Article

Journal of Attention Disorders
2021, Vol. 25(13) 1908–1918

DOI: 10.1177/1087054720945019
journals.sagepub.com/home/jad
SAGE

# Infant Attentional Behaviors Are Associated with ADHD Symptomatology and Executive Function in Early Childhood

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## Abstract

**Objective:** We explored associations between infant attentional behaviors as measured by the First Year Inventory (FYIv2.0) and dimensional ratings of ADHD symptomatology and executive function (EF) in early childhood. **Methods:** This study included parents ($N=229$) who filled out the FYIv2.0 when their children were 12 months of age. When children were approximately 54 months (4.5 years) of age, parents completed reports of children's ADHD symptomatology and EF abilities. Correlation and regression analyses were conducted among measures. **Results:** We found significant associations among the variables of interest, both cross-sectionally and longitudinally, as well as gender differences. Notably, non-social sensory attention (NSA) was significantly related to 54-month ADHD symptom severity. All three 12-month attention variables were significantly related to 54-month EF. **Conclusion:** Results suggest that infant attentional behaviors predict later ADHD-related behaviors in early childhood. Future research should explore associations using laboratory-based measures and could inform early intervention efforts. *(J. of Att. Dis. 2021; 25(13) 1908-1918)*

**Keywords**
ADHD, ADHD-associated problems, executive function, early childhood, infant attention

ADHD is a neurodevelopmental disorder consisting of symptoms of inattention and/or hyperactivity-impulsivity that interfere with daily functioning (American Psychiatric Association, 2013). ADHD is one of the most common neurodevelopmental disorders in the United States (Danielson et al., 2018), with substantial research documenting its effects on a wide range of childhood outcomes, including social and emotional development (Wehmeier et al., 2010) and academic achievement (Arnold et al., 2015).

Individuals with ADHD struggle in particular with executive function (EF; Craig et al., 2016; Willcutt et al., 2005), which is conceptualized as a set of higher-order cognitive processes that underlie, control, and regulate goal-directed behaviors (Baggetta & Alexander, 2016; Hughes & Ensor, 2005). Divergences in the development of EF could result in a number of impairments of key processes, including decision making, emotion regulation, social competence, and learning. EF in older children and adults is most often broken into three primary factors: working memory (or updating), inhibition, and shifting (or cognitive flexibility; Miyake et al., 2000). In younger children, however, EF is typically considered a unitary construct, with overlapping behaviors that load onto one common factor (Wiebe et al., 2011; Willoughby & Blair, 2016).

Among the large body of existing research on EF deficits in ADHD, most studies have reported impaired performance on EF-related tasks for those with ADHD. In fact, EF measures have been used to effectively discriminate between children with and without ADHD, with measures of response inhibition and working memory being the strongest contributors to this discrimination (Holmes et al., 2010). However, not all children with ADHD exhibit EF impairment. For example, Lambek et al. (2010) found that, although their ADHD group displayed EF impairment, not every child with ADHD exhibited EF deficits, and the children varied in what aspects of EF were specifically impaired. Relatedly, the majority of research linking EF deficits with ADHD compare children with and without a diagnosis.

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*Dr. Reznick is honored posthumously for his contributions to this study.

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Arguably, however, ADHD may best be approached from a dimensional perspective, as subthreshold ADHD symptoms are also related to a range of deficits (Gambin & Święcicka, 2016; Hong et al., 2014; Neely et al., 2016). Although there has been little examination of associations between dimensional measures of ADHD symptomatology and EF, existing research has specifically considered symptoms of inattention and hyperactivity in relation to aspects of EF (Neely et al., 2016; Takeuchi et al., 2013).

Although most research on ADHD in children focuses on the middle childhood age range, when diagnoses are more common, some studies have examined how symptoms of ADHD are related to EF abilities in preschool-aged children, before most would receive a definitive diagnosis (see Pauli-Pott & Becker, 2011 for a review). For example, ADHD symptoms in preschool children have been associated with deficits in aspects of executive function, such as working memory and inhibition, as measured by both task-based assessments (Skogan et al., 2014; Thorell & Wåhlstedt, 2006), and parent report (Miranda et al., 2015). Additional research has found that the association between inhibitory control deficits and ADHD symptoms in preschool-aged children is linear in nature (Sonuga-Barke et al., 2002), providing further support for consideration of ADHD from a dimensional perspective in young children.

