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# The analysis of Attention Network in ADHD, attention problems and typically developing subjects

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## Abstract

*The aim of this work is to analyze the three dimensions of attention, namely vigilance, selectivity and orienting, as identified in Attention Network Theory (ANT), in subjects with ADHD, with attention problems and with typical development. Fourteen ADHD, fifteen with attention problems and fifteen typically developing subjects were tested on ANT. Results showed that children with ADHD obtained low scores for accuracy and a high score for RT. It has also emerged that children with ADHD show no deficits for orienting and vigilance network, but they show deficits in the efficiency of the executive network compared to children with attention problems and typically developed.*

*Keywords:* Attention network; ADHD; Vigilance; Selectivity; Orienting.

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# 1. Introduction

Attention is an important and complex cognitive function, depending on mutually interacting neural systems of the brain. According to the Attention Network Theory (Posner & Petersen, 1990), the attention system includes three networks: the alerting or vigilance network, the orientation or selection network and the executive or conflict network. The alerting network is concerned with an individual's ability to achieve and maintain a state of increased sensitivity to incoming information; the orienting network manages the ability to select and focus on the stimulus to be attended, and the executive control network manages the ability to control our own behavior to achieve intended goals and resolve conflict among alternative responses (Federico, Marotta, Adriani, Maccari, & Casagrande, 2013). The functioning of the three networks has been widely investigated by using cue-target reaction time tasks (RT) and tasks implying a conflict (Salo, Gabay, Fassbender, & Henik, 2011). The above mentioned theory describes functionally attention networks that are related to distinct cerebral structures and neurotransmitters: the alerting network (locus coeruleus, parietal and right frontal cortex) which is modulated by noradrenaline; the orienting network (frontal eye fields, superior colliculus, temporal parietal junction and superior parietal cortex) which is modulated by acetylcholine and the executive attention or conflict network (basal ganglia, anterior cingulate and lateral ventral prefrontal cortex) which is modulated by dopamine (Posner & Rothbart, 2007). Fan, Candliss, Sommer, Raz and Posner (2002) demonstrated that the ANT provides a reliable measure of each network (alerting, orienting and executive attention). In addition, they suggested that each network was independent of the others by showing no significant correlations among the network scores. However, they also reported an interaction between the cue condition and target congruency (as have others, see, e.g., Ishigami & Klein, 2011), suggesting some lack of independence among the networks. An important question is whether social information influences the efficiency of the three networks. Posner (2004) examined children aged 10 compared with adults, using ANT in the children and adult version. Reaction times and accuracy showed improvements proportionally with age and positive values were found in the average efficiency of each network. Moreover, a substantial improvement in response quickness emerged after the age of 10, while the results concerning conflict show no significant variation after the age of 7, and scores concerning orienting do not change across the different age ranges. Reaction time (RT) measures obtained from the ANT can be used to quantify the processing efficiency within each of these networks (i.e., alerting, orienting and executive function) as well as potential interactions between the three systems (Callejas, Lupianez, & Tudela, 2004; Callejas, Lupianez, Funes, & Tudela, 2005). Berger and Posner (2005) and Fan *et al.* (2002) showed that the attention network model is of fundamental interest in the studies of attentional disorders, including the Attention Deficit Hyperactivity Disorder (ADHD). Booth, Carlson and Tucker (2007) discovered that the performance on a neurocognitive measure of alerting differentiates ADHD combined and inattentive subtypes; the performance of 16 attention-deficit hyperactivity disorder (ADHD)/C, 26 ADHD/IA, and 24 control children was compared using a computer reaction time task designed to measure the effects of Posner's orienting, conflict and alerting attentional systems. This work suggested that the cognitive performance of "non-hyperactive" groups was characterized by features of slow information processing, drowsiness, sluggishness, low levels of alertness, and mild problems with memory/orientation (Barkley, Du Paul, & McMurray, 1990; McBurnett, Lahey, & Pfiffner, 1993; Lahey, Schaughency, Frame, & Strauss, 1994) whereas the performance of those with "hyperactivity" was characterized by distractibility, difficulty concentrating, sloppiness, and disorganization (Lahey, Carlson, & Frick, 1997; Carlson & Mann, 2000). These findings have led to the suggestion that ADHD/IA represents the expression of unique cognitive deficits (Barkley & Mariani, 1997; Milich, Balentine, & Lynam, 2001) however, data documenting such differences at the neurocognitive level remain lacking. Attempts to identify a core deficit in ADHD are complicated by the existence of multiple neural networks of attention associated with various cognitive processes and clinical manifestations. Hyperactivity and the executive control of behavior in ADHD has been predominantly linked to frontal lobe functioning, whereas inattention in ADHD has been linked to the frontal lobes as well as to right parietal and midline subcortical regions involved