Review article

Voluntary and Automatic Orienting of Attention in Children with Attention Deficit Hyperactivity Disorder

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Received: 19-08-2019 – **Accepted:** 09-12-2020

DOI: 10.15761/0101-60830000000298

ABSTRACT

Objective: Voluntary and automatic orienting of attention enable proper processing of environmental information. Few studies have assessed how this process varies during development in children with attention deficit hyperactivity disorder (ADHD). **Methods:** This study analyzed voluntary and automatic orienting in 30 children with ADHD and 30 age and sex matched controls (Control group-CG). Two experiments assessed voluntary and automatic orienting by recording reaction times (RT) to conditions in relation to temporal interval, spatial position, cue validity and age. The RT medians calculated for each condition and participant were analyzed using ANOVA to compare ADHD and CG. **Results:** Children with ADHD exhibited globally higher RT than the CG group. They also showed prejudices during the reorienting process and demonstrated adequate voluntary orienting for shorter intervals. In automatic task, there was no group interaction, expressing early facilitation, but not inhibition of return. **Conclusion:** These results identify correlations of ADHD and the children's age in relation to voluntary and automatic orienting of attention.

de Castro Mariani MM / Arch Clin Psychiatry. 2021;48(3):155-161

Keywords: Voluntary orientating, Automatic orientating, Attention deficit hyperactivity disorder, Children, Development

Introduction

Attention is a cognitive process related to neural mechanisms that control the appropriate selection of information for planning adaptive behavioral responses [1]. Although the selectivity of attention allows an individual to focus on the relevant objects or events, either by voluntary or automatic control, the interaction of these processes enables proper processing of information from the environment [2]. The voluntary orienting of attention to a local position, while ignoring other spatial positions, can be manipulated to induce individuals to expect more likely targets to be in one place than another. The use of an arrow indicating the target's probable position of appearance can previously someone's attention (-) [3]. Moreover, studies on automatic orienting of attention can use unexpected stimulus on the visual field to attract attention. Posner and Cohen [4] observed that, when the visual stimulus is not expected, a reduction in reaction time (RT) to subsequent targets that occur at the same position up to 150 ms. On the other hand, RT increases when the cue target intervals exceed 200 ms. This early facilitation process is described by Posner and Cohen as the automatic direction of attention to the peripheral stimulus position [4]. The slowness, after facilitation period, called inhibition of return (IOR), expresses a difficulty in redirecting attention to the visual field positions previously stimulated. This effect contributes to improving exploratory behavior by directing attention easily to new spatial positions [5-7].

Elucidating the emergence and maturation of cognitive processes during development is fundamental to understanding the processes of the organism-environment interaction. Follow-up studies of child development demonstrated significant changes in the control systems, which led to a greater understanding of the attentional aspects and served as a reference for new forms of interventions [8,9] analyzed the voluntary and automatic orienting of attention during childhood development in 74 children with 6 to 11 years old and with typical development. They verify systematic reduction of the RT in older children in both conditions. For the automatic orienting, RT was shorter in the ipsilateral than in

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the contralateral condition; however, for older children, the RT differences between these two conditions decreased. This profile may be the result of the maturation of the attentional system related to childhood development, contributing thus to a more effective environment exploration.

The model of attention deficit hyperactivity disorder (ADHD) has been used in several studies to understand the cognitive development of attention in childhood and adolescence. ADHD is a neurodevelopmental disorder defined by impaired in attention and/or hyperactivity-impulsivity at levels that are inconsistent with age or the developmental level. Inattention is expressed by the inability to focus on a task, not listening, and losing materials, while hyperactivity-impulsivity involves an excessive activity, fidgeting, difficulty to remain seated, inability to wait, and intruding into other people's activities or conversations [10]. Signs of inattention and/or hyperactivity-impulsivity may vary with age and level of development and maturation [11,12].

Thus, care must be taken to establish an accurate diagnosis [13,14]. Recently, neurobiology, genetics, neuroimaging, and neuropsychological studies expressed several important advances in identifying the regions involved in attentional processes and related to executive control and inhibitory or with a delay in structural brain maturation and a specific decline in the cerebellar gray matter [15-17].

