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# Automatic Deficits can lead to executive deficits in ADHD

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Abstract

It has been well documented an executive dysfunction in children with Attention Deficit Hyperactivity Disorder (ADHD) and with Reading Disorder (RD). The purpose of the present study was to test an alternative hypothesis that deficits in executive functioning within ADHD may be partially due to an impairment of the automatic processing. In addition, since the co-occurrence between ADHD and RD, we tested the hypothesis that the automatic processing may be a possible common cognitive factor between ADHD and RD. We investigated the automatic processing of selective visual attention through two experiments. 12 children with ADHD, 17 with ADHD+RD and 29 typically developing children, matched for age and gender, performed two tasks: Visual Information Processing Task and Clock Test. As expected, ADHD and ADHD+RD groups differed from the control group in controlled process task, suggesting a deficit in executive functioning. All clinical subjects also exhibited a lower performance in automatic processes, compared to control group. The results of this study suggest that executive deficits within ADHD can be partially due to an impairment of automatic processing.

Key words: : Attention deficit hyperactivity disorder, reading disability, executive functions, automatic processing, selective visual attention.

## Introduction

The main theoretical conceptualizations regarding the etiology of Attention Deficit Hyperactivity Disorder (ADHD) suggest that the core of problems in ADHD is related to: inhibition (Barkley, 1997, 1998, 2003, 2006; Nigg, 2010), reduced working memory (Pennington & Ozonoff, 1996), and a more general executive dysfunction (Brown, 2002, 2006). These views are all consistent with the diagnostic criteria set forth by the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (American Psychiatric Association, 2000), and the recently released Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (American Psychiatric Association, 2013). These theories are also relatively consistent with behavioral observations (Barkley & Murphy, 2010) with evidence that working memory deficits may also contribute to observed problems with inhibition and variable attention span such as impulsively committing an act, losing track of others' conversations, and similar difficulties (Alderson, Rapport, Hudec, Sarver, & Kofler, 2010; Brow, Roth, & Katz, 2015).

Children with ADHD have difficulty in maintaining attention, in focusing their attention on a task, and, in particular, inhibiting visual and sound distrac¬tors. In addition to attention difficulties, these children present impairments in working memory, autobiographical memory and moreover an inhibition deficit and planning difficulties (Fabio, 2017; Fabio, Castriciano, & Rondanini, 2015; Fabio & Caprì, 2015).

Although, some studies supported correlations between ADHD and difficulties with inhibition, attention, and working memory, other research relieved that many children with ADHD did not show executive dysfunctions (Nigg, 2013; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Therefore, such findings suggest that a general executive dysfunction model may be an insufficient

explanation for ADHD (Borella, de Ribaupierre, Cornoldi, & Chicherio, 2013; Brow, Roth, & Katz, 2015). Recently, Hurks et al. (2004) and Fabio et al. (2001, 2009, 2012) proposed the possibility that deficit in executive functioning within ADHD may be partially due to an impairment of the automatic processing. In other words, the authors put forth an alternative hypothesis that ADHD symptoms may emerge from an underlying executive dysfunction, partially related to difficulties in the automatic processing of basic skills.

The alternative hypothesis that children with ADHD fail to develop automatic processing has been less investigated. Some authors showed that children with ADHD do not perform as well as controls in situations demanding automatic and/or more controlled processing strategies (Hazell et al., 1999), whereas other authors did not (Van der Meere, 2005). Recent studies, instead, found that ADHD children had a deficit in automaticity process (Hurks et al, 2004; Fabio, Castriciano, & Rondanini, 2012). The purpose of the present study was to give a contribution to the Automatic Deficit Hypothesis within ADHD. Given that the co-occurrence between ADHD and reading disability (RD) is well documented (August & Garfinkel 1990; Dykman & Ackerman 1991; Trzesniewski, Moffitt, Caspi, Taylor, & Maughan, 2006; Willcutt et al., 2010), we tested the automatic deficit hypothesis in both children with ADHD and subjects with ADHD and RD. The logic of our investigation was that this comorbidity association could reflect shared aetiological bases between RD and ADHD inattention symptoms. In this regard, Willcutt et al. (2010) recently conducted a systematic meta-analysis of all published neuropsychological studies of childhood disorders to identify cognitive risk factors that might explain comorbidity between RD, ADHD, and other complex disorders. The results of the review and a series of empirical studies, suggested that the strongest candidates for a shared cognitive weakness in RD and ADHD were processing speed, response variability, and verbal working memory (Rucklidge & Tannock, 2002; Shanahan et al., 2006; Willcutt, Pennington, Olson, Chabildas, & Hulslander, 2005). In addition, several studies found deficits in response inhibition in groups with RD (Purvis & Tannock, 2000; Willcutt, Pennington, Olson, Chabildas, & Hulslander, 2005), suggesting that additional research is needed to clarify the nature of this association.