in the regulation of attention and arousal (Posner & Swanson, 2002) but these relationships have not been established in the subtypes. Multiple components of attention associated with unique neural systems have been described in the literature (e.g., Posner & Petersen, 1990). Hence, it is not surprising that many different neuroanatomical regions have been implicated in the origins of ADHD. This discrimination of attention as a multifaceted construct (both cognitively and anatomically) comes to the forefront when considering research involving ADHD subtypes, or ADHD groups of mixed type, that may not share a unique attention deficit. Specifically, recent efforts to identify the neurocognitive correlates of the subtypes have relied almost exclusively on tests of EF that may have limited relevance for the ADHD/IA subtype. According to the model proposed by Posner and Raichle (1994) attentional networks that in the brain can be broadly categorized into conflict resolution, orienting, and alerting systems, each with different yet interrelated function. The conflict resolution system involves regions of the pre-frontal cortex and basal ganglia and is responsible for the executive control of attention, an aspect of self-regulation that appears to be deficient in the ADHD/C subtype. Alternatively, the orienting system has anatomical foci in the parietal lobes, parts of the midbrain and thalamus, and is responsible for visual orienting and shifting attention. This system is presumed to facilitate automatic processes associated with visual-spatial processing and the disengaging and re-engaging of attention (Posner & Raichle, 1994). The third system of attention proposed by Posner and Raichle (1994), the alerting system, involves the locus coeruleus nucleus of the midbrain and its connections to the frontal and parietal lobes of the right hemisphere. The integrity of the alerting system plays a critical role in arousal, vigilance, and maintaining readiness to react, and may be particularly sensitive to attentional differences in disordered populations (Posner & Petersen, 1990). Accordingly, Posner and Raichle's model (1994) of separate yet interconnected networks of attention in the brain provides a theoretical model for examining the attentional correlates of the ADHD subtypes. Booth *et al.* (2007) investigated the cognitive mechanisms underlying inattention in ADHD sub-types. Posner's model proposing three distinct neural networks of attention provides a theoretically sound model for examining potentially different bases for the attentional problems of the ADHD/C versus ADHD/IA subtypes. It is hypothesized that the conflict resolution component may be most relevant to the former and the alerting component to the latter group. The demonstration of a pattern of differential attentional deficits between the subtypes may have etiological and clinical significance, and would provide further validation and refinement of the DSM-IV distinction (Booth *et al.,* 2007). The results of the work of Booth *et al.* (2007) concluded that the ADHD subjects are slower and more variable than typical developing individuals. Subjects with ADHD are described frequently as ubiquitously slower and more variable than their unaffected peers, and ADHD-related reaction time variability is considered by many to reflect a unique, stable and etiologically important characteristic of the disorder (Willcutt & Carlson, 2005). Hence, some of the confusion in the literature regarding the neurocognitive underpinnings of ADHD likely arises from the false assumption that the overt behaviors characterizing ADHD represent unitary neurocognitive constructs/processes (Booth *et al.*, 2007). Probably the most striking finding of significant subtype differences on neurocognitive measures has been demonstrated by studies showing that the combined type performed worse than the inattentive type on measures of inhibition (Nigg, John, Blaskey, Huang-Pollock, Willicut, Hinshaw *et al.*, 2002). It is noted by Posner and colleagues that there is little empirical support for the involvement of the orienting network in ADHD pathology. It is not clear if the neural pathways involved in orienting contribute to the impairment of attention observed in this population (Berger & Posner, 2005). Lundervold, Adolfsdottir, Halleland, Halmoy, Plessen and Haavik (2011) investigated whether adults with ADHD performed differently from controls on measures of accuracy, variability and vigilance as well as the control network. The sex distribution was similar in the two groups, but the ADHD group was significantly older and their score on a test of intellectual function (WAIS) was significantly lower than in the control group. The two groups did not differ on the measures of the three attention networks, but the ADHD group was generally less accurate and showed a higher variability through the task. The significance was only retained for the accuracy measure when age and IQ scores were controlled for. Within the ADHD group, individuals reporting affective fluctuations were slower and obtained a lower score on the alerting network and a higher score on the conflict network than those without these symptoms. The significance was retained for the alerting network, but not the conflict network when we controlled for the total ASRS and IQ scores. Adults with ADHD were characterized by impairment on accuracy and variability measures calculated from the ANT. Within the ADHD group, adults reporting affective fluctuations seemed to be more alert (i.e., less impacted by alerting cues), but slower and more distracted by conflicting stimuli than the subgroup without such fluctuations. The results suggest that the two ADHD subgroups are characterized by distinct patterns of attentional problems, and that the symptoms assessed by MDQ contribute to the cognitive heterogeneity characterizing groups of individuals with ADHD.