This set of characteristics can cause interference in social, academic, or occupational functioning. Thus, to study prejudices caused by ADHD will contribute to comprehending attention as a cognitive function required for effective integration of organism and environment. Previous studies investigated the neuropsychological functioning of children with ADHD, and they have demonstrated significant differences between children with ADHD years and normal controls [13].

Inappropriate selection of environmental information can affect information processing, causing difficulties in adaptation. Neuropsychological assessment can highlight the skills that remain preserved or become impaired in ADHD. It may also contribute to diagnosis process and establish early cognitive interventions to promote suitable development [18]. Previous reports on cognitive assessments in ADHD indicated the need for developing tools to the characterization of children with complaints of inattention and hyperactivity by using objective indicators [18]. However, even studies that employed computerized methods to assess attention have ignored attentional aspects such as the automatic and voluntary orientating in children with ADHD. So, studies to identify the specific prejudices, both in voluntary and automatic orienting, can contribute to a better characterization of the attention systems and the cognitive prejudices associated with ADHD.

The Inhibition of return (IOF) allows to study how the attention retracts from a spatial region to concentrate in other regions, quantify with what speed this reorientation takes place and quantify the inhibitory process on the previously served region [19]. Studies on the IOR in children with ADHD were limited. Li et al. studied whether the IOR in oculomotor planning was compromised in children with ADHD and reported that the IOR magnitude was slightly smaller in children with ADHD in comparison with controls [20]. Fillmore et al. evaluated the deficits in intentionally and reflexively controlled inhibition of attention using saccade and manual RT tasks in 50 children with ADHD [21]. They observed that, with respect to reflexively controlled inhibition, the groups with combined symptoms exhibited impaired reflexive inhibition, whereas the predominantly inattentive group was considerably less impaired. Fillmore et al. affirmed that there is reliable evidence that children with ADHD present deficits of intentional inhibitory mechanisms. However, little is still known about the extent of the impairments of the automatic inhibitory mechanisms in these children [21].

Deficits in the attention control, compromise selection of environmental stimuli, leading to inefficient stimulus processing and can also affect other cognitive processes such as memory, learning, self-organization, and choice of behavioral strategies for planning and organization of adaptive actions, that are typically present in ADHD. Therefore, this study analyzed the voluntary and automatic orienting of attention in children with ADHD to evaluate the effects of IOR and early facilitation.

Methods

Participants

In total, 60 children participated in this study, and were assigned to two groups, namely ADHD and control (CG) group, depending on ADHD diagnosis. The ADHD group consisted of 30 children (8 girls and 22 boys; average age: 9.1 ± 1.5 years) selected for convenience among those evaluated using a protocol comprising neuropsychological, behavioral, and medical-neurological assessments specifically for complains of ADHD at Developmental Disorders Graduate Program, Center for Health and Biological Sciences, Mackenzie Presbyterian University [18]. The children included in this study were diagnosed after completing the assessment and for this reason did not use medication at the time of the assessment. All of them received a report indicating the need for medical monitoring in the case of diagnostic confirmation, after the process was completed.

The CG consisted of 30 healthy children (8 girls and 22 boys; average age, 8.9 ± 1.5 years old) from private and public schools from São Paulo, with no signs of ADHD or other neurodevelopmental disorder, according to clinical history, and matched with ADHD group for age, sex, and education level. Additional analysis factor considered the within-group age, comparing performance of Half-Younger and Half-Older children in both the ADHD group and CG. Previous findings [9] indicated differences in the voluntary and automatic attention system in relation to development. The Half-Younger children of the ADHD group and CG had an average age of 7.9 ± 1.0 years and 7.8 ± 1.1 years, respectively. The Half-Older children of the EG and CG had an average age of 10.3 ± 0.8 years and 10.1 ± 0.8 years. The Committee on Research Involving Human Subjects at Mackenzie Presbyterian University approved the methodological procedures used here (CEP/UPM 1229/04/2010 and CAAE 0037.0272.000-10).

