e.g., Gottfried, 1984; Scarr, Weinberg, & Waldman, 1993). A margin of validity in mental development appears to obtain in the child independent of environmental contributions. Moreover, other noncognitive mediators of validity might arise within the child, rather than from the child's experience. Succeeding in infancy at habituation and in childhood on mental assessments presumably requires possessing motor skills as well as a persistent or vigilant temperament style. However, habituation in infancy is predictive of later cognitive function over and above infant temperament and spontaneous infant motor activity (Bornstein & Colombo, 2010; Bornstein et al., 2006).

In a research program with VLBW preterm and term infant (for sample characteristics, see Rose et al., 2001, 2002), Rose, Feldman, Jankowski, and van Rossem (2005 Rose, Feldman, Jankowski, and van Rossem (2008) found lower performance in preterms' childhood cognitive scores. Furthermore, preterms' childhood cognitive outcome was mediated by disadvantages in information processing during infancy. For example, 12-month-old preterms scored lower than 12-month-old terms on two common attention variables (i.e., look duration and shift rate) and encoding speed (see also Rose et al., 2001, 2002). In a "cognitive cascade," these variables influenced visual recognition memory and representational competence, which, in turn, influenced mental status at 2 and 3 years of age (Rose et al., 2008).

By including both preterms and terms in a common experimental design, this research program directly compares the developmental trajectories of the two groups. This research provides evidence for striking differences in habituation and dishabituation performance between preterm and term infants. Moreover, the study suggests that preterms' relative disadvantage in later cognitive development might be traced back to early attention differences. The existence of a substantial relation between early visual performance and later cognitive outcome in preterms has been confirmed in multiple investigations (e.g., Cohen & Parmelee, 1983; Ortiz-Mantilla, Choudhury, Leevers, & Benasich, 2008; Rose & Wallace, 1985a, 1985b; Sigman et al., 1997; Sigman, Cohen, Beckwith, Asarnow, & Parmelee, 1991).

4. Visual Habituation and Dishabituation in Preterm versus Term Infants

Overall, empirical findings point to a difference in visual habituation-dishabituation performance between preterm and term infants. Under the comparator model, longer looking during habituation and weaker dishabituation responses in preterms imply disadvantages in stimulus encoding and stimulus discrimination capabilities. We now explore these differences. Furthermore, we analyze the roles of additional risk-factors, including age and experimental conditions (i.e., the experimental procedure and the kind of stimuli). Van de Weijer-Bergsma et al. (2008) reported that attention development in preterms is inferior to that in terms. These authors primarily concentrated on infants' ability to orient, maintain attention, and shift between objects and events, but not on visual habituation and dishabituation. By focusing on visual habituation-dishabituation, the present review complements van de Weijer-Bergsma et al. (2008).

4.1 Sampling

Tables 1–4 list studies that empirically compared visual habituation-dishabituation performance of preterm and term infants. These studies are included in the present review. The studies are further subdivided into investigations of preterm samples without additional risk factors (Tables 1 and 2) and investigations of preterm samples with additional risks (Tables 3 and 4). Risk factors are listed in Table 4. They include IVH, RDS (e.g., Landry, Leslie, Fletcher, & Francis, 1985;Rose, Feldman, McCarton, & Wolfson, 1988), hyaline membrane disease (Cohen, 1981), and cardiac anomalies (Millar, Weir, & Supramian, 1991). In two studies, the nature of additional risk factors was not specified (Caron & Caron, 1981;Holmes, Reich, & Gyurke, 1989), making it difficult to draw firm conclusions about the samples. For preterm samples without additional risks, 12 publications with 27 comparisons are included; for preterm samples with additional risks, 12 publications with 41 comparisons are included. The studies selected were found using a computerized search of PSYCLIT supplemented by exhaustive examination of relevant literatures. For each empirical comparison, Tables 1 and 3 contain information about (corrected) age at time of testing, stimuli, habituation and dishabituation measures, and habituation and dishabituation performance of the preterm and term participants. In addition, the tables document whether a significant difference between preterms' and terms' habituation and dishabituation results was found. The tables also contain one-tailed probabilities p and effect sizes d for significant group differences ($p \leq .05$). Probabilities and effect sizes refer to t tests comparing means. Probabilities were one-tailed because all significant group differences indicated that, as expected, preterms had lower scores than terms. Unfortunately, not all publications provided sufficient information to compute t statistics. Effect sizes were estimated according to Cohen (1977;Buchner, Erdfelder, & Faul, 1997). Cohen's effect size conventions were used: d = 0.20 as "small"; d = 0.50 as "medium"; and d = 0.80 as "large." Tables 2 and 4 complement Tables 1 and 3 by listing samples size, gestational age, postmenstrual age at time of testing, birth weight, and additional characteristics of the preterm samples.

4.2 Non-risk Preterm Infants

According to Table 1, only a small number of significant differences between preterms and terms emerged in visual habituation or visual dishabituation variables. Only very few effect sizes and probabilities could be computed. However, computed effect sizes were of medium or even large magnitude. For habituation differences between terms and preterms in habituation, Friedman, Jacobs, and Werthmann (1981) obtained a large effect size of d = 0.84 (p = .01) and Kopp, Sigman, Parmelee, and Jeffrey (1975) found a significant result (p = .04) with a medium effect size of d = 0.51. For group differences in dishabituation performance, effect sizes were large in both study 2 conducted by Mash, Quinn, Dobson, and Narter (1998), $d > 0.80$ (p = .002), and study 1 conducted by Rose (1983), d = 0.77 (p = .01). A medium effect size was obtained in study 1 conducted by Rose, Gottfried, and Bridger (1979), d = 0.48. Significance in this study, however, was weak, p = .08. Furthermore, in most studies, like their term counterparts, preterms displayed significant habituation and dishabituation.

4.2.1 Habituation—In all studies that tested infants during the neonatal period, meaning that term infants were tested within the first 3 days after birth, habituation performance in non-risk preterms is lower than that in term infants (Field, Woodson, Cohen, Greenberg, Garcia, & Collins, 1983; Friedman et al., 1981, d = 0.84, p = .01; Kopp et al., 1975, d = 0.51, p = .04; Sigman, Kopp, Littman, & Parmelee, 1977). In these studies, stimuli employed were checkerboard patterns of varying complexity (Kopp et al., 1975; Sigman et al., 1977), facial expressions (Field et al., 1983), or colored 3D forms (Friedman et al., 1981). When using facial expressions, Field et al. (1983) additionally established that young preterms were not able to discriminate targets. In the other studies with neonates, dishabituation performance was not assessed.

In the Field et al. (1983) study, for the preterm sample, date of testing was not determined by the infants' corrected age. Instead, infants were assessed directly after birth. In contrast, in all other studies, preterms were equivalent to their term counterparts in terms of postmenstrual age, meaning that they were tested when having reached their expected date of birth. Hence, not only are preterms' habituation skills lower than those of terms directly after birth, as shown in Field et al. (1983) for example, but also when they had had the opportunity to accrue extrauterine experience for about 6 to 7 weeks, as shown in the other studies with infants in the neonatal period. From this pattern of findings we conclude that the effect of (pre)maturity is stronger than the effect of postnatal experience, which appears not to compensate for the loss of intrauterine development. Beyond the neonatal period, the initial disadvantage in preterm habituation performance abates rapidly. According to Bonin et al. (1998), at the latest at (corrected) age 2 months, preterms have made up for their encoding disadvantage. Unfortunately, the reasons for this "catch up" are not clear. That is, it is unknown whether maturation or extrauterine experiences are responsible for the recovery of brain structures underlying preterm infants' habituation performance.

