Temperament at 7, 12, and 25 Months in Children at Familial Risk for ADHD

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As part of a longitudinal investigation of infants at familial risk for attention-deficit hyperactivity disorder (ADHD), mothers and fathers independently completed temperament ratings on their infants. In this paper, we examine the 7-, 12-, and 25-month temperament of 58 boys, 36 of whom were considered at familial risk for ADHD and 22 of whom were in the comparison group. Risk for ADHD was based on self-reported ADHD symptoms in the father. In addition, the influence of informant gender on temperament ratings was examined. The ADHD risk group received significantly higher scores for activity level and anger and lower scores for attentional shift, appropriate allocation of attention and inhibitory control. Their scores were also significantly lower on a composite measure of effortful control. Taken together, these findings offer support for the view of a link between early temperament and risk for ADHD. The only informant gender difference was for the activity level; mothers rated their sons as more active than did fathers. Copyright \textcopyright 2008 John Wiley & Sons, Ltd.

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In the realm of developmental psychopathology, certain temperamental predispositions are thought to increase the likelihood of the development of behaviour and emotional problems. Rothbart and her colleagues (Rothbart & Bates, 1998; Rothbart, Posner, & Hershey, 1995) suggest that temperament may be related to psychopathology in a number of ways. In some instances, the linkage may be direct, forming a continuum from extremes of temperament to psychopathology, or it may be indirectly linked to outcome as part of a chain of events. In other instances, temperament × temperament or temperament × environment interac-

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tions may act in such a way as to increase or decrease the likelihood of an adverse outcome. One of the psychopathologies of childhood in which temperament has a putative role is attention-deficit hyperactivity disorder (ADHD). In recent years, the etiological and phenotypic heterogeneity of ADHD has led a number of investigators to suggest that there are multiple pathways to the development of ADHD and that certain temperament domains may provide early behavioural markers for one or more of these pathways (Nigg, Goldsmith, & Sachek, 2004; Sonuga-Barke, Auerbach, Campbell, Daley, & Thompson, 2005). These behavioural markers may, in fact, be early precursors of the disorder. If not directly linked to the disorder, they may function as risk factors for ADHD or moderators of eventual outcome (Nigg et al., 2004).

One conceptualization of the temperament that has provided a foundation for thinking about its role in the development of ADHD and in the delineation of possible behavioural markers is that of Mary Rothbart (Auerbach, Atzaba-Poria, Berger, & Landau, 2004; Auerbach et al., 2005; Nigg et al., 2004). According to Rothbart (1989), temperament can be defined as constitutionally based individual differences in reactivity and regulation with differences in their expression already apparent early in life. Reactivity reflects individual variation in responsivity to change in the environment, while self-regulation is a process whereby reactivity can be modulated. Although regulatory processes are active in the first year of life, higher-order regulatory processes, such as inhibitory control and effortful control, are dependent on the development of the prefrontal cortex and only begin to come online towards the end of the first year, with their development continuing throughout the preschool years and onwards.

Children with ADHD have been characterized as showing extremes of reactivity, both hypo- and hyper-reactivity, and difficulties with self-regulation, particularly inhibitory and effortful control, although there is accumulating evidence that some of these difficulties with reactivity and regulation are not necessarily specific to ADHD (Anderson, Hinshaw, & Simmel, 1994; Belsky, Kuang-Hua, & Crinc, 1998; Campbell, 2000; Nigg et al., 2004). As Nigg et al. (2004) point out, the co-morbidity of ADHD both with externalizing disorders, such as conduct disorder, and internalizing disorders, such as anxiety, make the understanding of ADHD within a temperament framework complex. A possible first step in unraveling this complexity might be a prospective longitudinal study examining the temperament of children at familial risk for ADHD from infancy to early childhood. This is one the purposes of the Ben-Gurion Infant Development Study (BIDS) and the primary aim of the present paper is to examine the relationship between risk for ADHD and temperament in the first two years of life.

Effortful control is an important means of regulating reactivity and one that develops from the end of the first year of life through the preschool years (Rothbart & Ahadi, 1994; Rothbart, Ahadi, & Evans, 2000). Shifting and focusing attention, attentional persistence, and inhibiting prepotent responses are core components of effortful control and enable children to regulate their reactions to environmental input whether it be emotion-arousing input or cognitively demanding input. Difficulties with effortful control, i.e. attention regulation and inhibitory control, in children with ADHD have been well documented (see Barkley, 1997; Nigg, 2001; Van der Meere, 2002). Sonuga-Barke, Dalen, Daley, and Remington (2002) found deficits in inhibitory control to be associated with ADHD symptoms in a sample of 3- to 5-year old children. Recently, Goldsmith, Lemery, and Essex (2004) reported on shared genetic variance between early
effortful control and later ADHD symptomatology supporting a continuum model of ADHD.

Individual differences in attentional behaviours are clearly observable and measurable during the first years of life. Parent rating of infant and toddler attention is both reliable and stable (Goldsmith, 1996; Rothbart, 1981). Ruff, Capozzoli, Dubiner, and Parrinello (1990) found that by 10 months of age, infants showed consistent individual differences in vigilant behaviour. Attentional behaviours also differentiate between risk and non-risk groups from infancy through preschool. In BIDS, we found that the ADHD risk group showed less focused attention (interest) at 7 months and less vigilance at 12 months than did the comparison group (Auerbach et al., 2005; Berger et al., 2007). In a sample of hard-to-manage preschoolers, higher levels of inattention and lower impulse control were more characteristic of these boys than of an age-matched control group (Campbell, March, Pierce, Ewing, & Szumoski, 1991; Campbell, Pierce, Moore, Marakovitz, & Newby, 1996).