Relatively little research has examined behaviors in even younger children (i.e., infants or toddlers) in relation to ADHD or ADHD symptoms specifically, although research has considered overlapping precursors to ADHD and autism spectrum disorder (ASD) such as effortful control, temperament, or even motor delays (see Johnson et al., 2015 for a review). Surprisingly, however, exploration of the links between features of infant attention and later ADHD symptomatology has been neglected (Johnson et al., 2015; Visser et al., 2016), although one study reported associations between distractibility in infancy and risk for ADHD (Holmboe et al., 2010). Aspects of infant attention have been repeatedly linked to individual differences in other behaviors such as temperament (Papageorgiou et al., 2015), EF (Cuevas & Bell, 2013), intelligence (Sigman et al., 1997), and self-regulation (Graziano et al., 2011; Rothbart et al., 2008), as well as to behaviors commonly associated with ADHD, such as effortful control (Kochanska et al., 2000; Papageorgiou et al., 2014) and hyperactivity (Lawson & Ruff, 2004).

Joint attention in infancy has been recognized as a strong predictor of later social and cognitive abilities, including many abilities that are implicated in ADHD (e.g., Mundy et al., 2007; Schietecatte et al., 2012). For example, both responding to joint attention (RJA) and initiating joint attention (IJA) have been linked to later language skills (Delgado et al., 2002; Mundy et al., 1990), social competence (Vaughan Van Hecke et al., 2007) and self- and emotion-regulatory behaviors in early development (Morales et al., 2005; Vaughan Van Hecke et al., 2011). The joint attention systems have also been related to the emergence of executive control (Posner et al., 2012). Many of these associations have been explored fairly extensively in children with ASD; however, there is limited research extending these findings to children with ADHD.

One of the main difficulties in prospective research in atypical development is the feasibility of testing large numbers of infants in order to obtain data on a range of developmental abilities. Parent-report surveys have a number of benefits, including ease of administration for parents, and researchers' ability to collect data from larger samples in a cost-effective manner. The First Year Inventory v. 2.0 (FYIv2.0; Baranek et al., 2003; Reznick et al., 2007) is a parent-report measure of infant behavior that was designed to identify infants at risk for an eventual diagnosis of ASD. Researchers obtained completed FYIv2.0s from the parents of more than 8,700 children over the course of a multi-year study. Infants who scored above established criteria on two domains of ASD risk (social-communication and sensory-regulatory) were flagged as "at risk" for an eventual diagnosis of ASD and were invited to participate in a randomized control trial of an early intervention (Baranek et al., 2015; Watson et al., 2017). Infants who did not score as "at risk" were available for other research projects, and a subset of parents of these children constitutes the sample of the present study.

Preceding the current study, FYIv2.0 items were used to create three attention-based constructs representing social and nonsocial aspects of infant attention that could be useful in predicting typical and atypical patterns of development (Stephens et al., 2017). These constructs are Responding to Social Attention (RSA), Initiating Social Attention (ISA), and Nonsocial Sensory Attention (NSA). In both RSA and ISA, the interaction is triadic: the initiator is communicating that the responder should shift attention toward a particular stimulus. RSA refers specifically to a child's subsequent response (or lack of response or delayed response) to an adult's initiation of a bid for attention and/or interaction with a child. ISA involves a child's active bid for a social partner's attention for a variety of purposes, including drawing attention to him- or herself, acquiring a desired object, toy or other item or engaging in a desired activity. NSA refers to the degree to and manner in which a child attends to and/or acts on objects, sensory features of objects, or his/her own body.

In the current study, we used the FYIv2.0 attention constructs to predict scores on a measure of ADHD symptomatology in early childhood. Because any interpretation of significant findings between these variables could be attributed partially to the nature of the items in both surveys (i.e., designed to identify "problematic" behaviors), we also considered FYIv2.0 attention constructs in relation to parent-reported EF.