As Table 1 shows, in some studies, abstract two-dimensional patterns, such as curved black lines on a white background and arrangements of identical dots, have served as experimental stimuli (see Table 1). Overall, these studies provide no evidence for differences between preterms and terms. This finding may be due to there being no information-processing disadvantages in the preterm infants. Alternatively, abstract 2D patterns may be unsuited to detect group differences in visual habituation and dishabituation.

In some studies, it can be questioned whether infants were able to detect differences between the experimental displays, whether they were able to encode the habituation stimulus, and whether there was a difference between terms' and preterms' habituation-dishabituation (Fagan, Fantz, & Miranda, 1971, quoted from Fantz, Fagan, & Miranda, 1975; Rose, 1980; Rose et al., 1979). In these studies, a familiarization technique was used by either presenting a stimulus for a fixed amount of time prescribed by the experimenter ("fixed presentation duration procedure") or presenting a stimulus until the infant had inspected it for a predetermined fixed amount of time ("fixed fixation duration procedure"). Studies that have used such fixed procedures usually present familiar and novel test displays simultaneously, that is side by side during the follow-on period. Looking times toward the test displays are compared to establish a novelty preference. A problem with this procedure is the possible continuation of habituation during the dishabituation period, especially when very short fixed duration times are used (e.g., Hunter & Ames, 1988). More specifically, when employing short fixed fixation or presentation durations, the experimenter might end the stimulus exposure period before the infant has habituated. In this case, the infant might continue to habituate during the posthabituation period, that is, the infant might continue to inspect the familiar stimulus. As a consequence, the infant's attention will be either distributed evenly across the test displays or the infant might display a familiarity preference. For example, in Rose et al. (1979) the exposure period lasted until the infant had accumulated 20 sec of looking at a stimulus. Subsequently, unlike term infants, 6-month-old preterms did not display a preference for a novel test stimulus. Because it cannot be determined whether the preterm infants' encoding was complete after 20 sec of looking, it remains open whether the null result established in the test phase was due to preterm infants' inability to discriminate between the test displays. It is possible that preterms could perceive the difference between test displays, but that they also tended to continue habituation. As a result, their looking was distributed equally between the test stimuli. As a further consequence, in such paradigms it cannot be determined whether preterms' "habituation" and "dishabituation" were comparable to the terms' "habituation" and "dishabituation".

4.2.2 Dishabituation—There is evidence that non-risk preterms' dishabituation capabilities are inferior to those of terms during the first months of life. Sigman and Parmelee (1974) reported that 4-month-old preterms could not distinguish between very distinct displays (a checkerboard pattern vs. abstract 2D patterns). Rose (1983), who used abstract 3D forms, reported that 6-month-old preterms did not discriminate between stimuli. Finally, Mash et al. (1998) established that 3.5-month-old preterms were not able to distinguish between cats and dogs in a habituation categorization task. Effect sizes were large, $d = 0.77$ for Rose (1983) and $d > 0.80$ for Mash et al. (1998), indicating that the group differences were robust. After about 6 to 7 months of age, preterms' dishabituation scores are reportedly no longer different from those of terms (Rose, 1980, 1983; Rose, Gottfried, & Bridger, 1978, 1979). It should be noted that empirical evidence on older preterms' dishabituation performance is poor and is primarily based on tests with abstract 2D stimuli.

4.3 Preterm Infants with Additional Risks

For samples of preterms exposed to additional complications (see Tables 3 and 4), several studies report disadvantaged visual habituation and dishabituation performance. The most frequently reported risk factors in preterm birth are IVH and RDS complications (e.g., Landry et al., 1985;Rose et al., 1988). The kinds of additional strains preterms are exposed to are summarized in Table 4.

4.3.1 Habituation performance in risk preterms with no IVH or RDS complications—Unfortunately, only a few studies have investigated habituation and dishabituation in samples of preterms who had experienced few risk factors. Effect size comparing terms' and preterms' habituation results could be derived for the study conducted by Spungen, Kurtzberg, and Vaughan (1985). The effect size was large, $d > 0.80$ ($p = .001$). Spungen et al. tested infants in the neonatal period. Analogous to investigations with non-risk preterms (e.g., Friedman et al., 1981), the study revealed reduced habituation performance. Generally, beyond the neonatal period, visual habituation in risk preterms (with no IVH or RDS complications) appears to be similar to that in terms (Caron & Caron, 1981; Holmes et al., 1989).

4.3.2 Habituation performance in risk preterms with IVH and/or RDS complications—Neither IVH nor RDS complications automatically result in habituation problems. Effect sizes in the studies which found significant differences between preterms and terms were predominantly medium. In Rose et al. (1988), when tested with naturalistic faces and geometric 3D forms, no difference was found between 7-month-old preterms with RDS and 7-month-old terms. With abstract patterns, however, a significant difference between groups, with an effect size of $d = 0.49$ ($p = .01$), emerged. In Millar et al. (1991), the use of abstract patterns revealed inferior habituation results in 7.5-month-old preterms. Again, naturalistic faces produced no differences between samples. By contrast, Landry et al. (1985) reported that both 7-month-old preterms with RDS and 7-month-old preterms with RDS plus IVH habituated reliably to abstract patterns. Moreover, the habituation data for the preterms did not deviate significantly from the habituation data for terms.

Rose et al. (2001, 2002), who had tested preterms with a high IVH and RDS rate, also found successful habituation at ages 5, 8, and 13 months. Unlike Landry et al. (1985), who confronted their infant participants with one habituation-dishabituation task, Rose et al. (2001) used a series of comparisons. More specifically, the infants had to solve 5 face comparison tasks and 4 pattern comparison tasks. Despite preterms both habituating and dishabituating, they did not rival the terms' performance: Only the 13-month-old preterms' habituation efficiency was completely comparable to that of their term counterparts. The 5- and the 8-month-old preterms' habituation results were relatively diminished vis-à-vis those of the terms with small to medium effect sizes. Another design was chosen by Rose et al. (2002) who presented infants with multiple pairs of infant faces. From one trial to the next, one face remained constant while the other one changed. This continuous familiarization procedure was run until the infants consistently preferred the novel stimulus (see also Fantz, 1964; Roder, Bushnell, & Sasseville, 2000). Preterms 5, 7, and 12.5 months of age needed more trials than terms to habituate, $d = 0.47$, $d = 0.46$, and $d = 0.34$, respectively.

The study conducted by Ross et al. (1992) more conclusively implies that IVH per se negatively impacts habituation performance in preterms. The authors tested two groups of preterms, one of which suffered from IVH and one which did not. The group with IVH achieved lower habituation scores than the term control group, *d* = 0.61, whereas there was no difference in habituation between preterms with no IVH and terms.