For all these reasons, the main aims of this study were two. The first was to verify whether deficits of executive functions (EFs) could be at least partly due to a deficit in the automatic processing in children with ADHD. The second was to test the hypothesis that a possible common cognitive factor between ADHD and RD may be the automatic processing. The underlying logic of our investigation was that whether the basic processes are not well automatized, they will result in a high cognitive load and compete for limited resources used by EFs.

Automatic processes can be observed by examining differences in the automatization of basic skills, because these processes can be accomplished simultaneously with other cognitive processes without interference (Fabio & Cossutta, 2001; Melnik & Das, 1992). In the current research, we investigated the automatic processing of selective visual attention using two paradigms in children with ADHD, ADHD and RD (clinical groups) and in control subjects without ADHD (typically developing group) matched for age and gender. In the first study, the Merrill's (1992) procedure on automaticity with the dual-task interference paradigm was used; in the second study the Clock Test (Moron, 1977) with automatic procedure was employed. As aforementioned, the weakness in processing speed in ADHD and RD has been well documented (Rucklidge & Tannock, 2002; Willcutt, Pennington, Olson, Chabildas, & Hulslander, 2005). Therefore, group differences in processing speed and correct responses were predicted. Because faster processing speed in encoding information can lead to an efficient automaticity process, we also expected differences in automaticity indices.

## First Study

The specific aims of the first study were two fold. Firstly, as suggested by the Johnston and Heinz (1978) and D'Angelo, Milliken, Jiménez, & Lupiáñez, (2013; 2014), the features of task has relevance to the processes of automaticity. Hence, the first aim was to verify whether the features of task can affect the automatic processing of selective visual attention. In this study both semantic and physical characteristics of the task were included. The underlying logic was the following: when selective attention was focused on the physical characteristics of the stimulus, participants could use less cognitive resources, decreasing the reply time, and increasing accuracy. When selective attention was focused on the semantic characteristics of the stimulus, participants could use more cognitive resources, increasing the reply time, and decreasing accuracy.

The second aim was to analyse Merril's (1992) theory of automaticity. If typically developing, ADHD and ADHD+RD participants were able to perform the tasks at perceptual and semantic level equally well, in the absence and in the presence of memory load both, the selective visual attention was automatic. Otherwise, if clinical groups performed equally well than normally developing group at perceptual level and not at semantic level, this can lead to a single specific EFs deficit.

## Methods

### Participants

In the first phase of this study, participants were selected from a sample of 880 students (320 females and 560 males) attending public primary schools in Lombardy, a region of Northern Italy. Students ranged from 9 to 10 years and were attending to the 3rd, the fourth and the 5th years of school. All participants were Italian.

All participants, through their parents, gave written informed consent. The procedure described in the following sections was observed in all schools that decided to participate. To select students with ADHD symptoms, two phases were followed.

The pre-test phase involved the administration of two questionnaires, which were conducted by teachers to their students:

1. The Italian adaptation of the American ADHD Rating Scale-IV, called SDAI, was devised by Marzocchi and Cornoldi (2000). The SDAI can be used to highlight the subtypes of ADHD and it consists of 18 items, which correspond to the symptoms described and listed in the DSM-V (American Psychiatric Association, 2013), containing two subscales of 9 items each: one related to inattention and the other hyperactivity-impulsivity. The teacher, for each item that will indicate the severity of behavioural disorders of children, gives a score ranging from 0 = absent behaviour to 3 = very frequent behaviour. The cut-off for each item is 1.5 points. It is, therefore, considered problematic behaviour of a child if, in at least one subscale, an overall score equal to or greater than 14 is achieved.

2. The Italian adaptation of the Disruptive Behaviour Disorder Rating Scale, called SCOD, was devised by Marzocchi et al. (2001). The SCOD is present in two versions: one for parents (Scala Comportamenti Dirompenti - Genitori; SCOD-G) and one for teachers (Scala Comportamenti Dirompenti - Insegnanti; SCOD-I). The SCOD consists of 42 items and can be divided into four subscales, respectively: a rating scale of aggressive behavior; information about the socioeconomic family, a series of 5 items related to school learning problems, and general information aimed at discriminating against individuals with ADHD from other related diagnosis.

