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Regulation of emotion in ADHD: Can children with ADHD override the natural tendency to approach positive and avoid negative pictures?

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Abstract

Studies have demonstrated inefficient use of antecedent-focused emotion regulation strategies in children with ADHD attention-deficit/hyperactivity disorder (ADHD). In the current study we tested for the first time if ADHD is also associated with difficulties in response-focused strategies by measuring the ability to override action tendencies induced by emotional information. Performance data on a computer based approach-avoidance paradigm of 28 children with ADHD and 38 typically developing children between 8 and 15 years of age were analyzed comparing a congruent condition in which they were instructed to approach positive and avoid negative pictures and an incongruent condition where they had to override these automatic reactions and approach negative and avoid positive pictures. Children also rated the valence and salience of the pictures. Children with ADHD and typically developing children rated the emotional valence of the pictures appropriately and similarly, while positive pictures were rated as more arousing by children with ADHD. Solid congruency effects were found indicating that the task measured response-focused emotion regulation, however groups did not differ in this respect. Our findings do not support a deficit in emotion regulation in ADHD in terms of the ability to override natural tendencies to approach positive and avoid negative pictures.

Keywords: ADHD; emotion regulation; approach-avoidance; children

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a prevalent neurodevelopmental disorder, characterized by attention problems and/or hyperactive and impulsive behavior (American Psychiatric Association, 2013; Willcutt, 2012). In addition to these core symptoms, emotional dysregulation has been recognized as an important additional feature of ADHD (Shaw, Stringaris, Nigg, & Leibenluft, 2014). Parents and teachers portray children with ADHD as having difficulties in regulating emotions, over-reacting emotionally to everyday situations and experiencing more intense emotional reactions (Anastopoulos et al., 2011). Children with ADHD are also often emotionally labile (Anastopoulos et al., 2011; Skirrow, McLoughlin, Kuntsi, & Asherson, 2009; Sobanski et al., 2010; Stringaris & Goodman, 2009), displaying mood swings, short-temperedness, irritability, and low frustration tolerance (Sobanski et al., 2010). The prevalence rates for emotional dysregulation in ADHD range from 25% to 45% in children and from 30% to 70% in adults (Shaw et al., 2014). Assigning this tendency to ADHD is complicated by the frequent comorbidity of ADHD with internalizing or externalizing disorders characterized by emotional problems like anxiety/depression, and disruptive behavior disorders (Angold, Costello, & Erkanli, 1999; Jensen et al., 2001; Kowatch, Youngstrom, Danielyan, & Findling, 2005; Meinzer, Pettit, & Viswesvaran, 2014; Tsang et al., 2015; Waschbusch, 2002).

Emotion regulation is defined as the modulation of our emotions and of the experience and expression of these emotions in order to reach a certain goal (Gross, 2015). Several methods have been applied in research to study emotion regulation difficulties in ADHD. Besides questionnaires, either self- or parent-report (for an overview of studies, see Shaw et al., 2014), observational methods have frequently been applied (e.g., Abikoff et al., 2002; Maedgen & Carlson, 2000; Scime & Norvilitis, 2006; Walcott & Landau, 2004), indicating more

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aggression, more maladaptive emotion regulation strategies and less adaptive strategies.

These studies, which often observe children acting in the face of emotionally challenging situations (e.g., performing a difficult task; delay gratification), have sometimes shown increased negative affect in ADHD, suggesting diminished emotion regulation. However, it is difficult to attribute differences in the way children *react* to provocative situations (i.e., emotional reactivity) to difficulties in *regulating* these reactions (i.e., emotion regulation). Researchers have tried to address this by implementing experimental designs in their studies; these studies are however relatively scarce. Mostly, these studies have focused on executive control in emotionally provocative contexts (e.g., emotional stroop task; emotional working memory task). The picture provided by these studies is inconsistent. Some studies have reported increased interference of emotional stimuli on task performance in children and adolescents with ADHD compared to typically developing peers (Köchel, Leutgeb, & Schienle, 2014; López-Martín, Albert, Fernández-Jaén, & Carretié, 2013; Posner et al., 2011), while other studies found no impairment in emotion regulation compared to a typically developing group. For instance, Passarotti, Sweeney, and Pavuluri (2010) and Van Cauwenberge, Sonuga-Barke, Hoppenbrouwers, Van Leeuwen, and Wiersema (2015) reported that patients with ADHD experienced no increase in interference specifically from irrelevant emotional information in a working memory task – patients with ADHD performed worse than controls on all tasks presenting irrelevant information irrespective of emotional content. The latter authors concluded that the clinically observed problems with emotion regulation in some children with ADHD may merely be a reflection of more generic problems with interference control (Van Cauwenberge et al., 2015).

