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Positive Emotional Attention Bias in Young Children with Symptoms of ADHD

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Abstract

Children with attention-deficit/hyperactivity disorder (ADHD) often experience emotional dysregulation. Dysregulation can arise from heightened attention to emotional stimuli. Emotional attention biases are associated with a number of adverse socioemotional outcomes including reward sensitivity and externalizing behaviors. As reward sensitivity and externalizing behaviors are common in children with ADHD, the aim of the current study was to determine whether emotional attention biases are evident in young children with clinically significant ADHD symptoms. To test this, children with ($n = 18$) and without ($n = 15$) symptoms of ADHD were tested on a Dot Probe task. Provided recent evidence that emotional attention biases are attenuated by sleep, the task was performed before and after overnight sleep. Children with ADHD symptoms displayed positive, but not negative, attention biases at both time points whereas typically developing children did not preferentially attend toward or away from positive or negative stimuli. Sleep did not alter attention biases in either group. Collectively, these results indicate that children with ADHD symptoms have stable, positive attention biases.

Keywords

ADHD; sleep; emotion; development; attention biases

Emotional dysregulation is reported in 25–45% of children with attention-deficit/hyperactivity disorder (ADHD; Shaw, Stringaris, Nigg, & Leibenluft, 2014). As a consequence of emotional dysregulation, children with ADHD are often characterized as emotionally reactive, short-tempered, and irritable (Barkley, 2006; Shaw et al., 2014). Children with ADHD also have high risk of socioemotional deficits that are detrimental to healthy development (Jensen et al., 2001). As such, identifying factors that contribute to emotional dysregulation in ADHD may improve outcomes in this population.

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Emotional dysregulation arises from improper ‘top-down’ processes including heightened attention to emotional stimuli (Shaw et al., 2014). Preferential allocation of attention toward emotional stimuli is referred to as emotional attention bias. Although emotional attention biases have not been directly assessed in a young ADHD population, evidence suggests that attention toward emotional stimuli is altered in ADHD. For example, adolescents with ADHD have slower reaction times (RT) to negative versus positive stimuli in an emotional Stroop task (Passarotti, Sweeney, & Pavuluri, 2010a). Similarly, when passively viewing negative facial stimuli, neural markers of attention to facial stimuli (specifically fear faces) are reduced in young children with ADHD symptoms (Flegenheimer, Lugo-Candelas, Harvey, & McDermott, 2017). Collectively, these studies suggest that children with ADHD may have an attention bias away from negative stimuli and an attention bias toward positive stimuli.

In typically developing (TD) populations, attention biases toward negative stimuli are consistently related to maladaptive outcomes such as anxiety and social difficulties (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007 for review). Outcomes associated with positive attention biases, on the other hand, are mixed. Among children placed into high quality foster care, attention biases toward positive stimuli were associated with adaptive outcomes, including higher rates of social engagement and prosocial behaviors and fewer externalizing and emotionally withdrawn behaviors (Troller-Renfree, McDermott, Nelson, Zeanah, & Fox, 2015). However, positive attention biases have also been linked to maladaptive outcomes ranging from approach-oriented behaviors associated with heightened reward sensitivity (Castellanos et al., 2009; Freeman, Morgan, Beesley, & Curran, 2012) to externalizing behaviors (Morales, Perez-Edgar, & Buss, 2016).

Relative to TD children, those with ADHD have greater reward sensitivity (Tripp & Alsop, 2001) and have heightened rates of anxiety and externalizing behaviors (Jensen et al., 2001), which can hinder adaptive development. Emotional attention biases have been linked to these outcomes and may underlie the development of comorbid psychopathology in children with ADHD. However, little is known about the nature of attention biases in children with ADHD symptoms. As such, understanding these processes early in development, as these comorbid conditions are emerging, may be particularly useful and may point to critical targets for early intervention.

Current Study

The aim of the current study was to determine if emotional attention biases are evident in young children with ADHD symptoms. Emotional attention biases were evaluated in children between 4–8 years of age, the age range in which ADHD symptoms first emerge (Applegate et al., 1997), in an effort to identify critical targets for early intervention. Based on recent studies (Williams et al., 2008; Flegenheimer et al., 2017), we hypothesized that children with symptoms of ADHD would display a bias away from negative stimuli. In accordance with results of Passarotti et al. (2010a), we hypothesized that children with ADHD symptoms would be biased toward positive stimuli. We did not expect to observe negative or positive attention biases in TD children.