## Method

### Participants

Parents were recruited from the database of completed FYIv2.0s when their children were within 2 months of turning 54 months (4.5 years) of age. The database included contact information for parents who filled out the FYIv2.0 when their children were 12 months and who agreed to be contacted for follow-up studies but excluded infants who met the risk criteria for invitation to the intervention study. Parents and their children were recruited via phone call by trained research assistants and then emailed a link to our online surveys. Reminder emails were sent up to two times as necessary. Of the 618 parents contacted (i.e., with whom we were able to speak), most agreed to complete the online surveys ($N=361$).

At least partially completed survey data were obtained from 77.3% of parents who agreed to participate ($N=276$), with 83.3% of these completing the surveys discussed in this study ($N=230$). We excluded one additional survey based on parent report of a major medical event, resulting in a sample of 229. All surveys were completed within 2 months of children turning 54 months (4.5 years) of age. Table 1 includes full sample demographic information. Though there were similar numbers of boys and girls for whom parents completed the surveys, the sample was otherwise fairly homogenous. A majority of the sample (87.8%) was White, and most mothers reported high levels of education (92.6% had at least a 4-year college degree).

**Table 1.** Participant Demographics.

| | *M* (*SD*) |
|---|---|
| Age at follow-up (months) | 54.8 (0.99) |
| | *N* (%) |
| Gender | |
| Boys | 122 (53.3) |
| Girls | 107 (46.7) |
| Race | |
| White | 201 (87.8) |
| Black or African American | 4 (1.7) |
| Asian | 1 (0.4) |
| Other or mixed race | 23 (10.0) |
| Maternal education | |
| Less than 4-year college degree | 17 (7.4) |
| 4-year college degree | 103 (45.0) |
| Masters or professional degree | 109 (47.6) |
| Parent-reported diagnoses | |
| ASD | 4 (1.7) |
| Sensory processing/integration | 5 (2.2) |
| Language or communication | 12 (5.2) |
| Other | 1 (0.4) |

### Measures

The First Year Inventory v. 2.0 (FYIv2.0; Baranek et al., 2003): The FYIv2.0 is a 63-item parent-report questionnaire measuring 12-month-olds' behaviors representing two domains of behaviors relevant to ASD: social-communication and sensory-regulatory. Each of the domains was subdivided into four constructs (Reznick et al., 2007). Most items ($n=46$) are rated on a 4-point scale (never, seldom, sometimes, often); there are also 14 multiple choice items, two open-ended questions about concerns and physical/medical characteristics of the child, and one item about consonant sounds produced by the child. The FYIv2.0 generated risk scores for the following outcomes: social-communication, sensory-regulatory, total risk, and risk percentile. For detailed information regarding the creation, scoring, and validation of the FYIv2.0, refer to Reznick et al. (2007), Watson et al. (2007), and Turner-Brown et al. (2013).

FYIv2.0 items were used to create three attention-based constructs: Responding to Social Attention (RSA), Initiating Social Attention (ISA), and Nonsocial Sensory Attention (NSA; Stephens et al., 2017). Scores for these attention constructs were generated using the continuous scoring method described in Stephens et al., with higher scores reflecting greater deficits in attention behaviors.

*ADHD Rating Scale-IV—Preschool Version* (DuPaul et al., 1998; McGoey et al., 2007): The ADHD Rating Scale is a norm-referenced checklist that measures ADHD symptomatology and is based on diagnostic criteria of ADHD in the Diagnostic and Statistical Manual of Mental Disorders—Fourth edition (DSM-IV; American Psychiatric Association, 1994). At the time of data collection, the ADHD rating scale had not yet been updated to reflect DSM-V criteria for ADHD. The preschool version of the ADHD Rating Scale was adapted to include examples of behaviors appropriate for children aged 3 to 5 years (McGoey et al., 2007). Parents are asked to report the frequency of specific behaviors over the past 6 months on a 4-point Likert scale ranging from "Never or Rarely" to "Very Often." The rating scale generates a total raw score as well as two subscales: Inattention and Hyperactivity/Impulsivity. The ADHD Rating Scale-IV—Preschool Version demonstrates high internal consistency (*alphas* ranging from .86 to .96) and test–retest reliability (.78 to .90).