One reactivity domain clearly relevant to ADHD is the activity level. Hyperactivity is a defining characteristic of ADHD and has high heritability (Goodman & Stevenson, 1989). Individual differences in the activity level are seen as early as the first months of life (Rothbart, 1989) and in BIDS, the ADHD risk group showed a marginally higher level of neonatal activity than the comparison group and at 7 months, this group had higher levels of activity according to the mother report (Auerbach et al., 2004, 2005). From the second year, activity level is predictive of the school-age activity level in normal and risk samples (Buss, Block, & Block, 1980; Campbell, Pierce, March, Ewing, & Szumowski, 1994; Lemery, Essex, & Smider, 2002).

Early negative emotionality, and more specifically anger, has been associated with ADHD symptomatology in several studies. Children with ADHD were reported by their mothers to have been fussy, irritable, and active as infants (Weiss & Hechtman, 1993). Prospectively, negative emotionality and persistent crying in infancy have been associated with attentional problems and hyperactivity in childhood (Rende, 1993; Wolke, Rizzo, & Woods, 2002). From 6 months of age, anger is clearly differentiated as a negative emotion (Sroufe, 1995) and anger and its regulation are associated with ADHD from preschool through adulthood (Douglas & Parry, 1994; Mash & Johnson, 1982; Ramirez et al., 1997). In BIDS, neonatal negative emotionality and 7-month anger reactivity were higher for the ADHD risk group than the comparison group (Auerbach et al., 2004, 2005). However, neither negative emotionality nor anger in infancy seem to be a specific behavioural sign of risk for problems of attention and hyperactivity since both have been associated with negative behaviour and psychopathology, particularly externalizing problems, in childhood (Melnick & Hinshaw, 2000; Riese, 1987; Sanson, Smart, Prior, & Oberkland, 1993). In fact, negative emotionality and anger may indicate a special susceptibility to the rearing environment rather than a characteristic directly related to the development of externalizing psychopathology (Belsky et al., 1998).

Parent ratings are often used to assess child temperament. There is modest-to-moderate agreement when mothers and fathers both report on the temperament of their young children suggesting that these measures not only reflect child temperament characteristics but also contextual factors and parental characteristics (Mangelsdorf, Schoppe, & Buur, 2000). The types of interactions between parents and their young children differ, which may contribute to the different impressions they have of the temperament of their infants. Mothers’ interactions with their infants are usually organized around caretaking activities; and social
and conventional games characterize play between mothers and infants. In contrast, the role of the father has some of the characteristics of a playmate, with fathers engaging in more physical, high-intensity games (Lamb, 1977; Power & Parke, 1983; Sun & Roopnarine, 1996; Yogman, 1981). The different interaction patterns begin early in life; and as early as 3–4 weeks, parents differ in their ratings of infant temperament with mothers rating their infants as more active and more difficult but predictable than fathers (Greenbaum, Auerbach, & Guttman, 1989). Parental ratings are also influenced by personality and psycho-pathology with the caveat that research on this topic has been limited to mothers. Maternal extraversion, depression, anxiety, and hostility have been found to be associated with the judgments they make about their children’s temperament (Bates, Freeland, & Lounsbury, 1979; Goldsmith, Losoya, Bradshaw, & Campos, 1994; Mangelsdorf, Gunnar, Kestenbaum, Lang, & Andreas, 1990). While these associations may be interpreted as reflecting the subjectivity of the ratings, they may also reflect shared genetic variance with the child (Rothbart & Bates, 1998). In spite of these potential sources of reporting bias, parent reports are a major source of information about temperament during infancy and childhood and are considered a generally valid measure of child temperament (Lemery, Goldsmith, Klinnert, & Mrazek, 1999; Rothbart & Bates, 1998; Rothbart & Goldsmith, 1985). These report measures make use of a parent’s intimate knowledge of the child’s emotional and behaviour reactions to different situations. The present paper is based on parent-reported temperament independently rated by mothers and fathers, thus providing an opportunity to obtain a more complete picture of child temperament.

The specific purpose of the present paper is to examine parent ratings of the temperament of young boys at familial risk for ADHD at three age points: 7, 12, and 25 months. These boys are participants in BIDS, which is a longitudinal study using a high-risk paradigm to investigate possible early behavioural markers of ADHD. In this paradigm, individuals at high genetic risk for a disorder—usually first-degree relatives of patients—are targeted as the subject population in infancy or childhood and then followed over time to identify possible early behavioural markers of the disorder. The evidence that ADHD is a familial disorder is compelling (Barkley, DuPaul, & McMurray, 1990). First-degree relatives of children with ADHD are 7.6 times more likely to have the disorder than are relatives of normal children (Biederman et al., 1992). Furthermore, 60% of children with a parent with ADHD are likely to receive a childhood diagnosis of ADHD (Biederman et al., 1995) and 25–30% of parents of children with ADHD have significant levels of ADHD symptomatology themselves (Barkley, 1990). The high heritability estimates (75–90%) for ADHD in twin studies support a strong genetic contribution (Goodman & Stevenson, 1989; Levy, Hay, McStephen, Wood, & Waldman, 1997) and recent evidence from molecular genetics further attests to a genetic basis of the disorder. A number of studies have found the dopamine D4 receptor gene (DRD4) (Farraone et al., 1999; LaHoste et al., 1996) and the dopamine transporter gene (DAT1) (Cook et al., 1995; Gill, Daly, Heron, Hawi, & Fitzgerald, 1997) to be associated with ADHD.