Another relevant issue in the study of ADHD subjects is the continuum of the dimensionality of the disease. Most behavior checklists for attention problems or attention deficit/hyperactivity disorder (ADHD) such as the Child Behavior Checklist (CBCL; Achenbach and Rescorla, 2001) have a narrow range of scores, focusing on the extent to which problems are present (Marzocchi & Cornoldi, 2000; Lubke, Hudziak, Derks, van Bijsterveldt, & Boomsma, 2009; Fabio & Antonietti, 2012). There has been much debate on the merits and limitations of defining disorders categorically versus dimensionally. It has been proposed that measuring attention on a continuum, from positive attention skills to attention problems, will add value to our understanding of ADHD and related problems (Polderman, Derks, Hudziak, Verhulst, & Dorret, 2007). Fan *et al.* (2002) studied the characteristic patterns of ANT results in children diagnosed with ADHD by including measures of error types and variability besides the conventional measures of the three attention networks. Results showed that children with ADHD obtained low scores with reference to the accuracy and a high variability rate in performance, thus showing an inattentive response stile. It has also emerged that those children show deficits as for sustained attention and vigilance, a more variable reaction time to cue-target and a higher rate of errors in terms of omission and commission if compared to the control group. Most of the studies using ANT have focused on the RT measures of the three attention networks, even though studies using measures from continuous performance tasks have stressed that accuracy is more affected than RT in children diagnosed with ADHD. Assuming the theoretical relevance of the continuum of attention measures, the aim of the present study is to understand whether the results of Fan *et al.* (2002) are specific of subjects with ADHD pathology or if they can be extended to subjects with attention difficulties. As previously highlighted, most children show attention problems, but they have not the ADHD pathology. The main aim of this research is to analyze the three dimensions of attention, namely vigilance, selectivity and orienting, as identified in ANT, in subjects with different attention levels, high, low and in an ADHD group. More precisely the aims are twofold: the first is to analyze the efficiency of the alerting and the orienting networks by comparing performance in the different types of cue condition, in the three different types of subjects. The second aim is to analyze the efficiency of the executive network comparing performance in the different types of target congruency condition (congruent and incongruent).

## 2. Method

### *2.1. Participants*

280 children aged from 7 to 10 (mean 8.5 *SD* 1.2), 130 male and 150 female participated in the experiment. In this pre-test phase the teachers completed two questionnaires: The SDAI scale (Marzocchi & Cornoldi, 2000) and the SCOD scale (Marzocchi, Oosterlaan, De Meo, Di Pietro,

Pezzica, Cavolina *et al*., 2001). Based on the results of SDAI and SCOD, the children, were assigned to one of three different groups: normal level of attention (15), low level of attention (15) and ADHD subjects (14). The ratio for the division into groups was the results obtained on the SDAI scale. The 75° percentile was taken as a cutoff. The subjects falling within the 75° percentile have been identified as normal level attention, and they were matched on gender and age with the children with ADHD; while subjects exceeding the 75° percentile have been considered as having attention problems, they were matched on gender and age with the children with ADHD, too. Based on the SDAI scale, the SCOD scale and a clinical interview, the ADHD group was identified (Tab. 1).

### *2.2. Intelligence assessment*

For intelligence assessment the Raven's Progressive Matrices (Alderton & Larson, 1990) were used. The first test is formed by four series (A, B, C, D) of increasing complexity which each include 12 items (incomplete figures). The subject must complete an abstract figure choosing among six alternatives. The test has three versions: Standard Matrices (SPM) for adults (Raven, 2006), Advanced Matrices (APM) (Alderton & Larson, 1990) intelligently gifted people and Colored Matrices (CPM) for children and handicapped people (Raven, 1936), which was the one used in this study because the sample was children. This version is formed by three series (A, Ab, B).

Summarizing, inclusion criteria for the ADHD group were: 1) a positive screening for ADHD based on the Attention-Deficit/hyperactivity Disorder Scale (SDAI - teacher version; Marzocchi & Cornoldi, 2000); 2) a negative screening for Disruptive behaviour Disorder (DBD), based on the Disruptive Behavior Disorder Rating Scale (SCOD - teacher version; Marzocchi *et al*., 2001; Italian translation Pelham's Disruptive Behaviour Disorder Rating Scale); 3) a clinical diagnosis from a specialized psychologist; 4) no learning disabilities and neurological, psychiatric disorders.