*Childhood Executive Functioning Inventory* (CHEXI; Thorell & Nyberg, 2008). The CHEXI is a 26-item parent-report inventory designed to measure executive function in children. Parents rate each item on a 5-point scale from 1 (definitely not true) to 5 (definitely true). The CHEXI includes items divided into four subscales: working memory, planning, inhibition, and regulation. These four scales load onto two factors: inhibition (items from the inhibition and regulation subscales) and working memory (items from the working memory and planning subscales). Factors demonstrate high internal consistency ($\alpha > .85$) and test–retest reliability ($r > .74$; Catale et al., 2015; Thorell & Nyberg, 2008).

### *Statistical Analysis*

All data analysis was performed using SAS 9.4. Descriptive statistics were generated to explore variable means and standard deviations. Given typical gender-related differences in the measures included in this study, independent samples *t*-tests were conducted to determine whether common patterns existed in our sample. Next, bivariate correlations were calculated to explore associations among variables of interest and covariates. For the primary analyses, regression models were estimated, predicting scores on the ADHD rating scale and the CHEXI from FYIv2.0 attention constructs. All regression models included child covariates of gender and age at time of survey as well as maternal education.

## Results

Study variables from the FYIv2.0, ADHD rating scale, and the CHEXI were explored to establish psychometric properties as well as differences across demographic variables. Significant gender differences were found for all three FYIv2.0 attention variables ($p < .05$), with boys scoring significantly higher (i.e., worse) on all three attention constructs (RSA, ISA, and NSA) in comparison to girls. In addition, all 54-month variables had statistically significant gender differences (all $p < .0001$), with parents reporting boys as having more ADHD- or EF-related behavioral deficits (see Table 2 for variable descriptive statistics). No differences were found based on maternal education or child's age, though these variables were included as covariates in all analyses.

Bivariate correlations between all of the 54-month variables were significant, with large or medium effect sizes (see Table 3). Further, correlations suggest that of the three FYIv2.0 attention variables, NSA is more closely related to the 54-month ADHD and EF variables (see Table 3).

Consistent with the bivariate correlation results, regression models predicting 54-month ADHD rating scale scores from 12-month FYIv2.0 attention variables suggest that NSA is a better predictor than RSA or ISA of later ADHD behaviors (total, inattention, and hyperactivity/impulsivity) when controlling for child gender, age, and maternal education (see Table 4). Models predicting CHEXI index scores from FYIv2.0 attention variables show similarly strong predictive value for NSA. Additionally, RSA was significantly associated with both the working memory and inhibition indexes, and ISA was significantly related to working memory after controlling for relevant covariates (see Table 4).

## Discussion

The goal of this study was to explore associations between aspects of infant attention and ratings of ADHD symptoms and executive function in preschool children. Notably, we found consistent significant associations between 12-month nonsocial sensory attention (NSA) and 4.5-year ADHD symptoms and EF behaviors. Unsurprisingly, we also found strong significant associations between the ADHD and EF measures at 4.5 years. Though this is partly attributable to the mode of assessment (parent-report), it is also consistent with the wealth of previous research describing links between ADHD and deficits in EF as described in the introduction.

In light of the limited prior research exploring the associations between infant attention and later ADHD symptomatology, a primary strength of the current study is our exploration of infant attentional behaviors in relation to ADHD symptoms specifically. Even though ratings at both time points were provided by parents, the ratings were on different measures and separated by approximately 3.5 years. Significant associations between aspects of attention in infancy and early childhood, such as reported in this study, have the potential to inform directions of later research. For example, in the current study, NSA was the FYIv2.0 attention variable most consistently associated with later ADHD and EF behaviors. This may be explained by the fact that the items in the NSA construct refer to behaviors that include visually examining, acting on or exploring nonsocial stimuli including objects, body parts, or sensory features of the nonsocial environment. Although the FYIv2.0 items in this construct were designed with ASD in mind, many of the behaviors have also been observed in children with ADHD. Multiple studies have reported that individuals with ADHD have a higher prevalence of atypical sensory responsivity compared to those without ADHD (Panagiotidi et al., 2017; Pfeiffer et al., 2015; Shimizu et al., 2014). Shimizu et al. (2014) found that children with ADHD had a greater prevalence of atypical sensory modulation and nearly all other sensory processing problems, as well as strong correlations between a variety of sensory processing and modulation impairments and inappropriate behavior and learning responses. Pfeiffer et al. (2015) indicated greater sensory modulation concerns across all sensory domains in children with ADHD relative to controls. In one of the only previous studies examining attentional behaviors in infancy in relation to ADHD, Holmboe et al. (2010) reported a link between a genetic polymorphism commonly studied in relation to ADHD and higher levels of distractibility in typically-developing infants. Distractibility may be directly linked to a child's ability to appropriately filter out irrelevant sensory information (Friedman-Hill et al., 2010; Yochman et al., 2004). Our results support the findings of this previous research and expand on it by also considering ratings of EF.