The high-risk research paradigm is of particular value in investigating disorders with low prevalence in the general population (Garmezy & Streitman, 1974). ADHD has a prevalence of 3–5% (American Psychiatric Association, 1994) with the disorder being more common in boys than in girls, both in epidemiological and in clinical populations (3:1–9:1, respectively) (American Psychiatric Association, 1994; Szatmari, Offord, & Boyle, 1989). In our study, families were
recruited based on the number of ADHD symptoms in the father and infants were assigned to an ADHD risk group or a comparison group based on this symptomatology.

Based on studies showing both concurrent and predictive associations between effortful control (and its components), activity level, and anger with ADHD, we expected that infants at risk for ADHD would be rated as lower in effortful control, as having higher levels of activity, and as angrier than infants not at risk for ADHD. Lower levels of effortful control would be expressed by difficulties with attentional control and inhibitory control.

Mothers and fathers were used as independent sources for the assessment of temperament in the present study. This allowed us to examine whether mothers and fathers differed in their ratings of child temperament. On the basis of observed differences in parental styles of interaction, we hypothesized that mothers and fathers might differ in their ratings of soothability and activity level. Mothers, given their greater experience in caretaking interactions, would be expected to rate their infants as easier to soothe. As for the activity level, fathers might rate their infants as more active than mothers since they engage in more physical activities with the infant, but in light of the Greenbaum et al. (1989) findings, mothers may continue to rate their infants as more active than do fathers even beyond the neonatal period. The father’s level of symptomatology determined group placement in the present study and gave us the opportunity to examine whether these fathers differed from the rest of the sample in their perception of their infants’ temperament.

METHOD

Participants

The present sample is part of a large longitudinal sample and consists of 58 boys for whom there were complete temperament questionnaire data at three ages: 7 (M = 7.34, S.D. = 0.62), 12 (M = 12.50, S.D. = 0.74), and 25 (M = 25.80, S.D. = 1.31) months old. At these ages, mothers (N = 56) and fathers (N = 57) completed temperament ratings on them.

Recruitment into the study occurred in the Maternity Ward of the Soroka Medical Center in Beer Sheva. Two-parent families who were either native-born Israelis or immigrants who had studied in Israel and spoke Hebrew and had healthy newborn boys were approached. If the family was interested in joining a longitudinal study, the father was asked to complete a questionnaire that included items assessing ADHD symptomatology (see Auerbach et al., 2004). Entry into the study was based on the number of positive responses (yes–no format) fathers made to 18 DSM-IV ADHD items (American Psychiatric Association, 1994) on a questionnaire they completed in the hospital after the birth of their sons. Criteria for recruitment into the ADHD risk group were positive responses to \( \geq 7 \) symptoms and recruitment into the comparison group were positive responses to \( \leq 3 \) symptoms. A cutoff score of at least seven symptoms for the risk group was decided upon because it was high enough above the mean to indicate moderate symptomatology and low enough to ensure a large enough risk sample to follow longitudinally. Although this number of symptoms is lower than required for a childhood diagnosis of ADHD, it is in line with other studies of adult ADHD where self-reported symptoms were one of the measures (Faraone, Biederman, Feighner, & Monuteaux, 2000; Young, Toone, & Tyson, 2003).
The mean number of paternal symptoms in the present sample was 9.81 (N = 36, S.D. = 2.21) in the risk group and 1.32 (N = 22, S.D. = 1.04) in the comparison group. There were no differences between the groups on parental education, age, and the number of children in a family. There were also no group differences in ADHD symptomatology in the mothers who completed a questionnaire assessing ADHD symptoms during an early home visit, with ADHD symptomatology being low in both groups. For a fuller description of the recruitment procedures and demographic information, see Auerbach et al. (2004).

As mentioned, only a subsample of our longitudinal sample was used for the current report. Rather than estimate missing values, it was decided to select a subsample based on the completeness of temperament report data. A comparison of those children with complete data, and those with partial data, revealed no differences in temperament ratings, level of paternal ADHD symptomatology, or demographic variables.

**Measures and Procedure**

**Infant temperament measure**

In the present study, at 7 and 12 months, the 1978 version of the Infant Behaviour Questionnaire (IBQ, Rothbart, 1981) with the addition of two scales of the 1998 version of the IBQ (Rothbart, 1998) was used to assess temperament. The IBQ is a parent questionnaire assessing infant temperament in the first year of life based on Rothbart’s (1981) model of temperament. Parents are asked to rate on a seven-point scale the relative frequency of occurrence of specific infant reactions in concrete situations during the previous 2 weeks. The 1978 version IBQ consists of six behavioural scales: Activity Level, Distress to Limitations (Anger), Distress to Sudden or Novel Stimuli (Fear), Duration of Orienting (Interest), Smiling and Laughter (Pleasure), and Soothability. The Attentional Shift and Perceptual Sensitivity scales of the 1998 revision were also used in the present study. The Attentional Shift scale at 7 months was reduced to 3 items and at 12 months to 6 items from its original 12 items because of the extremely low intercorrelations among the items. *À priori*, only 8 items from the Perceptual Sensitivity scales were used; those deemed relevant to the environs and nature of the study.

**Toddler temperament measure**

The short version of the Toddler Behaviour Questionnaire (TBAQ; Goldsmith, 2000) was used to assess temperament at 25 months. It consisted of 120 items that form 11 scales: Activity Level, Anger Proneness, Appropriate Allocation of Attention, Inhibitory Control, Interest/Persistence, Object Fear, Perceptual Sensitivity, Pleasure, Sadness, Social Fearfulness, and Soothability. Of the two scales measuring fear, Object Fear is closer in content to the Distress to Novelty scale of the IBQ than is the Social Fearfulness scale. The TBAQ was designed to be a continuation of the IBQ and the same 7-point rating format was used, with parents being asked to rate toddler reactions over the last month. In the current study, one item was dropped from the Anger scale and two items were dropped from the Sadness scale because of their low correlations with other items in the scales.