4.3.3 Dishabituation performance in risk preterms with no IVH or RDS complications—Caron and Caron (1981) administered face-nonface, above-below, same face-different face, and neutral face-smiling face tasks to preterm and term infants 3, 4, 5, and 5.5 months of age, respectively. The preterms had been "in intensive care for complications of varying severity." During the habituation period, different exemplars of each stimulus type were shown. Following habituation, infants were presented with two new displays, a "familiar" pattern and a "novel" pattern. The familiar pattern required component discrimination, and the novel pattern required configural discrimination. For the component discrimination task, the shape of some or all elements within the pattern was changed, whereas the elements' overall arrangement within the pattern remained constant. For the configural discrimination, the overall arrangement of the pattern's elements was changed, whereas the shape of the elements remained constant. Dishabituation was defined as recovery of attention, meaning that looking times toward the test displays were compared to looking times in the last two habituation trials. At 3, 4, and 5 months of age, preterm infants' responses to the component change did not differ from those of term infants. In contrast, preterms' sensitivity to the configural change was lower than that of terms. No difference between the groups was observed at 5.5 months. In sum, the preterms' disadvantage observed until about 5 months of age was restricted to their ability to react to configural changes, but did not undermine their ability to extract component changes. This finding matches results from comparisons between infants who tend to engage in prolonged inspections of mainly one part of a visual pattern ("long-lookers") and infants who tend to scan all parts of a pattern with short fixations and many shifts ("short-lookers") (e.g., Bronson, 1991; Frick & Colombo, 1996; Jankowski & Rose, 1997): Like long lookers, during the habituation period preterms might concentrate on examining a few local areas of the stimulus with prolonged fixations and succeed thereby in perceiving component changes, but have difficulties solving configural discrimination tasks. Caron and Caron (1981) did not ascertain a difference between experimental groups at 5.5 months. Hence, the study suggests that preterms' dishabituation performance remains relatively disadvantaged until about 5 months.

4.3.4 Dishabituation performance in preterms with IVH and/or RDS complications—IVH is thought to entail an impairment of the hippocampus (e.g., Luciana, 2003) and, as a consequence, of cognitive function (as memory). On these grounds, one might expect that preterms with IVH complications display lower dishabituation scores than terms. Experimental findings only partially support this prediction. Effect sizes vary between *d* = 0.26 and *d* = 0.72. The lowest effect size was established for 8-month-old infants who were tested by Rose et al. (2001) using abstract patterns. The highest effect size belongs to the investigation conducted by Rose et al. (1988) who found that 7-month-old preterms tested with abstract patterns achieved lower dishabituation scores than terms. This divergence in results indicates that there is no clear relation between effect size and abstract patterns for the same age group. In Rose et al. (2001), where a high incidence of both IVH and RDS was established, lower novelty preferences were observed in the preterm sample. This disadvantage, however, was present at 5 months of age when naturalistic faces served as experimental displays, *d* = 0.30 (*p* = .02), but not when abstract patterns were used. At 8 months of age, a disadvantage was observed for both naturalistic faces, *d* = 0.37 (*p* = .01), and abstract patterns, *d* = 0.26 (*p* = .04). A disadvantage was also noted at 13 months for abstract patterns, *d* = 0.41 (*p* = 006), but not for faces. A nearly significant (*p* = .055), but robust (*d* = 0.64) disadvantage in visual dishabituation was found by Landry et al. (1985) for

7-month-old preterms with both IVH and RDS. For a second group of preterms with RDS only, no group difference emerged.

Given that Landry et al. (1985) presented RDS infants with abstract patterns (black dots), one might assume that, as found with non-risk preterms, abstract patterns are unsuited for detecting dishabituation disadvantages in preterms with RDS. However, Millar et al. (1991) found disadvantages in 7.5-month-old preterms with RDS complications when using polychromatic lines. Possibly, the addition of salient features like color to abstract patterns might reveal differences between preterms and terms with these stimuli. Millar et al. (1991) also showed that the use of faces is not advantageous because the authors did not establish a disadvantage with this kind of experimental stimulus material. A special stimulus was utilized by Ross et al. (1992). Ten-month-old preterms with IVH were as good as were terms at distinguishing between a line drawing of a face and a scrambled version of the line drawing. Unfortunately, comparability of samples was restricted because preterm age was not corrected.

5. Discussion and Conclusions

The main goal of this meta-analysis was to review studies of visual habituation-dishabituation performance of preterm infants, especially compared to that of terms. Preterms were divided into those without additional medical risk factors (Tables 1 and 2) and those with additional risk factors (Tables 3 and 4).

5.1 Meta-analytical Results from Studies with Non-risk Preterm Infants

The following five conclusions can be drawn for preterms in whom no additional disorders were observed (see also Tables 1 and 2):

- **a.** Overall, most studies with non-risk preterms do not find significant differences in either habituation or dishabituation performance compared with term infants. Furthermore, in most studies, patterns of habituation and dishabituation in nonrisk preterms do not differ from those obtained from their term counterparts. If a significant effect was discerned, the size of the effect was predominantly medium.
- **b.** In many studies, abstract two-dimensional patterns serve as experimental stimuli. This raises the question of whether the preterms in these studies were disadvantaged to terms or whether conclusion (a) is an artifact of using mainly simple abstract two-dimensional patterns, which might generally fail to elicit group differences in the development of mental functions. Some studies with risk preterms reveal diminished habituation and dishabituation performance when using abstract patterns. Accordingly, abstract patterns are apparently suited to reveal disadvantages in preterms, meaning that the lack of differences between low-risk preterms and their term counterparts may point to there being no diminished habituation-dishabituation capabilities in preterm samples. Nevertheless, systematic research is needed to investigate what kind of stimuli can be successfully employed to reveal disadvantages in both low- and high-risk preterms.
- **c.** Term babies’ habituation performance exceeds that of preterms when assessed during the neonatal period. This observation can be regarded as robust, not only because it obtains in all existing studies with neonates, but particularly because these studies used different stimulus materials. Furthermore, for two out of four studies with neonates, effect sizes could be determined. These effect sizes indicated medium, d = 0.51 (Kopp et al., 1975) and large group differences, d = 0.84 (Friedman et al., 1981).

d. Beyond the neonatal period, disadvantages in preterms' visual habituation tend to attenuate. It should be noted that looking behavior might be based on different processes at different ages. Possibly, look durations during the first weeks are biased by alertness processes, which are assumed to strongly influence look durations during the first weeks of life (e.g., Colombo, 2001), and longer looking in preterms on the expected due date might be attributable to higher overall alertness (van de Weijer-Bergsma et al., 2008). After the neonatal period, driven by the posterior attentional system, duration of looking during the habituation phase might be a purer measure of stimulus processing, and observed non-significant differences between preterms' and terms' habituation scores might reflect equal encoding capabilities.

e. Some studies report a disadvantage in preterms' dishabituation abilities. From about 6 months of age on, however, the disadvantage in preterms' visual dishabituation has attenuated.

In sum, prematurity per se does not inevitably entail long-lasting delays in the development of non-risk infants' habituation-dishabituation skills. The results for preterms with additional risk factors, however, point to more concerning delays in cognitive development.

5.2 Meta-analytic Results from Studies with Risk Preterm Infants

a. In general, for samples of preterms who have additional risks, many studies report inferior visual habituation and dishabituation results (see Tables 3 and 4). Studies with high-risk preterm samples were subdivided into those testing preterms with IVH or RDS problems and those testing preterms with other complications such as neonatal jaundice or cardiac anomalies. Generally, the first group of preterms displays poorer habituation-dishabituation scores than the second group of preterms.

b. Neither IVH nor RDS complications automatically eventuate in adverse preterm habituation and dishabituation. On the whole, however, researchers suggest that both habituation and dishabituation performance in preterms who experience these complications is diminished at least during the first year of life. Effect sizes were mainly medium for habituation measures and small to medium for dishabituation measures. The high incidence of lowered habituation-dishabituation scores in these risk preterms, as compared to the scores in non-risk preterms or in preterms with other handicaps, provides evidence that IVH and RDS complications might exert a strong negative impact on cognitive development.

c. For preterms who were exposed to risk factors other than IVH and RDS complications, visual habituation may be disadvantaged during the neonatal period only.

d. Furthermore, for these preterms, disadvantages in the ability to dishabituate start to remit by about 5 months. The results for high-risk preterms who did not experience IVH or RDS complications are, therefore, basically the same as for preterms without additional risk factors.