In the above-mentioned experimental studies, emotion regulation is indexed by the child's ability to maintain adequate task performance while distracted by task-irrelevant emotional information. This aspect of emotion regulation, the ability to attribute attention to a particular

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task in the presence of emotional information, relates to the antecedent-focused strategy of attentional deployment in the process model of Gross (2015). Besides antecedent-focused strategies, response-focused strategies can be employed to modulate the behavioral and physiological response tendencies activated by emotions, referred to as response modulation in the model of Gross. Overriding deep seated action tendencies (i.e., the behavioral response tendencies) that lead us to approach positive and attractive and avoid negative or punitive emotional stimuli or situations forms a crucial aspect of effective emotion regulation because it is a fundamental element in the ability to resist temptations or to face dangerous and difficult situations (Bamford et al., 2015; Ent, Baumeister, & Tice, 2015; Gross, 2015). Therefore, in the current study, we applied an approach-avoidance paradigm, in which participants have to modulate their natural action tendencies in responding to emotional pictures (Bamford et al., 2015; Chen & Bargh, 1999). The ability to override natural approach-avoidance action tendencies is less influenced by general cognitive control abilities. This is because, in the approach-avoidance paradigm, participants are specifically instructed to regulate their natural action tendencies to emotional stimuli, while load on other cognitive control abilities is kept to a minimum. In contrast, in other experimental paradigms, the aim is to maintain cognitive performance in the context of interfering irrelevant emotional stimuli and results also depend on general cognitive control abilities (Van Cauwenberge et al., 2015).

This is the first study to use the approach-avoidance paradigm to study emotion regulation in ADHD. The paradigm is based on the idea that these tendencies are biologically rooted in the reinforcement sensitivity systems (Gray & McNaughton, 2000). The behavioral activation system (BAS) is activated when we are faced with signals of reward, resulting in approach behavior, whereas the fight-flight-freeze system (FFFS) is sensitive to punishment and promotes avoidance. The behavioral inhibition system (BIS) is activated in the presence of conflicting cues, giving rise to inhibition of ongoing behavior (Gray & McNaughton, 2000). It

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has been reported that symptoms of inattention in ADHD are underpinned by an overactive BIS (Gomez & Corr, 2010; Heym, Kantini, Checkley, & Cassaday, 2015; Hundt, Kimbrel, Mitchell, & Nelson-Gray, 2008; Mitchell & Nelson-Gray, 2006). Findings with regard to hyperactivity/impulsivity are less consistent as it has been associated with higher and lower levels of BAS (Gomez & Corr, 2010; Heym et al., 2015), but also higher and lower levels of BIS (Heym et al., 2015; Hundt et al., 2008; Mitchell & Nelson-Gray, 2006). In addition, there is some evidence for a link between hyperactivity/impulsivity and increased FFFS (Heym et al., 2015). The measure of response modulation, in the approach-avoidance paradigm, is derived by comparing a condition where participants are instructed to approach positive and avoid negative emotional stimuli (congruent condition) and one where the instruction is to avoid positive and approach negative emotional stimuli (incongruent condition). This latter condition instructs individuals to apply response modulation. Previous studies in the typical population have shown that reaction times are faster in the congruent compared to the incongruent condition as one would predict (Bamford et al., 2015; Bamford & Ward, 2008; Chen & Bargh, 1999; Phaf, Mohr, Rotteveel, & Wicherts, 2014). This congruency effect reflects the additional effort/cognitive resources needed to override the natural approach-avoidance action tendencies; a greater congruency effect therefore indexes more difficulties in response modulation. The approach-avoidance effect has been shown to appear for many types of emotional stimuli and across several versions of the paradigm (see for a meta-analysis Phaf et al., 2014). Importantly, the approach-avoidance paradigm has successfully been used in children, adults and clinical samples (e.g., Brown et al., 2014; Deckers, Roelofs, Muris, & Rinck, 2014; Klein, Becker, & Rinck, 2011), and the congruency effect has been externally validated as an index of emotion regulation in a recent study that demonstrated a link between the congruency effect and electrophysiological indices of emotion regulation (Bamford et al., 2015). We hypothesized that if emotion regulation difficulties in children

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with ADHD involve insufficient use of response-focused strategies, they would have a larger congruency effect than typically developing children.