Given the importance of effortful control for a study of risk for ADHD, a composite variable was formed called *Effortful Control*. It consisted of three variables that are considered core components of effortful control and that were measured at 25 months: Appropriate Allocation of Attention, Inhibitory Control,
and Interest. These variables were significantly intercorrelated for both mother and father reports in the present study.

Table 1 presents Cronbach alphas for each IBQ and TBAQ scale by age and informant.

Mothers and fathers independently completed the questionnaires at each of the three ages. For 51 children, both mothers and fathers completed the questionnaires. For 7 children, either the mother or the father completed the questionnaire. At 7 months, the questionnaires were completed during a visit to the developmental laboratory at the Ben-Gurion University. At 12 and 25 months, the questionnaires were completed during a home visit. Both in the laboratory and at the home visit, research assistants were present to assist the parents in the completion of the questionnaire. The research assistants were blind as to the risk status of the child. At each assessment period, parents received detailed explanations of the procedure and signed informed consent. All stages of the research received departmental ethics approval.

Data Analyses

The data were analysed using $2 \times 2 \times 3$ repeated measure analysis of variances (ANOVAs). Group (ADHD risk, comparison) and parent informant (mother, father) were the between-subjects measures and age (7, 12, 25 months) was the within-subject repeated measure. The Attentional Shift scale was limited to 7 and 12 months. At 25 months, there were four scales (Appropriate Allocation of Attention, Inhibitory Control, Sadness, Social Fearfulness) that were unique to that age period; therefore, $2 \times 2$ ANOVAs were used in the analyses of these scales and in the analysis of Effortful Control. An examination of the sources of significant effects was done for $p$-values <0.05. Univariate analyses were done when there were significant interaction effects. Since in a high-risk study it is of interest to know at which age group effects may be stronger, it was decided to use univariate analyses for this purpose even when the group $\times$ age interactions were not significant but on the condition that there were significant group effects. Neuman–Kuels post hoc analyses were used to examine significant age effects.

Table 1. IBQ and TBAQ Cronbach alphas by age and informant

<table>
<thead>
<tr>
<th>Temperament scales</th>
<th>Mothers</th>
<th></th>
<th></th>
<th></th>
<th>Fathers</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 months</td>
<td>12 months</td>
<td>24 months</td>
<td>7 months</td>
<td>12 months</td>
<td>24 months</td>
<td></td>
</tr>
<tr>
<td>Activity level</td>
<td>0.72</td>
<td>0.78</td>
<td>0.74</td>
<td>0.73</td>
<td>0.70</td>
<td>0.63</td>
<td></td>
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<tr>
<td>Anger</td>
<td>0.79</td>
<td>0.81</td>
<td>0.70</td>
<td>0.78</td>
<td>0.71</td>
<td>0.80</td>
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</tr>
<tr>
<td>Attentional shift</td>
<td>0.64</td>
<td>0.56</td>
<td>0.73</td>
<td>0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fear</td>
<td>0.73</td>
<td>0.81</td>
<td>0.66</td>
<td>0.72</td>
<td>0.78</td>
<td>0.70</td>
<td></td>
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<tr>
<td>Interest</td>
<td>0.82</td>
<td>0.78</td>
<td>0.75</td>
<td>0.78</td>
<td>0.75</td>
<td>0.75</td>
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<tr>
<td>Perceptual sensitivity</td>
<td>0.70</td>
<td>0.71</td>
<td>0.53</td>
<td>0.80</td>
<td>0.84</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Pleasure</td>
<td>0.80</td>
<td>0.78</td>
<td>0.72</td>
<td>0.75</td>
<td>0.80</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Soothability</td>
<td>0.78</td>
<td>0.78</td>
<td>0.66</td>
<td>0.85</td>
<td>0.80</td>
<td>0.66</td>
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<tr>
<td>Attention allocation</td>
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<td>0.75</td>
<td>0.79</td>
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<tr>
<td>Inhibitory control</td>
<td>0.85</td>
<td></td>
<td>0.80</td>
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<td></td>
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<tr>
<td>Sadness</td>
<td>0.69</td>
<td></td>
<td>0.67</td>
<td></td>
<td></td>
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<tr>
<td>Social fear</td>
<td>0.74</td>
<td></td>
<td>0.74</td>
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<td></td>
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<tr>
<td>Effortful control</td>
<td>0.76</td>
<td></td>
<td>0.83</td>
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</tbody>
</table>
RESULTS

Means and standard deviations for the ADHD and comparison groups are presented in Table 2, and age effects with their F-values are presented in Table 3.