**Table 2.** Study Variable Descriptive Statistics and Comparisons by Gender.

| | Total sample $M$ ($SD$) | Boys ($n$ = 122) $M$ ($SD$) | Girls ($n$ = 107) $M$ ($SD$) | Boys vs. girls $t$, $p$ |
|---|---|---|---|---|
| RSA mean | 1.35 (0.24) | 1.38 (0.25) | 1.32 (0.21) | 2.06, .041 |
| ISA mean | 1.58 (0.44) | 1.63 (0.46) | 1.52 (0.40) | 1.98, .048 |
| NSA mean | 1.64 (0.35) | 1.69 (0.34) | 1.58 (0.35) | 2.45, .015 |
| Total ADHD raw score | 10.62 (7.94) | 12.93 (8.60) | 7.99 (6.17) | 5.04, <.0001 |
| Inattention | 4.68 (3.98) | 5.86 (4.16) | 3.34 (3.30) | 5.11, <.0001 |
| Hyperactivity | 5.94 (4.69) | 7.07 (5.24) | 4.65 (3.57) | 4.12, <.0001 |
| Working Memory Index | 1.93 (0.67) | 2.14 (0.68) | 1.70 (0.57) | 5.29, <.0001 |
| Inhibition Index | 2.45 (0.73) | 2.69 (0.72) | 2.18 (0.64) | 5.58, <.0001 |

**Table 3.** Bivariate Correlations Among Study Variables.

| | RSA | ISA | NSA | Total ADHD | Inattention | Hyperactivity | WM Index |
|---|---|---|---|---|---|---|---|
| RSA | — | | | | | | |
| ISA | .60*** | — | | | | | |
| NSA | .27*** | .11 | — | | | | |
| Total raw | .13+ | .14* | .32*** | — | | | |
| Inattention | .14* | .17** | .32*** | +++ | — | | |
| Hyperactivity | .10 | .09 | .27*** | +++ | .68*** | — | |
| WM Index | .30*** | .25** | .33*** | .65*** | .75*** | .47*** | |
| Inhibition Index | .20** | .14* | .37*** | .77*** | .75*** | .66*** | .78*** |

*Note.* Total ADHD raw score is computed as a sum of the inattention and hyperactivity subscales. WM = working memory.
*$p$ < .05. **$p$ < .01. ***$p$ < .0001. +$p$ < .10. +++Correlation not valid.

We chose to include measures of EF in addition to ratings of ADHD symptomatology because of the strong established links between ADHD and EF deficits. Our results suggest that measures of EF may be similarly related to early sensory behaviors, as NSA was also significantly related to both working memory and inhibition. Aspects of EF such as working memory and inhibition may exert top-down control over prepotent responses to distracting stimuli and therefore help regulate sensory processing. The two social attention variables, RSA and ISA, were not significantly correlated with ADHD symptom severity at 4.5 years. However, RSA was significantly associated with both the working memory and inhibition indexes, and ISA was significantly related to working memory. This finding is consistent with other studies that found IJA to be linked to certain aspects of executive function, such as working memory and response inhibition (McEvoy et al., 1993; Mundy et al., 2000). Our results suggest that these social aspects of attention are associated with EF but not ADHD symptoms, a pattern aligned with well-known associations between EF and ASD as measured by both diagnostic status and dimensional methods (Happé et al., 2006; Ozonoff & McEvoy, 1994; Stephens et al., 2018). It is possible that impairments in all three attention constructs (RSA, ISA, and NSA) in an infant may be predictive of ASD, possibly comorbid with ADHD, whereas deficits specific to NSA may be a better indicator of ADHD without ASD.