Method

Participants

Eighty one children aged 8 to 15 years old (38 with ADHD and 43 typically developing controls) took part in the study. The children in the ADHD group were partly recruited from the Flemish longitudinal cohort study 'JOnG!' (more information on the aims and design in Grietens, Hoppenbrouwers, Desoete, Wiersema, & Van Leeuwen, 2010), and partly from local clinics and via advertisements. The typically developing (TD) children were recruited from the study 'JOnG!', from local schools and via advertisements. All the children with ADHD had a formal clinical diagnosis of ADHD when they entered the study. In addition, this diagnosis was verified and confirmed for all but five children (who were excluded) using the Diagnostic Interview Schedule for Children – IV (DISC-IV; Schaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000; Dutch translation: Ferdinand & van der Ende, 2002), based on the Diagnostic and Statistical Manual of Mental Disorders - IV-TR criteria (DSM-IV-TR, American Psychiatric Association, 2000). Table 1 presents the distribution of subtypes in our study sample and the number of children with comorbid ODD, as identified with the DISC. Children taking medication for ADHD were drug free for at least 24 hours prior to testing. Children were excluded from the study if they had an IQ below 80 (one TD child) as estimated with a shortened version of the Wechsler Intelligence Scale for Children - Third edition – NL (WISC-III-NL; Grégoire, 2000; Wechsler, 1991; Dutch translation: Kort et al., 2005) and scored above the threshold on the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003; Dutch translation: Warreyn, Raymaekers, & Roeyers, 2004)

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suggesting the presence of autism spectrum disorder symptoms (four children with ADHD and two TD children). In the TD group, a screening instrument for symptoms of ADHD was used to exclude subclinical manifestations of ADHD. Two TD children were excluded because they met the threshold on the ADHD scale of the Disruptive Behavior Disorder Rating Scale (DBDRS; Pelham, Gnagy, Greenslade, & Milich, 1992; Dutch translation: Oosterlaan et al., 2008). One child with ADHD's data was unavailable due to faulty equipment leaving the ADHD group with 28 children compared to 38 TD children. The groups did not differ in terms of age, sex or IQ. Not surprisingly, the ADHD group had higher scores on the SCQ and DBDRS for inattention and hyperactivity/impulsivity (Table 1).

Measures

Approach-avoidance task.

The approach-avoidance task in the current study was based on the computer-based task used by Bamford et al. (2015) and Bamford and Ward (2008). A valenced picture (7 by 5 cm in size; either positive or negative) was presented on each trial on a white background. It was paired with a grey square of the same size by its side (either left or right). The children were instructed to evaluate the picture and to approach or avoid it by pressing one of two marked keys on the computer keyboard. The pictures were a selection of 30 positive (e.g., chocolate, smiling children) and 30 negative pictures (e.g., a snake, a wounded person) from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention [CSEA-NIMH], 1999; Lang, Bradley, & Cuthbert, 2008), chosen to be suitable for children (McManis, Bradley, Berg, Cuthbert, & Lang, 2001). There were two conditions, a congruent and an incongruent condition, presented in a random order. In the congruent condition, the children had to approach the picture if they evaluated it as positive (explained in the

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Table 1

Descriptive Characteristics for the Study Sample

Variables	TD		ADHD		χ^2 (df)	p
	n		n			
Gender (boys/girls)	26/12		19/9		< 0.01 (1)	.961
ADHD-C			11			
ADHD-IA			13			
ADHD-HI			4			
ODD ^a			11			
	M	SD	M	SD	t (df)	p
Age (years)	11.16	2.62	11.11	2.69	0.08 (64)	.939
Estimated IQ	107.34	13.47	102.93	12.25	1.37 (64)	.177
DBDRS - INATT	10.92	1.24	14.18	1.63	-9.22 (64)	< .001
DBDRS - HYP/IMP	10.45	0.95	13.96	2.59	-6.88 (64)	< .001
SCQ - TOT	4.24	3.35	6.79	3.80	-2.89 (64)	.005

Note. ^a None of the children in the study sample scored above the cutoff for conduct problems in the DISC-IV.