The lack of differences between preterms with no additional strains and preterms with complications other than IVH or RDS problems also indicates that additional complications like abnormal tone or cardiac anomalies apparently do not adversely affect preterms' cognitive development. To elucidate the impact of perceptual, motor, social, and emotional (risk) factors on preterms' short- and long-term cognitive development, it is indispensible to carefully pinpoint all available information on these factors in future research.

5.3 Visual Habituation and Dishabituation as Early Cognitive Measures in Preterm Samples

In light of the results of this review, preterms' dishabituation performance is generally more delayed than is their habituation performance. One major risk factor to preterms is intraventricular hemorrhage. IVH can impair the hippocampus, which is assumed to contribute to (recognition) memory (e.g., Axmacher, Schmitz, Wagner, Elger, & Fell, 2008; Kirwan et al., 2008; Kumaran & Maguire, 2008; Nelson, 1997). Kavšek (2004b) found a robust correlation of .50 between dishabituation measures and later cognitive outcomes for risk samples. For non-risk infants, this correlation amounted to .32. This difference might be accounted for by a higher long-term stability of latent processes assessed by dishabituation tasks, if these latent processes are damaged. In other words, disadvantages in those preterms' latent processes, which generate both overt dishabituation behavior as well as later cognitive outcome scores, might persist, thereby entailing a high statistical association between early and later manifest test scores. In a study with VLBW preterms, Ortiz-Mantilla et al. (2008) found that both infant novelty preference and speed of processing were related to children's later cognitive abilities. Furthermore, these associations were more robust in preterms than in a term control group. The longitudinal research on preterms' and terms' development conducted by Rose et al. (2005, 2008) confirms that visual recognition memory is well suited to predict later general developmental level as assessed by the Bayley Scales of Infant Development. Rose, Feldman, and Jankowski (2009) extended those results with findings that infant memory, including visual recognition memory, is related to 36-month language scores. In sum, infant visual dishabituation tasks may be useful in the identification of early cognitive disadvantages in risk preterm infants and might be employed to predict their later cognitive achievement.

From a clinical perspective, it is also relevant to explore whether infant habituation and dishabituation, as early markers of basic cognitive processes, can be improved. Research has shown that cognitive, emotional, and behavioral development in preterms is influenced by endogenous factors and by environmental variables (e.g., Sesma & Georgieff, 2003). More specifically, caregivers' scaffolding behaviors, such as directing the infant's attention to an object and providing appropriate levels of stimulation during interaction, play a crucial role in preterm infant development (e.g., Bacharach & Baumeister, 1998; Schmidt & Lawson, 2002; Taylor, Anthony, Aghara, Smith, & Landry, 2008; Veddovi, Gibson, Kenny, Bowen, & Starte, 2004). Research should make an effort to identify the strategies by which parents can compensate and promote their preterm infants' delayed development (e.g., Dilworth-Bart, Poehlmann, Hilgendorf, Miller, & Lambert, 2009; Landry, Garner, Swank, & Baldwin, 1996; Smith, Landry, Swank, & Baldwin, 1996; Weiss, Wilson, Seed, & Paul, 2001). Beckwith, Cohen, and their colleagues observed both preterm infants and caregivers' behaviors in their homes (Beckwith & Cohen, 1984; Beckwith, Cohen, Kopp, Parmelee, & Marcy, 1976). Development of the preterms was then followed longitudinally (e.g., Cohen, 1995; Cohen et al., 1996; Cohen, Parmelee, Beckwith, & Sigman, 1986; Sigman et al., 1997; Sigman et al., 1991). The original preterm sample consisted of infants with a gestational age at birth of 37 weeks or less and a birth weight of 2500 g or less who suffered from various medical complications (see Sigman, 1983). Cognitive performance at 18 years of age was predicted by fixation duration in infancy (Sigman et al., 1997). Furthermore, this relation was moderated by early maternal stimulation. More specifically, infants with short look durations whose mothers displayed a high vocalization rate had higher scores as adolescents than infants with longer fixation durations whose mothers vocalized less to them.

From a theoretical point of view, the differential sensitivities of habituation and dishabituation in revealing differences between preterms and terms found in the present review argue for a modular view of habituation-dishabituation processes (e.g., Colombo & Janowsky, 1998). Such a view articulates with the comparator model, according to which habituation reflects the ability to encode stimulus information, whereas dishabituation taps the ability to extract the difference between the memory trace of the habituation stimulus and novel visual information.

In accord with the comparator model, the present review hypothesized that preterms' habituation and dishabituation scores should be lower than those of terms, if these scores are manifestations of basic cognitive processes. Altogether, the studies listed in Tables 1–4, in which differences between preterms and terms are enumerated, confirm this prediction.

It should be noted that several studies did not observe that preterms lag behind terms, even if high-risk preterms served as participants (e.g., Landry et al., 1985). Reasons for the variability of results are, for the most part, unclear. They could include unattractive and therefore improper stimuli and insensitive testing procedures. Future studies should systematically elucidate the role of kind, degree, and number of preterm dysfunctions as well as of age, stimulus material, and habituation-dishabituation procedure. An early promising approach was pursued by Caron and Caron (1981), who tested infants between 3 and 5.5 months of age for their ability to respond to both component and configural stimulus differences (see also Caron, Caron, & Glass, 1983). Unlike term infants, in the first 5 months preterms displayed a significantly diminished capacity to extract configural stimulus differences.

Another procedure to increase the likelihood of revealing more exact habituation and dishabituation performance is to test infants in multiple tasks in lieu of testing them in only one habituation-dishabituation task. Indeed, with a battery of tasks, Rose et al. (2001) ascertained group differences in 5-, 8-, and 13-month-old preterm and term infants (see Table 3). Increasing the number of tasks can also improve reliability of habituation-dishabituation measures and, as a consequence, their predictive power.

5.4 Future Directions

One problem researchers face when trying to identify the cause of poor developmental outcomes among preterm infants is that risk factors co-occur. Previous work has attempted to determine whether it is prematurity itself, or factors associated with prematurity, which put some preterm infants at increased risk for a variety of disadvantages whilst leaving others relatively unimpaired. Preterm infants are exposed to the extrauterine environment up to 3 months before normative biological expectations. In the United States, prematurity and low birth weight are linked to socioeconomic disadvantage (Paneth, 1995). Preterm births are more common in poor, ill-nourished, and socially stressed families, and it is not known how great an impact these factors have, separately or together. The caregiving environment of preterm infants has been described as less than optimal, with more intrusive, less sensitive and responsive, and less mutually satisfying interactions (Brachfeld et al, 1980; Feldman & Eidelman, 2006; Forcada-Guex, Pierrehumbert, Borghini, Moessinger & Muller-Nix, 2006; Glazebrook et al., 2007; Holditch-Davis, Schwartz, Black & Scher, 2007). Studies of healthy preterm infants and mothers consistently show that infants are more passive and reactive, and that their mothers are more active and directive, than are term infants of comparable age and their mothers (Teti, O'Connell, & Reiner, 1996). Feldman and Eidelman (2006) found that preterm infants, whose mothers showed more intrusive behavior that was uncoordinated with infant state, level of social engagement, or the infant's cues, displayed poorer cognitive functioning at 24 months. Preterm babies who grow up in enriching, supportive homes do better, whereas those in more deprived environments develop more poorly (Bradley et al., 1994; Forcada-Guex et al., Goldberg, & DiVitto, 2002). Therefore, the environments in which preterm infants are reared are not only at risk due to socioeconomic disadvantage but also due to the nature of the delivery (and subsequent NICU stay) and non-optimal parent-infant interactions. Many preterm and low birth weight infants are at both medical and environmental risk.