Materials and procedure

Experiments 1 and 2 were designed to assess the differences regarding the voluntary and automatic attentional orientation, respectively. Both experiments used the manual RT to visual targets as a measure of attention manipulation according to procedures published elsewhere [9,22,23]. For the stimulus presentation and data collection, we used an Itautec Infoway laptop computer (Pentium Dual Core 2.10 GHz, 3 GB RAM). E-Prime version 2.0 software (Psychology Software Tools) controlled the computer routines for the generation of the stimuli and response recording. The stimuli occurred in white on a black background presented under suprathreshold and photopic conditions to be easily distinguished from the background. The experiments took place in dim light and low noise room with the presence of the researcher and participant [9,18].

Experiment 1: Voluntary orienting of attention

First, a fixation point (FP) appeared in the center of the computer screen, along with two boxes presented on the right and left sides. After a random interval ranging from 800 to 1,800 ms, an arrow pointing to the left or right sides appeared beside the FP. After 300 or 800 ms of arrow presentation, a target (filled square) was displayed inside one of the two boxes until the participant pressed the spacebar or until 1,500 ms elapsed. The target appeared either, at the location indicated by the arrow (i.e., valid condition; 70% of the presentations) on at the opposite position indicated by the arrow (i.e., invalid condition; 30% of the presentations). The participants had to fixate on the FP, directing their attention to the position indicated by the arrow and responding to it as soon as possible, regardless of the target's position (Figure 1).

Experiment 2: Automatic orienting of attention

Initially, a FP appeared in the center of the screen, with two boxes, one to the right and the other to the left side. After 700 ms, one of the two boxes turned brighter (with a probability of 50%). After an interval of 100 or 800 ms, a target (filled square) appeared inside one of the two boxes until the participant pressed the spacebar or until 1,500 ms elapsed (Figure 1). In the ipsilateral condition, the target appeared at the same position as the first stimulus, and in contralateral condition, it appeared at the opposite position. The participants were instructed to fixate on the FP, ignore the first stimulus, and respond to the target as fast as possible, regardless of the target's location.

Statistical analysis

The median RT was calculated for each experimental condition and each participant separately. These values were analyzed using the General Linear Model followed by pairwise comparisons (Newman–Keuls test) using StatSoft, Inc. STATISTICA (data analysis software system), version 10. The level of significance was set at 5%.

For Experiment 1, the data were analyzed with repeated measures analysis of variance (ANOVA) using the following factors: Categorical, i.e., Group (TDAH group × CG) and Age (Half-Younger × Half-Older) and dependent variables, i.e., cue validity (valid and invalid conditions) and cue-target interval (300 and 800 ms). The median RT for each condition in Experiment 2 was also analyzed with the following factors: Categorical, i.e., Group (TDAH group × CG) and Age (Half-Younger × Half-Older) and dependent variables, i.e., cue-target spatial correlation (ipsilateral and contralateral conditions) and cue-target interval (100 and 800 ms).

Results and discussion

Experiment 1: Voluntary orienting of attention

We observed a significant interaction involving the group factor. namely the interaction between group and cue-target interval ($F_{[1, 58]} = 11{,}579$, $P = .00121$), demonstrating a significant increase of RT for CG ($P < .001$) for the short interval (300 ms) of the cue target (*544.9*) compared with the long interval (800 ms) of the cue target (*490.4*). For the CG, no differences were noted between short (*475,1*) and long intervals (*477.8*).