3. The MT test (Cornoldi, Colpo, & Gruppo, 1998) and Decoding Reading Test (Cornoldi, &Colpo, 1998). In the MT test, the first story is suited to and standardized for the children's school grade, followed by 10 multiple choice questions relating to the characters and events mentioned in the story. Participants were asked to choose the correct response based on their understanding of the

story. Scoring comprised 1 point for each correct response. Normal performance is five or more correct choices. This test was administered to select students with normal reading comprehension abilities. The reliability coefficient of the test is $\alpha = .60$ (Cornoldi, Colpo, & Gruppo, 1998). The Decoding Reading Test (Cornoldi, Colpo, & Gruppo, 1998) required the subjects to read a text aloud. The number and type of errors made were evaluated. Separate scores were calculated for speed and accuracy. With regard to accuracy, a score of 1 was attributed for each long pause, or addition or omission of syllables, words, or lines. A score of 0.5 was attributed for each stress error, hesitation, or self-correction. Normal performance is 6 or less errors. With regard to speed, the total score was obtained by calculating the seconds per number of syllables of text read. Normal performance was a score of .80s/syllable or less. This test was administered to identify participants with reading difficulties. The reliability coefficient of test is $\alpha = .75$ for accuracy and $\alpha = .64$ for speed (Cornoldi, Colpo, & Gruppo, 1998). Teachers administered all the scales to their students.

Based on data collected through three questionnaires, the final sample of the present research consists of 30 participants divided into three groups (two clinical groups and one control group):

• Group 1 consists of 12 children with ADHD (3 female and 9 males), that had an overall score equal to or greater than 14 in both SDAI subscales, that were negative to other diagnostic problems and had an overall score of five or greater in MT test, and finally a score of 6 or less in accuracy and a speed of .80 or less in speed of Decoding Reading Test.

• Group 2 consists of 17 children with ADHD + RD (6 female and 11 males), that had an overall score equal to or greater than 14 in both SDAI subscales, that were negative to other diagnostic problems and had an overall score of four or fewer in

MT test, and finally a score of 7 or more in accuracy and a speed of .90 or more in speed of Decoding Reading Test.

• Group 3 consists of 29 typically developing control children (9 female and 20 males). The control group participants were recruited from the same classroom of each of the ADHD children and they were individually matched for age and gender. They met no disorder identified by SDAI and SCOD, were not diagnosed as affected by behavioural, emotional and/or relational problems by the specialised psychologists, had normal an overall score of five or greater in MT Test, and finally they had a normal performance in Decoding Reading Test.

To estimate children's IQ, the Wechsler Intelligence Scale for Children – Revised Edition (WISC-R; Wechsler, 1991) was administered. Demographic and clinical characteristics of ADHD and control children are summarized in Table 1.

Table 1 Demographic statistics

| Group | Measures | |
|---|---|---|
| ADHD | N of boys/girls | 9/3 |
| | Age (mean (SD)) | 9 (1.9) |
| | IQ | 97.1 (6.2) |
| | SDAI - distractibility | 19.3 (2.6) |
| | SDAI - hyperactivity | 14.4 (5.9) |
| ADHD+RD | N of boys/girls | 11/6 |
| | Age (mean (SD)) | 9 (1.6) |
| | IQ | 88.9 (6.3) |
| | SDAI - distractibility | 18.4 (2.8) |
| | SDAI - hyperactivity | 10.7 (2.1) |
| CONTROL | N of boys/girls | 20/9 |
| | Age (mean (SD)) | 9 (1.8) |
| | IQ | 107 (7.4) |

| | |
|---|---|
| SDAI - distractibility | 1.02 (0.5) |
| SDAI - hyperactivity | 0.00 (0.00) |

As expected, the ADHD, the ADHD+RD and the control group differed significantly on SDAI (subscale distractibility), $F(2, 42)=221{,}6$, $p<0{,}001$, $d=0.62$, and on SDAI (subscale hyperactivity), $F(2, 42)=18{,}11$, $p<0.001$, $d= 0.58$.

A one-way analysis of variance (ANOVA) showed that IQ scores of ADHD and ADHD/ RD children were significantly lower than the IQ scores of the control group, $F(2, 42)=20{,}53$, $p<0.01$, $d=0.66$. Therefore all analyses, including a group factor, were additionally analyzed with IQ added as a covariant factor. Informed consent was obtained from all children and their parents.

Visual information processing task

The visual information processing task, used in this experiment, was a variation of the tasks described by Melnik and Das (1992). In the first task, participants were asked to circle, as quickly as possible, the pairs of pictures that were physically identical, whereas in the second task they were asked to circle, as quickly as possible too, stimuli belonging to the same semantic category. Each task was repeated three times for each subject.