TD = typically developing children; ADHD-C = diagnosis of combined subtype of ADHD as identified with the DISC-IV; ADHD-IA = diagnosis of inattentive subtype of ADHD as identified with the DISC-IV; ADHD-HI = diagnosis of hyperactive/impulsive subtype of ADHD as identified with the DISC-IV; ODD = diagnosis of ODD as identified with the DISC-IV; Estimated IQ = estimated total IQ based on the subtests similarities, picture arrangement, block design, and vocabulary of the WISC-III-NL; DBDRS - INATT = standard score for the inattentive subscale of the DBDRS; DBDRS - HYP/IMP = standard score for the hyperactive/impulsive subscale of the DBDRS; SCQ - TOT = total score for the SCQ.

instructions as “If you like the picture, press on the red button on the same side of the picture. The pictures that you like will come towards you”). If they judged it as negative, they were asked to avoid the picture by pressing the key on the side of the grey square (“if you don’t like

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the picture, press on the red button on the side of the square. The pictures that you don't like will move away from you"). Approach presses led to the picture getting larger on the screen in a way that made it appear to be coming closer while the grey square appeared to move away. Avoidant responses had the opposite effect. In the incongruent condition, the participants received the opposite instructions. Children had to press the button on the side of the grey square to avoid positive pictures and the button on the picture side to approach negative pictures with these button presses make the pictures "move away" or "move closer" to the child respectively. Every picture was shown twice in each condition, once on each side, to counterbalance for position resulting in a total of 120 trials per child per condition. Trials started with a fixation cross, presented for 500 ms on a white screen. Subsequently, the picture and the grey square appeared simultaneously and remained on the screen until the child responded. After the response, the final changed size of the pictures remained for 2000 ms on the screen. Each condition started with 24 practice trials (with different pictures than the ones in the actual conditions) to ascertain comprehension of the task. Respondents received both written and verbal instructions at the start, and verbal feedback on their performance during the practice trials. In case the child did not comprehend the task completely, the practice trials were repeated. Trials in which the children responded incorrectly (e.g., approaching a positive picture when they were asked to avoid it) were removed from the dataset. The mean percentage of incorrect trials did not differ between groups (12.92 ($SD = 13.25$) for TD versus 13.08 ($SD = 12.04$) for ADHD, $t(65) = -0.05$, $p = .959$). Reaction times shorter than 250 ms were also removed along with outlier reaction times using a cutoff of three standard deviations from the mean. In all 87% of responses were included in the analysis.

Rating of the pictures.

The 60 pictures presented in the task were evaluated by the children using the Self-Assessment Manikin computer administered task (SAM; Bradley & Lang, 1994; Lang, 1980). Both valence and arousal ratings were obtained through scores on a 5-point Likert scale in two separate conditions in a random order. Valence was scored from *negative* (1) over *neutral* (3) to *positive* (5) and arousal from *not arousing* (1) to *high arousing* (5).

Procedure

After receiving informed consent from both parent and child, the computer tasks and the intelligence test were administered in a fixed order: the approach-avoidance task first, the rating task next and finally the intelligence test. The parents of the children with ADHD were interviewed by an experienced psychologist, while the children performed the tasks. Parent and child also filled in questionnaires either before or after the experiment. If the questionnaires were too difficult for the child, the parents were allowed to explain the items but not to decide on the answers.

Analysis

The rating task was analyzed with two 2 (Picture type: positive picture vs negative picture) x 2 (Group: ADHD vs TD children) ANOVAs with valence and arousal ratings as the dependent variable. The approach-avoidance task was analyzed using a 2 (Condition: congruent vs incongruent) x 2 (Valence: positive picture vs negative picture) x 2 (Group: ADHD vs TD children) repeated measures ANOVA with mean reaction time (RT) as the dependent variable. The *F*-values of the univariate tests are reported and significant effects were further evaluated with ANOVAs. Effect sizes are also reported.