Recent research indicates that naps attenuate emotional attention biases in TD preschool-aged children (Cremone, Kurdziel, Fraticelli-Torres, McDermott, & Spencer, 2016). However, the role of overnight sleep on emotional attention in children has not yet been studied. Moreover, previous studies evaluating sleep in young children are limited and have primarily focused on the role of sleep in emotional memory consolidation (see Prehn-Kristensen, Munz, Molzow, Wilhelm, Wiesner, & Baving, 2013). To characterize relations between sleep and emotional attention, the current study examined the effect of overnight sleep on emotional attention biases in young children with and without ADHD symptoms. We hypothesized that emotional attention biases would be reduced following overnight sleep in TD children. As sleep problems are common in ADHD (Owens, 2005; Yoon, Jain, & Shapiro, 2012; Weiss, Craig, Davies, Schibuk, & Stein, 2015), we did not predict that sleep would affect emotional attention biases in children with ADHD symptoms.

Materials and Methods

Participants

Thirty-three children, 4–8 years of age, participated in the study. Children were recruited from a larger study assessing emotional competence in young children with ADHD symptoms (Lugo-Candelas, Flegenheimer, McDermott, & Harvey, 2016) as well as community advertisements and the Child Studies Database at the University of Massachusetts Amherst. ADHD is not typically diagnosed until children enroll in formal schooling (approximately 7 years of age; Applegate et al., 1997). Yet, we were interested in a point of early intervention. As such, a formal diagnosis of ADHD was not a required for participation. Rather, caregivers completed a pre-screening phone interview to determine the child's eligibility and group placement (ADHD or TD control) using the Diagnostic Interview Schedule for Children IV (DISC-IV; Shaffer, Fischer, Lucas, Dulcan, & Schwab-Stone, 2000). Children were eligible to participate if they had normal or corrected-to-normal vision and no diagnosed sleep disorder, intellectual disability, or developmental delay (as reported by caregivers).

The ADHD group was composed of children who had at least six symptoms of hyperactivity/impulsivity, at least three of which were present in two settings, from the ADHD section of the DISC-IV (Shaffer et al., 2000). Symptoms of hyperactivity/impulsivity were used to determine ADHD status because the presentation of inattentive symptoms typically has a later age of onset (Applegate et al., 1997). Typically developing controls were defined as having three or fewer symptoms on the ADHD section of DISC-IV.

Of the 33 children screened into the study, 18 (5 F; $M_{age} = 6.70$, $SD = 1.07$ years) were assigned to the ADHD group. Seven children in the ADHD group (0 F; $M_{age} = 6.70$, $SD = 1.07$ years) had a formal diagnosis of ADHD. Two of the children with a formal diagnosis were taking medications for ADHD symptom management and were asked to abstain from using medications for ADHD 48 h prior of the overnight visit.¹ Fifteen children (4 F; $M_{age} = 6.73$, $SD = 0.71$ years) were classified as TD controls. TD controls did not report taking any

¹The results of the omnibus ANOVA were unchanged when children with a formal diagnosis of ADHD ($n = 7$, data missing from 1 child) and when children taking medications for ADHD ($n = 2$) were excluded from analyses.

medications. Participant demographics, average group symptom ratings, and average group sleep durations are presented in Table 1.

Dot Probe Task

In the Dot Probe task, happy/neutral and angry/neutral face pairs were presented on a computer screen (1000 ms) following the presentation of a central fixation mark (500 ms). A probe (yellow star) then appeared in place of one of the previously presented faces in the face pair (1100 ms). Trials were “congruent” if the probe appeared in place of the emotional face (i.e., happy or angry) and “incongruent” if the probe appeared in place of the neutral face (see Figure 1A and Cremone et al., 2016). Children were instructed to press one of two buttons (left versus right) on a computer mouse to indicate the location of the probe on the screen as quickly and accurately as possible. A blank screen was presented between trials (750 or 1250 ms, randomized).

Procedure

Procedures were approved by the Institutional Review Board at the University of Massachusetts Amherst. Caregivers consented to their child’s participation and child verbal assent was obtained before commencing with experimental procedures.

Caregivers and children were scheduled to arrive at the laboratory approximately one hour before the child’s typical bedtime. Upon arrival, children completed the initial, pre-sleep assessment on the Dot Probe task. Children were given eight practice trials to ensure that they understood task instructions. Subsequently, children were presented with two blocks of 32 experimental trials each. There were two pseudo-random trial orders used for all participants (counterbalanced across participants). The task took approximately 10–15 minutes to complete.