A strength of the current study is the use of a dimensional outcome measure of ADHD. There is substantial research examining group differences in EF abilities, comparing children diagnosed with ADHD to typically-developing controls. However, the structure of these analyses neglects a key group of individuals: those with subthreshold ADHD symptoms who would not receive a diagnosis but who are likely to demonstrate many of the deficits often associated with ADHD (Hong et al., 2014). By utilizing a dimensional approach to ADHD symptom severity, the current study was able to focus on the full range of functioning and potential impairment. The use of dimensional approaches has the potential to identify individuals who might benefit from early, pre-emptive interventions designed to prevent or attenuate the disabilities that can develop from the cascading effects of impairments in attention or EF on learning and adaptation.

In this sample, boys were rated as having higher (worse) attention behaviors in infancy, which is consistent with previous research. For example, even as newborns, girls display better discrimination of and attention to verbal stimuli than do boys (Friederici et al., 2008; Friedman & Jacobs, 1981). In addition, girls tend to show better eye contact during the first year of life (Leeb & Rejskind, 2004) and engage in higher joint attention levels (Olafsen et al., 2006), which thus may facilitate their response to verbal communication

**Table 4.** Models Predicting 54-Month ADHD Symptoms and EF From 12-Month Attention Scores.

| | Total raw | | Inattention | | Hyperactivity | | Working Memory Index | | Inhibition Index | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *B* (*SE*) | $pr^2$ | *B* (*SE*) | $pr^2$ | *B* (*SE*) | $pr^2$ | *B* (*SE*) | $pr^2$ | *B* (*SE*) | $pr^2$ |
| RSA | 3.01 (2.15) | .02 | 1.70 (1.07) | .02 | 1.31 (1.29) | .01 | 0.73 (0.17)*** | .09 | 0.48 (0.19)* | .04 |
| Gender | −4.79 (1.01)*** | .09 | −2.42 (0.51)*** | .09 | −2.37 (0.61)** | .06 | −0.40 (0.04)*** | .10 | −0.48 (0.09)*** | .11 |
| Mat Edu | −0.42 (0.55) | .00 | −0.17 (0.28) | .00 | −0.26 (0.33) | .00 | −0.02 (0.04) | .00 | −0.03 (0.05) | .00 |
| Age | −0.21 (0.51) | .00 | 0.03 (0.25) | .00 | −0.24 (0.31) | .00 | −0.01 (0.04) | .00 | 0.03 (0.05) | .00 |
| ISA | 1.88 (1.16) | .02 | 1.22 (0.58)* | .03 | 0.66 (0.70) | .01 | 0.33 (0.09)** | .06 | 0.16 (0.10) | .02 |
| Gender | −4.77 (1.01)*** | .09 | −2.39 (0.50)*** | .09 | −2.38 (0.61)** | .06 | −0.41 (0.08)*** | .10 | −0.49 (0.09)*** | .00 |
| Mat Edu | −0.49 (0.55) | .00 | −0.21 (0.28) | .00 | −0.28 (0.33) | .00 | −0.03 (0.05) | .00 | −0.03 (0.05) | .11 |
| Age | −0.18 (0.51) | .00 | 0.05 (0.25) | .00 | −0.23 (0.31) | .00 | −0.00 (0.04) | .00 | 0.04 (0.05) | .00 |
| NSA | 6.14 (1.41)*** | .10 | 3.08 (0.70)*** | .10 | 3.06 (0.86)** | .07 | 0.55 (0.12)*** | .11 | 0.69 (0.12)*** | .14 |
| Gender | −4.27 (0.98)*** | .08 | −2.18 (0.49)*** | .07 | −2.10 (0.60)** | .05 | −0.38 (0.08)*** | .09 | −0.43 (0.09)*** | .10 |
| Mat Edu | −0.21 (0.54) | .00 | −0.06 (0.27) | .00 | −0.15 (0.33) | .00 | 0.00 (0.04) | .00 | 0.00 (.05) | .00 |
| Age | −0.13 (0.49) | .00 | 0.07 (0.25) | .00 | −0.20 (0.30) | .00 | 0.00 (0.04) | .00 | 0.04 (0.04) | .00 |

*Note.* Mat Edu = maternal education.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .0001$.

and to the nonverbal signals accompanying it. Gender differences were also present in the ADHD and EF measures at 4.5 years, findings that are consistent with existing research. Studies have shown that boys diagnosed with ADHD show higher ratings in hyperactivity, impulsivity and other externalizing behaviors, compared to girls with ADHD (Gaub & Carlson, 1997; Gershon, 2002).