Results

Rating of the Pictures

The main effect of group on arousal ratings was not significant ($F(1,64) = 1.13, p = .292, \eta^2 = .02$). There was a significant effect of picture type and picture type by group on arousal ratings ($F(1,64) = 9.05, p = .004, \eta^2 = .12$ and $F(1,64) = 7.87, p = .007, \eta^2 = .11$ respectively). The arousal score for the negative pictures was overall higher than for the positive (see Table 2). Children with ADHD did not differ from TD children with respect to these negative pictures ($F(1,64) = 1.17, p = .283, \eta^2 = .02$), but the ratings for the positive pictures were higher for the ADHD group ($F(1,64) = 5.63, p = .021, \eta^2 = .08$). The results for valence showed a significant effect of picture type ($F(1,64) = 380.46, p < .001, \eta^2 = .86$), with higher valence for the positive than negative pictures. The main group effect and picture type by group effect were not significant ($F(1,64) = 0.11, p = .737, \eta^2 < .01$ and $F(1,64) = .15, p = .702, \eta^2 < .01$).

Table 2

Means (and Standard Deviations) for the Rating of Arousal and Valence of Positive and Negative Pictures

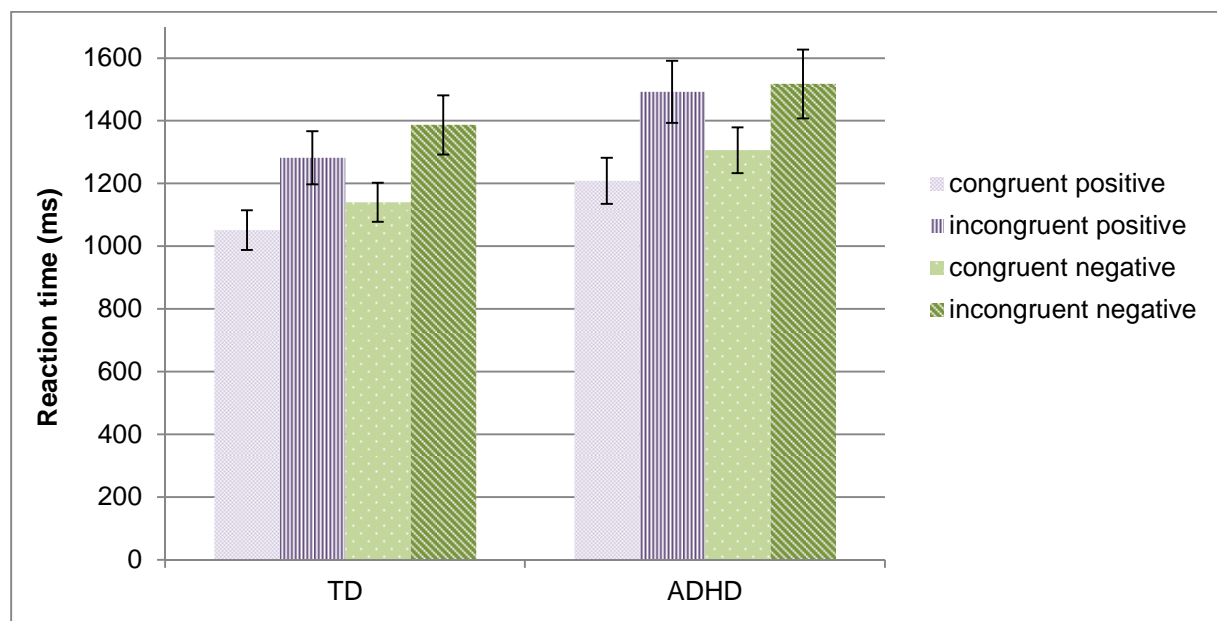
Rating variable	TD ^a		ADHD	
	Positive	Negative	Positive	Negative
Arousal	2.91 (1.09)	3.76 (0.76)	3.51 (0.87)	3.54 (0.88)
Valence	4.20 (0.63)	1.84 (0.69)	4.28 (0.43)	1.82 (0.56)

Note. ^a TD = typically developing children.