Following the pre-sleep assessment, children and caregivers slept in separate beds in the same room in the laboratory overnight. Experimenters recorded the length of time children slept (experimental sleep duration). Approximately 30 minutes after wake onset (to mitigate sleep inertia), children completed the Dot Probe task once more with a unique trial order (post-sleep assessment). Caregivers were provided monetary compensation and children were given an age-appropriate prize for their participation.

Statistical Analyses

For each child, positive and negative attention bias scores were calculated separately for pre- and post-sleep assessments. Consistent with previous literature (MacLeod, Mathews, & Tata, 1986; Cremone et al., 2016), attention bias scores were calculated by subtracting the RT for correct congruent trials (probe behind emotional face) from the RT for correct incongruent trials (probe behind neutral face). Thus, an attention bias score greater than zero represents attention toward the emotional stimuli whereas an attention bias score less than zero represents avoidance of the emotional stimuli.

A mixed-design ANOVA was used to assess emotional attention biases in the two groups of children across pre- and post-sleep assessments. Time of assessment (pre- and post-sleep)

and emotion (happy and angry) were entered as within-subject factors and group (ADHD and TD) was entered as a between-subject factor. The results of this ANOVA motivated follow-up one-sample *t*-tests to confirm the presence (or absence) of emotional attention biases, independently, within each group (Cremone et al., 2016). Additionally, independent samples *t*-tests to compare emotional attention biases between groups (ADHD vs. TD). Because there was no significant effect of time, pre- and post-sleep assessments were collapsed in these analyses.

Results

Participant demographics are presented in Table 1. Child age, $t(31) = -.08, p = .937$, gender, $X^2(1, N = 33) = .01, p = .943$, and ethnicity, $X^2(4, N = 33) = 6.25, p = .182$, were not significantly different between groups. Not surprisingly, children in the ADHD group had significantly more symptoms of hyperactivity/impulsivity and inattention than children in the TD group ($ps < .001$). Overnight sleep duration on the experimental night did not differ between groups, $t(31) = -.53, p = .599$.

In the mixed-design ANOVA, the main effects of time, emotion, and group were not significant ($ps > .310$). The two-way interactions between time and group and time and emotion were not significant ($ps > .215$). Likewise, the three-way interaction between time, emotion, and group was not significant, $F(1, 31) = 2.29, p = .978$. However, the group by emotion interaction was significant, $F(1, 31) = 5.72, p = .023, \eta_p^2 = .156$ (see Figure 1B), suggesting that emotional attention biases differed among children with and without ADHD symptoms.

One-sample *t*-tests confirmed the emergence of emotional attention biases in these groups. Children with symptoms of ADHD had significant attention biases toward positive stimuli (happy faces), $t(17) = 2.42, p = .027$, 95% CI [2.23, 33.09]. Typically developing children had no significant attention bias for positive stimuli, $t(14) = -1.61, p = .130$, 95% CI [-25.82, 3.68]. Negative attention biases were not observed in either group ($ps > .483$).

Independent samples *t*-tests were then used to compare emotional attention biases between children with and without ADHD symptoms. Attention biases toward positive stimuli were significantly greater in children with ADHD symptoms, as compared to TD children, $t(31) = 2.82, p = .008$, 95% CI [7.96, 49.49]. Negative attention biases did not differ between groups, $t(31) = -.81, p = .422$.

Discussion

Our findings indicate that young children with ADHD symptoms have attention biases toward positive, but not negative, stimuli. Typically developing children, on the other hand, do not have attention biases toward either positive or negative emotional stimuli. Attention biases were not influenced by sleep, suggesting that vigilance to positive stimuli is stable in children with ADHD symptoms.

In TD populations, positive attention biases have been linked to adverse outcomes such as reward sensitivity (Castellanos et al., 2009; Freeman et al., 2012) and externalizing

behaviors (Morales et al., 2016). Relative to TD children, those with ADHD have heightened levels of reward sensitivity (Tripp & Alsop, 2001) as well as greater rates of externalizing behaviors (Jensen et al., 2001). Preferential attention toward positive stimuli may contribute to these outcomes by impairing the ability to learn from other socioemotional cues intended to shape behavior (e.g., punishment; Shaw et al., 2014).

Neuroimaging data support this hypothesis, as accumulating evidence suggests that neural responses to emotional stimuli differ among individuals with and without ADHD. Relative to TD controls, children with ADHD have reduced activation of the PFC in the presence of negative stimuli and increased activation of the PFC in the presence of positive stimuli during an emotional Stroop task (Passarotti, Sweeney, & Pavuluri, 2010a; Posner, Maia, Fair, Peterson, Sonuga-Barke, & Nagel, 2011) and an emotional working memory task (Passarotti, Sweeney, & Pavuluri, 2010b). Additionally, individuals with ADHD have increased connectivity between the ventral striatum and the PFC and decreased connectivity between these regions and the networks that support attention allocation (Tomasi & Volkow, 2012; Costa Dias et al., 2013). As such, additional studies utilizing neuroimaging are needed to better understand relations between neural activity and emotional attention in children with ADHD.