Activity

There was a significant main effect for Activity Level for both group, \( F[1, 112] = 13.03, p < 0.0005 \), and informant, \( F[1, 112] = 10.24, p < 0.005 \). The ADHD risk group was rated as having significantly higher levels of activity than the comparison group and the differences were significant at all three ages (7 months: \( F[1, 112] = 10.26, p < 0.01 \); 12 months: \( F[1, 112] = 4.46, p < 0.05 \); 25 months: \( F[1, 112] = 5.54, p < 0.01 \)). Mothers also rated their sons as having significantly higher levels of activity than did fathers (mother: \( M = 4.48, \text{ S.D.} = 0.08 \); father: \( M = 4.13, \text{ S.D.} = 0.08 \)) and did so at 7 and 12 months, with a trend at 25 months (7 months: \( F[1, 112] = 7.29, p < 0.01 \); 12 months: \( F[1, 112] = 5.16, p < 0.05 \); 25 months: \( F[1, 112] = 3.44, p = 0.07 \)). Although the group by age interaction was non-significant, there was a significant age effect, Table 2. Means and standard deviations for the ADHD risk group and comparison group

<table>
<thead>
<tr>
<th>Temperament scales</th>
<th>ADHD risk ( M \pm \text{S.D.} )</th>
<th>Comparison ( M \pm \text{S.D.} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 months</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity level</td>
<td>4.24 ± 0.81</td>
<td>3.75 ± 0.79</td>
</tr>
<tr>
<td>Attentional shift</td>
<td>4.38 ± 1.24</td>
<td>4.95 ± 1.23</td>
</tr>
<tr>
<td>Interest</td>
<td>4.50 ± 1.01</td>
<td>4.81 ± 0.90</td>
</tr>
<tr>
<td>Anger</td>
<td>3.84 ± 0.80</td>
<td>3.68 ± 0.85</td>
</tr>
<tr>
<td>Fear</td>
<td>2.59 ± 0.72</td>
<td>2.46 ± 0.84</td>
</tr>
<tr>
<td>Pleasure</td>
<td>5.59 ± 0.72</td>
<td>5.75 ± 0.65</td>
</tr>
<tr>
<td>Perceptual sensitivity</td>
<td>3.94 ± 1.50</td>
<td>4.11 ± 1.15</td>
</tr>
<tr>
<td>Soothability</td>
<td>5.00 ± 1.08</td>
<td>4.86 ± 1.86</td>
</tr>
<tr>
<td>12 months</td>
<td></td>
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<tr>
<td>Activity level</td>
<td>4.43 ± 0.74</td>
<td>4.12 ± 0.79</td>
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<tr>
<td>Attentional shift</td>
<td>4.58 ± 0.90</td>
<td>4.78 ± 0.88</td>
</tr>
<tr>
<td>Interest</td>
<td>4.29 ± 0.98</td>
<td>4.57 ± 1.04</td>
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<tr>
<td>Fear</td>
<td>2.94 ± 0.77</td>
<td>2.79 ± 0.88</td>
</tr>
<tr>
<td>Anger</td>
<td>4.28 ± 0.72</td>
<td>3.94 ± 0.88</td>
</tr>
<tr>
<td>Pleasure</td>
<td>5.54 ± 0.77</td>
<td>5.68 ± 0.73</td>
</tr>
<tr>
<td>Perceptual sensitivity</td>
<td>4.26 ± 1.42</td>
<td>4.28 ± 1.22</td>
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<tr>
<td>Soothability</td>
<td>4.98 ± 0.97</td>
<td>5.07 ± 1.03</td>
</tr>
<tr>
<td>24 months</td>
<td></td>
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<tr>
<td>Activity</td>
<td>4.84 ± 0.88</td>
<td>4.45 ± 0.74</td>
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<tr>
<td>Attention allocation</td>
<td>3.94 ± 0.64</td>
<td>4.33 ± 0.66</td>
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<tr>
<td>Inhibitory control</td>
<td>3.50 ± 0.76</td>
<td>4.22 ± 0.91</td>
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<tr>
<td>Interest</td>
<td>4.21 ± 0.88</td>
<td>4.45 ± 0.99</td>
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<tr>
<td>Anger</td>
<td>4.46 ± 1.03</td>
<td>4.06 ± 1.18</td>
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<tr>
<td>Sadness</td>
<td>4.03 ± 0.89</td>
<td>3.61 ± 0.91</td>
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<tr>
<td>Object fear</td>
<td>2.66 ± 0.88</td>
<td>2.54 ± 0.87</td>
</tr>
<tr>
<td>Social fear</td>
<td>3.82 ± 1.06</td>
<td>3.76 ± 0.93</td>
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<tr>
<td>Perceptual sensitivity</td>
<td>3.15 ± 0.77</td>
<td>3.05 ± 0.83</td>
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<tr>
<td>Pleasure</td>
<td>5.37 ± 0.78</td>
<td>5.61 ± 0.66</td>
</tr>
<tr>
<td>Soothability</td>
<td>4.98 ± 0.80</td>
<td>5.30 ± 0.70</td>
</tr>
<tr>
<td>Effortful control</td>
<td>3.88 ± 0.60</td>
<td>4.33 ± 0.75</td>
</tr>
</tbody>
</table>
Further probing of the data revealed that the activity level increased significantly from 7 to 12 months ($p < 0.0001$) and from 12 to 25 months ($p < 0.0001$).

**Attention**

There was a significant group effect for Attentional Shift, $F[1, 105] = 5.81$, $p < 0.05$, with the ADHD risk group being rated lower than the comparison group, that is, the ADHD risk group showed less intentional shifts of attention than the comparison group. The effect was significant at 7 months ($p < 0.05$).

**Effortful Control**

Effortful Control two components, Appropriate Allocation of Attention and Inhibitory Control, showed significant group effects with a borderline main effect for Interest. For the composite Effortful Control, there was a significant group difference, $F(1, 112) = 12.17$, $p < 0.001$, with the ADHD risk group receiving lower scores than the comparison group. For Appropriate Allocation of Attention, there was a significant main effect for the group, $F[1, 112] = 9.36$, $p < 0.005$, with the ADHD risk group receiving lower scores than the comparison group. There was a significant group main effect for Inhibitory Control, $F[1, 112] = 20.39$, $p < 0.0001$. The ADHD risk group was rated as having significantly lower levels of inhibitory control than the comparison group. There was a near significant group main effect for Interest, $F[1, 112] = 3.75$, $p < 0.055$, with the ADHD risk group receiving lower scores than the comparison group. There was a significant age effect for Interest, $F[2, 224] = 5.12$, $p < 0.01$. Infants received lower ratings on Interest across age with significant differences between 7 months and both 12 months ($p < 0.05$) and 25 months ($p < 0.01$).