Results of the Approach-Avoidance Task

There was a significant effect of condition ($F(1,64) = 25.72, p < .001, \eta^2 = .29$): reaction times were slower in the incongruent condition compared to the congruent condition. In addition, the effect of valence was significant ($F(1,64) = 16.00, p < .001, \eta^2 = .20$), with reaction times to positive pictures being faster than to negative pictures. These effects are demonstrated in Figure 1. The effect of group ($F(1,64) = 2.53, p = .117, \eta^2 = .04$), and the interactions between group and condition ($F(1,64) = 0.01, p = .928, \eta^2 < .001$), and group and valence ($F(1,64) = 0.77, p = .383, \eta^2 = .01$) were not statistically significant. No other effects were significant (all p 's $> .330$).

Fig. 1 Estimated marginal means and standard errors for reaction time in the congruent and incongruent condition for positive and negative pictures in typically developing (TD) children and children with ADHD



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Controlling for age, gender and arousal effects did not change this pattern of results, as including age or the arousal rating of positive pictures as a covariate in the analyses or gender as a factor, did not result in any significant group (or interaction with group) effects (all p 's > .072). Only a marginally significant group effect appeared, indicating that children with ADHD tended to be overall slower in their responses (irrespective of congruency) than TD children. Also excluding children with ADHD with comorbid ODD or only including these children in the analyses did not influence these results (all p 's > .10). A correlational analysis was performed to see whether the magnitude of the congruency effect was related to ADHD symptoms severity, but did not reveal any significant association ($r = -.02, p = .921$).

Visual inspection of the data raised the possibility that the order in which the conditions, although counterbalanced, were presented may have had an influence on the congruency effect as it affected the two groups. Therefore, analyses were repeated adding order as a factor in the model. There were significant effects of condition ($F(1,62) = 36.68, p < .001, \eta^2 = .37$), valence ($F(1,62) = 17.09, p < .001, \eta^2 = .22$), and order ($F(1,62) = 12.29, p = .001, \eta^2 = .17$) and the interactions order by condition and order by valence were significant ($F(1,62) = 23.79, p < .001, \eta^2 = .28$ and $F(1,62) = 3.98, p = .050, \eta^2 = .06$ respectively). The main congruency effect was absent if children received the congruent condition prior to the incongruent condition. The effect of group ($F(1,62) = 3.69, p = .059, \eta^2 = .06$) and the interaction between group and order approached significance ($F(1,62) = 3.38, p = .071, \eta^2 = .05$). Crucially, the interaction between group and condition was not significant ($F(1,62) = 0.09, p = .770, \eta^2 < .01$), nor were other interactions (p 's > .360).

To be certain that the effect of order was not distorting the results we reran the analyses for both orders of conditions separately. Crucially in neither set of analyses there was an

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interaction between group and condition (congruent condition first - $F(1,32) = 0.01, p = .934, \eta^2 < .001$; incongruent condition first $F(1,30) = 0.16, p = .690, \eta^2 = .01$).

Discussion

In the current study we investigated an important element of emotion regulation in children with ADHD - the ability to override automatic or natural tendencies to approach positive and avoid negative pictures. Our hypothesis was that if emotional dysregulation in children with ADHD includes insufficient use of response-focused strategies, they would show a greater impact of incongruency of response (approach versus avoidance) to emotional content of pictures (positive versus negative) indicating more difficulties with response modulation. Across groups, responses were slower for incongruent than congruent action responses, which indicated that the task worked. However, this congruency effect was not different between the ADHD and TD groups and controlling for arousal effects, order effects, age, gender or comorbid ODD did not change this finding. Moreover, the congruency effect in the ADHD group was not related to ADHD symptoms severity. This indicates that at least for this group of children with ADHD, we could not find support for impairment in the ability to regulate emotional responses to positively and negatively valenced pictures.

Although the findings clearly do not provide support for a deficit in response-focused emotion regulation in ADHD, a null finding does not necessarily imply that (all) children with ADHD are not impaired in the modulation of their emotional responses. First, the power of the analyses might have been too small to detect a difference between groups. However, the effect size for the interaction effect of condition and group was small ($<.001$) and with the current effect size and a power of .80 a very large sample size ($N > 1.000$) would be needed to find a statistical significant effect. Second, sample characteristics may have played a role.