In 1981 only 9.4% of births were preterm in the United States (Davidoff et al., 2006). NHS Maternity Statistics for 2006 showed that approximately 7% of births in England were preterm based on gestational age. According to the European Perinatal Health Report, in 2004, about 8.9% of births in Germany and 7% of births in Slovenia had a gestational age < 37 weeks (EURO-PERISTAT Project, 2008). In addition, Steer (2005) claimed the main burden for preterm birth exists in developing countries. There is little accurate worldwide data due to differential use of gestational age and birth weight to define preterm birth by countries, with developing countries tending to rely more on birth weight than gestational age (Behrman & Butler, 2006). Iatrogenic preterm birth occurs in about 25% (range 8.7%–35.2%) of all preterm births, PPROM accounts for another 25% (range 7.1%–51.2%), and the final 50% of preterm births is accounted for by idiopathic preterm birth (range 23.2%–64.1%). Iatrogenic preterm birth, due to maternal illness or developing fetal compromise, is most common in developed countries and is responsible for almost half of births at 28 to 35 weeks' gestation (Steer, 2005). PPROM occurs more often in disadvantaged populations, with infection usually regarded as the main cause. Idiopathic preterm birth is more frequent in populations without established risk factors. Within countries, etiologies of preterm birth differ with each infant having a unique combination of risk factors and exposures (Behrman & Butler, 2006).

By highlighting the potential of habituation-dishabituation measures to reveal differences between preterms and terms, the present review points to the value of constructing new infant assessments using the habituation-dishabituation paradigm. Such tests should evaluate habituation and dishabituation separately because both measures are distinguished by sufficient effect sizes. Moreover, the predictive validity of both measures should be high to secure that they assess long-term disadvantages. Our review shows that preterms can be successfully tested, even during the neonatal period, making it possible very early to identify and then foster preterms who are at risk for cognitive delays.

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Table 1

Studies with Preterms with no Additional Complications

Authors	Infant Age at Time of Testing[1] *M (SD)*	Stimuli	Habituation Measure	Dishabituation Measure	Difference in Stimulus Encoding? [2] *p*[3]/*d*[4]	Difference in Stimulus Discrimination? [2] *p*[3]/*d*[4]	Habituation in Preterms?[5]	Dishabituation in preterms?[5]	Habituation in Terms?[5]	Dishabituation in Terms?[5]
Bonin, Pomerleau, & Malcuit (1998) measurement 1	2.0	naturalistic faces naturalistic children's faces, abstract patterns	infant-controlled FFD[6]	recovery of attention novelty preference	— —[7]	— —[7]	+[8] +[9]	+ +	+[8] +[9]	+ +
measurement 2	3.92	naturalistic faces naturalistic children's faces, abstract patterns	infant-controlled FFD	recovery of attention novelty preference	— —[7]	— —[7]	+[8] +[9]	+ +	+[8] +[9]	+ +
measurement 3	5.94	naturalistic faces naturalistic children's faces, abstract patterns	infant-controlled FFD	recovery of attention novelty preference	— —[7]	— —[7]	+[8] +[9]	+ +	+[8] +[9]	+ +
Fagan, Fantz, & Miranda (1971, quoted from Fantz, Fagan, & Miranda (1975)	1.15–2.08 2.54–4.16[11]	abstract patterns abstract patterns	FFD or FPD[10] FFD or FPD	novelty preference novelty preference	not given —[7]	not given —	?[12] +[9]	?[12] +	?[12] +[9]	?[12] +
Field, Woodson, D. Cohen, Greenberg, Garcia, & Collins (1983)	neonatal period (no age correction)	naturalistic facial emotional expressions	infant-controlled	recovery of attention	+[20]	+[20]	+	+	+	+
Friedman, Jacobs, & Werthmann (1981)	neonatal period	green vs. red real box	infant-controlled	not tested	+ .01/0.84	not tested	+[8]	not tested	+[8]	not tested
Kopp, Sigman, Parmelee, & Jeffrey (1975)	neonatal period	checkerboard patterns	FPD	not tested	+ .04/0.51[21]	not tested	not given	not tested	not given	not tested
Mash, Quinn, Dobson, & Narter (1998) study 1	preterms: 3.58 terms: 3.14	dot patterns (to "above" vs. "below" categories)	FPD	novelty preference	—	—	—[13]	+	—[13]	+

Authors	Infant Age at Time of Testing[1] *M (SD)*	Stimuli	Habituation Measure	Dishabituation Measure	Difference in Stimulus Encoding? [2] p^3/d^4	Difference in Stimulus Discrimination? [2] p^3/d^4	Habituation in Preterms?[5]	Dishabituation in preterms?[5]	Habituation in Terms?[5]	Dishabituation in Terms?[5]
study 2[14]	preterms: 3.58 terms: 3.72	naturalistic pictures of cats and dogs (categorization task)	FPD	novelty preference	—	+ .002/1.08	—	—	—	+
Rose (1980) study 1	preterms: 6.34 terms: 6.31	abstract patterns abstract patterns naturalistic faces	FFD FFD FFD	novelty preference	?[16] —[7] ?[16]	?[16] — ?[16]	?[17] ?[17] ?[17]	?[17] ?[17] ?[17]	+[9] ?[17] +[9]	+ ?[17] +
study 2[15]	preterms: 6.34 terms: 6.31	abstract patterns abstract patterns naturalistic faces	FFD FFD FFD	novelty preference	—[7] —[7] —[7]	— — —	+[9] ?[17] +[9]	+ ?[17] +	+[9] ?[17] +[9]	+ ?[17] +
Rose (1983) study 1	preterms: 6.67 terms: 6.4	abstract real 3D patterns	FFD	novelty preference	—[18]	+[18] .01/0.77	+[9]	+	+[9]	+
study 2	preterms: 13.0 terms: 12.8	abstract real 3D patterns	FFD	novelty preference	—[18]	—[18]	+[9]	+	+[9]	+
Rose, Gottfried, & Bridger (1978) study 1	preterms: 12.56 terms: 12.33	abstract patterns	FFD	novelty preference	—[7]	—	+[9]	+	+[9]	+
study 2[14]	preterms: 12.56 terms: 12.47	abstract patterns	FFD	novelty preference	—[7]	—	+[9]	+	+[9]	+
Rose, Gottfried, & Bridger (1979) study 1	preterms: 6.6 terms: 6.88	abstract patterns	FFD	novelty preference	?[16]	?[16] .08/0.48	?[17]	?[17]	+[9]	+
study 2	preterms: 12.33 terms: 12.49	abstract patterns	FFD	novelty preference	—[7]	—	+[9]	+	+[9]	+
Sigman, Kopp, Littman, & Parmelee (1977)	neonatal period	checkerboard patterns	FPD	not tested	+[22]	not tested	not given	not tested	not given	not tested
Sigman & Parmelee (1974)	preterms[19]: 4.16 terms: 4.39	checkerboard pattern vs. abstract patterns	FPD	novelty preference	—	+[23]	+	—	+	+

Notes. Standard deviations are given in parentheses.