Figure 1. Physically identical task

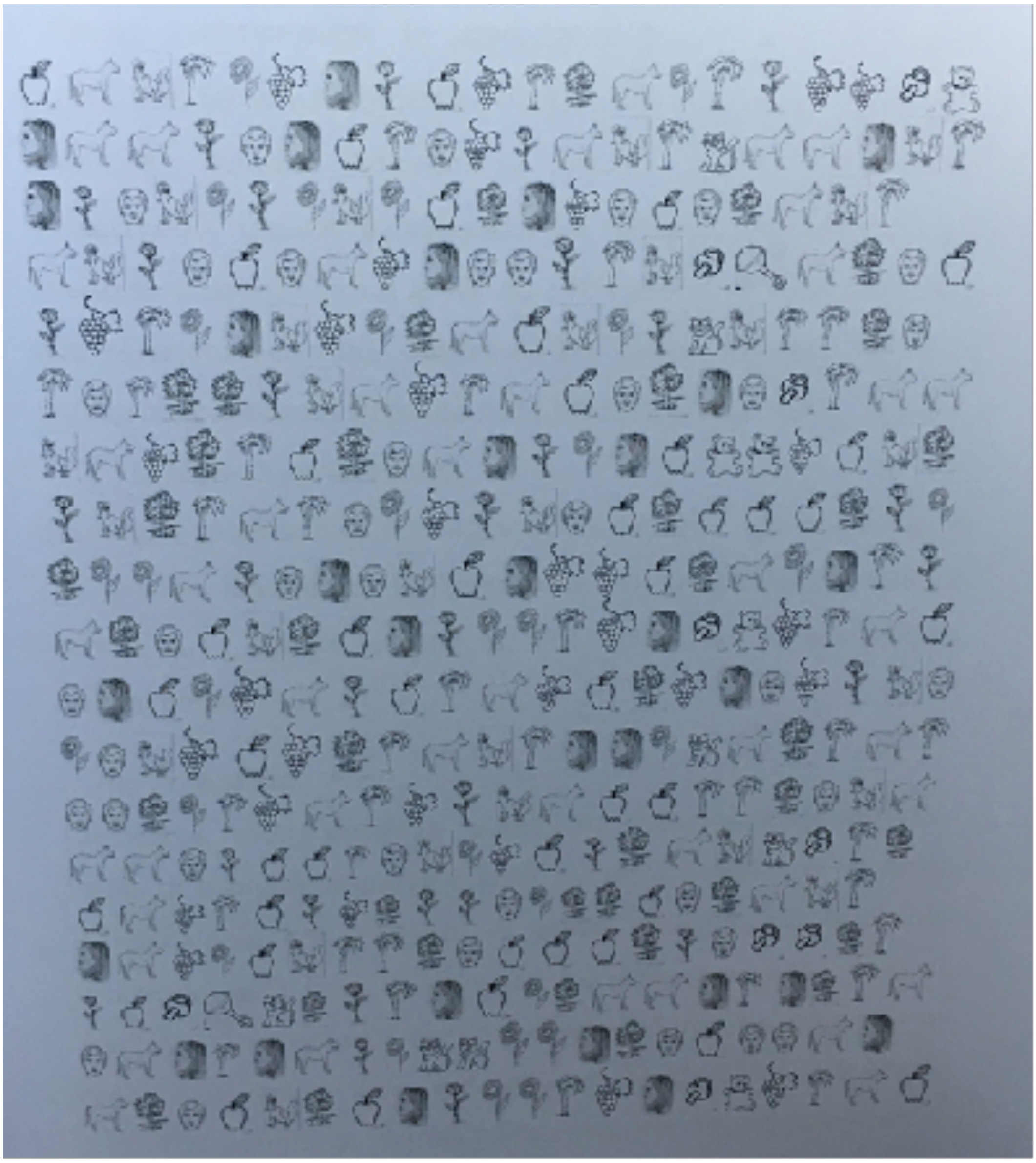

Figure 2. Semantic identical task

The pictures consisted of fruits (strawberries and grapes), flowers (roses and daisies), trees (palms and elm trees), faces (in frontal and profile view) and animals (dinosaurs and dogs) (fig. 1 and 2). The full permutation of the five categories resulted in 120 pairs. Within these pairs, 84 were selected at random. Stimuli were presented on a single sheet of paper, A-4 paper, showing all 84 pairs of stimuli in a 7 by 12 matrix.

## Procedure

The children were tested in a silent classroom of the school. Prior to conducting the experiment, memory load was determined for each subject using the subtest of digit span of the WISC-R. Participants also completed the WISC-R to measure IQ. After these preliminary measures, they performed the visual information processing task. Therefore, during the experiment the methodology of memory load was integrated with the methodology of the function of codification. In other words, participants had to repeat a list of numbers while they performed the visual information processing task. Memory load was manipulated by increasing or decreasing the memory set. The purpose was to measure the level of cognitive load that interfered with performance in clinical and control groups. Automatic processes, indeed, can be accomplished simultaneously with other cognitive processes without interference. Thus, difference on interference of memory load could reflect a difference in automatic performance in participants with and without ADHD.