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ADHD is known to be a heterogeneous condition. The sample included in the current study consisted of children with ADHD predominantly inattentive type (ADHD-IA), ADHD combined type (ADHD-C), and ADHD predominantly hyperactive/impulsive type (ADHD-HI). Different subtypes may be characterized by different deficits and emotional dysregulation has been differently associated with the symptom clusters (Chhabildas, Pennington, & Willcutt, 2001; Maedgen & Carlson, 2000; Martel, 2009; Schmitz et al., 2002). With the current sample size, it was not possible to systematically compare subtypes. Future studies are warranted to investigate this further and to see whether the current results generalize to other samples of children with ADHD. Third, measurement issues such as task validity might have accounted for the null results. However, it is important to note that the expected task effects were found across groups, weakening this argument of task validity.

The lack of evidence for emotion regulation problems adds to the inconsistency of findings regarding emotion regulation in ADHD. While several studies evidenced impaired emotion regulation in ADHD (e.g., Köchel et al., 2014; López-Martín et al., 2013; Maedgen & Carlson, 2000; Melnick & Hinshaw, 2000; Posner et al., 2011; Scime & Norvilitis, 2006; Walcott & Landau, 2004), others did not find a specific deficit in emotion regulation but were able to show that the difficulties in suppressing emotional interfering information in ADHD may be attributed to a generic interference deficit (Passarotti et al., 2010; Van Cauwenberge et al., 2015). The inconsistency between our findings and previous findings, evidencing impaired emotion regulation, could be attributed to a different focus on strategies of emotion regulation. Whereas other experimental studies focused on antecedent-focused strategies, the current study is the first to investigate emotion regulation in ADHD by evaluating the ability to override natural action tendencies in responding to emotional pictures. The results of the approach-avoidance paradigm are less subject to differences in general cognitive control abilities as compared to the paradigms used in previous studies which measure cognitive

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control performance in a context of interfering irrelevant emotional stimuli (Van Cauwenberge et al., 2015). In the approach-avoidance paradigm, the load on other cognitive control abilities is minimal and importantly it involves an explicit instruction to regulate emotions rather than just the instruction to perform another task as good as possible in the context of emotionally provocative stimuli. Moreover, the paradigms used in previous studies may have captured other abilities besides emotional interference (e.g., reading ability or naming speed in the stroop task, see van Mourik, Oosterlaan, & Sergeant, 2005). However, the findings with regard to emotional dysregulation in ADHD across other studies with an experimental design are also not consistent, which may be caused by other factors such as the various emotional stimuli that are used; IAPS-pictures, emotional faces, or emotional words may not elicit the same interfering effects (Kujawa, Klein, & Hajcak, 2012; Rellecke, Palazova, Sommer, & Schacht, 2011). In addition, characteristics of the sample and heterogeneity of ADHD samples can cause difficulties in the comparison of results. For example, some studies only included boys (López-Martín et al., 2013) or children with combined subtype of ADHD (Passarotti et al., 2010). In the current study a sample of boys and girls was included, spread among the three DSMS-IV subtypes of ADHD.

Our results could have implications for theoretical models of the ADHD related BIS/BAS hypothesis. Differences in levels of BAS (higher or lower levels) and BIS (higher or lower levels), as well as an increased FFFS have been associated with hyperactivity/impulsivity and an overactive BIS has been linked to inattentive symptoms (Gomez & Corr, 2010; Heym et al., 2015; Hundt et al., 2008; Mitchell & Nelson-Gray, 2006). Differences in BAS and FFFS would imply differences in approach and avoidance behavior. An underactive BIS would imply problems with the modulation of BAS versus FFFS activity in case of goal conflict. In the current study, no differences were observed between TD children and children with ADHD regarding approach or avoidance reactions, hence these results are not supportive of

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BAS and FFFS dysfunction in the current sample of children with ADHD. The lack of a group difference in the congruency effects, reflective of performance in the presence of goal conflict, suggests intact BIS activation in these children with ADHD. It is however important to mention that the use of different methodologies may hamper comparison of results between existing studies and ours, as we applied an approach-avoidance task and did not administer BIS/BAS questionnaires. Our task provides information limited to one specific point in time and instructed children specifically to suppress their natural reaction pattern whereas the questionnaires inquire about general, natural tendencies in behavior over a certain period of time (see for a similar argument Samyn, Roeyers, Bijttebier, Rosseel, & Wiersema, 2015 on measures of effortful control). Moreover, our ADHD sample consisted of children with predominantly inattentive (13), predominantly hyperactive-impulsive (4), or combined subtype (11). Because symptoms of inattention and hyperactivity/impulsivity have been differently related to the reward sensitivity systems, it is difficult to draw conclusions based on the total group of children with ADHD.