The American Psychological Association's ethical standards were met in the conduct of this study and the Human Ethics Committee of the CSECS of our University approved the study protocol.

To select students with ADHD symptoms, two phases were followed.

Table 1 - *Characteristics of study participants (means and SD in parentheses are reported).*

| Groups | Measures | Values |
|---|---|---|
| **ADHD** | No. of boys/girls | 10/4 |
| | Age | 8.70 (0.91) |
| | IQ | 96.50 (6.72) |
| | SDAI - distractibility | 19.81 (2.45) |
| | SDAI - hyperactivity | 15.43 (6.01) |
| | SCOD - DBD | 2.72 (2.52) |
| | SCOD - LP | 3.61 (3.42) |
| **Low level of attention** | No. of boys/girls | 10/5 |
| | Age | 8.41 (1.10) |
| | IQ | 98.50 (7.21) |
| | SDAI - distractibility | 10.85 (3.21) |
| | SDAI - hyperactivity | 6.75 (2.52) |
| | SCOD - DBD | 2.90 (2.7) |
| | SCOD - LP | 3.50 (3.21) |
| **Normally developing** | No. of boys/girls | 10/5 |
| | Age | 8.60 (1.22) |
| | IQ | 101.51 (5.92) |
| | SDAI - distractibility | 1.00 (0.20) |
| | SDAI - hyperactivity | 1.60 (1.31) |
| | SCOD - DBD | 1.32 (1.10) |
| | SCOD - LP | 3.22 (3.12) |

### *2.2.1. First phase*

The Italian adaptation of the American ADHD Rating Scale-IV: School Version (DuPaul, Power, Anastopoulos, & Reid, 1998) and the Italian adaptation of the Disruptive Behavior Disorder Rating Scale (Pelham, 1993) were used. The development of both the original psychometric instruments was based on the DSM-IV criteria for ADHD (American Psychiatric Association, 1984). The Italian adaptation of the American ADHD Rating Scale-IV, called SDAI, was devised by Marzocchi and Cornoldi (2000). The Italian adaptation of the Disruptive Behavior Disorder Rating Scale, called SCOD, was devised by Marzocchi *et al.* (2001). The use of these scales as a first screening is a well-known method to identify learners with ADHD symptoms (Ford, Gadde, Hakansson, & Snehota, 2003).

SDAI includes two subscales, each constituted by 9 items: distractibility or inattentivity (I) and hyperactivity (H). Items are endorsed on a four-point scale: Never or rarely (0), Sometimes (1), Often (2) and Very often (3). The possible total score that an individual can reach on each of the subscales ranges from 0 to 27. The cutoff criterion for both subclass is 14. If an individual obtains a score exceeding the cutoff in the first subscale only, he/she is classified as belonging to the ADHD-I (inattentive) subgroup; if he/she exceeds the cutoff in the second subscale only, he/she belongs to the ADHD-H (hyperactive) subgroup; if he/she exceeds the cutoff in both the subclass, he/she is classified as ADHD-C (combined, namely, both inattentive and hyperactive).

SCOD is composed of 13 items. Eight items provide a disruptive behavior disorder index and 5 items provide a LP (learning problems) index in both mathematical and linguistic areas. Items are scored on a four-point scale: Never or rarely (0), Sometimes (1), Often (2) and Very often (3). The possible total score that an individual can reach on the disruptive behavior disorder subscale ranges from 0 to 24 and the cutoff criterion is 12. The possible total score that an individual can obtain on the LP subscale ranges from 0 to 15 and the cutoff score is 8.

The psychometric evidence supporting SDAI can be summarized as follows. Marzocchi and Cornoldi (2000) reported on month test-retest reliability of .89 for the inattentive and .95 for the hyperactivity subscales; SDAI internal reliability was .97 and .94, respectively, for the inattentive and hyperactivity subscales. Regards to SCOD, Marzocchi *et al.* (2001) reported a one-month test-retest reliability of .92 for the disruptive behavior disorder and of .89 for the LP subscales. Internal reliability for the two subscales was, respectively, .88 and .86.

SDAI and SCOD scales were applied to all students enrolled in the schools, which agreed to participate in the investigation. For each student, the teacher who played the role of tutor was asked to fill in SDAI and SCOD. The teachers were told that, if they were uncertain about how to endorse some items of the scales and/or were lacking of relevant information, they could involve one or more colleagues in filling in the scales so to reach a shared response.