In contrast to positive stimuli, neither group preferentially attended toward negative stimuli. In TD populations, the lack of a negative attention bias is indicative of “normative” socioemotional functioning (e.g., MacLeod, Mathews, & Tata, 1986; Waters, Lipp, & Spencer, 2004). Rather, negative attention biases are consistently reported among anxious individuals (Cisler & Koster, 2010). Although children with ADHD typically have high levels of anxiety (Jensen et al., 2001), our ADHD sample did not have an attention bias toward or away from negative stimuli. This result contrasts with evidence that children with ADHD have attenuated neural responses to negative stimuli (Flegenhimer et al., 2017). Collectively, these findings suggest that attention toward negative stimuli may be similar among TD and ADHD children at the behavioral level, but neural processing of negative stimuli may differ between these groups. Future studies utilizing electrophysiology should assess the neural underpinnings of emotional attention biases in a larger sample of children with ADHD, and varying levels of anxiety, to assess the role of negative attention biases in developmental psychopathology.

The results of the current study suggest that emotional attention biases are unchanged following overnight sleep in children with and without symptoms of ADHD. Our hypothesis regarding the sleep-dependent reduction of emotional attention biases in TD children was based on the results of a study evaluating emotional attention following a mid-day nap in preschoolers. These children exhibited emotional attention biases when nap-deprived; however, those attention biases were mitigated when children napped (Cremone et al., 2016). In young children, particularly children who nap habitually, naps are needed to reduce the emotional load that accumulates over the day. If deprived of a nap, the emotional load continues to accumulate and can enhance attention to emotional stimuli. Since naps are less common in older children, we hypothesized that emotional attention biases would be greater in the evening and reduced the morning following overnight sleep. However, this hypothesis was not supported by data in the current study. Together, these data suggest that,

among TD children, attention toward emotional stimuli is heightened following sleep deprivation (i.e., nap deprivation) but unchanged following a period of sleep (i.e., nap and overnight sleep). In accordance with our hypothesis, emotional attention biases were unchanged following overnight sleep in children with ADHD symptoms.

Conclusions

To our knowledge, this study is the first to assess group differences in emotional attention biases between young children with and without ADHD symptoms. Our results indicate that children with ADHD symptoms exhibit attention biases toward positive, but not negative, stimuli whereas TD children do not direct attention toward or away from positive or negative stimuli, regardless of having slept or not. Positive attention biases are associated with maladaptive outcomes (i.e., reward sensitivity and externalizing behaviors) in TD populations. We hypothesize that the presence of emotional attention biases may interfere with the interpretation of socioemotional cues needed to shape adaptive behaviors throughout development (Corbett & Glidden, 2000) and, consequently, contribute to emotional dysregulation in children with ADHD. Specifically, positive attention biases may be associated with heightened reward sensitivity in children with ADHD, causing overreliance on positive cues (i.e., reward), which may contribute to symptomatology.

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Figure 1.

(A) Order and duration of stimulus presentation during the Dot Probe task. Congruent trials were those in which the probe appeared in place of the emotional face (left). Incongruent trials were those in which the probe appeared in place of the neutral face (right). (B) Attention biases to happy and angry stimuli for children with and without symptoms of ADHD (collapsed across pre- and post-sleep assessments). Note: Marginal means are presented from the mixed-design ANOVA; Error bars represent standard error

Table 1.

Participant demographics.

	ADHD	TD	
	Mean (SD)	Mean (SD)	<i>p</i> -value
Participant Demographics			
Age (years)	6.70 (1.07)	6.73 (0.71)	0.942
Gender (Females: Males)	5:13	4:11	0.943
Hyperactive Symptoms	7.28 (1.02)	0.27 (0.80)	0.001 ^a
Inattentive Symptoms	6.06 (2.13)	0.67 (1.59)	0.001 ^a
Experimental Sleep Duration (mins)	562.72 (72.32)	575.53 (64.62)	0.599

Notes: *p*-values from independent samples *t*-tests (age, symptoms, and experimental sleep duration) and a chi-squared test (gender) used to compare variables between groups.

^a95% CIs of the difference between groups = [6.35, 7.67] and [4.03, 6.75], respectively.