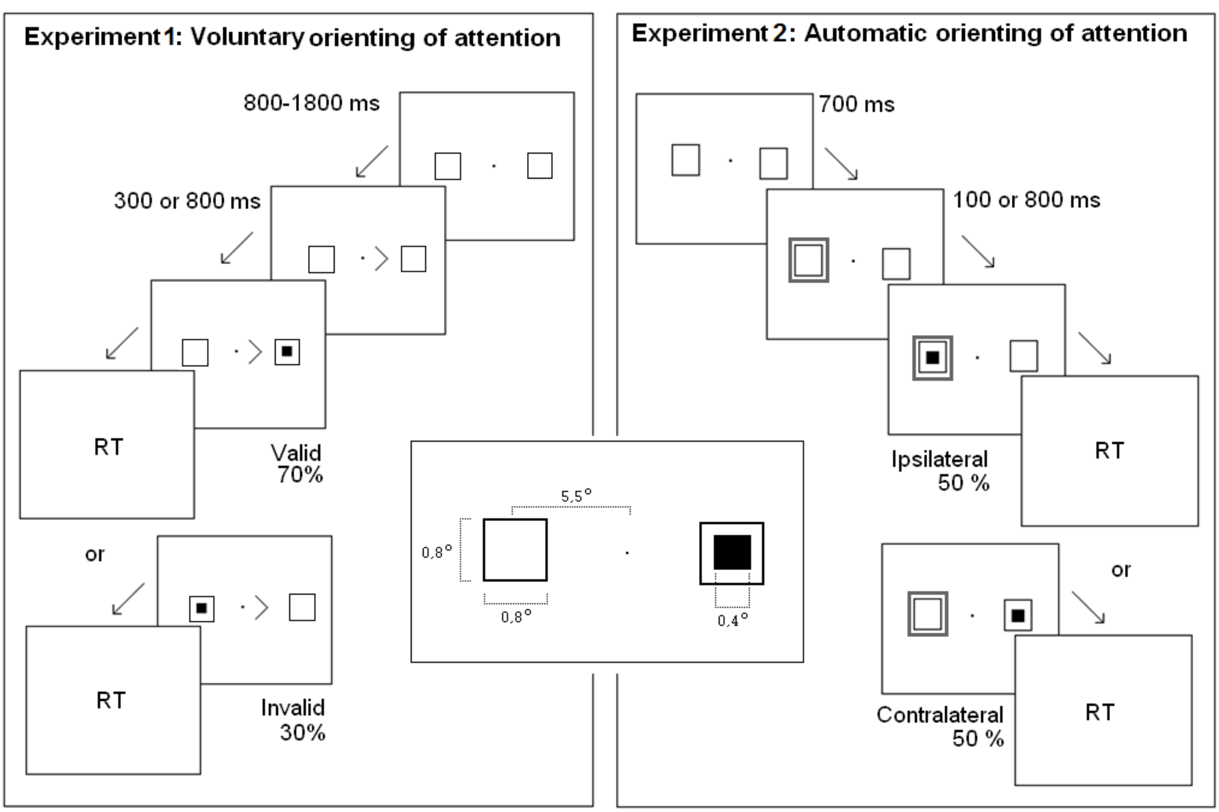

Figure 1. The temporal sequence of the stimuli presentation in Experiment 1 and 2. The sequence of stimulus presentation is the same as the one used by Lellis et al. (2013). The distance and size of the stimuli were measured in visual angle.

A significant effect of cue validity was found ($F_{[1, 58]}$ = *34,002, P < .001*). Manual RTs were faster in the valid condition than in the invalid condition (Figure 2). When the target appeared at the location indicated by the cue, RTs were lower (455,1) than when the target appeared on the opposite side (539,0). A significant effect of the cue-target interval was also found ($F_{[1, 58]}$ = *14,115, P = .0004*). RTs were faster (482,7) for the long (800 ms) cue-target interval than for the short (511,4) cue-target interval (300 ms). This observation can be explained by the fact that the 800-ms interval provided more time to direct attention toward the cued correct spatial position. Nevertheless, the ADHD group exhibited higher RTs in the invalid condition than the CG (Figure 2), demonstrating prejudices in reorienting attention after an invalid previous targeting. Araujo and Carreiro (2009) [21] demonstrated similar results in adults whereby increased RTs in function of increased signs of inattention and hyperactivity were observed. On the other hand, the shorter cue target interval of 300 ms caused an increase of RT in the ADHD group compared with CG. The cue appearance mobilizes resources to direct attention to the target's probable position, an operation that could be prejudiced in the ADHD group who, thus, may require more time to orient or reorient their attention. This fact is also observed during the developing period in younger children [9].