[1] Age at time of testing in months. For the preterm infants, age is corrected (= age from expected date of birth). Age of both preterms and terms is given if age at time of testing was different.

[2] +: A significant difference between preterms and terms to the disadvantage of the preterms was observed. —: No significant difference between preterms and terms was observed.

[3] One-tailed probability for value of *t* comparing group means.

[4] Effect size according to Cohen (1977).

[5] + A significant habituation/dishabituation was observed. —: No significant habituation/dishabituation was observed.

[6] FFD: Fixed fixation duration.

[7] : Deduced from there being no group difference in dishabituation performance.

[8] : An infant-controlled habituation procedure was used. Hence, the infants are considered as having habituated.

[9] Deduced from there being a significant dishabituation. Hence, the infants must have successfully habituated.

[10] FPD: Fixed presentation duration.

[11] The participants were tested every two weeks. The whole testing period was subdivided into two phases; results obtained in each phase were comparable.

[12] Habituation might have interfered with dishabituation: There was no significant dishabituation; whether the infants had habituated was not tested. Hence, it is possible that the infants continued to habituate (i.e., to look at the familiar stimulus) during the dishabituation phase, thereby suppressing a clear dishabituation reaction.

[13] Despite there being no significant decrease in fixation during the habituation period, the infants displayed a significant dishabituation.

[14] The same preterms, but different groups of terms were investigated in studies 1 and 2.

[15] The same terms, but different groups of preterms were investigated in studies 1 and 2.

[16] Term infants displayed a significant dishabituation reaction. In the preterm infants, however, no significant dishabituation response was observed. Due to using a fixed fixation duration habituation procedure, it remains unclear whether the preterms continued to look at the habituation stimulus during the dishabituation period, that is, to encode the habituation stimulus, thereby producing a null result. If so, the dishabituation response in the preterms might be confounded with continuation of habituation, and it remains unclear whether or not the preterms' ability to display a novelty response is inferior to that of the terms. Furthermore, the non-significant dishabituation in combination with a fixed fixation duration habituation procedure leaves open whether the preterm infants had habituated. Hence, it cannot be determined whether or not their habituation performance was comparable to that of the terms.

[17] There was no significant dishabituation response. Due to using a fixed fixation duration habituation procedure, it remains unclear whether the infants continued to look at the habituation stimulus during the dishabituation period, that is, to encode the habituation stimulus, thereby producing a null result. If so, the dishabituation reaction in the infants might be confounded with continuation of habituation and it is unclear whether or not the infants were able to discriminate between the posthabituation stimuli. Furthermore, the non-significant dishabituation in combination with a fixed fixation duration habituation procedure leaves open whether the infants had habituated.

[18] See the main text for a comment.

[19] The preterms failed to habituate and to dishabituate.

[20] Group differences were assessed by a common measure, $F(2,92) = 5.41$, $p = .006$.

[21] Values for total fixation. Values for first fixation are $p = .02$, $d = 0.62$.

[22] $F(1,38) = 5.45$, $p = .025$.

[23] Values for the groups × stimulus novelty interaction are $F(1,36) = 14.33$, $p < .01$.

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Table 2

Studies with Preterms with no Additional Complications: Sample Characteristics

Authors	Preterms					Terms
	n	GA[1] *M (SD)*	PA[2] *M (SD)*	BW[3] *M (SD)*	Sample Characteristics	*n*
Bonin, Pomerleau, & Malcuit (1998) measurement 1	34	32.15 (2.36)	48.71	1,712.35 (392.71)		36
measurement 2	34		57.0			36
measurement 3	34		65.71			36
Fagan, Fantz, & Miranda (1971, quoted from Fantz, Fagan, & Miranda (1975)	44	36.2	45–58; infants were tested every two weeks			48
Field, Woodson, D. Cohen, Greenberg, Garcia, & Collins (1983)	48	35.4	35.4 (no age correction)	2,700		48
Friedman, Jacobs, & Werthmann (1981)	36	33.7 (2.2)	40.1	1,819.5 (387.8)	The initial sample consisted of 45 preterms and 23 terms.	15
Kopp, Sigman, Parmelee, & Jeffrey (1975)	25	32.6	40.1 (0.52)	< 2,500		25[4]
Mash, Quinn, Dobson, & Narter (1998) study 1	16	31.7 (2.0)	55.5	1,741.7 (460.2)		16
study 2	see study 1	see study 1	see study 1	see study 1		16
Rose (1980) study 1	18	33.0	67.7	1,633.3 (347.2)		18
study 2	18	32.7	67.7	1,582 (263.9)	Infants received tactual, proprioceptive, and vestibular stimulation within the first weeks after birth.	18
Rose (1983) study 1	20	34.5	68.9	1,802 (449.6)		20
study 2	20	34.6	96.3	1,820 (380.7)		20
Rose, Gottfried, & Bridger (1978) study 1	25–27	32.6 (2.5)	94	< 2,000	The initial sample consisted of 28 preterms and 39 middle-class terms.	23–25
study 2	see study 1	see study 1	see study 1	see study 1	Terms were from lower-class families.	27
Rose, Gottfried, & Bridger (1979) study 1	18	33.4 (1.6)	68.6	1,610 (270.7)		18
study 2	18	33.2 (2.4)	93	1,738 (249.6)		18
Sigman, Kopp, Littman, & Parmelee (1977)	28	33.2 (3.1)	40 (0.7)	1,926.7 (434.5)		28
Sigman & Parmelee (1974)	20	33.6	58	1,927.8		20

Notes. Standard deviations are given in parentheses.

[1]Gestational age in weeks.

[2]Postmenstrual age in weeks.

[3]Birth weight in grams.

[4]Data for the term infants are taken from Sigman, Kopp, Parmelee, & Jeffrey (1973).