#### *2.2.2. Second phase*

Children who exceeded the cutoff scores in one or both SDAI subscales (I and H) passed to the second phase for a clinical diagnosis carried out by a specialized psychologist during individual interviews. The psychologist conducted interviews to exclude ADHD-like symptoms as bipolar disorders (early onset bipolar disorder), Tourette's syndrome, childhood depression, oppositional defiant disorder, and so on. She also examined if the symptoms causing impairment were reported in two or more settings and the onset age of the disorder. She collected data from both parents and teachers. The interviews were also aimed at getting information about school achievement from parents, teachers, and students themselves. The psychologist used the Parent Interview for Children Symptoms (PICS-IV; Schachar, Crosbie, Barr, Ornstein, Kennedy, & Malone, 2005), a semi-structured interview for disruptive behavior disorders's diagnosis and for the screening of other psychiatric disorders After the individual clinical assessment, all those children who had behavioural disorders, who followed a medication regime or that had a psychopathology associated with anxiety, depression, psychosis or mental retardation were excluded from the study.

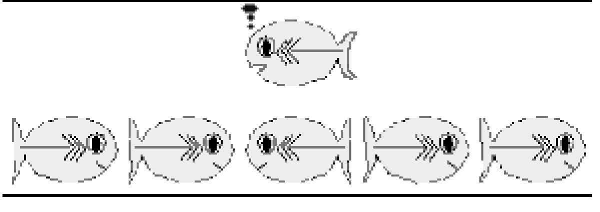
The final sample included: 14 students (10 males and 4 females) with ADHD-I, 15 students (10 males and 5 females) with low level attention and 15 students with normal level attention.

All participants and their parents gave written informed consent and the study was approved by the president of the school attended by participants.

### *2.3. Stimuli*

The target array consisted of a central target stimulus and four flanker stimuli. Each stimulus subtended 1.6° (degree of visual angle) and the contours of adjacent stimulus were separated by .21°. The five stimuli subtended a total of 8.84°.The target was presented either about 1° above or below fixation (Fig. 1).

Figure 1 - *Target stimulus and four flanker stimuli.*



Each target was preceded by one of four cue conditions: a center cue, a double cue, a spatial cue, or no cue. Each cue stimulus subtended 1.5° of visual angle. The Presentation software (Neurobehavioral Systems, Albany, CA, USA) was used to implement the children's version of the ANT (Rueda, Fan, McCandliss, Halparin, Gruber, Lercari *et al.*, 2004).

### *2.4. Procedure*

The children's version of the ANT (Rueda *et al.*, 2004) is a computer based reaction time (RT) task that measures alerting, orienting and conflict; the cognitive processes associated with Posner's three networks of attention. In our study, task instructions were presented on the computer screen and explained by the examiner. Children were instructed to visually fixate on a cross located in the center of the computer screen. They were then told a fish would appear either above or below the fixation point and that they were to "feed" that fish by pressing the right or left mouse click with the corresponding thumb in the same direction the fish was pointing. The target appears either alone (neutral) or with four additional fish, two flanking each side. In congruent trials, flanking fish point in the same direction as the target and in incongruent trials, they point in the opposite direction. The child was instructed to ignore flanking fish and respond based solely on the orientation of the center fish. Further, trials were either uncued or preceded by an asterisk to serve as an alerting &/or spatial cue. In the spatial cue condition, one asterisk appears either above or below the central fixation point and predicts the specific location of the upcoming target. In the central cue condition, one asterisk appears at the location of the central fixation point serving as an alerting cue, but providing no clue as to the specific location of the target stimuli. In the double cue condition, two asterisks appear, one above and one below the central fixation point, again providing alerting information, but no spatial information. Hence, trials consisted of a fixation period, cue or no cue, fixation period, target (i.e., a fish, either alone or flanked) and a final fixation period. After responding, auditory and visual feedback is presented to indicate whether the response is correct or incorrect. Following a correct response, the target fish is displayed blowing bubbles accompanied by a recording of a voice saying "whoohoo". Incorrect responses are followed by a single tone and no animation of the fish. The task consists of a practice of 24 trials followed by three 5-min test sessions of 48 trials; the trial conditions were counterbalanced across sessions. The total duration for each trial on the ANT is 4500ms. The first fixation period is variable in duration, from 400 to 1600ms, preceding the presentation of a spatial cue, and fixed at 200ms preceding the target in no cue trials. For the cued trials, either one or two asterisks are presented for 200ms. A 400ms fixation period marked the cue-target stimulus onset asynchrony. Stimuli are presented until a response is made or for a maximum of 2000ms. The three networks of attention are assessed by manipulations of flanker congruency and cue condition. Median reaction time values were obtained for each condition (i.e., median RT per cue condition across the flanker conditions and median RT for each flanker condition across cue conditions). The alerting score was calculated as the difference between the participant's median RT of double cue trials and the median RT of no cue trials. The orienting score was calculated as the difference between the median RT of the spatial cue trials and the median RT of the center cue, or control trials. Finally, the conflict score for each participant was calculated as the difference between the median RT of congruent trials and the median RT of incongruent trials. Mean scores across participants were then computed for each network effect. These values were calculated from the reaction time data of correct trials only.