There also were significant differences between boys and girls in parent reported EF, with girls rated significantly better in both working memory and inhibitory control. This is consistent with findings in other studies exploring gender differences in EF across the lifespan. For example, Mileva-Seitz et al. (2015) reported that 4-year-old girls outperformed boys on tests of inhibitory control. Additionally, Lynn and Irwing (2008) found that girls demonstrated better working memory during childhood and adolescence, but in adults, males performed better. These researchers suggest that since the advantage for girls is greater at a younger age, boys may make compensatory gains during middle childhood and adolescence.

A primary limitation to the current study is the reliance on parent-report measures. Although these are cost-effective and efficient techniques for obtaining data about infant behaviors, their validity is frequently undetermined. Complementing them with laboratory measures would provide a clearer picture. Moreover, these attention constructs were derived from the FYIv2.0, which is a measure of risk for ASD in both the social-communication and sensory-regulatory domains, so some of its items may not be the most suitable or relevant indicators for assessing attention behaviors in infants more broadly. Perhaps most notably, the sample analyzed in this study is very demographically homogenous; the majority of respondents were white mothers with high levels of education. Further, infants who scored above established criteria on the FYIv2.0 and were flagged as "at risk" were not included in this study, so we cannot be certain that our findings would extend across the full range of development. Both of these factors limit the generalizability of our findings. However, given the strength of the associations among study variables, it is reasonable to expect that results would likely extend to more diverse samples. Lastly, it is possible that the strong associations may be a factor of children's overall developmental trajectories. Including a measure of general ability as a covariate in analyses could help determine if infant attention and early childhood ADHD symptomatology and EF are associated above and beyond developmental level.

A primary goal of future research should be to explore these associations in children using laboratory-based assessments. For example, standardized measures such as the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Wechsler, 2012) or the NIH Toolbox (Zelazo & Bauer, 2013) include a number of scales that have been used to measure cognition in early childhood. Additionally, there are batteries specifically designed to study EF in preschool-aged children (Wiebe et al., 2011; Willoughby & Blair, 2011). Future research should also examine this association in larger, more diverse samples.

Additionally, it would be interesting to determine if these longitudinal associations held after a longer period of time. For example, if we were to follow-up with families when children were in middle or late childhood, would the patterns still hold? This would also allow for the collection of data regarding ADHD diagnoses. Although there are clear benefits to using a dimensional measure of symptomatology, it would be interesting to see if specific patterns of infant attentional behaviors were predictive of an actual diagnosis later in childhood. Lastly, a goal of future research is to determine if infant attentional behaviors associated with later ADHD could be potential targets for early intervention. Identifying early markers of risk for ADHD could inform intervention efforts designed to mediate some of the later deficits associated with the disorder, such as EF.

## Conclusion

In this study, we demonstrated that social and nonsocial sensory attention constructs, measured by parent report in 12-month-old infants, were associated with parent reported EF at 54 months of age, whereas only nonsocial sensory attention in infancy was significantly predictive of ADHD symptoms at preschool age. The use of a dimensional measure of emergent ADHD provides valuable insight into the full range of symptomatology. In the context of a very small literature examining variables in infancy that are related to later ADHD and associated behaviors, this study contributes unique findings regarding the longitudinal relationship between infant attention and ADHD symptoms in early childhood.

### Acknowledgments

We'd like to extend our gratitude to the many North Carolina families who participated in this research. Additionally, we are grateful to the Program for Early Autism Research, Leadership & Service (PEARLS) team, including co-investigators Grace Baranek, PhD, and Lauren Turner-Brown, PhD, for their role in the development of the FYIv2.0 and to the undergraduate researchers at the University of North Carolina at Chapel Hill who assisted with the follow-up study.

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by a grant from the Institute of Education Sciences, U.S. Department of Education (R324A100305) to the

University of North Carolina at Chapel Hill. The opinions expressed are those of the authors and do not represent views of the funding agency.

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