We also observed a significant difference ($F_{[1, 56]}$ = *8,3024, P = .00560*) in relation to Age (Half-Younger × Half-Older) in relation to voluntary orienting of attention. Younger (*RT = 547,8*) were slower compared with Older children (*RT = 446,3*). A significant interaction of this factor with cue-target spatial correlation ($F_{[1, 56]}$ = *3,6625, P = . 06077*) demonstrated that the Half-Younger children were globally slower and have greater difference between valid and invalid condition in comparison to older children (Figure 3).

Experiment 2: Automatic orienting of attention

A significant effect of group was found ($F_{[1, 58]}$ = *3,8950, P = .05*), whereby ADHD group were globally slower (*556,8*) than CG (*490,8*). No interactions involving this factor were observed. A significant effect of cue-target spatial correlation ($F_{[1, 58]}$ = *17,236, P = .00011*) and cue-target interval ($F_{[1, 58]}$ = *143,293, P < .0001*) were found. RTs with the 800-ms interval were shorter (472,0) compared with the 100-ms interval (575,7). A significant interaction between the cue-target interval and cue-target spatial correlation was observed ($F_{[1, 58]}$ = *6,5733, P = .01297*), demonstrating that RT in the ipsilateral condition with the 100-ms interval was reduced (*5546,7*) compared with the contralateral condition (*604,6*). No difference was found between the ipsilateral (*462,5*) and contralateral (*481,53*) conditions for the 800-ms interval. Fillmore et al. (2009) also observed that RTs are generally slower in the ADHD groups compared with those in the control group. This fact, as we observed, may be related to difficulties in redirecting attention after the appearance of the stimulus.

We also observed a significant difference ($F_{[1, 56]}$ = *11,661, P = .00119*) in relation to Age (Half-Younger × Half-Older) in relation

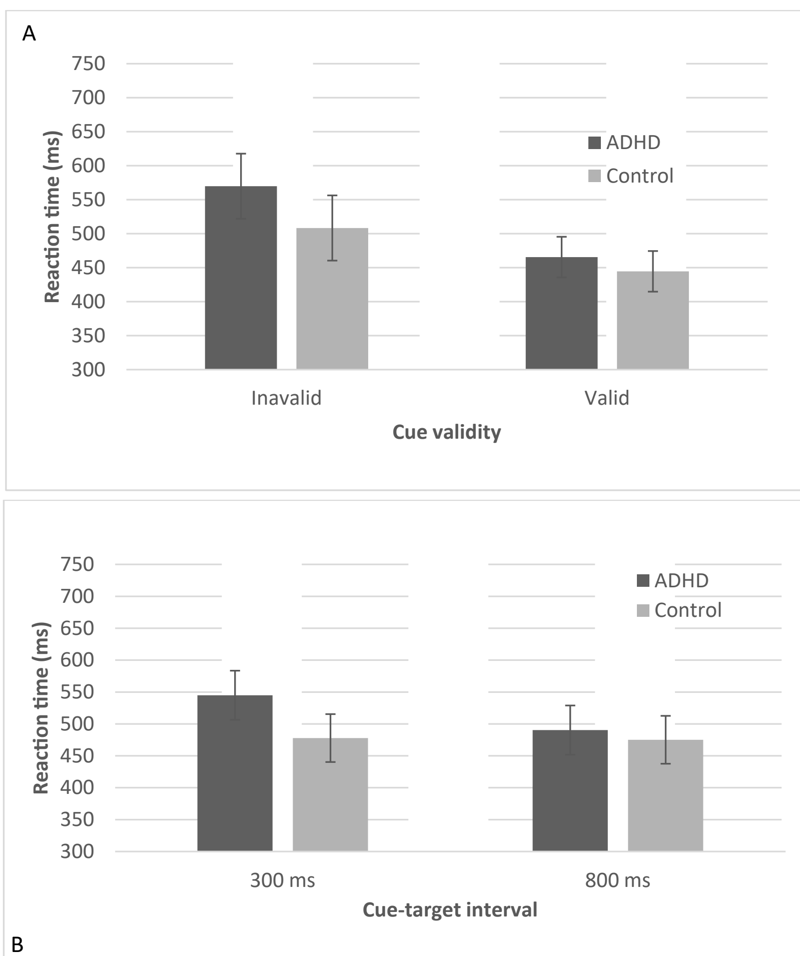

Figure 2. Reaction time (ms) in Experiment 1 (voluntary orienting) in function of the cue-target spatial relation (cue validity) for the attention deficit hyperactivity disorder (ADHD) and Control groups (A) and in function of the cue target interval (B).