### *2.5. Statistical analyses*

The data were analyzed using SPSS 14.0 for Windows. The descriptive statistics of the dependent variables were tabulated and examined. The alpha-level was set to .05 for all statistical tests. In case of significant effects, the effect size of the test was reported. The effect sizes were computed and categorized according to Cohen (1988). The Greenhouse-Geisser adjustment for non-sphericity was applied to probability values for repeated measures.

## 3. Results

Results are discussed with reference to the aims above presented, with reference to reaction time and accuracy index. With reference to reaction time, data were analyzed by a multivariate analysis Variance: 3 (groups: subjects with ADHD, subjects with low level attention and subjects with normal level attention) × 4 (cue: no cue, center, double, orienting) × 3 (condition: congruent, incongruent, neutral), with Groups as a between subjects factor and Cue and Condition as within subjects factors (Tab. 2).

Table 2 - *Means and standard deviations of RT in each experimental condition.*

| | | Normally developing subjects | | Subjects with attention problems | | Subjects with ADHD | |
|---|---|---|---|---|---|---|---|
| | | **M** | **DS** | **M** | **DS** | **M** | **DS** |
| **No cue** | congruent | 953.01 | 270.27 | 956.47 | 214.21 | 850.25 | 158.19 |
| | incongruent | 963.94 | 223.81 | 960.36 | 195.32 | 903.16 | 187.49 |
| | neutral | 884.65 | 194.57 | 897.95 | 163.18 | 777.00 | 131.09 |
| **Double cue** | congruent | 877.79 | 219.96 | 895.63 | 118.67 | 787.00 | 131.03 |
| | incongruent | 907.36 | 211.04 | 916.53 | 156.50 | 847.17 | 177.44 |
| | neutral | 875.44 | 257.32 | 880.47 | 224.66 | 773.33 | 186.78 |
| **Center cue** | congruent | 893.79 | 230.51 | 916.79 | 203.51 | 781.08 | 163.69 |
| | incongruent | 901.09 | 267.32 | 950.05 | 224.81 | 828.25 | 158.56 |
| | neutral | 856.22 | 218.91 | 851.53 | 172.10 | 751.58 | 151.64 |
| **Orienting cue** | congruent | 820.80 | 220.94 | 786.58 | 200.11 | 696.83 | 153.69 |
| | incongruent | 892.90 | 223.17 | 862.31 | 155.19 | 780.58 | 216.35 |
| | neutral | 773.32 | 292.04 | 758.47 | 269.43 | 696.33 | 195.57 |

The factor Groups shows significant effects, $F_{(2;\ 43)} = 12.3$, $p < .01$, $d = .68$. As we can see in table 2 the reaction times of ADHD group are lower than the other groups.

The post-hoc analysis confirmed that the normal level attention group and the low level attention group differed from the ADHD group, respectively $t = 8.14$, $p < .05$ and $t = 9.71$, $p < .05$. This means that when subjects show no clinical relevance, the ANT executive performance is similar in subjects with low level attention and subjects with normal level attention.

With reference to the first question addressed, the variable “condition” (congruent, incongruent, neutral) shows significant effects, $F_{(2;\ 43)} = 38.44$, $p < .001$, $d = .88$. When the condition was “incongruent” the reaction times of all subjects (namely hen other fishes, distraction stimuli, go in the opposite direction if compared to the central fish) become longer than in "congruent" condition. This emerges in all subjects, even though with a different trend. In fact, the interaction Groups × Condition shows significant effect, $F_{(4; 89)} = 1.4$, $p < .01$, $d = .78$, the mean difference between congruent and incongruent condition is higher in subjects with ADHD than in subjects with normal level attention and subjects with low level attention (respectively $t = 6.12$, $p < .01$ and $t = 5.22$, $p < .01$). This indicates that the subjects with ADHD, despite the speed of reaction times, show lower levels of executive performance than both subjects with normal level attention and subjects with low level attention. Data related to the accuracy index were obtained by summing errors and omissions during the administration of ANT. A one-way ANOVA was applied, assuming "groups" as independent variable and accuracy index as the dependent variable. Table 3 shows the means and the standard deviations related to the different groups of subjects.