**Affect**

The negative emotions of anger and sadness showed a significant group main effect. For Anger, the ADHD risk group was rated as showing more anger than the comparison group, $F[1, 112] = 4.52$, $p < 0.05$. Univariate analyses showed a significant difference at 12 months, $F[1, 112] = 4.61$, $p < 0.05$, and a trend at 25

---

**Table 3. Means and standard deviations for age comparisons**

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity level</td>
<td>4.16±0.80</td>
<td>4.32±0.77</td>
<td>4.70±0.85</td>
<td>24.50***</td>
</tr>
<tr>
<td>Anger</td>
<td>3.78±0.82</td>
<td>4.16±0.80</td>
<td>4.31±1.10</td>
<td>15.36***</td>
</tr>
<tr>
<td>Attentional shift</td>
<td>4.58±1.26</td>
<td>4.65±0.89</td>
<td>2.62±0.87</td>
<td>0.013</td>
</tr>
<tr>
<td>Fear</td>
<td>2.54±0.77</td>
<td>2.89±0.81</td>
<td>2.62±0.87</td>
<td>8.19***</td>
</tr>
<tr>
<td>Interest</td>
<td>4.61±0.98</td>
<td>4.39±1.00</td>
<td>4.30±0.93</td>
<td>5.13***</td>
</tr>
<tr>
<td>Perceptual sensitivity</td>
<td>4.00±1.39</td>
<td>4.27±1.34</td>
<td>3.11±0.79</td>
<td>31.81***</td>
</tr>
<tr>
<td>Pleasure</td>
<td>5.65±0.70</td>
<td>5.59±0.76</td>
<td>5.45±0.74</td>
<td>3.23*</td>
</tr>
<tr>
<td>Soothing</td>
<td>4.95±1.01</td>
<td>5.01±0.99</td>
<td>5.10±0.78</td>
<td>1.56</td>
</tr>
</tbody>
</table>

* $p<0.05$; ** $p<0.01$; *** $p<0.001$. 

$F[2, 224] = 24.5$, $p < 0.0001$. Further probing of the data revealed that the activity level increased significantly from 7 to 12 months ($p < 0.0001$) and from 12 to 25 months ($p < 0.0001$).
months, \( F[1, 112] = 4.46, p<0.07 \). There was also a significant age effect, \( F[2, 224] = 15.36, p<0.0001 \). Anger increased significantly from 7 to 12 months (\( p<0.0001 \)) and from 12 to 25 months (\( p<0.05 \)).

For Sadness, which was only measured at age 25 months, there was a significant group effect, \( F[1, 112] = 5.71, p<0.05 \). Higher levels of sadness were reported for the ADHD risk group than for the comparison group.

There was a significant interaction between group and informant for Fear, \( F[1, 112] = 4.53, p<0.05 \), and a significant age effect, \( F[2, 224] = 8.19, p<0.001 \). The interaction was accounted for by fathers in the comparison group who rated their sons as less fearful at 7 months, \( F[1, 57] = 4.20, p<0.05 \), and 12 months, \( F[1, 57] = 4.40, p<0.05 \), than fathers in the ADHD risk group rated their sons. The ratings of mothers in both groups fell between those of the fathers. Although the group by age interaction for Fear was non-significant, further probing of the data revealed Fear to be highest at 12 months. It increased significantly from 7 to 12 months (\( p<0.001 \)) and decreased significantly from 12 to 25 months (\( p<0.01 \)) with no difference between 7 and 25 months.

There were two dimensions for which there were only significant age effects: Pleasure, \( F[2, 224] = 3.23, p<0.05 \), and Perceptual Sensitivity, \( F[2, 216] = 31.81, p<0.0001 \). Pleasure was seen as decreasing with age. At 25 months, infants were rated as exhibiting less pleasure than at 7 months (\( p=0.051 \)). At 12 months, the difference also approached significance (\( p=0.06 \)). For Perceptual Sensitivity, there was a marginal increase in perceptual sensitivity from 7 to 12 months, \( p<0.10 \), then a significant decrease from 12 to 25 months (\( p<0.00001 \)). The level at 25 months was also significantly lower than the level at 7 months (\( p<0.0001 \)).

There were no significant main or interaction effects for Soothability or Social Fearfulness.

DISCUSSION

In the present paper, the temperament of infants at familial risk for ADHD and a matched comparison group of infants were rated by mothers and fathers at 7, 12, and 25 months. In line with our hypotheses, compared with the comparison group, the ADHD risk group was higher in activity level and anger and had more difficulty with attention, inhibitory control, and effortful control, albeit the absolute differences between the groups were small. Taken together, these findings offer support for a link between the temperament domains of reactivity and self-regulation and risk for ADHD (Nigg et al., 2004). The only informant difference was for activity level, with mothers, rather than fathers, perceiving their infants as more active.