As described above, the visual information processing task was repeated for three consecutive times. In order to evaluate the interference of memory load on the performance, in the second and third trial participants were asked to listen and repeat a list of numbers (memory load) read aloud by an experimenter, while they were performing the task. Memory load was manipulated by increasing or decreasing the memory set (full load = span-1 digits; half load = span-1/2 digits and no load = 0 digits), e.g. if a child reached the range of 8 in Digit Span Test, then the full load was 8, the half load was 8 • 1/2 = 4, and no load was Ø.

The whole experiment took about 20 minutes and the order of the tests was randomized. The clinical group and the control group were tested separately.

## Statistical analyses

The data were analysed using a 3 x 2 x 3 repeated measure analyses of variance (ANOVA), with one between (group: 3 normally developing, 2 ADHD and 1 ADHD/RD group) and two within factors (experimental condition: physical vs semantic identification and cognitive load: no-load, half-load and full-load). IQ was added as covariate. The descriptive statistics of the dependent variables were tabulated and examined. The alpha level was set to 0.05 for all statistical tests. In case of significant effects, the effect size of the test was reported. The effect sizes were computed and categorised according to Cohen (1988). The Greenhouse–Geisser adjustment for nonsphericity was applied to probability values for repeated measures. Regarding IQ scores and vocabulary scores, preliminary statistical analyses showed significant differences between the groups, $F(2, 55) = 10{,}96$, $p < .001$, Cohen's $d = 0.75$, and $F(2, 55) = 7{,}61$, $p < .01$.

Three measures of task performance were recorded:

- Number of seconds employed to complete the task (processing speed);

- Number of correct responses;

- Accuracy index: Number of false alarms (erroneous detection) plus number of misses (lack of detection).

## Results

### Speed performance

Table 2 shows the means and standard errors of the seconds employed to complete the task and overall numbers of errors.

The experimental condition was significant F(1, 42)= 87.6, p<.01, d= 0.65, all subjects presented a longer time of response in the physical identification than in the semantic identification (table 2).

Table 2 Means and standard errors for response time, correct responses and number of errors on physical and semantic identification

| | ADHD+RD | ADHD | Control |
|---|---|---|---|
| | M(SD) | M(SD) | M(SD) |
| Response time | | | |
| Physical identification | | | |
| Empty load | 83.5(7.31) | 63.2(7.31) | 66.0(7.31) |
| Half load | 90.1(7.31) | 72.3(7.31) | 67.3(7.31) |
| Full load | 100.2(10.48) | 76.7(10.48) | 91.5(10.48) |
| Semantic identification | | | |
| Empty load | 118.9(9.26) | 88.4(9.26) | 100.0(9.26) |
| Half load | 150.6(11.53) | 104.3(11.53) | 111.8(11.53) |
| Full load | 142.8(14.08) | 111.2(14.08) | 131.7(14.08) |
| Correct responses | | | |
| Physical identification | | | |
| Empty load | 18.4(0.38) | 18.4(0.38) | 19.3(0.38) |
| Half load | 18.5(0.36) | 19.1(0.36) | 19.2(0.36) |
| Full load | 18.5(0.46) | 18.8(0.46) | 18.2(0.46) |
| Semantic identification | | | |
| Empty load | 15.3(1.00) | 12.3(1.00) | 16.3(1.00) |
| Half load | 15.9(1.09) | 11.4(1.09) | 16.2(1.09) |
| Full load | 14.3(1.52) | 11.0(1.52) | 15.8(1.52) |

| | | | |
|---|---|---|---|
| Number of errors | | | |
| Physical identification | | | |
| Empty load | 1.7(0.43) | 1.8(0.43) | 0.7(0.43) |
| Half load | 1.6(0.35) | 1.0(0.35) | 0.9(0.35) |
| Full load | 1.6(0.46) | 1.3(0.46) | 1.9(0.46) |
| Semantic identification | | | |
| Empty load | 6.0(0.97) | 9.0(0.97) | 5.0(0.97) |
| Half load | 6.1(1.07) | 9.7(1.07) | 4.6(1.07) |
| Full load | 7.4(2.00) | 10.3(2.00) | 7.6(2.00) |

The “group” variable showed also significant effect $F(2, 42)=3.255$, $p<.05$, $d=0.55$, children with ADHD showed a shorter time of response than ADHD+RD and control groups.

Post hoc tests indicated that the performance of ADHD+RD group was significantly slower than the other groups. Results show that: (a) in the physical condition with half-load there are statistical differences comparing ADHD+RD and typically developing subjects (controls), $t=22.8$, $p=.05$, $d=0.51$; (b) in the semantic condition the factor “group” showed a significant effect; in particular ADHD+RD and ADHD group differed significantly, $t=30.5$, $p<.05$ (zero-load); ADHD+RD and control group also present statistical differences, $t=46.3$, $p<.01$ (half-load); finally ADHD and control group differed significantly, $t=38.8$, $p<.05$, (half-load).