Table 3 - *Means and standard deviations of accuracy indexes.*

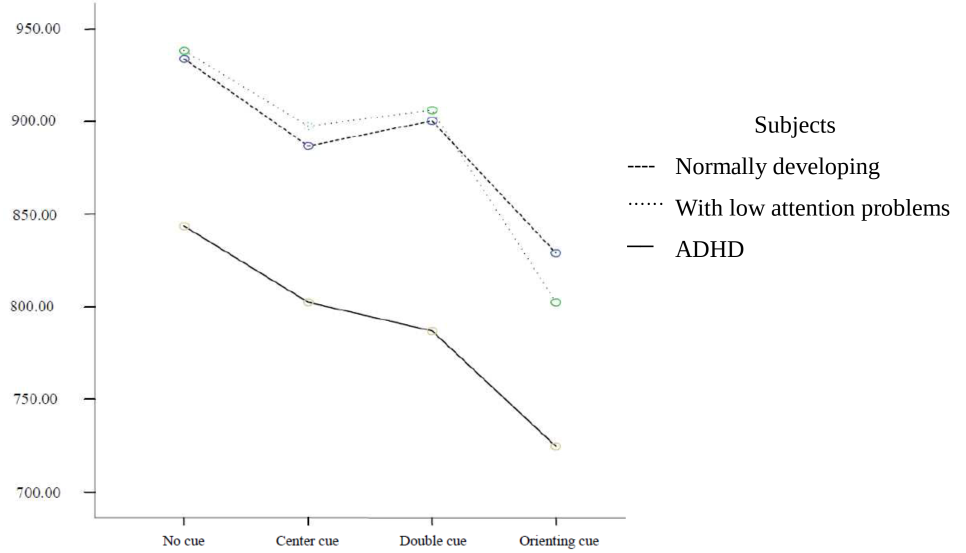
| **Subjects** | **M** | **DS** |
|---|---|---|
| **Without attention problems** | 95.98 | 5.49 |
| **With attention problems** | 96.68 | 3.76 |
| **ADHD** | 101.83 | 4.41 |

The factor group shows significant effects, $F_{(1; 89)} = 3.82$, $p < .05$, $d = .57$.

Post-hoc analysis on accuracy shows that the normal level attention group performs better than the low level attention group, $t = 4.14$, $p < .01$ and the low level attention group perform better than the ADHD group, $t = 4.85$, $p < .01$.

With reference to the second question addressed, the variable "Cue" shows significant effects $F_{(3; 89)} = 33.16$, $p < .001$, $d = .55$. In the condition "No cue" the reaction times tend to be higher while they are approximately comparable in the other two conditions: "Double cue" or a "Center cue"; instead, when there is an "Orienting cue" the reaction times tend to be significantly lower. The interaction Groups × Cues shows no significant effect. This means that the alerting and orienting networks presents the same trend, but ADHD subjects tend to be faster (Fig. 2).

Figure 2 - *TR Means for each condition cue.*




## 4. Discussion

Neuropsychological studies have related changes in neural networks involving the frontal lobe to impairment on tests of attention, primarily those defined within the concept of executive function (EF). The importance of EF is emphasized by the fact that impairment in childhood tends to increase into adulthood and it is associated with severity of ADHD symptoms and overall cognitive and everyday functioning. A cognitive model of ADHD should therefore describe and operationalize different levels of information processing, their interactions and neurobiological substrates. The Attention Network Model has been used to develop test paradigms that have become popular during the last decades. Fan *et al.* (2002) developed the Attention Network Test (ANT), and presented updated versions on the Internet. The ANT has recently been used to study cognitive characteristics of individuals with ADHD. A deviant activation pattern in all three networks has been found in FMRI studies of children with ADHD, but impairment was only found on the control network when the test was administrated according to standard procedure outside the scanner. The impact of ADHD symptoms on cognitive function is well documented. Recent studies have also shown that symptoms associated with affective disorders are crucial to understand the characteristics of cognition in children and adults with ADHD. Barkley and