Of the dimensions assessed at the three ages, the strongest findings were for activity level. Parents of infants in the ADHD risk group rated them as higher in activity than did parents of infants in the comparison group, and this was true for all three ages, significantly so. In fact, differences in activity level began to emerge in the neonatal period, during which the ADHD risk group had marginally higher activity levels than the comparison group, as measured by the Neonatal Behavioral Assessment Scales (Auerbach et al., 2005; Brazelton & Nugent, 1995). The consistency with which activity level is judged higher for infants at risk for ADHD makes it a strong candidate as an early behavioural marker of risk for ADHD, particularly in light of its ability to predict later activity in both clinical and normal populations from the second year of life (Buss et al., 1980; Campbell et al., 1994). By age 4, extreme levels of high activity, i.e. hyperactivity, predict the early onset of ADHD and its persistence (Sonuga-Barke et al., 2005).
Attentinal differences also seem to be appearing early in life in our sample. Infants in the ADHD risk group were rated as having more difficulty purposefully shifting their attention at 7 and 12 months, and at 25 months this difficulty expanded to include difficulties in the focusing and maintaining of attention. While the findings regarding attentional shift need to be viewed with caution because of the low Cronbach alphas and the few items in the scales, the items that did remain in the scales are those that assess the ability of the infant to appropriately disengage his attention. In addition, there were marginally significant differences for interest (Duration of Orienting), with the ADHD risk group rated as lower in interest than the comparison group. At 7 months in a laboratory assessment, the ADHD risk group also showed less interest in a block play task, and at 12 months, less vigilance in a puppet paradigm (Auerbach et al., 2004; Berger et al., 2007). Difficulties with attention are characteristic of children with ADHD and have been documented as early as preschool (Byrne, DeWolfe, & Bawden, 1998; Harper & Ottinger, 1992). Nevertheless, there is a question as to whether children with ADHD suffer from an attention deficit or a state regulation deficit that can affect attentional processes (Van der Meere, 2002).

Whether the inhibitory problems seen in ADHD are grounded in temperament or executive functioning (Barkley, 1997; Nigg, 2001; Nigg et al., 2004), there is general agreement that children with ADHD do have difficulties with inhibitory control; and in the current study, inhibitory difficulties were already apparent in 25-month-old toddlers at risk for ADHD. Inhibitory control begins to come online towards the end of the first year and continues to develop during the preschool years (Rothbart, 1989). Its normal development is contingent upon other concurrently developing systems, including language, memory, and attention (Kopp, 1982; Rothbart & Ahadi, 1994; Vaughn, Kopp, & Krakow, 1984), and appropriate input from the caretaking environment (Kopp, 1982; Olson, Bates, & Bayles, 1990; Silverman & Ragusa, 1990). Deviance in any one of these systems can adversely affect the development of inhibitory control. Attention and inhibitory control were intertwined in the present study, and together, were indicative of problems in effortful control for the ADHD risk group.

The difficulties of 25-month-old at-risk toddlers with effortful control, and its individual components of attention, inhibitory control, and interest provide support for effortful control as a potential liability marker for ADHD. The findings of Goldsmith et al. (2004) of shared genetic variance between early effortful control and later symptoms of ADHD suggest that effortful control may be a specific marker of liability for ADHD. Children who show difficulty on all three of these indices may be on a developmental pathway to ADHD. Whether the final outcome is ADHD depends, not insignificantly, on how the environment responds to these children who have difficulties with effortful control. Environment intervention in the form of parent training groups, similar to a program developed for preschool children with ADHD (Sonuga-Barke, Daley, Thompson, Laver-Bradbury, & Weeks, 2001), may deflect the child onto a more normative developmental pathway, although there is some question as to how effective these programs are for parents who themselves have high ADHD symptomatology (Harvey et al., 2003; Sonuga-Barke, Daley, & Thompson, 2002). Rueda, Rothbart, McCandliss, Saccomanno, and Posner (2005) have shown that preschool children can benefit from attention training in terms of an improvement in executive attention, and thus intervention programs directly targeting the child may prove to be useful in working with young children who are at risk for ADHD.
Anger, particularly at 12 months and to a certain extent at 25 months, also differed between the ADHD risk group and the comparison group. Although the IBQ differences at 7 months were not significant, higher anger reactivity was found for the ADHD risk group at this age when an attractive toy with which they were playing was placed behind a barrier (Auerbach et al., 2004). Difficulties with anger regulation and its association with ADHD have been found from preschool to adulthood (Douglas & Parry, 1994; Mash & Johnson, 1982; Ramirez et al., 1997), but these difficulties seem to be more characteristic for those with co-morbid externalizing disorders (Melnick & Hinshaw, 2000). Parents of the toddlers in the ADHD risk group also perceived them as higher in sadness than did parents of the comparison group toddlers. Phenotypically, sadness would seem to be more directly related to internalizing types of disorders, such as depression and anxiety, rather than to ADHD. Indeed, Lemery et al. (2002) found that parent-reported sadness, based on Rothbart’s Children’s Behaviour Questionnaire (1994), predicted mother-reported and father-reported internalizing behaviour at 5.5 years. Anxiety and mood disorders do co-occur with ADHD (Barkley, 2003), but without replication of our finding, it would be premature to draw any conclusion regarding a connection between sadness in infancy and risk for ADHD.

Parents were remarkably similar in their judgments of the levels of the different temperament dimensions. The dimension for which they differed was for activity level. Mothers, regardless of the group, perceived their sons as more active than did fathers. This is similar to the neonatal findings of Greenbaum et al. (1989) and extends them into the second year of life. Mothers and fathers may have different thresholds for judging how true a particular item, in this case activity, is for their child. The types of interactions mothers and fathers have with their young children differ in terms of physical intensity (Power & Park, 1983), and as a consequence, these patterns may influence the threshold for judgments about activity. Fathers may expect their sons to be active, and therefore, these boys may need to be much more active in order for them to receive the same rating that their mothers give them. Interestingly, unlike the association found between temperament ratings and maternal psychopathology, father ADHD symptomatology did not affect temperament ratings unless it jointly impacted on the ratings of both parents. Mothers and fathers in the ADHD risk group gave similar ratings to their sons’ temperament. Although mothers and fathers in both groups made their ratings independently, it is possible that the ratings do not reflect independent perceptions of the child but rather are the result of discussions about the child’s behaviour (Bates, 1980).