Table 3

Studies with Preterms who suffer from Additional Complications

Authors	Infant Age at Time of Testing[1] M (SD)	Stimuli	Habituation Measure	Dishabituation Measure	Difference in Stimulus Encoding?[2] p[3]/d[4]	Difference in Stimulus Discrimination?[2] p[3]/d[4]	Habituation in Preterms?[5]	Dishabituation in Preterms?[5]	Habituation in Terms?[5]	Dishabituation in Terms?[5]
Caron & Caron (1981; see also Caron, Caron, & Glass, 1983) measurement 1	2.77	line drawings of faces vs. non-faces with relational change	infant-controlled	novelty preference	— —	+ (configural discrimination/ conf) $p < .01$ — (component discrimination/ comp)	+[8] +[8]	— (conf) + (comp)	+[8] +[8]	+ (conf) — (comp)
measurement 2	4.16	above vs. below relational change	infant-controlled	novelty preference	— —	+ (conf) $p < .05$ — (comp)	+[8] +[8]	— (conf) + (comp)	+[8] +[8]	+ (conf) — (comp)
measurement 3	4.85	line drawings of faces with relational change	infant-controlled	novelty preference	— —	+ (conf) $p < .05$ — (comp)	+[8] +[8]	— (conf) + (comp)	+[8] +[8]	+ (conf) + (comp)
measurement 4	5.54	naturalistic faces: neutral vs. smile	infant-controlled	novelty preference	— —	— (conf) — (comp)	+[8] +[8]	— (conf) + (comp)	+[8] +[8]	+ (conf) — (comp)
Cohen (1981) measurement 1/study 1	4.62	naturalistic faces	infant-controlled	recovery of attention	—	—	+[8]	—	+[8]	—
measurement 1/study 2[14]	4.62	naturalistic faces	infant-controlled	recovery of attention	+	+	+[8]	+	+[8]	—
measurement 2	7.62	naturalistic faces	infant-controlled	recovery of attention	—	—	+[8]	+	+[8]	+
measurement 3	11.32	naturalistic faces	infant-controlled	recovery of attention	—	—	+[8]	+	+[8]	+
Holmes, Nagy Reich, Gyurke (1989) measurement 1	2	outline drawings of faces	FPD	novelty preference	—	not given	?[12]	?[12]	?[12]	?[12]
measurement 2	4	outline drawings of faces	FPD	novelty preference	—	?[20]	?[12]	?[12]	+[9]	+
measurement 3	6	outline drawings of faces	FPD	novelty preference	—	?[20]	?[12]	?[12]	+[9]	+
Landry, Leslie, Fletcher, & Francis (1985) study 1	7	abstract patterns	7 trials; length of each trial was infant-controlled	recovery of attention	—	— .055/0.64	+	+	+	+
study 2[15]	7	abstract patterns	7 trials; length of each trial was infant-controlled	recovery of attention	—	—	+	+	+	+
Lewis (1981)[21] study 1	3–6	abstract patterns vs. a naturalistic picture of a family	FPD	recovery of attention	—	not tested	—	—	—	not tested
study 2	9–12	see study 1	FPD	recovery of attention	+	not tested	—	—	+	not tested
study 3	18–24	see study 1	FPD	recovery of attention	—	not tested	+	+	+	not tested
Millar, Weir, & Supramiam (1991) study 1	preterms: 7.70 terms: 7.30	abstract patterns	FPD	recovery of attention	+[25]	+[23]	—	—	+	+
study 2[15]	preterms: 8.09 terms: 7.30	abstract patterns	FPD	recovery of attention	+[25]	+[23]	—	—	+	+
study 3	preterms: 6.86 terms: 7.70	naturalistic faces	FPD	recovery of attention	—[26]	—	+	+	+	+
study 4[22]	preterms: 6.79 terms: 7.70	naturalistic faces	FPD	recovery of attention	—[27]	—	+	+	+	+

Authors	Infant Age at Time of Testing[1] M (SD)	Stimuli	Habituation Measure	Dishabituation Measure	Difference in Stimulus Encoding?[2] p[3]/d[4]	Difference in Stimulus Discrimination?[2] p[3]/d[4]	Habituation in Preterms?[5]	Dishabituation in Preterms?[5]	Habituation in Terms?[5]	Dishabituation in Terms?[5]
Ortiz-Mantilla, Choudhoury, Leevers, & Benasich (2008) measurement 1	preterms: 6.7 terms: 6.6	naturalistic faces	infant-controlled	novelty preference	—	—	+	+	+	+
measurement 2	preterms: 9.7 terms: 9.6	naturalistic faces	infant-controlled	novelty preference	+[24] .005/0.82	—	+	+	+	+
Rose, Feldman, & Jankowski (2001) measurement 1	preterms: 5.22 terms: 5.27	naturalistic faces abstract patterns	FFD	novelty preference	+ .04/0.29 —	+ .02/0.30 —	+[9] +[9]	+ +	+[9] +[9]	+ +
measurement 2	preterms: 7.94 terms: 7.78	naturalistic faces abstract patterns	FFD	novelty preference	+ < .001/0.55 + .002/0.42	+ .01/0.37 + .04/0.26	+[9] +[9]	+ +	+[9] +[9]	+ +
measurement 3	preterms: 13.30 terms: 13.12	naturalistic faces abstract patterns	FFD	novelty preference	— —	— + .006/0.41	+[9] +[9]	+ +	+[9] +[9]	+ +
Rose, Feldman, & Jankowski (2002) measurement 1	preterms: 5.22 terms: 5.26	naturalistic faces of infants	continuous familiarization	not tested	+ .004/0.47	not tested	+	+	+	+
measurement 2	preterms: 7.16 terms: 7.09		continuous familiarization	not tested	+ .003/0.46	not tested	+	+	+	+
measurement 3	preterms: 12.38 terms: 12.84		continuous familiarization	not tested	+ .013/0.34	not tested	+	+	+	+
Rose, Feldman, McCarton, & Wolfson (1988)	7	abstract patterns naturalistic faces geometric 3D forms	FFD	novelty preference	+ .01/0.49 — —	?[16] .001/0.72 ?[16] .06/0.36 —	?[17] ?[17] ?[17]	?[17] ?[17] ?[17]	+[9] +[9] ?[17]	+ + ?[17]
Ross, Tesman, Auld, & Nass (1992) study 1	10 (no age correction)	outline drawing of a face vs. scrambled face	infant-controlled	novelty preference	+ .01/0.61	—	+[8]	+	+[8]	+
study 2[15]	10 (no age correction)	outline drawing of a face vs. scrambled face	infant-controlled	novelty preference	—	—	+[8]	+	+[8]	+
Spungen, Kurtzberg, & Vaugham (1985)	neonatal period	abstract patterns	infant-controlled	recovery of attention	+ .<.001/1.03	—	+[8]	—	+[8]	+

Notes. Standard deviations are given in parentheses.

[1]Age at time of testing in months. For the preterm infants, age is corrected (= age from expected date of birth). Age of both preterms and terms is given if age at time of testing was different.

[2]+: A significant difference between preterms and terms to the disadvantage of the preterms was observed. —: No significant difference between preterms and terms was observed.

[3]One-tailed probability for value of *t* comparing group means.

[4]Effect size according to Cohen (1977).

[5]+ A significant habituation/dishabituation was observed. —: No significant habituation/dishabituation was observed.

[6]FFD: Fixed fixation duration.

[7]: Deduced from there being no group difference in dishabituation performance.

[8]: An infant-controlled habituation procedure was used. Hence, the infants are considered as having habituated.

[9]Deduced from there being a significant dishabituation. Hence, the infants must have successfully habituated.

[10]FPD: Fixed presentation duration.

[11]The participants were tested every two weeks. The whole testing period was subdivided into two phases; results obtained in each phase were comparable.

[12]Habituation might have interfered with dishabituation: There was no significant dishabituation; whether the infants had habituated was not tested. Hence, it is possible that the infants continued to habituate (i.e., to look at the familiar stimulus) during the dishabituation phase, thereby suppressing a clear dishabituation reaction.

[13]Despite there being no significant decrease in fixation during the habituation period, the infants displayed a significant dishabituation.

[14]The same preterms, but different groups of terms were investigated in studies 1 and 2.

[15]The same terms, but different groups of preterms were investigated in studies 1 and 2.

[16]Term infants displayed a significant dishabituation reaction. In the preterm infants, however, no significant dishabituation response was observed. Due to using a fixed fixation duration habituation procedure, it remains unclear whether the preterms continued to look at the habituation stimulus during the dishabituation period, that is, to encode the habituation stimulus, thereby producing a null result. If so, the dishabituation response in the preterms might be confounded with continuation of habituation, and it remains unclear whether or not the preterms’ ability to display a novelty response is inferior to that of the terms. Furthermore, the non-significant dishabituation in combination with a fixed fixation duration habituation procedure leaves open whether the preterm infants had habituated. Hence, it cannot be determined whether or not their habituation performance was comparable to that of the terms.