Correct responses

As regards to correct responses, experimental condition shows a significant statistical effect, $F(1,42)=58.44$, $p<.01$, $d=0.62$, this indicates that in the physical identification task groups show higher correct responses than in semantic identification task. The "Group" variable also shows significant effect, the typically developing group had a higher performance than the ADHD group, $F(1, 42)=3.86$, $p<.05$, $d=0.52$. In the semantic task, ADHD group showed the worst performance. Post hoc analyses revealed significant group differences between ADHD, ADHD+RD and control group in the semantic task. ADHD subjects showed: (a) a significant difference in semantic task (zero-load) compared to ADHD+RD ($t=3.22$, $p=.044$) and typically developing group ($t=4.11$, $p<.01$), (b) a difference in semantic task (half-load) compared to ADHD+RD ($t=4.5$, $p=0.007$) and control group ($t=4.8$, $p=0.004$) and (c) a difference in semantic task (full-load) compared to control group ($t=4.8$, $p=0.035$).

Accuracy index

The overall number of errors (false alarms + the number of misses) was calculated. The experimental condition was significant $F(1, 42)=101.18$, $p=.0001$, $d=0.62$, the number of errors was higher in the semantic task than in the physical task. There was a significant interaction between experimental condition X Groups: $F(2, 42)=4.15$, $p=0.027$, $d=0.56$. This indicates that the ADHD group has a lower accuracy index in semantic identification task than the other groups.

Statistical analyses of Automatic Deficit Hypothesis

Data analysis related to Automatic Deficit Hypothesis shows a significant effect of load: $F(2, 84)=20.32$, $p<.01$, $d=0.63$. In both experimental conditions, the increase of the cognitive load was accompanied by a long time of response. The interaction Cognitive load X Groups was not significant. This result suggests that all subjects are sensitive in the same way to the level of cognitive load: the higher the load, the longer the time of response. With reference to correct responses and errors the cognitive load was not significant.

## Discussion

The present study aimed to provide a contribution to the hypothesis that deficits in executive functioning within ADHD may be partially due to an impairment of the automatic processing. In this first experiment, we investigated the automatic processing of selective visual attention using the visual information processing task in children with ADHD, ADHD+RD (clinical groups) and in control subjects without ADHD (typically developing group) matched for age and gender. Also, we measured if the level of cognitive load can interfere with performance, because automatic processes can be simultaneously accomplished with other cognitive processes without interference. Consequently, the possible interference of memory load could reflect a difference in automatic performance in participants with and without ADHD.

The results of the first study indicated that ADHD children were faster and ADHD+RD group were slower compared to the control group in both experimental conditions. As aforementioned, ADHD group was faster but this group was also more variable and inaccurate in semantic tasks. Moreover, all groups increased their time of response in semantic condition. Therefore, when the cognitive load increases, the time of execution gradually increases in all groups. With reference to correct responses, all groups showed a low performance in semantic tasks compared with physical tasks, but the ADHD group performance was better than the other groups. The cognitive load had no effect in either tasks. It was found an increase in error rates across experimental conditions for all groups. Precisely, the ADHD children had a higher level of errors than the other groups. Task performance was not sensitive to cognitive load. No significant load effect was observed in task performance, in both experimental conditions.

The findings described in this first study lead to two possible conclusions regarding how ADHD children perform in tasks demanding automatic and/or more controlled processing strategies. Firstly, the efficiency (speed and accuracy) of ADHD group in the physical condition, the fast and inaccurate performance in task demanding cognitive resources can be explained in terms of impulsive responding: they go on “running” even if the task requires a higher allocation of attentional capacity. The main finding is that in controlled mental processes, as in semantic tasks, ADHD subjects increase in error rate and decrease in the correct responses. It is possible that they exhibit inefficiencies in controlled tasks as they showed a deficit in executive functions, particularly, in self-monitoring processes and in inability to develop basic processing functions and they suffered when a task becomes more difficult.

As regards to profile of ADHD+RD group, these subjects are the slowest but with a number of correct responses and of errors similar to the performance of the control group. One explanation for this result is that children with ADHD+RD show a “hyper regulation”, they do not make errors or decrease the correct responses but they greatly reduce the speed of execution.

In conclusion, all subjects show a poorer performance when the cognitive load increases, thus, the results of the present first study offer no support for a specific deficit of automatic processing in children with ADHD.