The significant age differences between 7 and 12 months with higher scores for activity level, anger, and fear, and lower scores for interest, are consistent with those reported by Rothbart (1981) and Garstein and Rothbart (2006). Activity level and anger continued to increase in the second year. Fear increased significantly between 7 and 12 months, but the trajectory to 25 months varied depending whether the outcome was fear of objects or social fear. Interest, as measured by duration of orienting, continued to decrease over time. The changes seen in these temperament dimensions reflect the neuromaturational changes taking place between 7 and 25 months. Motorically, the child becomes increasingly mobile, leading to a greater variety of ways to be active. With age, children increasingly express anger when their goals are blocked, with anger reaching its peak during the ‘terrible twos’. As toddlers develop more strategies for evaluating and coping with fearful inanimate stimuli, there is a decrease in fear from age 12 to 25 months to a level similar to 7 months. Garstein and Rothbart (2006) suggest that lower levels of interest, that is, lower scores on the Duration of
Orienting scale, may be the result of maturational changes in the posterior attentional system, changes that continue into the second year of life, and therefore, may also account for the further decline on this scale at age 25 months. In contrast to Rothbart (1981) and Garstein and Rothbart (2006), we found a decrease, rather than an increase from 7 to 12 months for pleasure (smiling and laughter) and perceptual sensitivity.

There are a number of limitations to the present study. First of all, it is a selected subsample of a larger sample of children participating in our longitudinal study. The subsample in the present report was limited to the children in our longitudinal study who had parental report data at all three time points, thus allowing us to examine group and informant differences across ages. The lack of temperament and demographic differences between those with complete and those with partial temperament data suggest that our findings are not unique to the subsample. Second, the designation of ADHD risk was based on self-reported symptoms of ADHD by fathers and not a psychiatric diagnosis of ADHD. Consequently, the fathers of the risk group may not be as impaired as adults with a psychiatric diagnosis of ADHD. This being the case, it should work against finding differences between the ADHD risk and the comparison group. In fact, there were differences in directions compatible with the ADHD literature. Third, the sample is limited to boys. The decision to limit the sample to boys was made in light of the fact that the prevalence of ADHD is higher among boys than girls, and in order to increase the probability of having a large enough sample of children who will eventually develop ADHD. Having a sample of boys only does potentially, but not necessarily, limit the generalizability of our findings. The extent to which our findings will be applicable to girls at risk for ADHD may be tied to eventual referral status of the child. More gender differences are reported for referred than non-referred males and females and are likely the result of the higher rates of disruptive behaviour in males (Biederman et al., 2002, 2005; Gaub & Carlson, 1997). If this is the case, then early behavioural markers of vulnerability may be similar for both boys and girls who go on to develop ADHD, particularly those who are not characterized by early disruptive behaviour. A study of temperament characteristics of girls at risk for ADHD would shed light on this issue.

The low Cronbach alphas of some of the IBQ and TBAQ scales are a further limitation, e.g. Attentional Shift, and TBAQs are a further limitation of the study and, therefore, significant findings, or lack thereof, for these scales need to be viewed cautiously. In fact, The Attentional Shift scale was dropped from the Revised Infant Temperament Scale because of internal consistency problems (Garstein & Rothbart, 2006). Nevertheless, items from it were used in the present paper because of its relevance in studying infants at risk for ADHD.

Lastly, this paper has focused primarily on individual dimensions of temperament that may be implicated in the development of ADHD. At best, each of these dimensions will only make a small contribution to ADHD risk liability. Ultimately, only by considering constellations of risk behaviours together with environmental risk factors will it be possible to predict whether a particular developmental pathway will lead to ADHD. Based on the findings presented here and elsewhere (Auerbach et al., 2004, 2005; Berger et al., 2007), one pathway to ADHD attentional problems might be characterized by consistently low attention scores in infancy and toddlerhood. Another pathway, perhaps to ADHD with combined symptomatology of attention deficit and hyperactivity-impulsivity, might be characterized by high activity together with poor self-regulation, particularly low effortful control. The probability of such children
continuing on this pathway to ADHD, or being deflected to a more normative pathway, may depend to a great extent on the socialization practices of their parents. The lax, or overly reactive, parenting practices of some parents with ADHD (Harvey et al., 2003) would seem poorly suited for helping a child at risk for ADHD develop self-regulation. As our sample reaches school age and diagnostic assessments are carried out, we will be better able to map out potential pathways based on our observations and assessments of child and parent behaviour and of parent–child interactions over time.

As has been stressed in recent literature, our understanding of the development of psychopathology, including ADHD, will only be advanced when both genetic and environmental factors and their interactions are jointly investigated (Campbell, Shaw, & Gilliom, 2002; Rutter, 2003; Rutter et al., 1997; Sonuga-Barke et al., 2005). Future studies using a high-risk paradigm should include multi-level measures of genetic and environmental factors as part of their design. In order to gain a more comprehensive picture of developmental pathways to ADHD, it will be necessary to select risk samples that include mothers with ADHD and samples based on psychiatric diagnosis of ADHD in the parents. In the meantime, the current study contributes to the limited research on early developmental precursors to ADHD.

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