One could argue that the absence of a group difference in congruency effects in the current study may relate to the distinct evaluation of the pictures from the task by the children with ADHD or to the specific task we used. There were no group differences in arousal or valence rating for negative pictures, but children with ADHD rated the arousal of the positive pictures higher than TD children. This suggests that children with ADHD are more reactive to positive stimuli, which has been evidenced before in temperament research, that is higher levels of surgency have been found in children with ADHD (e.g., Martel, Gremillion, & Roberts, 2012). It is however unlikely that this difference explains the absence of response modulation differences between groups. If it was the opposite (lower arousal ratings) perhaps it could have contributed to not finding a group difference, but in this case, more arousing pictures would elicit stronger approach-avoidance reactions and therefore the ADHD group would

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have been expected to show a greater interference effect, indicating more difficulty regulating as a result of the greater reactivity. With regard to the task we used, it should be noted that for the implementation of the approach-avoidance paradigm several task versions are possible, with or without the use of a joystick. Unlike some other studies, we did not use a lever or joystick to initiate the actions of approach and avoidance. Instead, children had to press one of two buttons and saw their action reflected as an approach or avoidance reaction in the movement of the pictures on the screen. A recent meta-analysis, including 29 studies (Phaf et al., 2014), showed that there is no hard-wired relationship between approach-avoidance motivations and particular arm movements, and that approach-avoidance effects are even apparent when no physical arm movement is involved (abstract-manikin task; De Houwer, Crombez, Baeyens, & Hermans, 2001). Importantly, the authors also concluded that the crucial aspect seems to be the visual feedback that the stimuli come closer or move away. The task used in the current study has this important zooming feature and has been validated in other studies, of which one also included ERP measures (Bamford et al., 2015; Bamford & Ward, 2008; Spruyt et al., 2013). Furthermore, it is important to note that our results did confirm the presence of a congruency effect across groups, further validating the paradigm in children, without the use of a lever or joystick. This factor is therefore unlikely to have caused the absence of group differences in the present study.

Although not affecting the ADHD and TD groups differentially, the order in which the children received both conditions was found to be of importance. Not only was the overall RT of the children different according to the order of conditions, also the congruency effect was found to be influenced by the order. When children received the congruent condition first, followed by the incongruent condition, the main congruency effect was absent. This could possibly be related to a learning effect, causing children to react faster as the task proceeds, which masks the congruency effect. This may explain why a congruency effect did appear

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when the incongruent condition is presented first, followed by the congruent condition.

Nevertheless, to our knowledge, the effect of order in the approach-avoidance task has never been addressed before. Our findings indicate that future studies applying this paradigm should take order and potential learning effects into account.

The current study has many strengths. It is the first study comparing the ability of ADHD children to override prepared actions to emotional stimuli as an index of emotion regulation. Groups were not distinct with respect to age, gender distribution and intelligence and ratings of the children were obtained for the pictures used in the paradigm. The current study has important methodological and clinical implications as it further validates the use of an approach-avoidance paradigm in children and points to the importance of order of conditions. Moreover, to our knowledge, response-focused emotion regulation strategies have never been the focus of experimental studies in children with ADHD. Therefore, the findings add to our knowledge of emotion regulation strategies in children with ADHD. If future studies replicate our finding in other samples with children with ADHD, it could indicate that not all aspects of emotion regulation may be equally impaired and that different emotion regulation skills of children with ADHD should be well assessed in clinical practice. A limitation of the current study is that the sample size hampers the systematic investigation of effects of comorbidity such as ODD or anxiety. However, additional analyses excluding children with ADHD with comorbid ODD or only including these children did not influence the results. Another limitation relates to the heterogeneity of ADHD. As ADHD represents a heterogeneous condition, the current findings may not generalize to other samples with ADHD, hence replication studies are warranted.

Compliance with ethical standards

Conflict of interest: Professor Sonuga-Barke declares the following competing interests: fees for speaking, consultancy, research funding and conference support from Shire Pharma; speaker fees from Janssen Cilag, Consultancy from Neurotech solutions, Aarhus University, Copenhagen University and Berhanderling, Skolerne, Copenhagen, KU Leuven; book royalties from OUP and Jessica Kingsley.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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