[17]There was no significant dishabituation response. Due to using a fixed fixation duration habituation procedure, it remains unclear whether the infants continued to look at the habituation stimulus during the dishabituation period, that is, to encode the habituation stimulus, thereby producing a null result. If so, the dishabituation reaction in the infants might be confounded with continuation of habituation and it is unclear whether or not the infants were able to discriminate between the posthabituation stimuli. Furthermore, the non-significant dishabituation in combination with a fixed fixation duration habituation procedure leaves open whether the infants had habituated.

[18]See the main text for a comment.

[19]The preterms failed to habituate and to dishabituate.

[20]Term infants displayed a significant dishabituation reaction. In the preterm infants, however, no significant dishabituation response was observed. Due to not testing whether the infants had habituated, it remains unclear whether the preterms continued to look at the habituation stimulus during the dishabituation period, that is, to encode the habituation stimulus, thereby producing a null result. If so, the dishabituation response in the preterms might be confounded with continuation of habituation and it remains unclear whether or not the preterms’ ability to display a novelty response is inferior to that of the terms.

[21]It is not specified whether age had been corrected for prematurity.

[22]The same terms, but different groups of preterms were investigated in studies 3 and 4.

[23]Data from study 1 and 2 were assessed in a common ANOVA, $F(1,36) = 3.36$, $p = .07$.

[24]Result is based on trials needed to reach habituation criterion. Difference between preterms and terms in total looking time, however, was not statistically significant, $t(44) = 0.61$, $p = .27$, $d = 0.18$.

[25]Data from study 1 and 2 were assessed in a common ANOVA, $F(1,34) = 4.38$, $p < .05$.

[26]Data from study 3 and 4 were assessed in a common ANOVA, $F(2,43) = 2.82$, $p = .07$.

Table 4

Studies with Preterms who suffer from Additional Complications: Sample characteristics

Authors	Preterms					Terms
	n	GA[1] *M (SD)*	PA[2] *M (SD)*	BW[3] *M (SD)*	Sample Characteristics	*n*
Caron & Caron (1981; see also Caron, Caron, & Glass, 1983) measurement 1	22	33	52	1,620	Participants had been in intensive care for complications of varying severity.	22
measurement 2	22		58			22
measurement 3	22		61			22
measurement 4	20		64			22
Cohen (1981) measurement 1/study 1	11	33	60	1,956	All but 4 infants had the hyaline membrane disease and required respiratory assistance; 5 had seizures, 1 had severe hypocalcemia, and 1 had congenital heart disease. Number of participants is unequal from assessment to assessment, because only several infants were tested repeatedly.	12 lower-class infants
measurement 1/study 2	see study 1	see study 1	see study 1	see study 1		12 middle-class infants
measurement 2	9	29	73	1,963		14 lower-class infants
measurement 3	38	31	89	1662		15 lower-class infants
Holmes, Nagy Reich, Gyurke (1989) measurement 1	not available	33.4 (2.6)	48.66	2,134	Ill preterm infants.	not available
measurement 2	not available		57.33			7
measurement 3	not available		65.98			not available
Landry, Leslie, Fletcher, & Francis (1985) study 1	14	30.29 (1.82)	70.31	1,229.29 (181.30)	Infants with intraventricular hemorrhage and respiratory distress syndrome.	10
study 2	9	30.33 (2.50)	70.31	1,296.33 (259.68)	Infants without intraventricular hemorrhage and with respiratory distress syndrome.	10
Lewis (1981) study 1	22	“overhelming” premature infants	not given	not given	Infants with respiratory distress syndrome, with asphyxia or a combination of the two.	not given
study 2	19	see study 1	not given	not given	see study 1.	not given
study 3	30	see study 1	not given	not given	see study 1.	not given
Millar, Weir, & Supramiam (1991)	14	33.5	73.34	2,420	Infants with respiratory complications which required oxygen therapy during the neonatal period.	13

Authors	Preterms					Terms
	n	GA[1] *M (SD)*	PA[2] *M (SD)*	BW[3] *M (SD)*	Sample Characteristics	*n*
study 1						
study 2	15	36.7	75.01	2,850	Infants with non-respiratory neonatal risks: either infection, or cardiac anomalies, or minor physical anomalies, or toxaemia or pre-eclampsia, or neonatal jaundice.	13
study 3	19	32.9	69.70	1,990	see study 1.	14
study 4	16	36.4	69.39	2,610	see study 2.	14
Ortiz-Mantilla, Choudhoury, Leevers, & Benasich (2008) measurement 1	31[4]	29.6	69	976 (245.5)	The study started with 32 preterms and 32 terms in each age group. At birth, 17 infants weighted below 1,000 grams, 15 infants weighted between 1,000 grams and 1,500 grams. 19 infants were considered “low risk” according to their Nursery Neurobiological Risk Score, 4 were classified as “intermediate risk”, and 3 were classified as “high risk.” 6 children had intraventricular hemorrhage: Grade 1: 2; Grade 2: 2; Grade 3: 2.	23[4]
measurement 2	20[4]		82			26[4]
Rose, Feldman, & Jankowski (2001) measurement 1	50	29.6 (2.9) (7-month-olds)	62.6	1,107.9 (282.6) (7-month-olds)	Longitudinal study started with 50 preterms. At measurements 2 and 3, additional babies were tested. Small for gestational age: 33.9% of the sample. Respiratory distress syndrome: 50.8%. Intraventricular hemorrhage: no bleeding: 50.8%; Grade 1: 16.9%; Grade 2: 20.3%; Grade 3: 11.9%. 91% had very low birth weights (< 1,500 grams), and 39% had extremely low birth weights (< 1,000 grams).	153
measurement 2	59		74.4			144
measurement 3	56		97.6			126
Rose, Feldman, & Jankowski (2002) measurement 1	39	29.6 (2.9) (7-month- olds)	62.6	1,107.9 (282.6) (7-month-olds)	see Rose, Feldman, & Jankowski (2001).	134
measurement 2	48		71.0			128
measurement 3	55		93.6			117
Rose, Feldman, McCarton, & Wolfson (1988)	40 (habituation) 36 (dishabituation)	31.4	70.31	1,183.9 (210.9)	The study started with 56 preterms and 43 terms. For 40 preterms, habituation data were available. For 36 of the preterms, dishabituation data were available. 76% of the	39

Authors	Preterms					Terms
	n	GA[1] *M (SD)*	PA[2] *M (SD)*	BW[3] *M (SD)*	Sample Characteristics	*n*
					preterm sample were diagnosed as having respiratory distress syndrome.	
Ross, Tesman, Auld, & Nass (1992) study 1	30	30.2	73.5	1,431.1 (226)	Grade 1 or grade 2 hemorrhage (subendymal and intraventricular hemorrhage).	30
study 2	30	30.5	73.8	1,494.7 (256)	Infants with no hemorrhage.	30
Spungen, Kurtzberg, & Vaugham (1985)	17	32.0 (3.1)	40.02 (1.3)	1,219 (354)	Low birth weight infants. 38% of the sample displayed deviant visual-following; 25% had abnormal tone.	25

Notes. Standard deviations are given in parentheses.

[1] Gestational age in weeks.

[2] Postmenstrual age in weeks.

[3] Birth weight in grams.

[4] *n* is reconstructed from the respective publication.