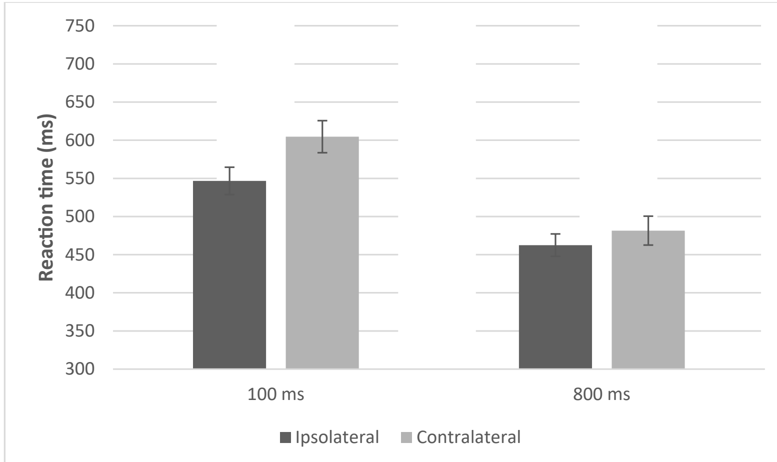

Figure 3. Reaction time (ms) in Experiment 2 (automatic orienting) in function of the cue-target interval for cue-target spatial relation, i.e. Ipso and Contralateral.

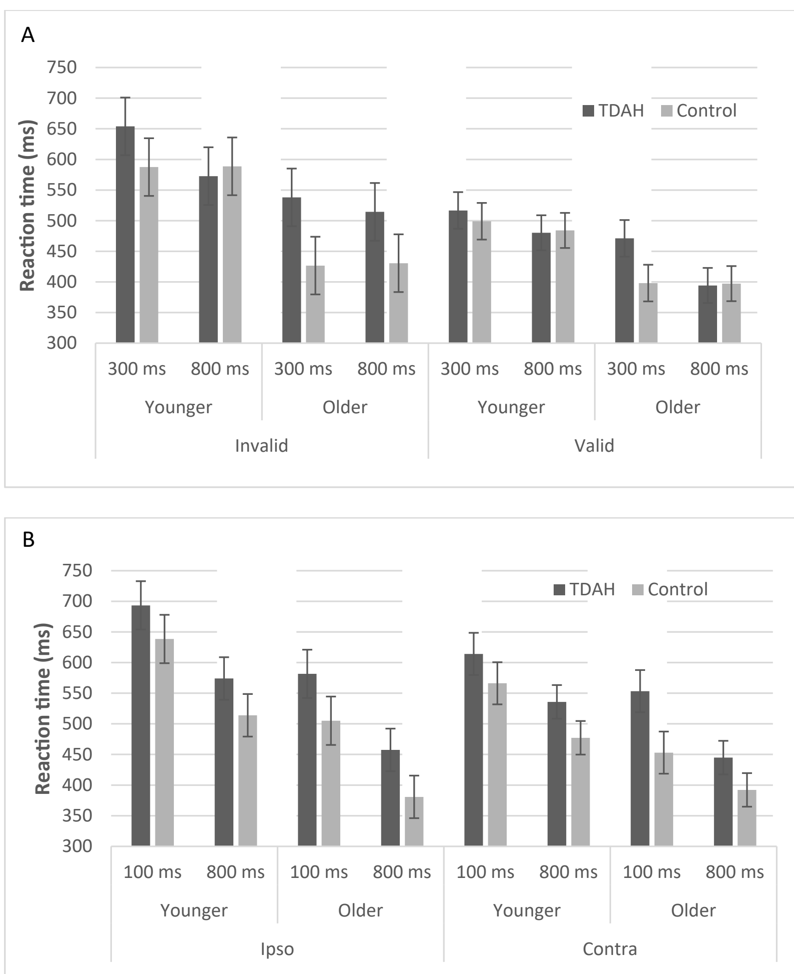

Figure 4. Reaction time (ms) in (A) Experiment 1 (voluntary orienting) and (B) Experiment 2 (automatic orienting) in function of the children's age, i.e., Half-Younger and Half-Older.