## Second Study

The specific aim of the second study was to examine the automatic processing of selective visual attention using the Clock Test (Moron, 1977). More precisely, we evaluated whether ADHD and ADHD+RD children had a lower index of automatization than typically developing children (control group). The underlying logical of our experiment is the following: automaticity can be studied through the multiple presentation of stimuli, it typically develops when the same stimuli have to be detected consistently over many trials. Consequently, we expected that ADHD groups showed a gradual improvement in responding to trials generated by a repeated training sequence, comparing to typically developing group.

To investigate the automatic processing, the Clock Test (Moron, 1977) was employed. It is a visual-spatial attention test used to examine the automaticity in previous works. For example, Szymura, Slabosz and Orzechowski (2001) and Fabio, Castriciano and Rondanini (2015) used the Clock Test to study the automatization process. In another research of Valle, Massaro, Castelli and Marchetti (2015), this test was used to evaluate the access to automatic process and the return to voluntary control.

## Methods

### Participants

The participants were the same of the first experiment.

### Clock test (Moron, 1977)

The process of automation was assessed by the Clock test, derived from the visual-spatial Zazzo cancellation test (Fabio, Antonietti, & Pravettoni, 2008; Moron, 1997; Zazzo, 1969, 1972). The clock test is presented on a A4 sheet that displays one clock showing 04:00 hour in the header line and a 16 × 25 matrix with a total of 400 randomly assorted watches similar to those in the header line. Only 40 of the matrix symbols are identical to the header symbol. The participant is instructed to mark only the identical one. Test duration is 2 minutes. After 2 minutes, the amount of falsely marked symbols is counted using a template solution. The task is to work as quick and accurately as possible. The parameters measured were: total amount of correct markings, amount of omitted symbols and amount of wrong markings.

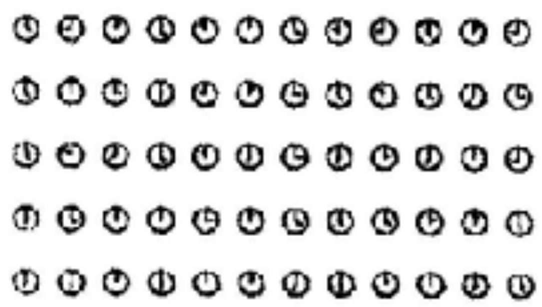

Figure 3. Clock test

Procedure

The children were tested in medium size groups (4-8 children) in a silent classroom of the school. They performed the Clock Test for three times. Short breaks (1 minute each) were provided after each repetition of the test. The clinical group and the control group were tested separately.

Statistical analyses

Data were analyzed using a 3 (subjects: normally developing vs ADHD vs ADHD/RD group) x 3 (trial number: first vs second vs third) ANOVA repeated measure design. IQ was added as covariate.

Three measures of task performance were recorded:

- The number of correct stimuli – SPEED (the number of targets detected in a period of 2 minutes of continuous attention);

- The number of false alarms – FA;

- The number of omissions – OM

On the basis of these measures another additional index of performance was calculated: the overall number of errors – D’ (FA+AM).

## Results

With reference to the number of correct responses, all groups increased their performance from trial to trial (table 3).

Table 3Means (and standard deviation) of correct responses and number of errors for the trials 1. 2 and 3.

| | ADHD+RD | ADHD | Control |
|---|---|---|---|
| | M (SD) | M (SD) | M (SD) |
| Correct responses | | | |
| Trial 1 | 7.9(1.43) | 12.8(1.43) | 13.6(1.43) |
| Trial 2 | 10.1(1.40) | 16.5(1.40) | 17.8(1.40) |
| Trial 3 | 10.9(1.79) | 16.5(1.79) | 17.1(1.79) |
| Number of errors | | | |
| Trial 1 | 10.0(2.87) | 11.7(2.87) | 4.4(2.87) |
| Trial 2 | 13.8(2.66) | 10.3(2.66) | 6.7(2.66) |
| Trial 3 | 16.9(3.30) | 16.4(3.30) | 5.3(3.30) |

Control and ADHD groups obtained similar results. It was found a significant effect in “trials” variable, $F(2,84)=12.188$, $p < 0.001$, $d=0.62$. As shown in fig. 1, all subjects increased their accuracy from trial to trial. The group factor also shows a significant effect, $F(2, 42)=6.99$, $p=0,004$, $d=0.72$.

Post hoc tests indicated that ADHD+RD group differed significantly from the other groups. More precisely, ADHD+RD differed both from ADHD group $t=5.7$, $p=.009$ and from control group $t=4.9$, $p=.023$ in the first trial. In the second trial, ADHD+RD again differed both from ADHD group $t=7.7$, $p=.001$ and from control group $t=6.9$, $p=.001$. In the third trial, ADHD+RD group differed both from ADHD group $t=6.2$, $p=.021$ and from typically developing group $t=6.97$, $p<.01$).