Murphy (2006) illustrated a close association between what they referred to as emotional regulation and metacognition, and a longitudinal study emphasized the predictive value of such symptoms on future cognitive and everyday functioning. Other studies have shown that symptoms associated with affective disorders are related to impairment of EF and motivation, and that children with ADHD and affective disorder (i.e., anxiety) are cognitively distinct from and more impaired than individuals in either condition on the measures defined within the concept of EF (Fabio, Castriciano, & Rondanini, 2012; Fabio & Caprì, 2015; Lundervold *et al*., 2011). This may be explained by the heightened arousal characterizing individuals with affective disorders and that this arousal contributes to cognitive impairment through its effect on EF Due to the high frequency of affective symptoms in adults with ADHD these results motivate further studies using the ANT to investigate characteristics of alerting and control networks. A recent meta-analytic review of 319 studies (Kofler, Rapport, Sarver, Raiker, Orban, Friedman *et al.*, 2013) showed that adults with ADHD did not differ from controls on ANT measures of the three attention networks, but they showed a lower accuracy, a higher intra-individual variability, and lower vigilance across the task. The study of Lundervold *et al.* (2011) instead, suggests that adults with ADHD are less accurate, have a higher level of variability and a lower vigilance than adults without ADHD, and that affective fluctuations make adults with ADHD more alert, but slower and more distracted by conflicting stimuli. Their results indicate that the cognitive heterogeneity among adults with ADHD - at least partly - is explained by affective symptoms. Their results emphasize the importance of characterizing and taking these symptoms into account in research and clinical work with adults with ADHD. Individuals with ADHD are described frequently as ubiquitously slower and more variable than their unaffected peers, and ADHD-related reaction time variability is considered by many to reflect unique, stable, and etiologically important characteristic of the disorder. The recent review critically evaluated these claims through meta-analytic synthesis and analysis of 319 published and unpublished studies of reaction time in children, adolescents and adults with ADHD relative to tipically developing groups, clinical control groups, and themselves (Kofler *et al.*, 2013). Overall, the results revealed that children and adolescents and adults with ADHD demonstrated robust, medium-to-large magnitude increases in intraindividual reaction time variability relative to typically developing individuals, even after accounting for sampling error, measurement, unreliability, publication bias, and ADHD subtypes. Individuals with ADHD continued to demonstrate large magnitude increased reaction time variability after accounting for motor processing speed, whereas slower motor processing speed was no longer detectable after accounting for reaction time variability. This pattern suggests directionality with regards to the reaction time variability / motor processing speed relationship, and contradicts ADHD model positing slower processing speed as a core deficit in ADHD (Russell, Oades, Tannock, Killeen, Auerbach, Johansen *et al.*, 2006). That is, individuals with ADHD in this review tended to be more variable, but not slower than their typically developing peers after controlling for their increased performance variability. The present work confirms that the reaction times of the subjects with ADHD are low, but their performances still remain less accurate.

## 5. Conclusion

With reference to the first question addressed, no group differences emerged in the efficiency of the alerting and the orienting networks by comparing performance of the three groups in the different types of cue condition. With reference to the second questions addressed, the analysis of the efficiency of the executive network, a significant interaction condition × group emerged; when the condition was “incongruent” the reaction times of all subjects tend to become longer than “congruent” condition. This emerged, even though with a different trend, both in subjects with ADHD and in the two other groups of subjects, but the mean difference between congruent and incongruent condition was higher in subjects with ADHD than in subjects with normal level attention and subjects with low level attention problems. This means that the subjects with ADHD employ more time to change the focus when the situation is incongruent; this difficulty indicates a deficit in the executive functions. As claimed by Posner and Fan (2007), the Attention Network Test (ANT) is designed to evaluate alerting, orienting, and executive attention within a single 30-min testing session that can be easily performed by children and patients. The ANT is a better tool for analyzing the subjects with ADHD (Posner & Fan, 2007), in this work the ANT confirmed that the reaction times of the subjects with ADHD are lower but less accurate. With reference to the measure of the attention of the subjects on a continuum, from positive attention skills to attention problems, in this research the subjects with attention problems do not show a similarity with the typical pattern of ANT resulted in children diagnosed with ADHD. Lubke *et al.* (2009) show that the pattern of symptom clustering provides support for an ADHD continuum with most DSM-IV ADHD cases falling into the extreme end of that continuum. In any case, the present study, assuming the subjects with problems of attention as the "middle" part, is not in line with the results of Lubke *et al.* (2009) because only the clinical group displayed the deficit in the efficiency of executive network. It seems to exist a threshold between subjects with attention problems and ADHD subjects. Anyway, as claimed by Posner & Fan (2007), the ANT produces reliable single subject estimates of alerting, orienting, and executive function, and further suggests that the efficiencies of these three networks are uncorrelated. There are, however, some interactions in which alerting and orienting can modulate the degree of interference from flankers. This procedure may be convenient and useful in evaluating attentional abnormalities associated with cases of brain injury, stroke, schizophrenia, and attention-deficit disorder.

Like every research study, this one also raises questions to be addressed in future work. For clinical purposes, we need validated thresholds to make a diagnosis. For research and clinical purpose, it may be important to understand what is the precise point in the continuum scale of the gravity of the symptoms that allow the executive functions the possibility to be inefficient.

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