to automatic orienting of attention. Younger (*RT = 576,7*) were slower compared with Older children (*RT = 471,1*). A significant interaction of this factor with cue-target spatial correlation ($F_{[1, 56]} = 3{,}9538$, $P = .03415$) demonstrated that the Half-Younger children were slower in the contralateral condition than in the ipsilateral, but not the Half-Older children (Figure 3). The early facilitation occurred because the RT on SOA of the 100-ms ipsilateral condition is produced faster than the contralateral condition. An unexpected stimulus appearance causes automatic direction of attention to its position, thus producing faster RT to a target appearing at the same position. At longer intervals, the IOR occurs, in which the RT to the opposite position becomes faster than that to the same position. However, the IOR was not observed in this experiment, probably in function of the children's age and their diagnosis with ADHD. Lellis et al. reported that IOR is expressed in function of a child's development [9]. Clohessy et al. reported that IOR develops rapidly between 3 and 6 months of age, in conjunction with the ability to program eye movements to specific locations [24]. Markant and Amso reported that learning in the context of IOR-based orienting was stable regardless of experience in infants, suggesting that selective attention serves as an online learning mechanism during visual exploration that is less sensitive to prior experience [25]. Li et al. reported slightly smaller IOR effects in the ADHD group, suggesting that the automatic inhibitory mechanism underlying this attentional process might be weaker in children with ADHD [20].

In recent revision of literature, van Moorselaar and Slagter conclude that selective attention relies on the ability to suppress distracting information [26]. They suggest that the brain can inhibit distracting information by integration of bottom-up and top-down process. We observed in our study that children in ADHD group exhibited higher RT in the invalid condition than the CG, demonstrating prejudices in reorienting attention after an invalid previous targeting. This point is particularly important in the study of ADHD and how during development children with attentional deficits can deal with environmental stimulus.

In relation to possible affection of ADHD on neural network, according to Long and Kuhl visual attention is supported by multiple frontoparietal attentional networks, but, it still remains unclear how stimulus features are represented within these networks and how they are influenced by attention [27]. So, as we demonstrate some attentional losses in terms of voluntary and automatic guidance in ADHD, it becomes possible to consider these deficits in understanding the disorder and contribute to diagnostic assessment and multimodal intervention.

Conclusion

Children with ADHD have higher RT in comparison with healthy controls. They also have prejudices in the reorienting process as observed during the invalid condition in Experiment 1 (voluntary orienting) and in directing their attention for shorter intervals (SOA of 300 ms). In Experiment 2 (automatic orienting), there was no interaction involving the group factor, and only early facilitation, but not IOR, was observed. This fact may be dependent on ADHD diagnosis and the age of the children ADHD is a complex condition with a heterogeneous presentation, so as much as we know about the damage in different attentional systems, including those associated with the attention guidance subsystems, they will better describe the set of damage to understand ADHD as a multiple variants and expression profiles of symptoms.

Some limitations of our work ought to be considered in future studies, such as the need to expand the number of participants to allow analyzes with greater statistical power in relation to age groups and a division according to the groups' symptomatologic complaints. Studies involving biological measures such as neuronal activity including cerebral hemodynamic responses as measured by near-infrared light (fNIRS), to show cerebral activation or deactivation of regions associated with voluntary and automatic orienting can help elucidate the association between symptom of ADHD and impairments in the basic cognitive processes in relation to the brain areas associated with them.

Financial support: CNPq processo no 448937/2014-0 e 311680/2013-5, Mackpesquisa, Capes Proex

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ADHD group demonstrating prejudices in reorienting attention after an invalid previous targeting.

Children with ADHD have prejudices in directing their attention for shorter intervals.

Younger children were slower in the contralateral condition than in the ipsilateral in comparison with older children.

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