These results show that children with ADHD and RD exhibited slower responses than ADHD and typically developing subjects.

As regards to the overall number of errors (false alarms + the number of misses) table 3 shows the means and deviation standards of errors for each group in the three trials. It was found a significant effect in the “group” variable, respectively $F(2, 84)=3.01$, $p=0.05$, $d=0.55$, and $F(1, 42)=57.96$, $p<0.001$, $d=0.64$.

Post hoc analyses indicated that ADHD+RD group did not differ from the ADHD group in all the trials. There were significant difference between clinical groups and control group. Precisely, typically developing group differed from ADHD+RD group $t=11.6$, $p=.02$ in the first trial, $t=10.5$, $p=.02$ in the second trial and $t=10.27$, $p=.02$ in the third and from ADHD group $t=11.1$, $p=.025$ in the first trial, $t=10.27$, $p=.001$ in the second trial and $t=9.98$, $p=.02$ in the third.

The typically developing children had a constant error rate across the three trials, whereas the clinic groups showed an increase in errors. This suggests two directions: typically developing subjects did not have deficit in automatic components, whereas the clinic groups had more difficulty in automatic processing because they increased errors. Moreover, children with ADHD+RD had a lower speed index and a higher number of errors, whereas ADHD showed a greater speed and a high level of errors. Both ADHD and ADHD/+RD subjects differed from the control group, but in different directions: the children with

ADHD+RD committed many errors and the ADHD group was faster than ADHD+RD group.

## Discussion

The specific aim of the second study was to examine the automatic processing of selective visual attention using the Clock Test (Moron, 1977) in children with ADHD, ADHD+RD and without ADHD and RD. The results suggested that there are differences between the groups considered. In accordance with Shiffrin and Schneider (1977), the automatization effect was assessed by speed and accuracy performance measures. All groups increased their response speed from trial 1 to trial 3. Furthermore, the clinic groups showed deterioration in the accuracy of their performance compared to the control group. Therefore, findings indicated that both clinic groups presented a lower automation index than typically developing subjects. Automatic processes require an increase of the response execution time and of the accuracy, but the performance of the clinical groups were not efficient, as illustrated by table 4:

Table 4 Description of performance of three groups

| Groups | Speed | Accuracy |
|---|---|---|
| ADHD | Fast | Inaccurate |
| ADHD+RD | Slow | Inaccurate |
| Control | Fast | Accurate |

## Conclusion

As we described in the first study, subjects with ADHD decreased the accuracy in the visual information processing task. This indicates that they have a worse performance on tasks demanding control strategies comparing typically developing subjects. The main explanation lead to two directions: executive or automatic deficits. Considering to executive deficit explanation, we argue that semantic identification process implies more executive resources; whereas concerning to automatic explanation we can assume that semantic identification process implies the improvement of underlying process automation. These two explanations are not opposite, but support the hypothesis that executive dysfunction within ADHD can partially due to a deficit of automatic processing. Precisely, given that automatic processes can be observed by examining differences in the automation of basic skills in children, and since in our studies we obtained deficits in the accuracy of performance, it is probable that children with ADHD are not able to accomplish simultaneously the cognitive pro¬cesses without interference (Fabio & Cossutta, 2001; Hasher & Zacks, 1979; Melnik & Das, 1992). For these reasons, we conclude that executive deficits are at least partially due to deficit in automatic processing. Therefore, the results of our studies support the hypothesis that ADHD symptoms may emerge from an underlying exsecutive dysfunction, partially related to difficulties in the automatic processing of basic skills.

In the current study, we also tested the hypothesis that a possible common cognitive factor between ADHD and RD may be the automatic processing. Conceptual models of complex disorders, such as RD and ADHD, typically implicate linear causal pathways in which a single risk factor led to a single neurocognitive deficit that provided a sufficient explanation of all the symptoms within the disorder (Willcutt et al., 2010). More recent theoretical models (Pennington, 2006; Sonuga-Barke, Sergeant, Nigg, & Willcutt, 2008; Willcutt, Sonuga-Barke, Nigg, & Sergeant, 2008) explicitly hypothesize that complex disorders are heterogeneous conditions that arise from the additive and interactive effects of multiple risk factors to lead to weaknesses in multiple cognitive domains. The results of our studies support the hypothesis that automatic processing deficits can be a candidate for shared risk factors between ADHD and RD.

The findings from our two studies make a first contribution to understand to what extent the automatic processing of basic skills, as attention, can have a role in the nature of the etiology of ADHD. Future studies need to have relatively large sample sizes and to verify further the type of experimental paradigm used in our two studies, in order to provide a deeper understanding of the automatic processing in ADHD.

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